Beam Background and BEAST

H. Nakayama(KEK)
on behalf of
Belle2 Beam background group

Goals of Beam Background Group

- Overall goals: **Estimate, measure, mitigate, and protect against** beam backgrounds
- Background sources
  - 4-fermion final state QED process (Lum.)
  - Touschek effect (Beam size and energy)
  - Beam-gas interactions (current, pressure)
  - Synchrotron radiation
  - Radiative Bhabha scattering (Lum.)
  - Injection BG
- Can result in instantaneous damage, long term damage, or excess occupancy in Belle II
- Want to measure all backgrounds, **validate MC primarily during phase 2 (BEAST)**. Use MC to extrapolate to phase 3.

Beam BG Group

- LEADER, BEAST: **S. Vahsen** (Hawaii)
- BEAST KEK liaison, BG simulation: **H. Nakayama** (KEK)

- Institutes:
  - KEK, Hawaii, Bonn, Trieste, MPI, Heidelberg, DESY, Wayne, NTU, IFCA, LAL, IPHC, etc..

- Significant support from accelerator colleagues
  - Beam loss simulation
  - BEAST machine study operation

Background simulation
(for design luminosity)

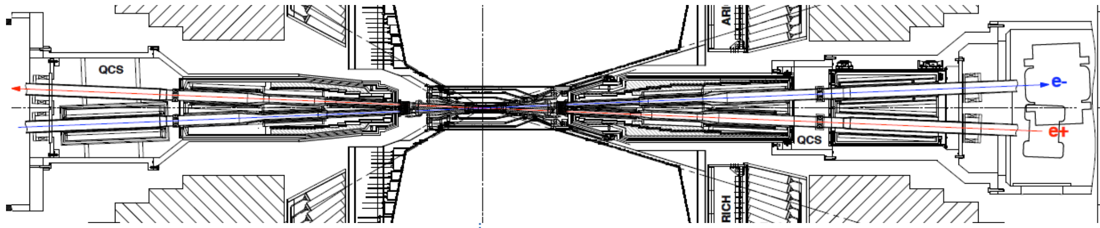
Background simulation updates

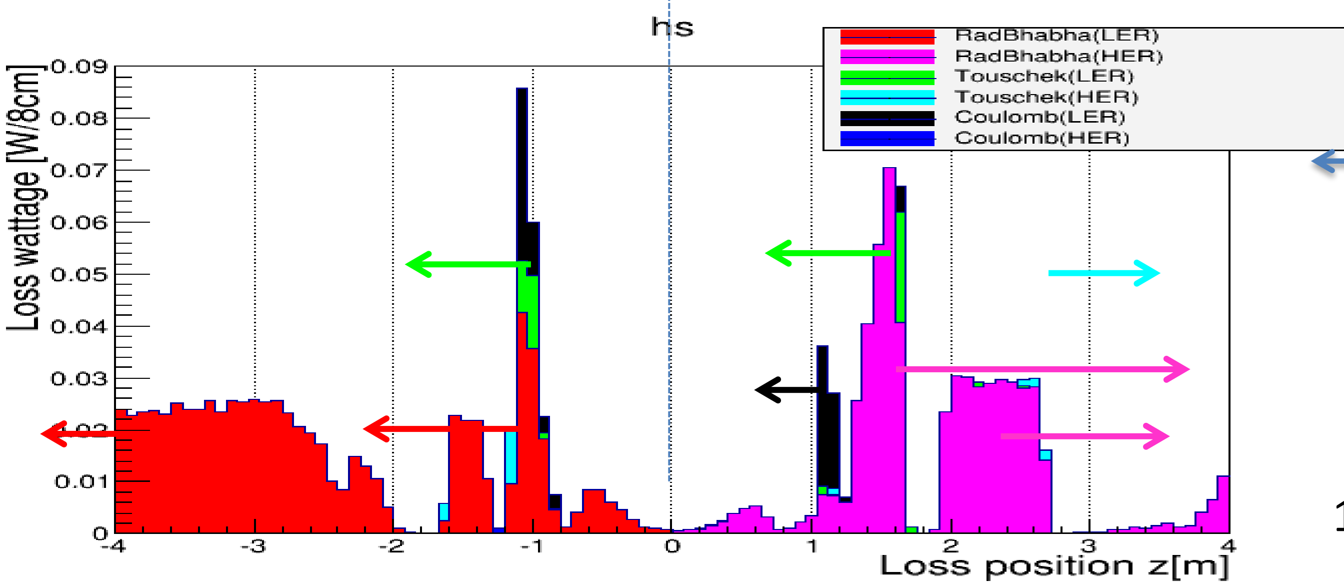
- In the last ARC, 8th campaign result was reported.
- 9th campaign
  - RBB_LER rate increased
    - we found the wrong LER lattice (solenoid off) was used before
  - B=1.5→1.2T was investigated
    - Only 20~30% decrease on TOP PMT rate (we need factor 3), 35% increase of PXD occupancy, challenge for tracking and accelerator optics tuning
- 10th/11th campaign
  - Only minor updates in shield geometry, loss rates
  - BG level dependence on collimator width are investigated

Ver. 2015.1.30
(11th campaign)

BG loss distribution

Loss wattage
= loss rate
  * energy of loss particle





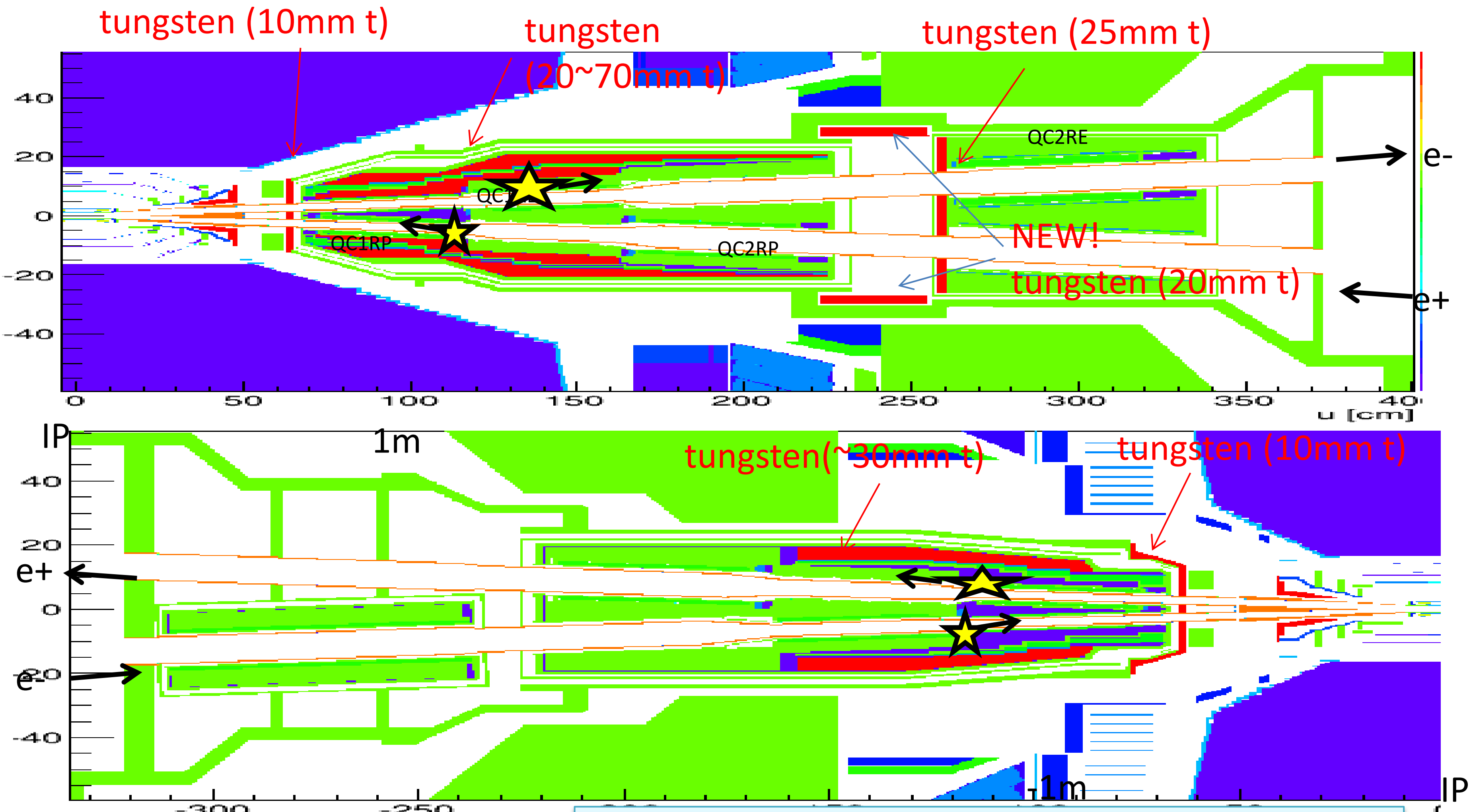
HER
(e-)

LER
(e+)

1GeV ,1GHz
= 0.16W

	LER (4GeV e+)	HER (7GeV e-)
Rad. Bhabha	0.74 W (eff. 1.2GHz)	0.59W (eff. 0.52GHz)
Touschek	0.05 W (0.08GHz)	0.02 W (0.02 GHz)
Coulomb	0.10 W (0.16GHz)	0.001W (0.001GHz)

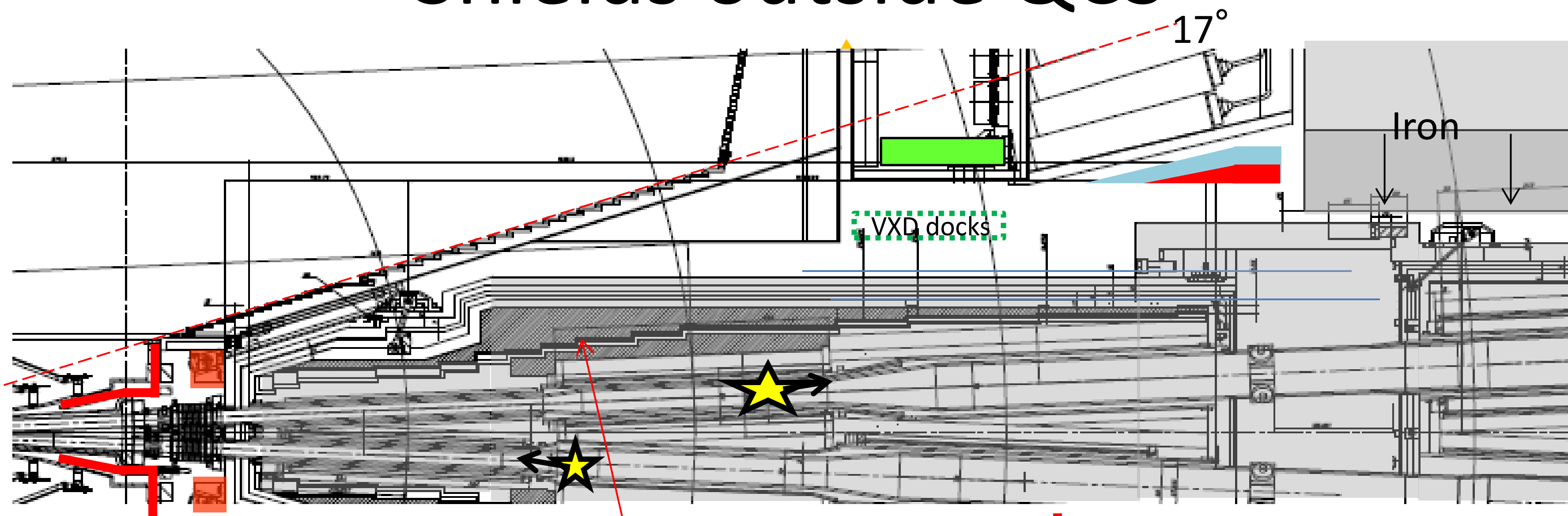
Tungsten shields in QCS cryostat



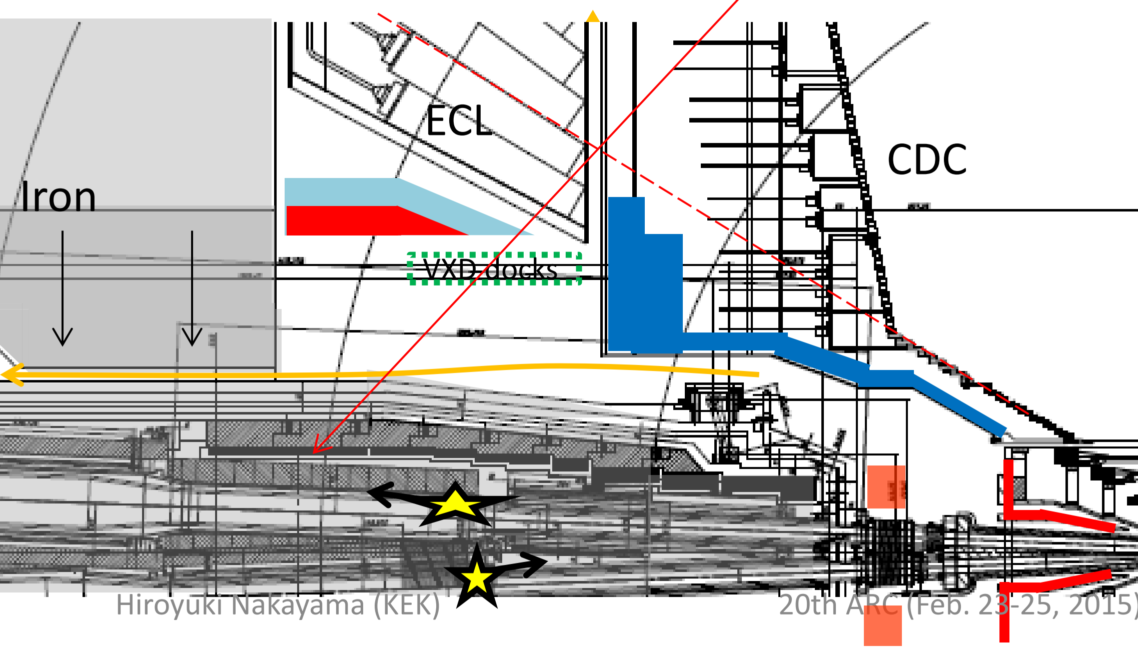
Major beam loss position by Touschek or Beam-gas

Thick tungsten shields can significantly stop background showers originated from |s|>65cm.

Shields outside QCS



Thick tungsten layers inside cryostat



Heavy metal shields to protect VXD from showers generated in cryostat

Neutron shield inside ARICH structure

Neutron shield for CDC elec. board. (Polyethylene)

ECL shield, included for ECL/ARICH simulation (Lead + Polyethylene)

RVC structure in front of QCS stops showers from RBB HER loss at z=60cm (6cm-thick SUS steel assumed)

11^{th} campaign results

20^{th} B2GM background parallel session:
http://kds.kek.jp/sessionDisplay.py?sessionId=203&confId=17439#20150203

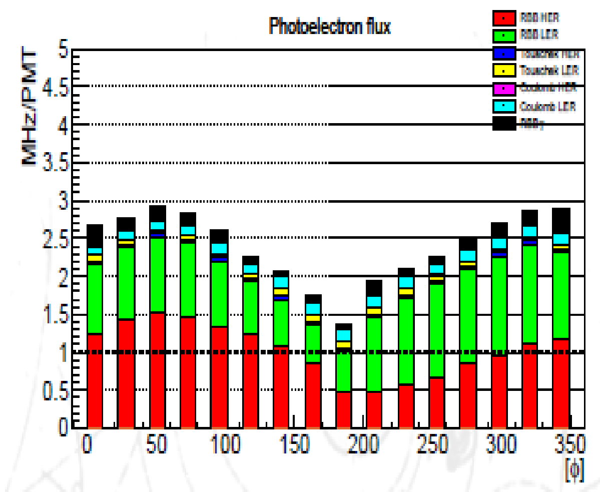
PXD, SVD: OK

Two photon occupancy (%)
layer 1: occ= 0.83 +- 0.05 (max= 0.90)
layer 3: clusters=176.14,
per sensor=12.58 +- 3.14 (max=18.64)

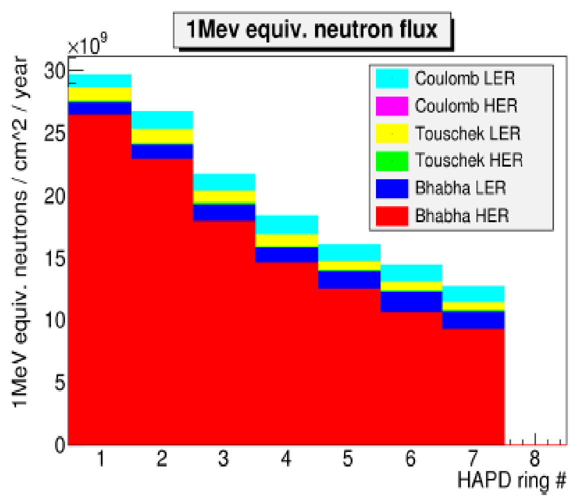
CDC: OK

	10^{th} campaign	11^{th} Campaign	Hardware requirement	Status
CDC hitrate *(kHz/wire)*	<185	<165	<200	ok
Total Dose *(Gy/year)*	<75	<72	<100	ok
Neutron flux *(neutron/cm²/year)*	<120	<110	<100*10⁹	ok

TOP: BAD (need factor x3)



ARICH:OK



ECL:OK

		11th Campaign
Crystal Radiation Dose (Gy/yr)	Forward	3
	Barrel	0.5
	Backward	3.1
Crystal Neutron Flux ($\times 10^9 yr^{-1} cm^{-2}$)	Forward	24
	Barrel	4
	Backward	12.5↓
Diode Radiation Dose (Gy/yr)	Forward	0.7↑
	Barrel	<0.2
	Backward	0.64↓
Diode Neutron Flux ($\times 10^9 yr^{-1} cm^{-2}$)	Forward	24
	Barrel	4
	Backward	12.5↓
Pileup Noise (MeV)	Forward	3.8↓
	Barrel	2
	Backward	5.4↓
Reconstructed Cluster		2.57↓

RBB_LER increased since the last BPAC

Summary for 11th campaign

listing SF<5 only
SF=Safety Factor

	11th campaign result	limit	SF
PXD occupancy	2photon:0.9% , SR:~0.2% (10th)	< 3%	3
CDC wire hit rate	165kHz	<200kHz	1.3
CDC Elec.Borad n-flux*	1.1	<1	1.5
CDC Elec.Board dose	72Gy/yr	<100 Gy/yr	1.3
TOP PMT rate	3MHz/PMT	<1 MHz/PMT	0.3
TOP PCB n-flux*	0.15	<0.5	3
ARICH HAPD n-flux*	0.3	<1	3
ECL crystal dose	3.1 Gy/yr	<10 Gy/yr	3
ECL diode n-flux*	0.24	<1	4
ECL pile-up noise	3.8/1MeV	0.8/0.2MeV at Belle-I	?

KLMs studies are not included

With "combined" shield at inner ECL

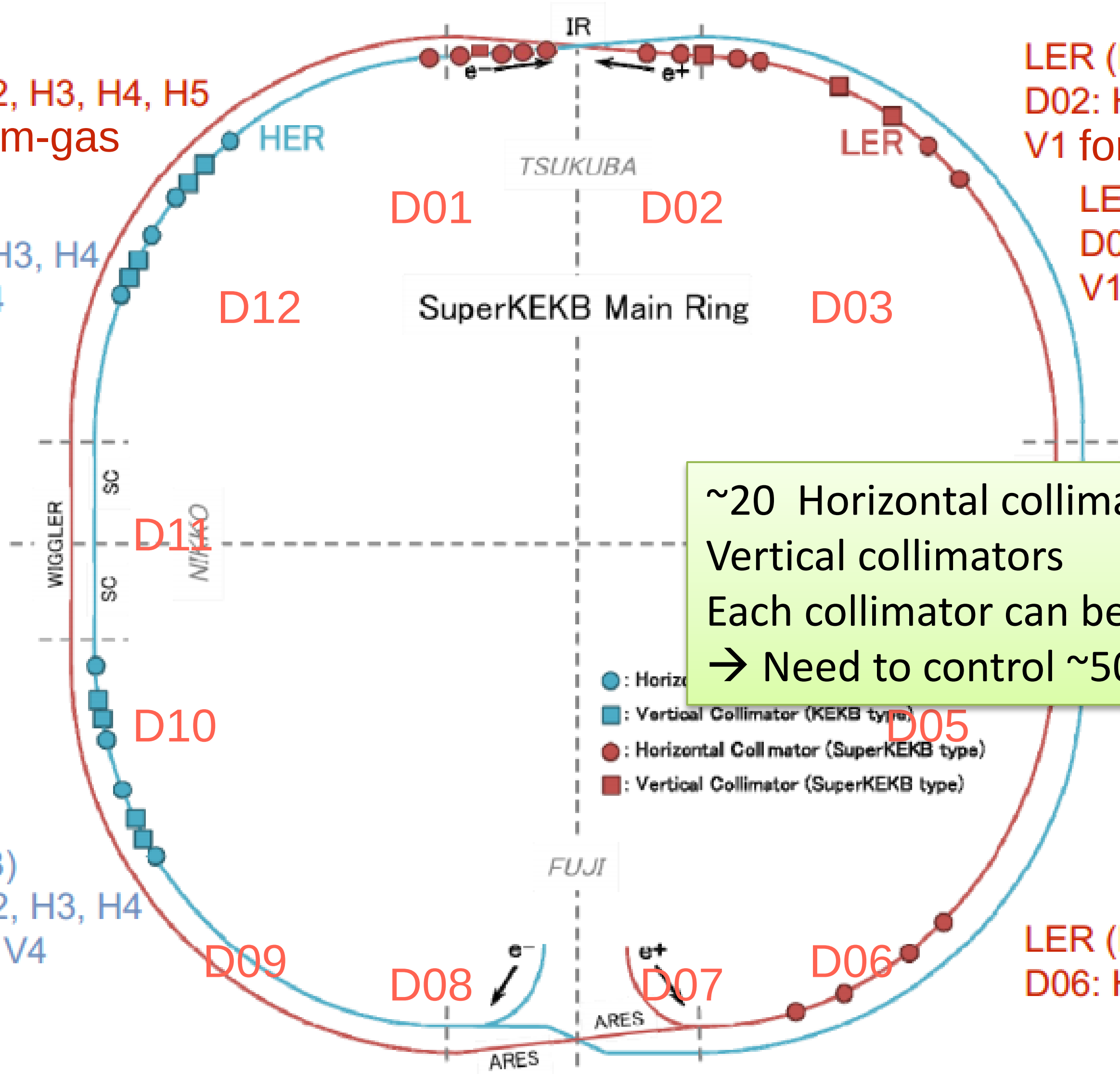
*neutron flux in unit of 10^{11} neutrons/cm2/yr, NIEL-damage weighted

SuperKEKB Collimators Location

HER (New)
D01: H1, H2, H3, H4, H5
V1 for Beam-gas

HER (KEKB)
D12: H1, H2, H3, H4
V1, V2, V3, V4

HER (KEKB)
D09: H1, H2, H3, H4
V1, V2, V3, V4



LER (New)
D02: H1, H2, H3, H4
V1 for Beam-gas

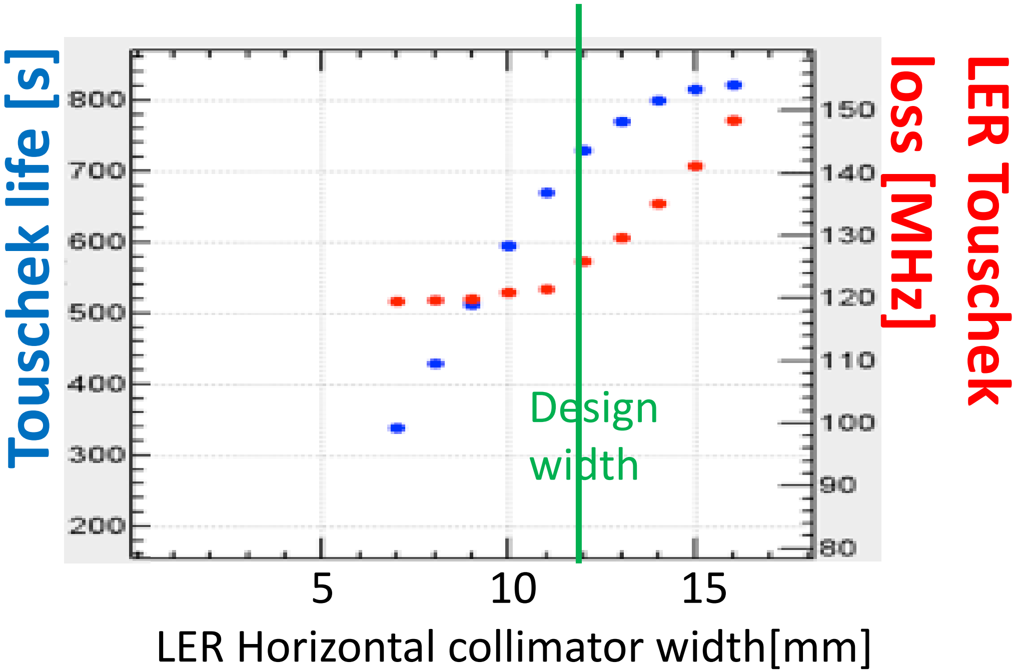
LER (New)
D03: H1, H2
V1, V2

~20 Horizontal collimators and 2 Vertical collimators
Each collimator can be asymmetric
→ Need to control ~50 parameters!

LER (New)
D06: H1, H2, H3, H4

Phase1: new collimators are only at LER D06 H1,H2

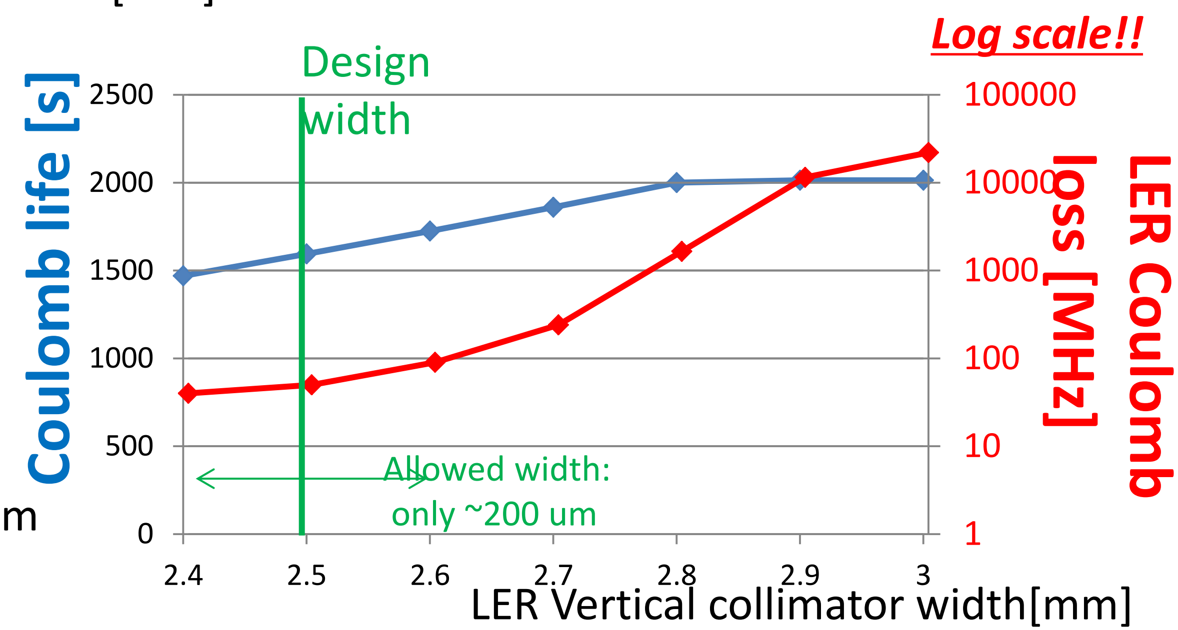
Loss rate vs. LER collimator width



<u>~10 horizontal collimators</u>
- for Touschek
- typical width: ~15mm

<u>1 vertical collimator</u>
- for Beam-gas Coulomb
- typical width: ~2.5 mm
- need careful control
  (mechanical precision: 50um)

Varying only 1 out of ~10 horizontal collimators

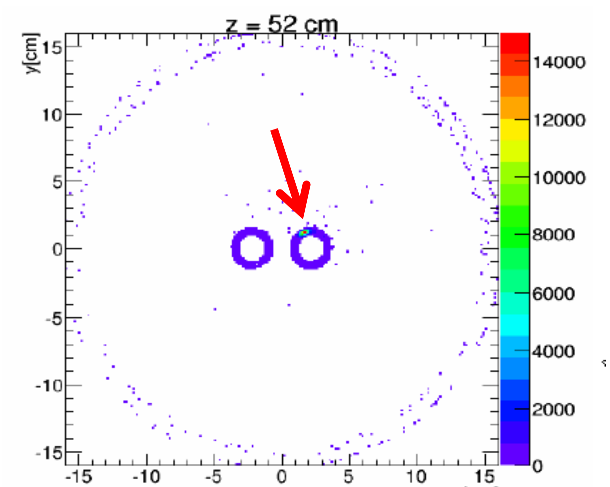


Narrower width is not allowed because TMC beam instability gets too large

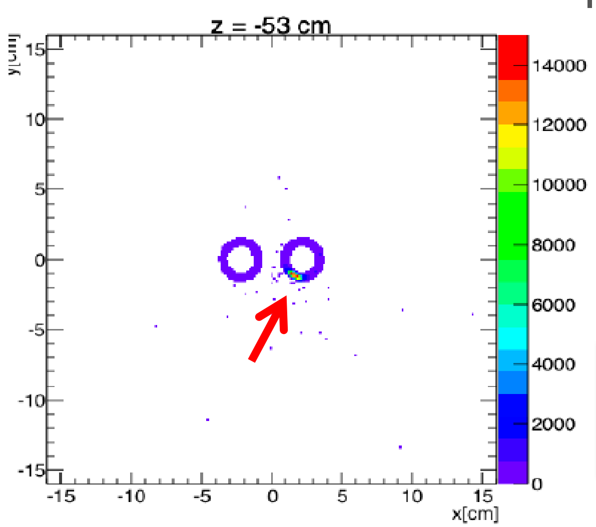
Add shield at RBB hot-spot?

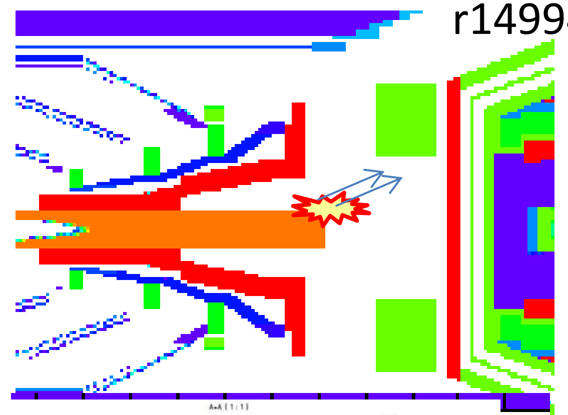
Origin of gammas contributing TOP hits

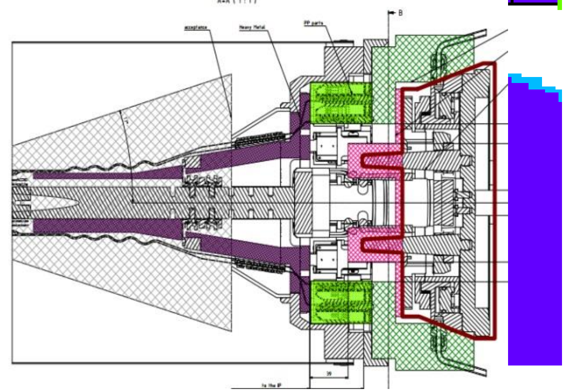
HER



LER







flange flange

Tara (TOP simulation) and Martin (VXD mechanics) are trying to find a space (very crowded actually) for additional shielding to cover hot spot.

Also, simulation geometry needs more realistic implementation (flanges, bellows,etc.).

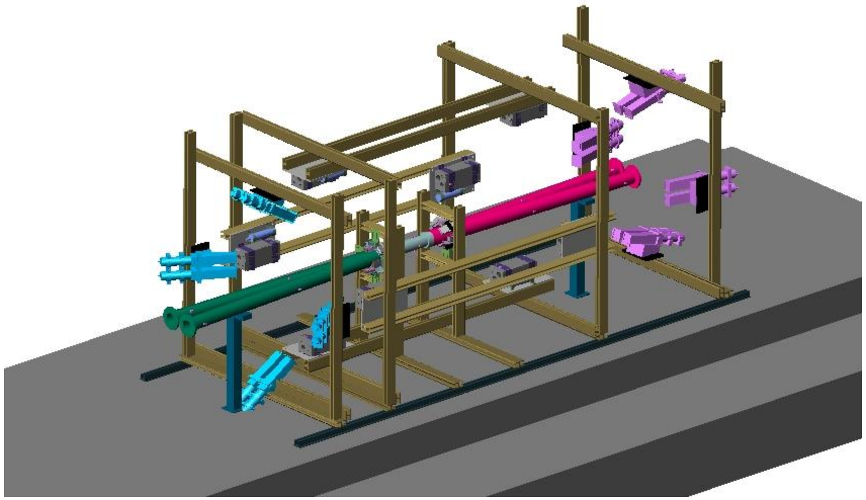
Adding shield around BPM/Bellows between QCS and IP beam pipe is effective to mitigate TOP BG. Space available?

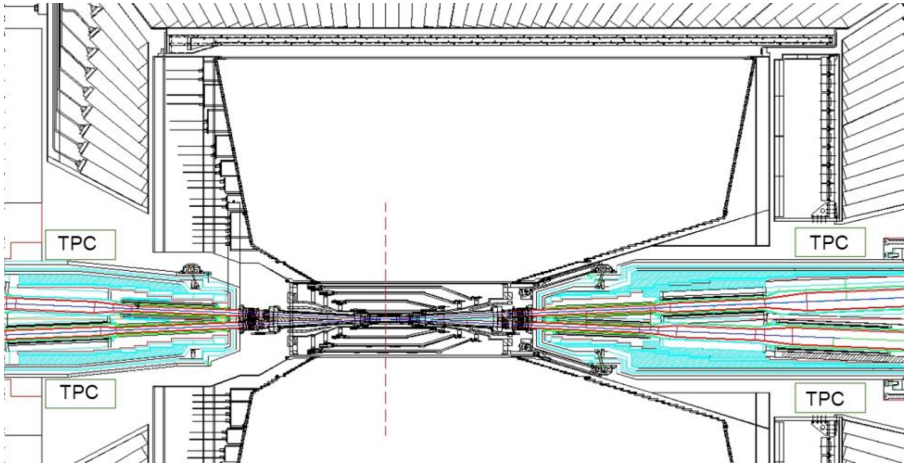
BG simulation summary

- After installing many tungsten shields and careful collimator tuning, simulation shows BG levels are acceptable() for 10 year-operation, except for TOP PMT lifetime
- For further mitigation, additional shield around BPM/bellows are being investigated, but the area is very crowded..
- Safety factor is not so big. Simulation/measurement crosscheck during BEAST period is very important
  - For example, tip-scattering on collimator head (to be simulated)
- Further investigation on possible missing contributions
  - Plan to also include “elastic” Bhabha scattering, spent e+e- from 2-photon process

BEAST

SuperKEKB: Two Commissioning Phases





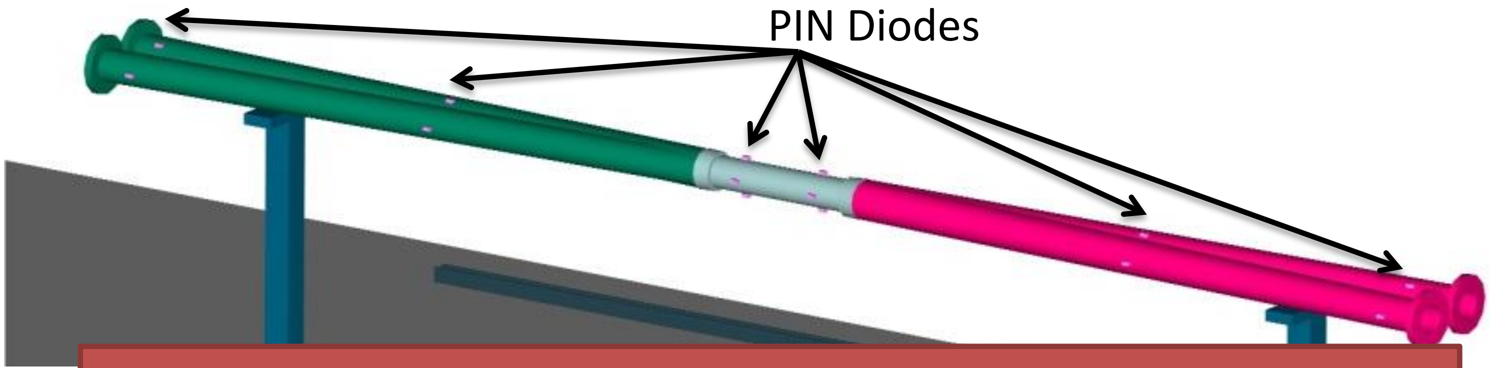
BEAST Phase 1: Jan 2016

- Vacuum scrubbing of beam pipe.
- No collisions. Belle will not roll-in.
- Variety of subsystems on fiberglass support structure
- **No Belle DAQ, only BEAST DAQ**

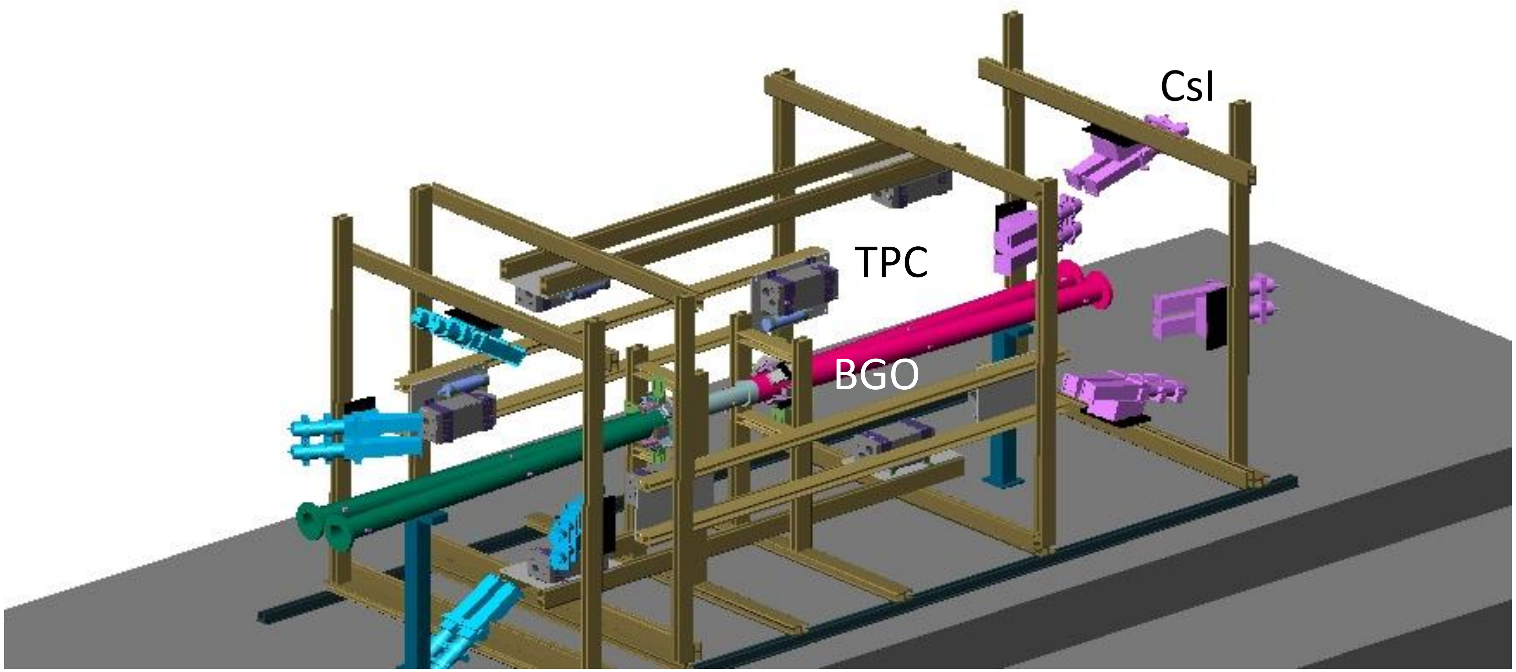
BEAST Phase 2: May (?) 2017

- Belle rolled in.
- VXD BEAST Assembly
  - Partial VXD ladders
  - Other BEAST sensors
- BEAST detectors in dock space and around QCS
- **BEAST DAQ & Belle DAQ**

Phase 1 Design

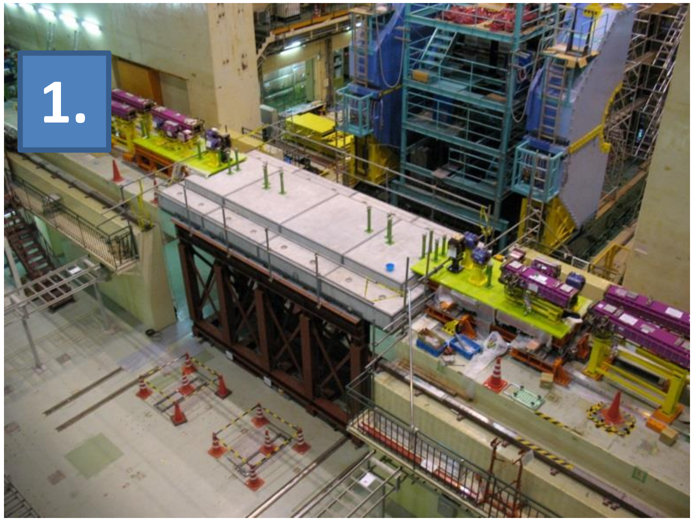


64 channels: 8 z-positions X 4 phi positions X 2 diodes

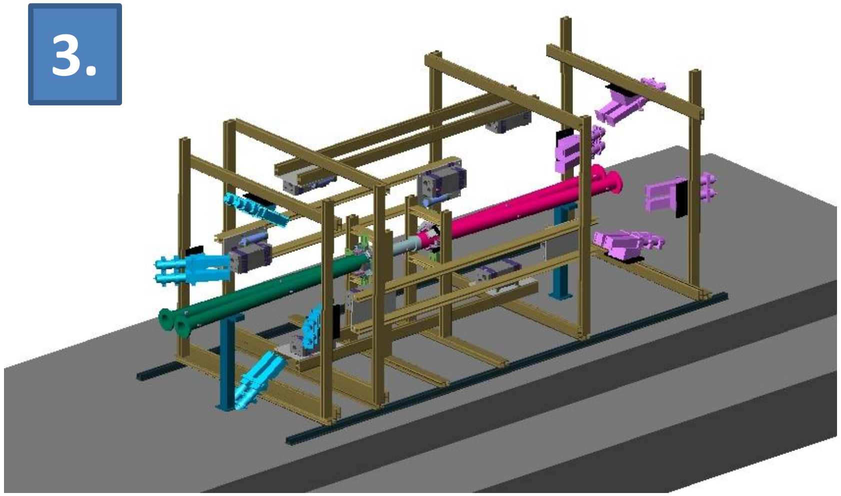


MiniBEAST integration test ongoing in Hawaii. Disassemble and ship to KEK in August.

Installation Plan, Phase 1



Install IP bridge: Completed



Install BEAST Phase 1 at IP: Sep & Oct 2015 [t.b.d.]

IP1 chamber for Phase 1.

Repair & Install IP chamber: ~April & May 2015

Add IP shield wall w/ crane Oct-Nov 2015 [tbd]

BEAST Phase 1 Activities

- Phase1 Priority: Vacuum scrubbing by machine group
- BEAST critical activities
  - Measure SR/particle dose (w/ PIN diodes) to **ensure it is "safe" to roll-in Belle and VXD Beast Setup**
  - Test beam abort system using VXD diamond sensors
  - Establish communication between Beast DAQ and collimator control
- BEAST "desired" activities
  - **First attempt to compare MC and Beast sensor measurement**
  - Touschek/beam-gas machine study (need emittance control bump)
  - Injection damping time measurement (although no LER damping ring)

Would like to request <=1 week for this at end of phase 1.

BEAST Phase2 study

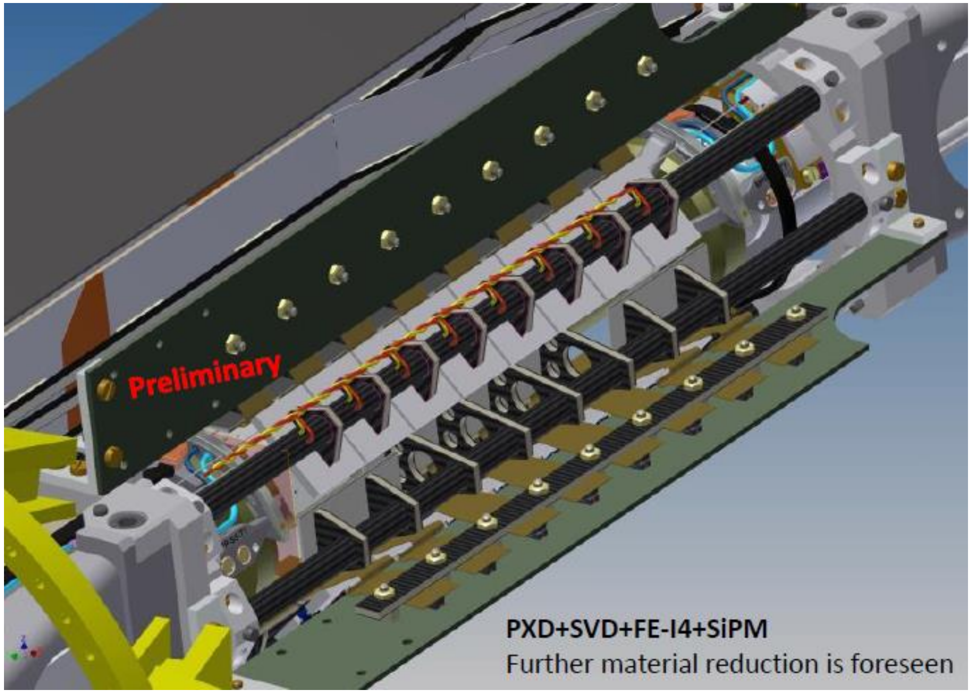
- **Phase2 is most similar to phase3, but still different**
  1. "Detuned" optics with smaller IR beta functions (less SR, Toucheck, Beam-gas)
  2. Worse vacuum level (more Beam-gas)
  3. Smaller luminosity (less RBB/2-photon)
  4. VXD ladders at phi ≠ 0 is missing in phase2
- **We need some extrapolation**
  - For 1, simulation/measurement comparison with detuned optics tells us how much we can believe simulation with final optics
    - Collimator secondary shower effect can be measured at phase2.
  - For 2. and 3. extrapolation is rather straightforward.
  - For 4, beast sensor measurements at phi≠0 is important.
- **Separate measurement of each BG sources** is important
  - Vary **beam size , vacuum level , luminosity** to disentangle Touschek, BeamGas, RBB and 2photon (same approach with 2010 BG study)
  - Validate simulation results with measurement

BEAST Phase2 study

- **Need all sub-detectors DAQ running** (at random trigger)
  - global Belle II DAQ (partial VXD, CDC, TOP, ARICH,BKLM,EKLM, TRG)
  - Extrapolate measured each sub-detector BG level to phase3
  - Sub-detector DQM records are useful for analysis
- **Other commissioning items during phase2 period**
  - Slow control (EPICS) communication, timing signals connection btw SuperKEKB-Belle2, beam abort/injection interlock
  - VXD CO2 cooling, injection noise damping-time measurement, PXD ROI finding etc…
  - **Collimator optimization study**
    - Simulation/measurement comparison with various collimator settings
    - Develop strategy how to reach optimal collimator setting

Phase 2 Detectors

- VXD BEAST assembly
  - SVD, PXD ladders at phi=0
  - Dedicated background and environment sensors (see next page)
- Scintillators and PIN diodes around QCS
- Neutron detector in dock space



Tremendous progress on BEAST VXD assembly mechanical design and plan

Feb. 4, 2015

Phase-2 sensors in VXD volume

sensor	contact person	number	location	DAQ	note
PXD + SVD	C. Marinas K. Nakamura	2 PXD ladders 4 SVD ladders	decided +X	Belle II DAQ	
diamond w/ PIN diode (beam BG, abort)	L. Vitale	4 diamonds 64 PIN diodes	diamond: decided	Belle II monitor DB (EPICS)	PIN diode location: around diamond and beam pipe
FE-I4 pixels (Synchrotron rad. and track multiplicity)	C. Marinas	3 arms	decided (90, 180, 270)	?	arm design has to be fixed
CLAWS (beam BG)	F. Simon	2 ladders	decided (135 and 225)	?	
Scintillator PIN diode (beam BG)	H. Nakayama K. Nakamura	~60 (scintillator) ? (PIN diode)	not decided	?	Basically put them around QCS
BGO (Bhabha events)	J. Liau	8 (if space allows)	under discussion	BEAST DAQ	Acceptance is overlapped with PXD cooling block.
temperature (NTC), humidity (DMT242B) (crosscheck for FOS)	L. Vitale	not decided	not decided	Belle II monitor DB	
FOS + L-shape (temp. and humidity)	I. Vila D. Moya	?	?	?	sensor on outer cover?
PLUME (beam BG)	I. Ripp-Baudot	1 ladder	not decided	EPICS DB BEAST DAQ?	baseline: PLUME-2 (hopefully PLUME-3)

See backup slides for more on these systems.

What is the end of phase 2?

- Accelerator reaches L ~ 10^{34} cm^{-2} s^{-1}
- VXD group agrees BG levels are acceptable, for safe installation of their detector – criteria to be defined in note
- All required VXD related protection systems and services have been tested and are functional (beam abort, interlock, VXD cooling, slow control, collimator strategy)

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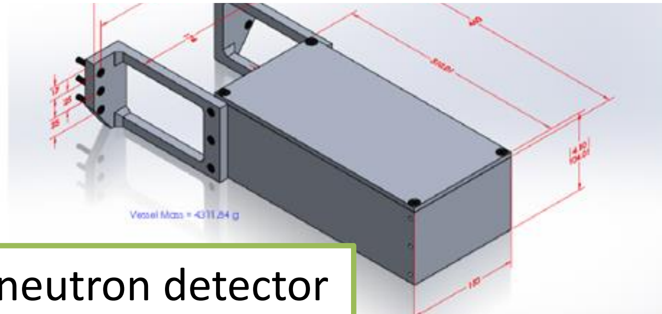
BEAST Conclusion & Outlook

- Beam Background group to perform a rich set of background measurements, both with BEAST detectors and Belle II
- BEAST detector construction more or less on (tight) schedule
- Next Major Milestones, phase 1
  - MiniBEAST at U. Hawaii: Jan 2015
  - Install BEAST at IP: approx. Aug – Oct 2015
  - Operate with first beams: mid Jan 2016
- Next Challenges, phase 2
  - Decide on PLUME and BGO inclusion in phase 2
  - Finalize VXD space mechanics, cable routing through dock space, Develop phase 2 installation plan w/ schedule
  - Complete document on measurement plan
- Critical Follow-up Issues
  - Agree on exact phase 1 install dates
  - Need to decide on BGO, PLUME inclusion
  - For BG/collimator studies, we request ~1 week in phase 1, ~2 weeks in phase 2

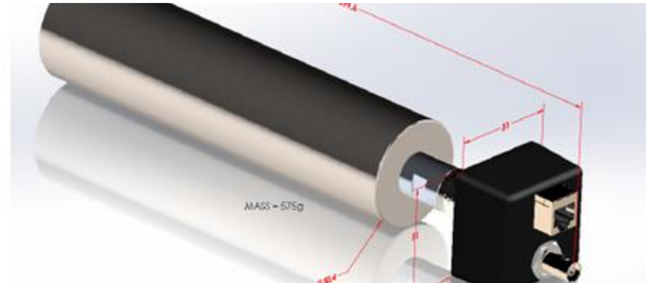
BEAST team surveying IP area

backup

Phase II: Dock Space

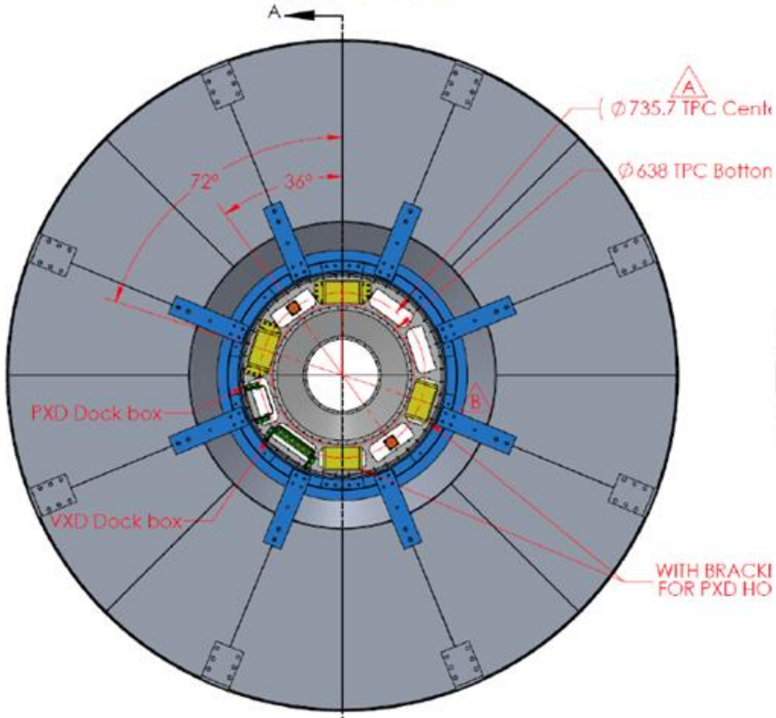


TPC fast neutron detector

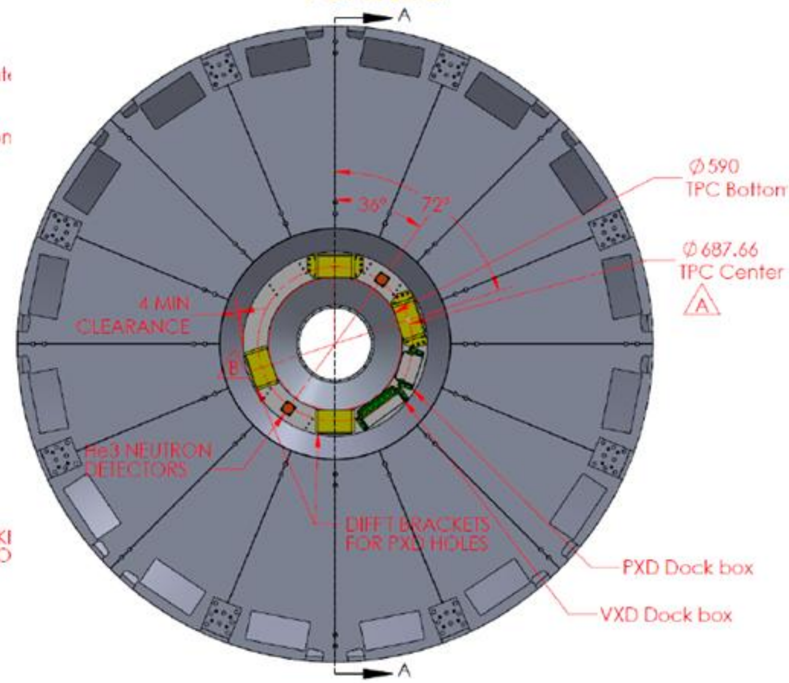


He-3 thermal neutron detectors

Backward



Forward

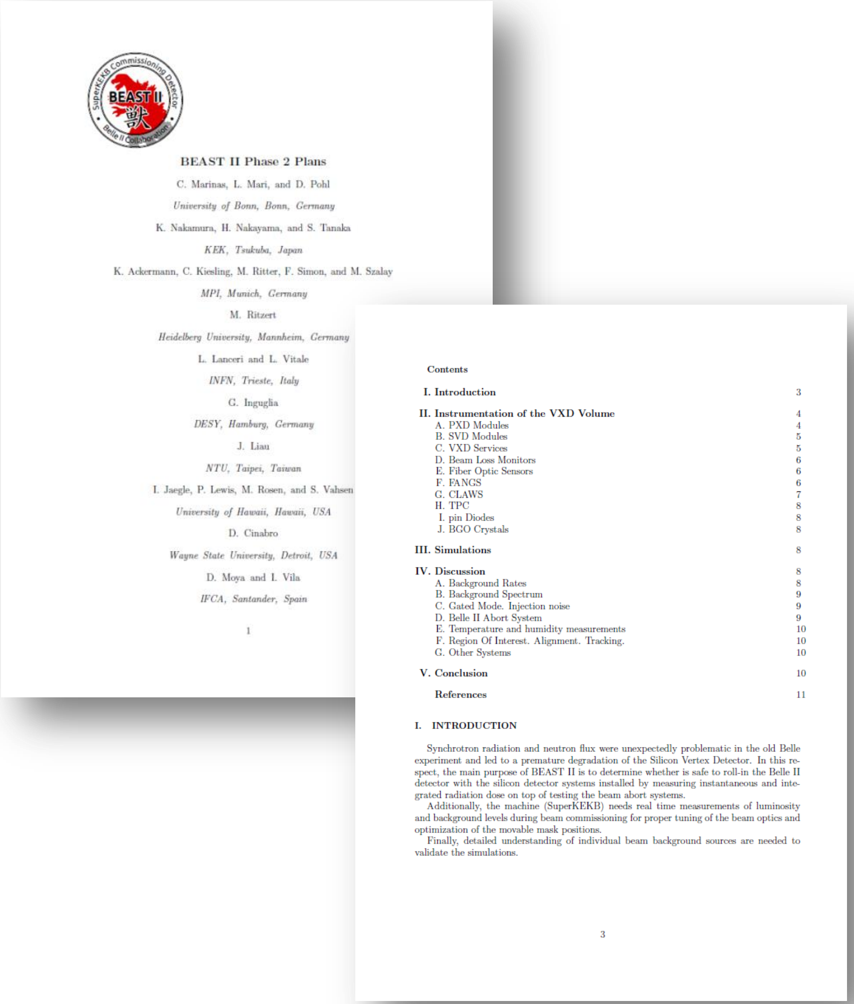


Neutron detectors in dock space will provide complimentary information. Neutrons hard to simulate.

Heroic CAD effort by Alexandre Beaulieu (Victoria) confirmed detectors fit into VXD docks.

Document for the BEAST detailed plan

- C. Marinas prepared VXD plans for phase 2 in detail
- We plan to expand this into Belle2Note, to cover all beam background plans
  - i.e. follow-up to outdated BEAST TDR



BEAST II Phase 2 Plans

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Contents

I. INTRODUCTION

Synchrotron radiation and neutron flux were unexpectedly problematic in the old Belle experiment and led to a premature degradation of the Silicon Vertex Detector. In this respect, the main purpose of BEAST II is to determine whether is safe to roll-in the Belle II detector with the silicon detector systems installed by measuring instantaneous and integrated radiation dose on top of testing the beam abort systems.

Additionally, the machine (SuperKEKB) needs real time measurements of luminosity and background levels during beam commissioning for proper tuning of the beam optics and optimization of the movable mask positions.

Finally, detailed understanding of individual beam background sources are needed to validate the simulations.

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Goal of Commissioning Phase 2

Many group working with different goals during phase 2. Beam background measurements are just a small part of the overall program

- Beam commissioning to start collision (machine group: KCG)
  - Forward luminosity monitors(ZDLM) for knob tuning
- BG measurements and mitigation (KEK Belle group: BCG)
  - BG studies of each component to check consistency with simulation
  - Studies of relation between VXD hits and monitor hits
  - Beam collimators control study
  - Neutron measurement (fast and slow)
- Belle II commissioning with partial VXD sensors (Belle II shift)
  - Full Belle II DAQ
  - Slow control (also communication with machine)
  - PXD RoI finding with CDC+SVD tracking data
  - Detector noise check
  - **And investigation and confirmation to install the full VXD**
- Optimization of interlock system
  - Slow info. Some alarms or abort by environmental or rad. Monitors, beam injection interlock
  - First info.: beam abort by hard wired signals

Goal of Commissioning Phase 2 (part II)

- Beam injection BG study (VXD group)
  - BG damping time measurement for Trigger veto gate
    - Requiring storing veto gate width to condition database
    - With moderate update timing
- First try of CO_2 cooling system for VXD sensors (VXD group)
  - Checking water vapor level by sucking air
  - cold and warm dry volume
- Detailed characterization of beam backgrounds (BEAST group)
  - Target luminosity at phase-2 is L ~ 10^{34} cm^{-2} s^{-1} , and BG structure is not exactly same as phase-3. We need somehow extrapolation to expect phase-3 beam BG.
    - how to extrapolate it?
      - We have a lot of monitor sensors, diamond sensors, 64 PIN diodes, FE-I4, CLOWS.
      - Effect from each BG component has to be measured separately
      - This extrapolation can be done only after the BG is well controlled by collimator studies.
      - Deferent BG components have different dependence for collimator setting.

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BG simulation tasks

- BBBREM+BHWIDE combined sample study -- Hiro, Chris, Funakoshi
  - Now only using BBBREM, which always emits 1photon
  - Include elastic scattering contribution with BHWIDE
- Two-photon spent e+/e- tracking by SAD, for outer detectors -- Hiro, Marin, Funakoshi
- RBB gamma -- Hiro
- SR simulation with Beast optics (both phase1/2) -- Yuri
- Beam-gas for Beast phase2 with detuned optics --Ohnishi
- Collimator dependence with fine steps (50um/100um/200um) -- Ohnishi
- EKLM polyethylene shield study – resume KLM group activity!
- Collimator secondary shower study -- Uvic student?
- SAD install in KEKCC clusters? – software group experts

Summary for 8th campaign

* Not including halo ,
mis-alignment effect

SF=Safety Factor

	8th campaign result	limit	SF
PXD occupancy	2photon:0.8% (from 7th), SR:~0.1%*	< 3%	<3
CDC wire hit rate	~100kHz	<200kHz	2
CDC Elec.Borad n-flux*	0.8	<1	1
CDC Elec.Board dose	~20Gy/yr	<100 Gy/yr	5
TOP PMT rate	2MHz/PMT	<1 MHz/PMT	0.5
TOP PCB n-flux*	0.5	<1	2
ARICH HAPD n-flux*	0.65	<1	1
ECL crystal dose	13Gy/yr	<10 Gy/yr	1
ECL diode n-flux*	1.2	<1	1
ECL pile-up noise	5/1MeV	0.8/0.2MeV at Belle-I	?

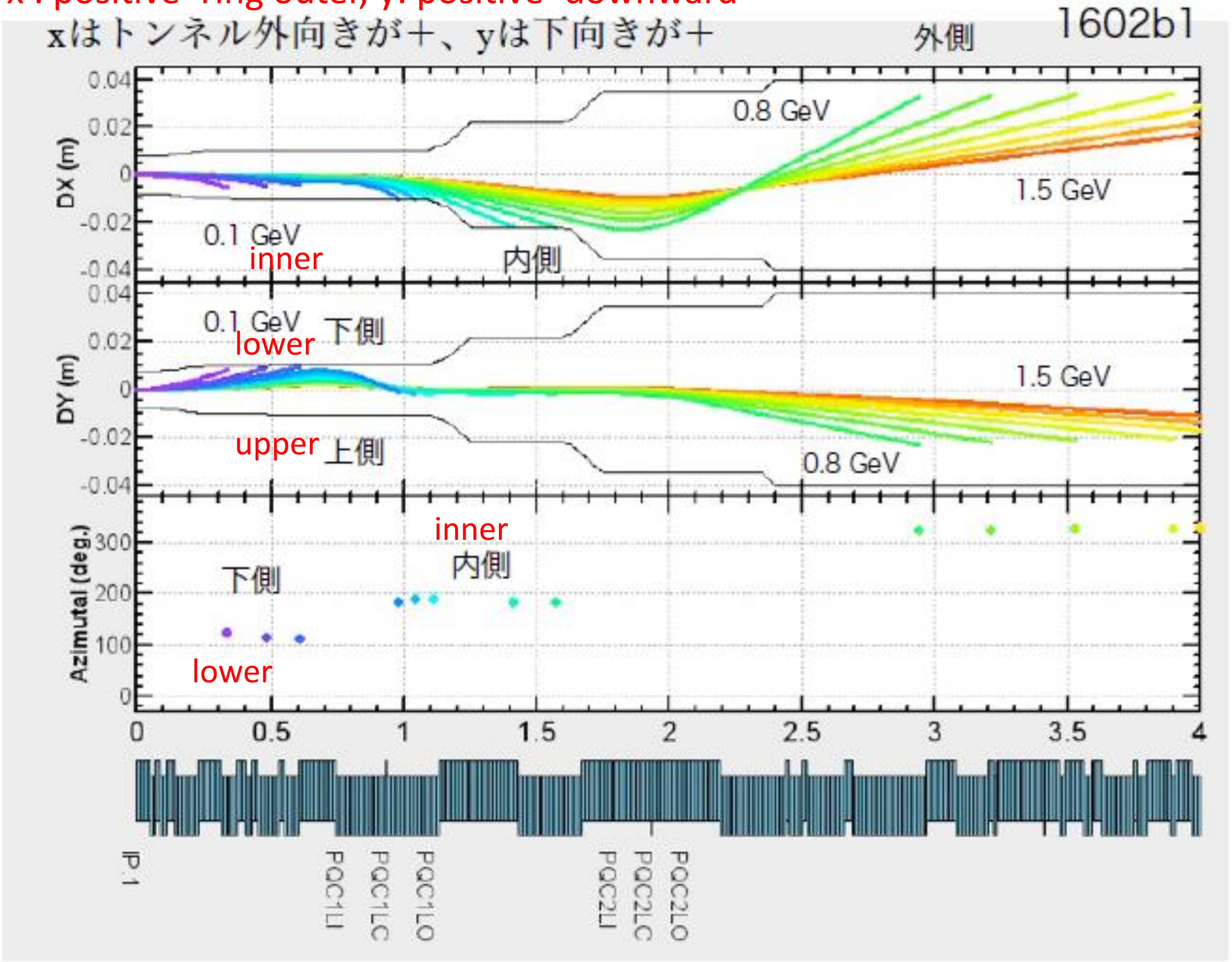
KLMs are not included
showing SF<5 only
(SVD is not shown 'cause it's very save)

With "combined" shield inside ECL

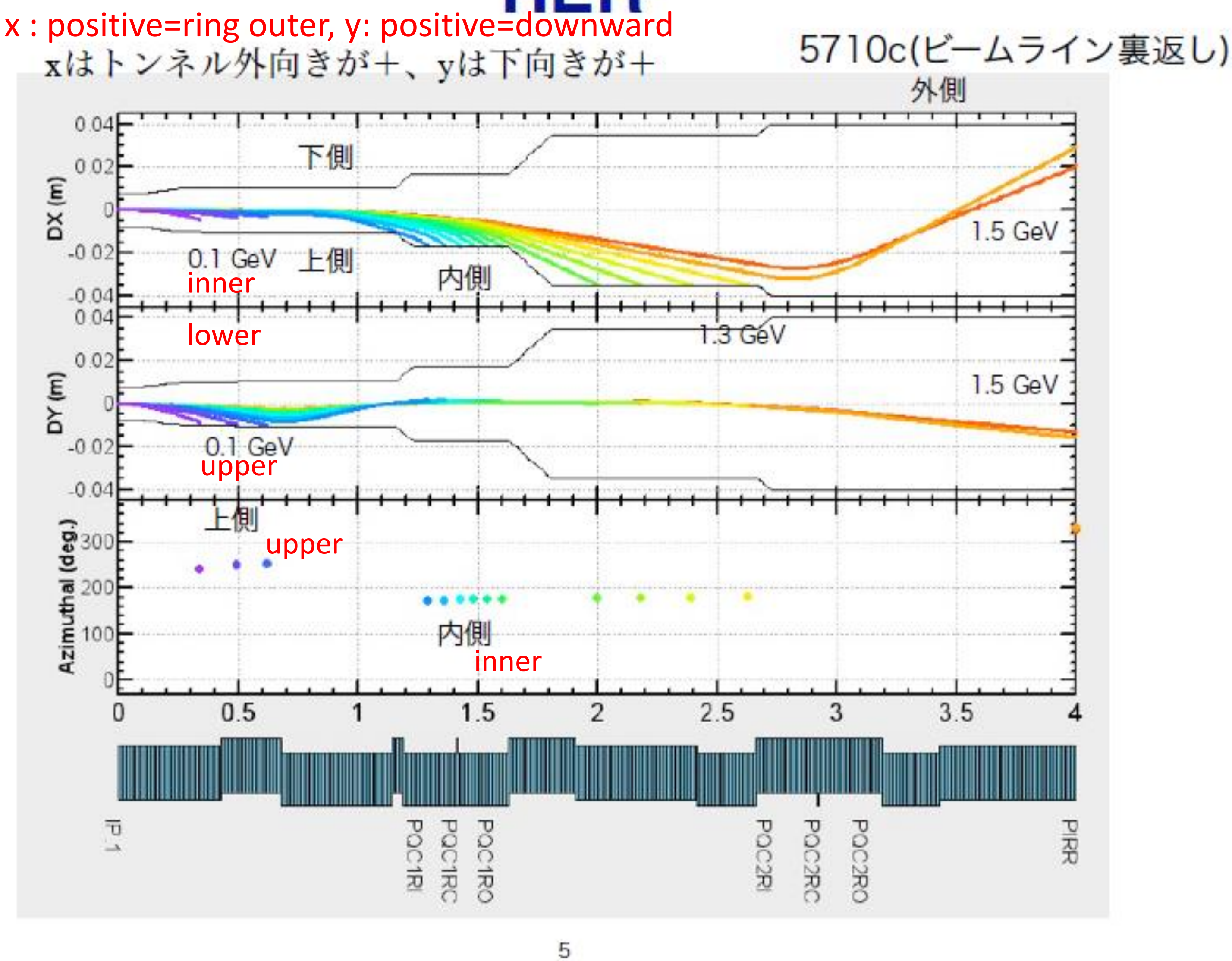
*neutron flux in unit of 10^{11} neutrons/cm2/yr, NIEL-damage weighted

LER

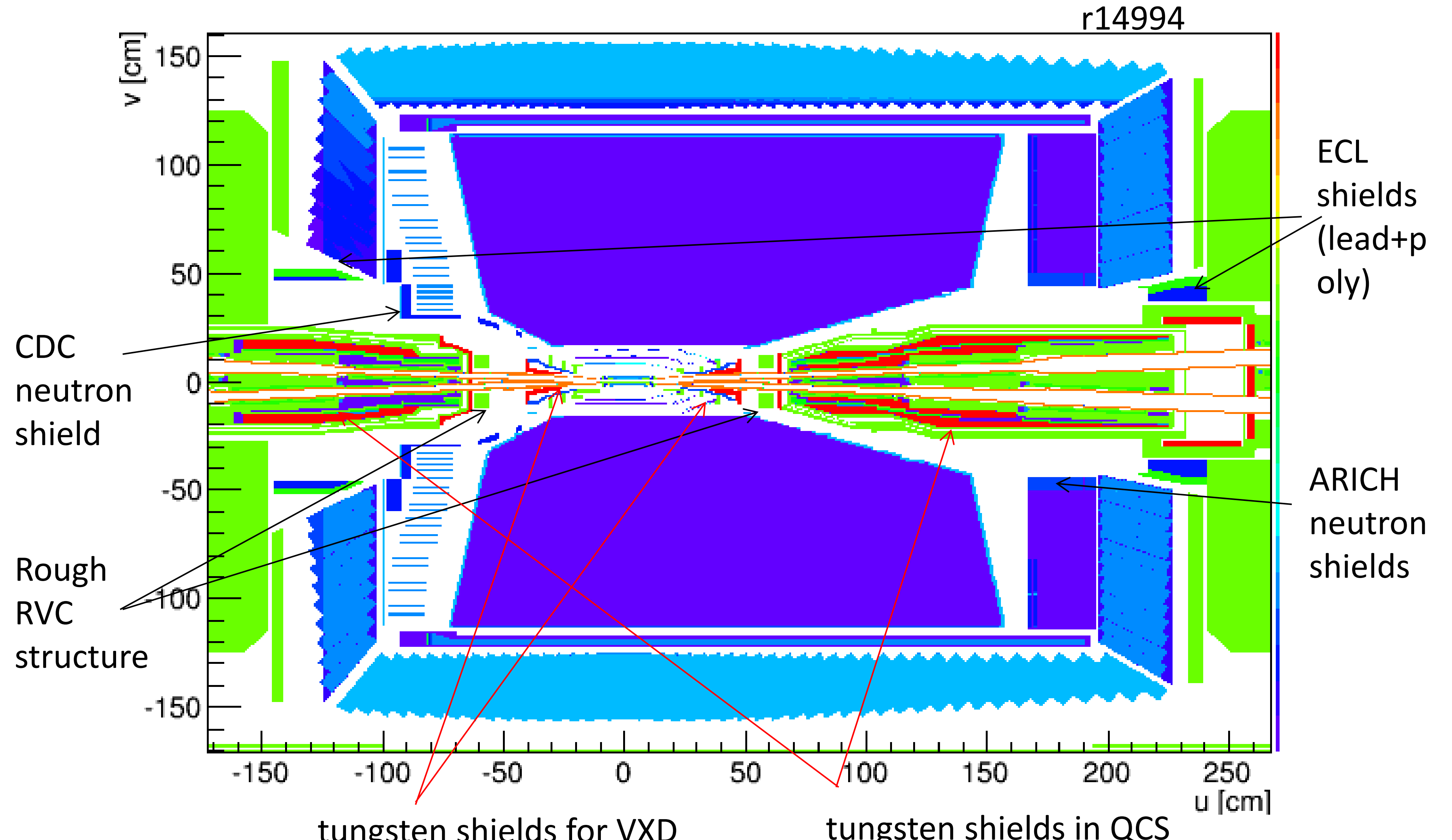
x : positive=ring outer, y: positive=downward



HER

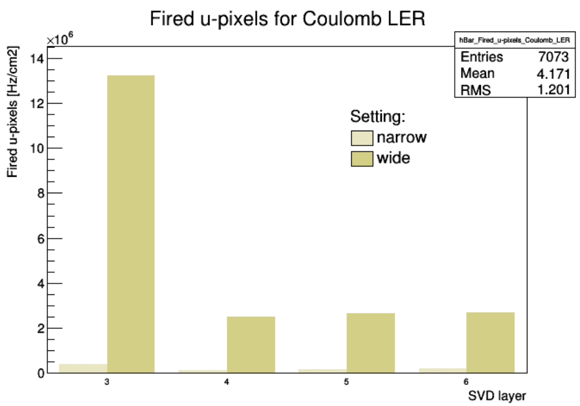

x : positive=ring outer, y: positive=downward
xはトンネル外向きが+、yは下向きが+
5710c(ビームライン裏返し)
外側
下側
上側
内側
0.1 GeV
inner
lower
1.3 GeV
1.5 GeV
upper
上側
upper
内側
inner
DX (m)
DY (m)
Azimuthal (deg.)
IP_1
PQC1RI
PQC1RC
PQC1RO
PQC2RI
PQC2RC
PQC2RO
PIRR
5

Simulation Geometry

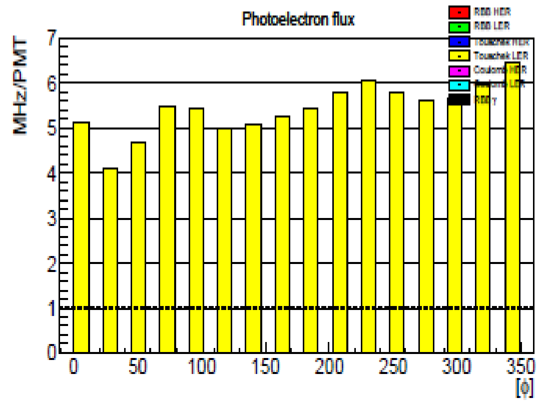


BG level with “1mm-wider” LER collimators

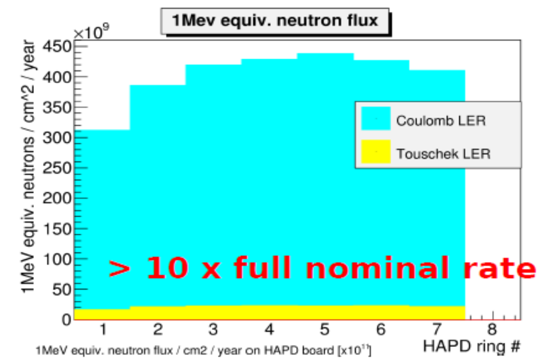
SVD



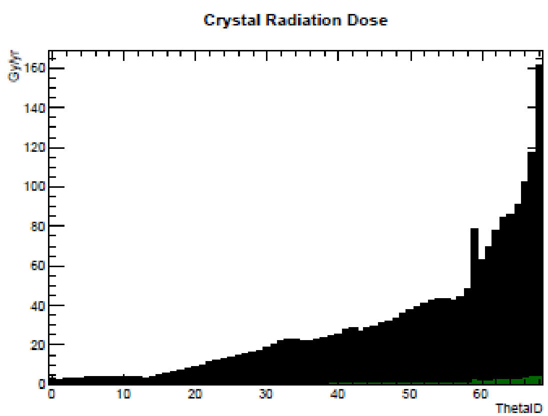
TOP



ARICH



ECL



50um/100um/200um-wider samples will be prepared

Nightmare for any detectors. Note that collimator precision is ~50um, so this should not happen!

IF such severe BG happens, we need to abort beams. VXD radiation sensor can issue aborts, but it only sees BG level in VXD volume. Outer detectors want to have their own BG monitors? (ECL dose monitor, etc.)

Characteristic BG hit distribution is seen for each of H/V collimator open situation. This helps to detect which collimator went wrong.

Question on Bhabha generator

- So far we used BBBREM for BG campaigns
  - BBBREM: always emit 1 photon
  - Minimum E_γ fraction= 1e-6 → 0.52 barn
  - Only $E_{lab}(e^+)$<3.85GeV, $E_{lab}(e^-)$<6.85GeV are used
    - Assuming small ΔE particles just go though QCS beam pipe
- All phase space contributing to detector BG is covered by BBBREM?
  - Elastic scattering?
  - Large angle scattering with small ΔE?

Two generators for different phase space regions

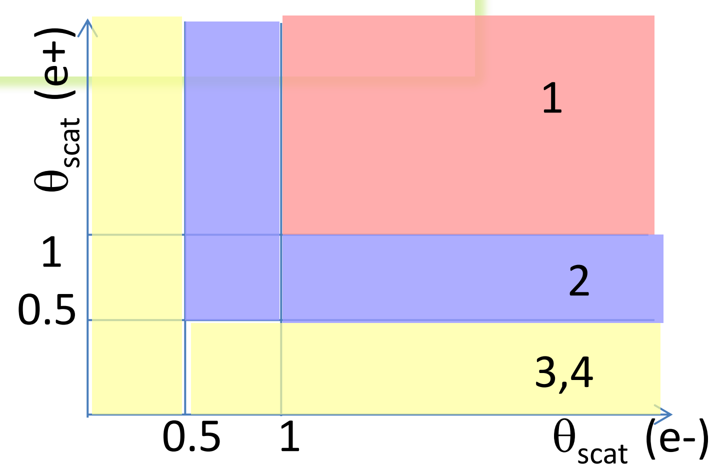
- Here is what I propose for the four samples:

1. $\mathrm{Min}(\theta_{scat}) > 1°$	BHWide	GEANT
2. $0.5° < \mathrm{Min}(\theta_{scat}) < 1°$	BHWide	accelerator group
3. $\mathrm{Min}(\theta_{scat}) < 0.5°$, back-to-back		neglect
4. $\mathrm{Min}(\theta_{scat}) < 0.5° + \gamma$	BBBrem	accelerator group

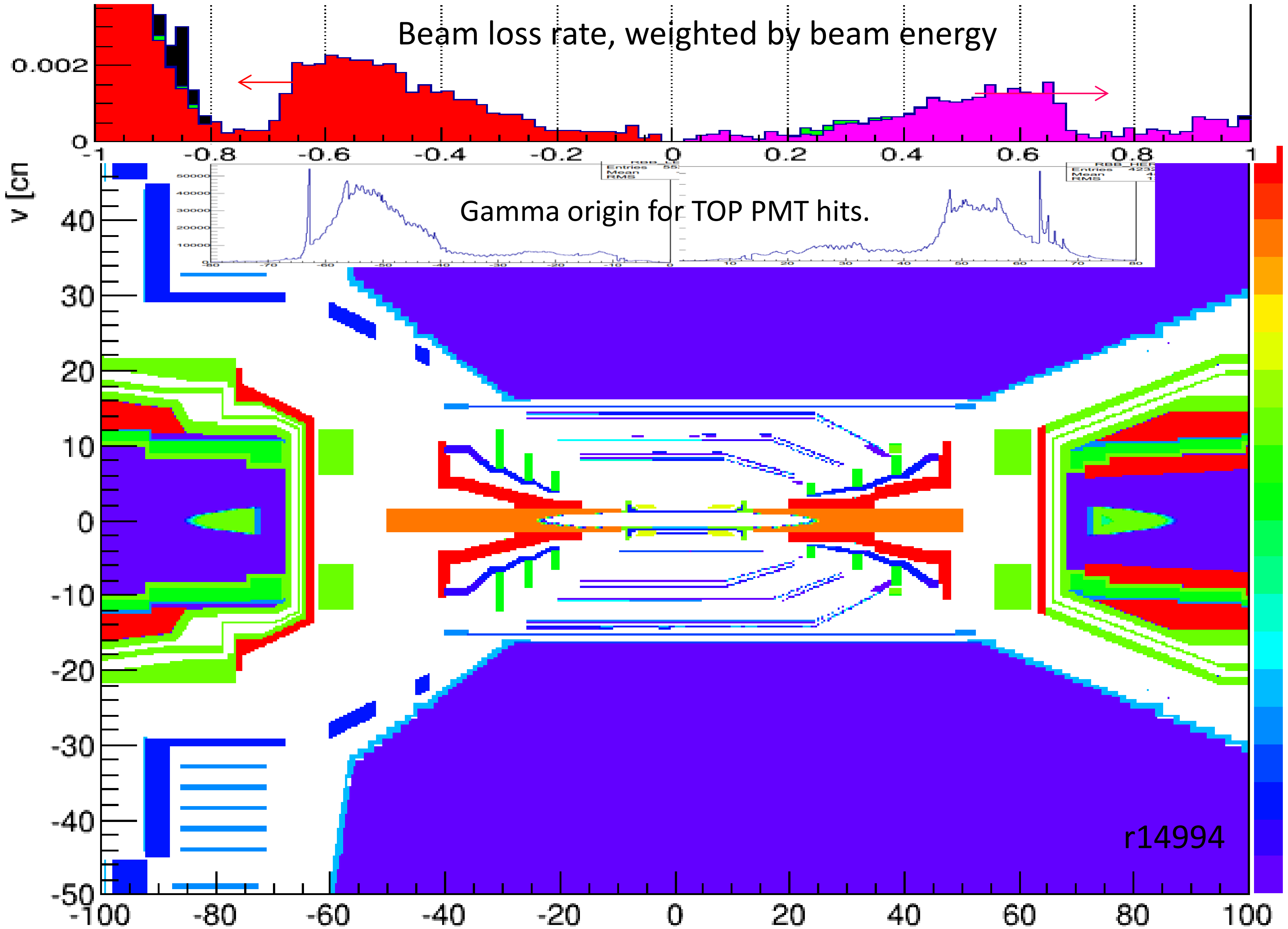
- I believe that the contribution from 2 is small compared to 1 and 4.

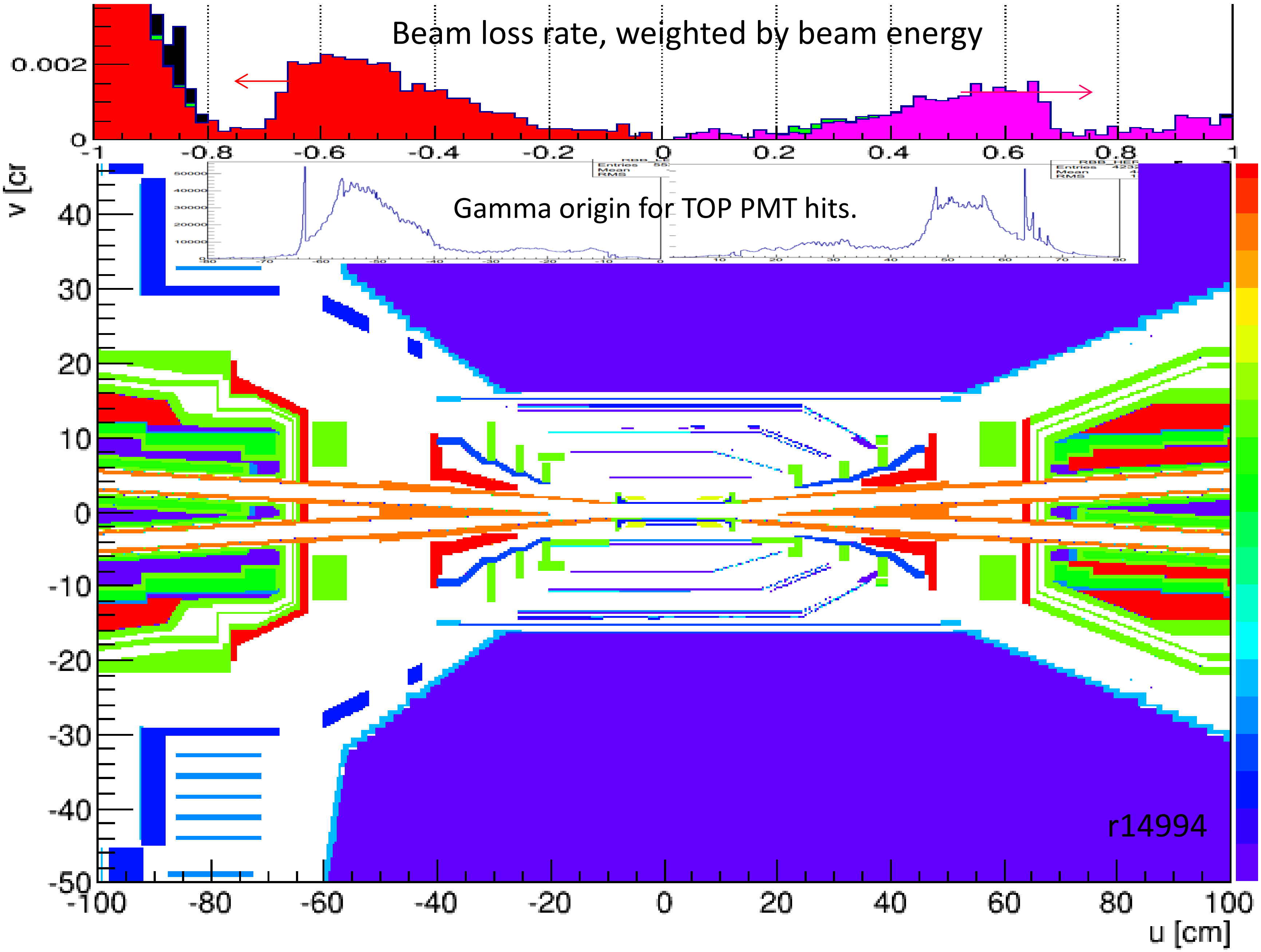
Detailed investigation by C. Hearty (UBC)

These regions are carefully chosen to avoid overlap between BBBREM and BHWIDE

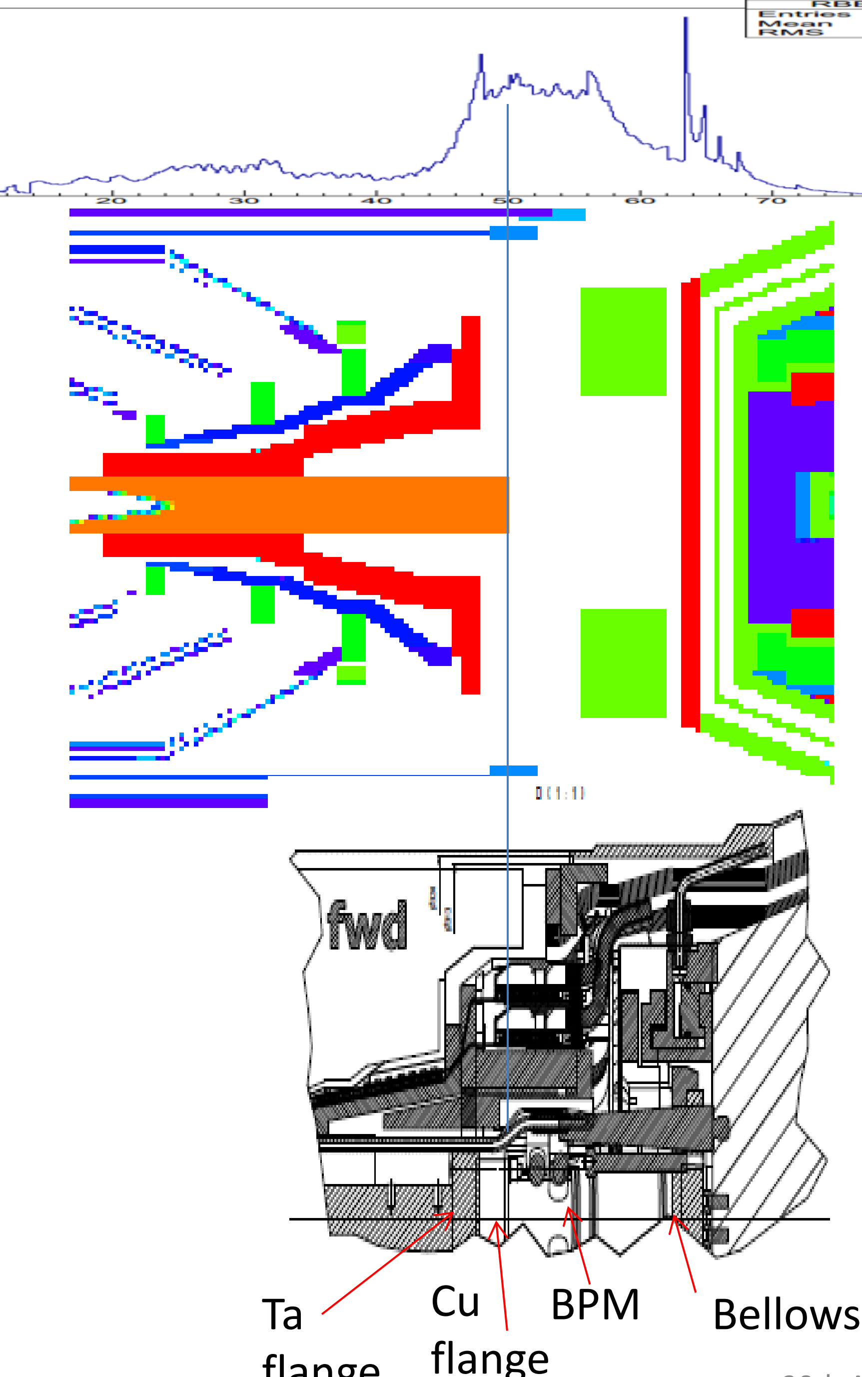


Included in next(12th) campaign


Beam loss rate, weighted by beam energy
Gamma origin for TOP PMT hits.
r14994



Beam loss rate, weighted by beam energy
Gamma origin for TOP PMT hits.
r14994
v [cm]
u [cm]



Around z=500~650mm, beam pipe is implemented as 5mm-thick Ta pipe.

In reality, there are
- 18mm-thick Ta flange(z=464~482mm)
- 18mm-thick Cu flange(z=482~500mm)
which gives further shielding effect.

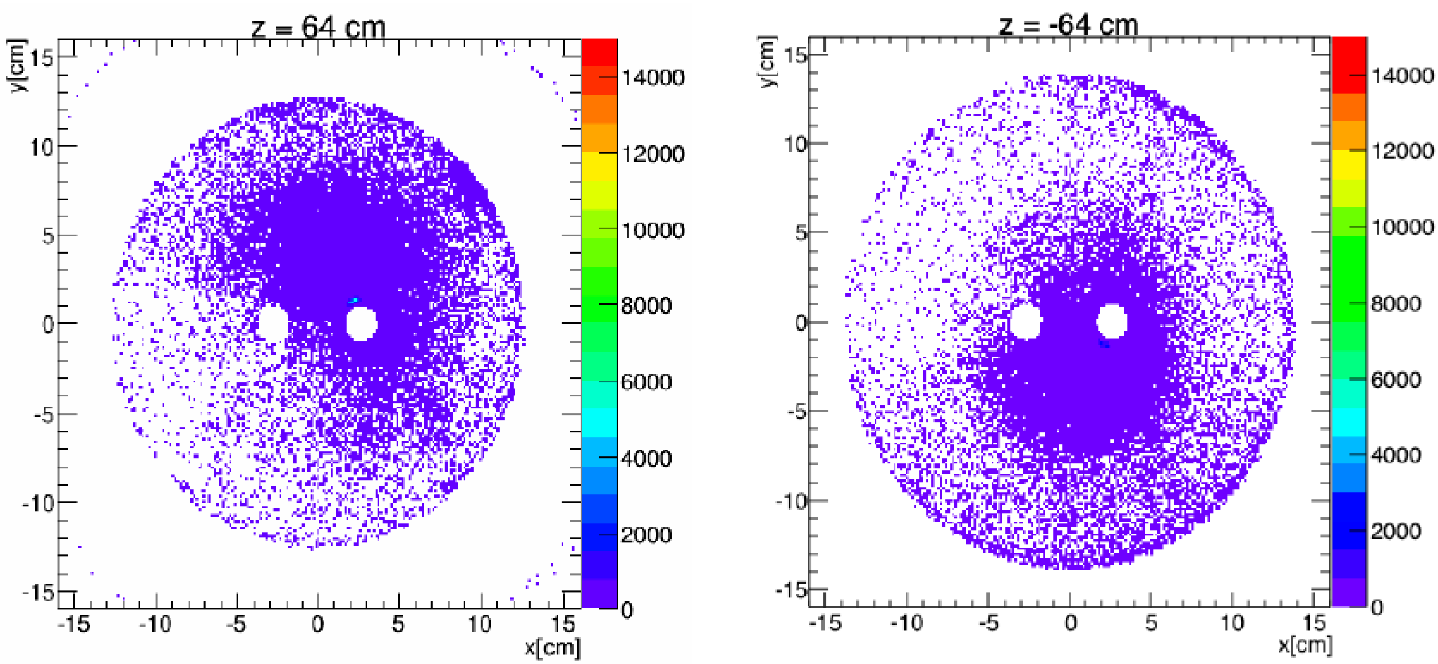
However, BPM beam pipe are only 7mm-thick Cu pipe and bellows are also thinner, which gives more shower leakage.

I was aware these pipes are thin, and assumed we are able to add some shielding here which is equivalent to 5mm-Ta.
I will update basf2 geometry soon.

RBB shower on QCS front plate to TOP

RBB Slices along z

HER | LER



hot: $47 < z < 55$ cm

hot: $-55 < z < -48$ cm

P. Krizan at TOP review in Nov. 2014

Strategy with PMT distribution

→ We can run in such background conditions, but ~half of the PMTs will have to be replaced.

How to distribute

- normal type MCP PMTs (average max. charge ~1.1 C/cm^2)
- ALD type MCP PMTs (average max. charge ~8.6 C/cm^2)

Decision:

- Equip bar boxes with only one type of PMTs

Arguments

- Experience in exchanging of PMTs in a bar box: few hours exercise
- The main job will be to get access to the service hatch of the bar box through cables, cooling etc of other detectors → we do not want to do it for all boxes!

Backup SR

Y. Soloviev(DESY)

Preamble

1. Generation of primary charged particle (beam) and simulation of SynchRad photon emission during propagation of initial particles through magnetic field (primary simulation, GEANT4 based) requires very large (unreal) CPU to get full picture of synchrotron radiation background (needs to generate hits in a few ROF to observe scattered photons).
An idea to generate only SynRad photons using vertex information for SynRad photons from primary simulation has been actualized (PV,YS) and speedup significantly the simulation.
Primary simulation is performed every time when geometry (lattice,beam pipe design etc.) is changed. Output of primary simulation is transformed into HEPEVt file which is used as input for the next step of simulation (occupancy estimation,creation of the background files etc).

2. Estimation of PXD occupancy and creation of background files for ideal alignment of the central beam pipe has been performed. Cross check: PySynRad (AM python based) and GEANT4 based approaches gives similar results for PXD occupancy (with the same lattice files).
Recently I have found the way how to modify *GeoBeamPipeCreator.cc* code, which I seem to have missed earlier, to include misalignment of central beam pipe in the simulation → PXD occupancy with misalignment.

3. Beam Halo.
Conservative estimation:
Uniform halo – 2D circular flat distribution of (X,X')/(Y,Y') in normalized coordinates with radius ***20*√εx/εy*** (half width = 20σxy of the core).
Normalization factor - assuming that fraction of tails beyond 10σxy = 1e-5 of the core. (KEKB TDR)
The fraction of tails beyond 10σx and beyond 30σy estimated from beam-beam simulation for SuperKEKB ≤ 5e-7 of the core.

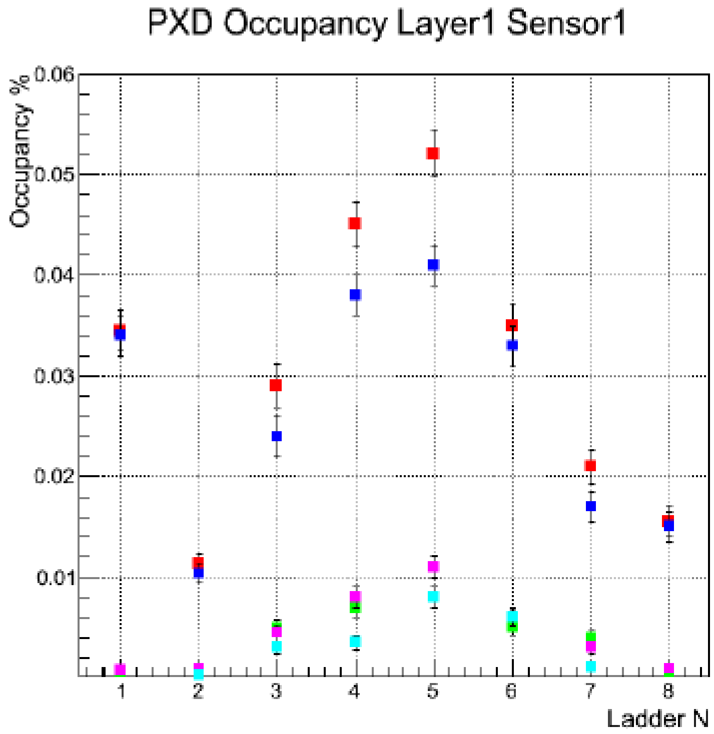
All results correspond to 4ROF (80μsec), for HER.

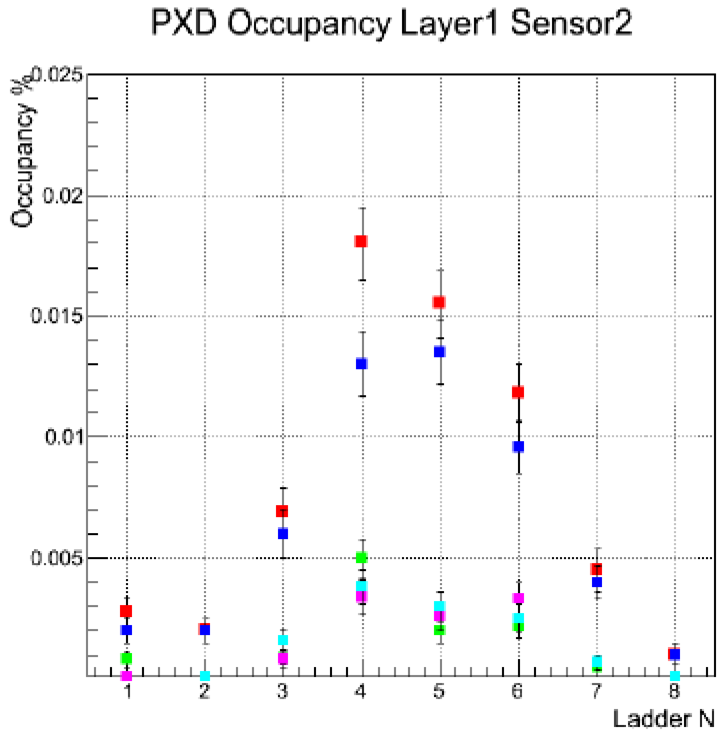
Y. Soloviev(DESY)

PXD occupancy Layer1

SR only!

Color Code
Ideal alignment
Misalignment -0.5mm
Misalignment +0.5mm
Uniform Beam Halo
Total =Ideal + Uniform Halo





23.01.2015 Y.Soloviev DESY 7th Belle2 VXD 3

Y. Soloviev(DESY)

Conclusion

Maximum expected occupancy

1. PXD occupancy for the beam core - **~(0.011 ± 0.001)%** at φ ~ π,both for ideal and misalignment cases.

2. Contribution of Beam Halo tails :
   (0.041 ± 0.002)% , assuming fraction of tails beyond 10σxy = 10e-5 (KEKB TDR), (conservative estimation).
   (0.0021 ± 0.0001)%, fraction of tails beyond 10σxy = 5e-7 (beam-beam simulation) at φ ~ π.

3. Total occupancy: **(0.052 ± 0.002)% (**conservative estimation).

Backup BEAST

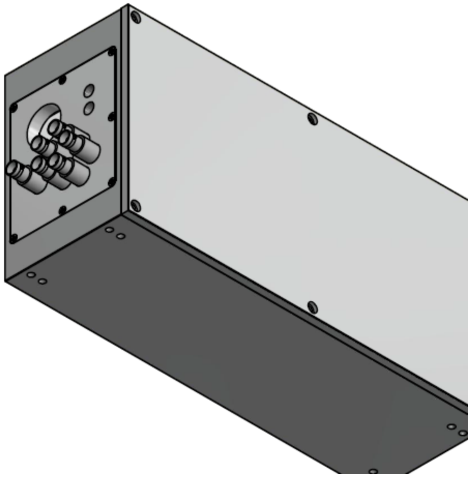
Phase 1: BEAST Detectors

sensor	contact person	number	Location	DAQ	Measures
PIN Diodes	D. Cinabro	64	decided	BEAST	X-ray & total ionizing dose
Beam abort: diamonds, final prototype	L. Vitale	4	decided	BEAST	Total ionizing dose
Micro-TPCs	S. Vahsen	2-4	decided	BEAST	Fast neutron rate and recoil spectrum (=directional info.)
He-3 tubes	S. De Jong / M. Roney	4	decided	BEAST	Thermal neutron rate
BGO	J. “Terry” Liau / Min-Zu Wang	8	decided	BEAST	EM particles ?
CsI Crystals (pure and Tl doped)	A. Beaulieu / M. Roney	6 pure, 6 doped	decided	BEAST	EM particles

Phase 1 Detector Status

- PIN Diodes
  - Amplifier rack boxes under construction, estimated completion in February.
- Micro-TPCs
  - Two prototypes exist, to be used in phase 1.
  - Large x-ray flux in phase 1 may saturation trigger. Working on hardware veto.
  - Vacuum vessel redesigned to fit into VXD dock space. Building 8 additional detectors in 2015 (for phase 2)

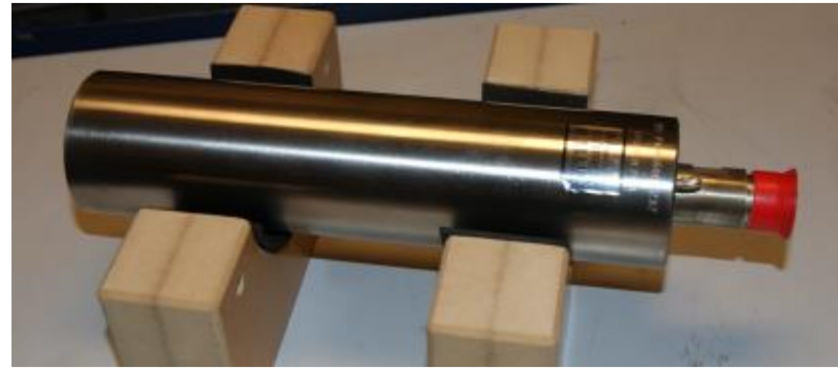
PIN diode amplifiers at Wayne State



TPC vessel - final design.

Phase 1 Detector Status II

- He-3 tubes
  - 1st tube being shipped to Hawaii.
  - Integrate into MiniBEAST in March.
  - Remaining tubes being purchased.
- BGO
  - Two crystals at Hawaii, getting integrated into DAQ.
  - Substantial work on DAQ electronics, 2 and 8 channel version
  - Critical issues:
    - Sufficiently sensitive for interesting measurements in phase 1? Can optical coupling be improved?
    - Still useful in phase 2 with material in front? With ECL present? Can VXD group accommodate back-to-back geometry needed for electron-position coincidence measurement?
    - NTU group to follow up with simulation. Depends on VXD group help regarding phi positions.

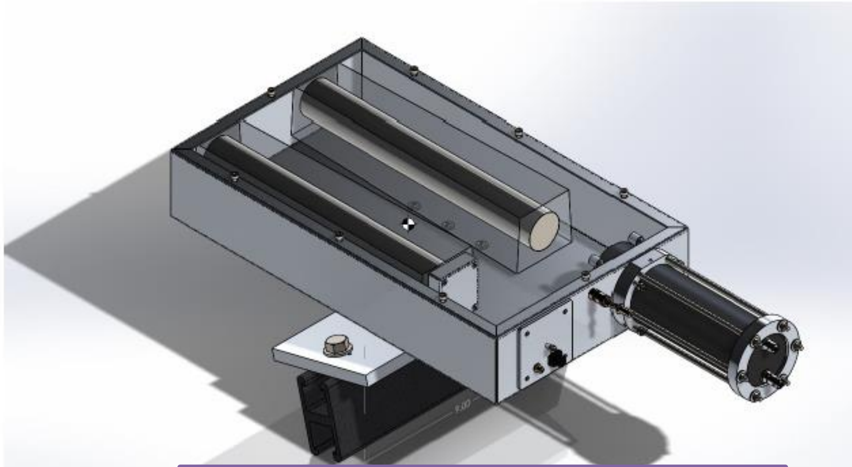


He-3 tube

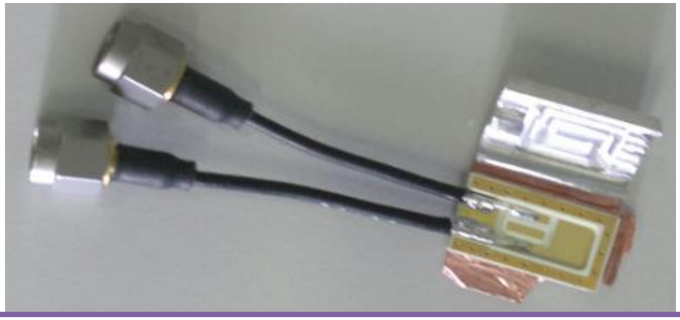
BGO crystal supports

Phase 1 Detector Status III

- CsI Crystals
  - Mechanical enclosure being sent to Hawaii
  - Crystals have been secured
  - Italian groups to participate
- Diamond Sensor Beam Abort system
  - SVD, PDX Packages developed
  - detailed characterization
  - DAQ developed



Holder for pair of CsI crystals.

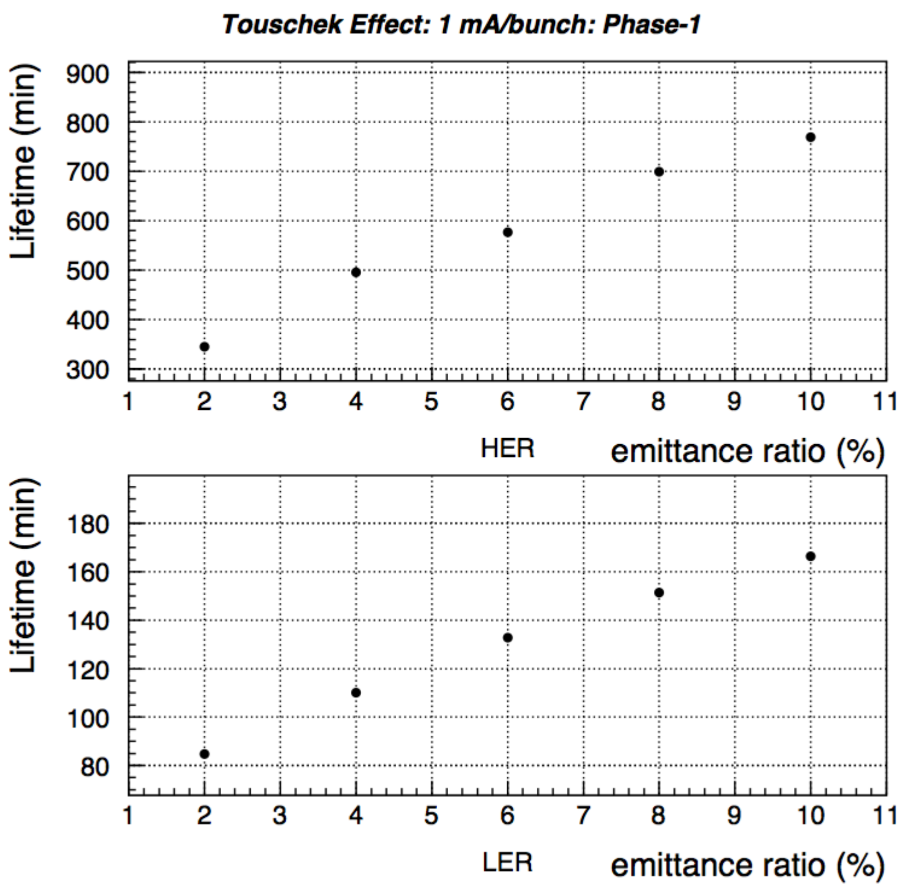


12 x 20 x 3.1 mm^3
multi-layer package for SVD

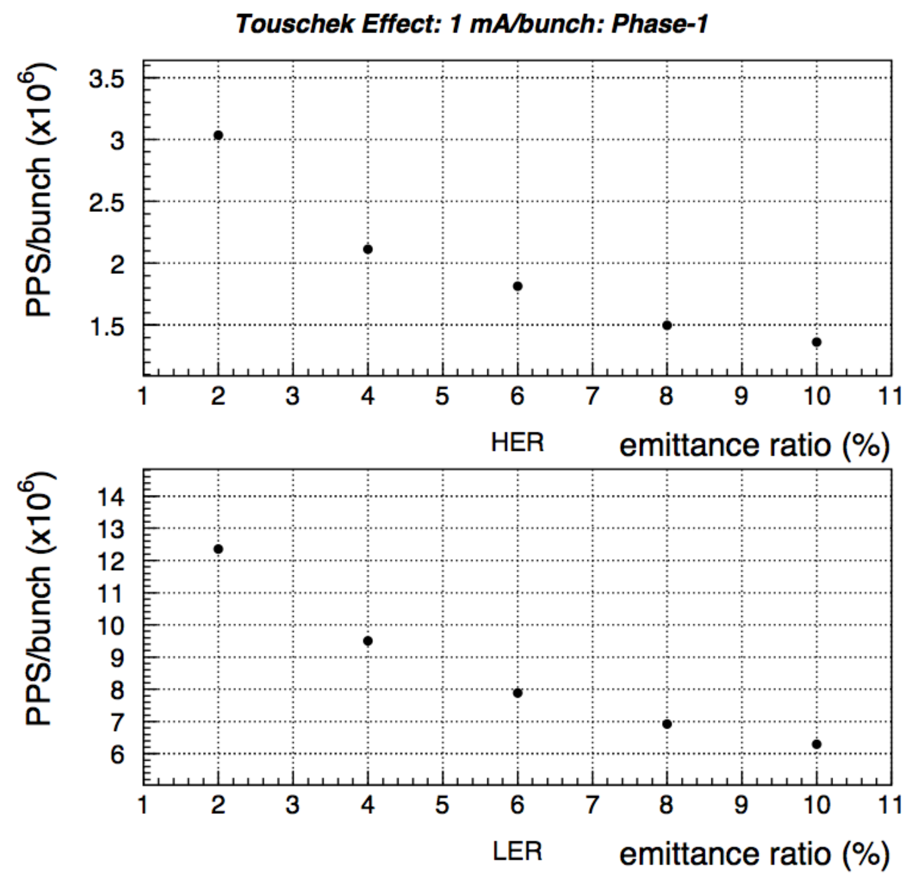
Excellent progress by all groups building BEAST Detector systems - too much to report!

Phase 1
Dynamic Aperture & Touschek Loss

bunch current = 1 mA



total loss/ring

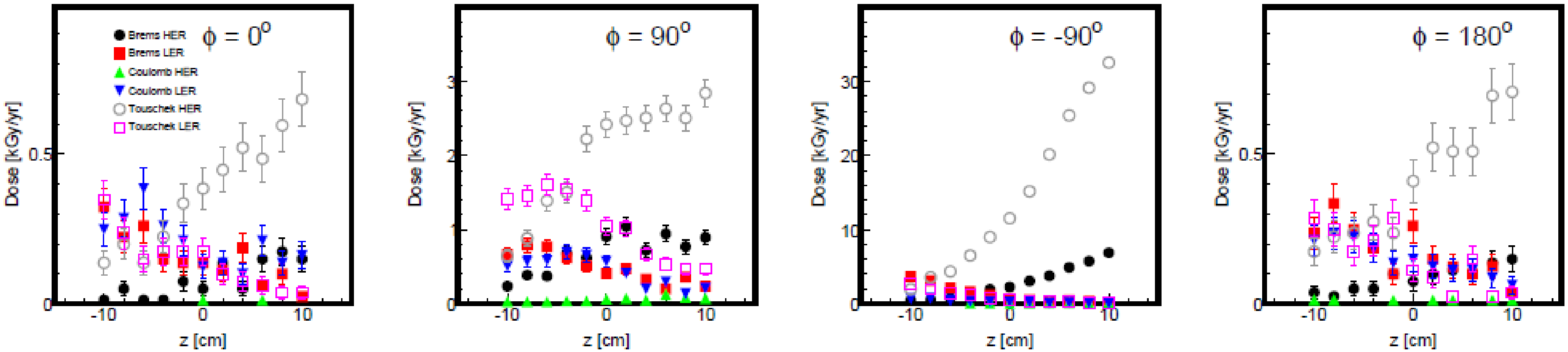


Emittance ratio is variable.

Beam-gas BG will vary by many order of magnitude. Touschek can also be varried.

Phase 1 Simulation

I. Jaegle



- We have a first phase-1 geometry and simulation in place (Jaegle, Ohnishi, Nakayama)
- Predicts ~1000 x higher backgrounds levels in phase 1 than during phase 3, even at good (10^{-9} torr vacuum)
- Different beam backgrounds have different ϕ & z dependence

> - First comparison of Touschek and Beamgas loss distribution against MC may be achievable in phase 1
> - <= 1 week, at end of phase 1
> - If feasible, would like to move neutron detectors once

What is the end of the phase-2 for the VXD commissioning

Important points to be considered:

- Beam BG intensities on PXD and SVD.
  - also during injection
  - We will study them with PXD+SVD hit occupancies, monitor hits, MC simulation.
  - correlation between PXD+SVD HV currents and beam BG hit occupancy.
- DAQ and slow control software
  - Basically this check has to be done before phase-2 operation.
  - stability in real hits
- Tracking and alignment performance.
  - hit occupancy dependence
  - alignment performance
  - available momentum (pT) in phase-2 VXD configuration?
- Interlock system
  - threshold determination and system reliability
- CO2 cooling system
  - temperature and humidity measurement
- Noise performance on PXD and SVD
  - S/N on PXD and SVD.
  - Grounding
- VETO gate in injection for PXD.
  - how to study it?

Example of discussion points from Nakamura San during BEAST Workshop

Request to Collaboration

- To disentangle different beam background sources, we'd like to reserve <2 weeks of phase 2
- Dedicated measurements when varying accelerator parameters (beam size, vacuum bumps, etc.)
- Requirements
  - Belle DAQ operational, running in random trigger mode
  - Belle DQM in place and available in EPICS
  - Stable accelerator and background conditions, rough beam collimator adjustment completed
- We suggest 1st week as soon as above is satisfied, 2nd week towards end of phase 2. Prefer groups of 2-3 days over continuous weeks.

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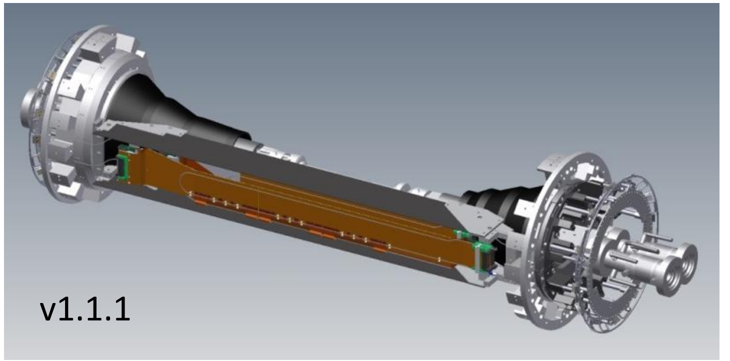
PXD

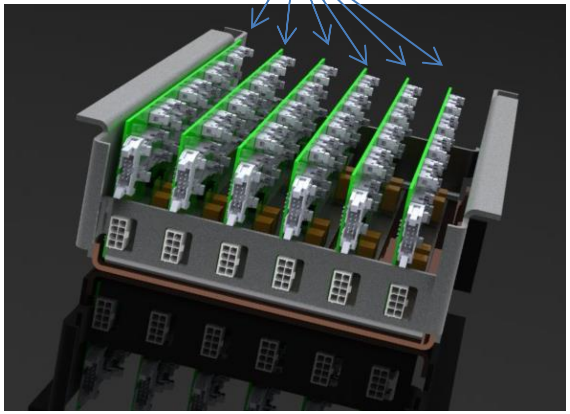
- **contact person**
  - C. Marinas
- **motivation and brief analysis plan**
  - hit occupancy and tracking study (ROI) under different machine configuration
  - spatial dependence of SR hits, injection BG
  - hit correlations with monitor sensors
  - injection VETO width study
  - CO_2 cooling study, noise study
- **what kind of data to be stored on DAQ**
  - same as phase-3
- **designs of sensor/package/support**
  - determined
- **number and locations**
  - determined: 2 ladders in 2 layers (0 deg. direction)
- **cables and space for service**
  - cables and cooling pipes (how many?)
- **readout system and DAQ**
  - DCD, DHP, ONSEN (partial setup of phase-3), Belle II DAQ
- **request for dock boxes**
  - how many?
- **request for Belle II clock, trigger, injection timing?**
- **any other requests**

SVD

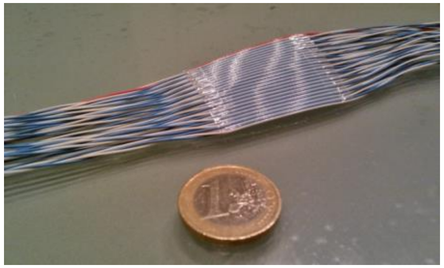
- **contact person**
  - K. Nakamura
- **motivation and brief analysis plan**
  - hit occupancy and tracking study under different machine configuration
  - spatial dependence of BG hits, injection BG
  - hit correlations with monitor sensors
  - CO2 cooling study, noise study
- **what kind of data to be stored on DAQ**
  - 6 samples of ADC values from sensor strips with 25nsec sampling rate above 0-suppression thresholds
- **designs of sensor/package/support**
  - determined
- **number and locations**
  - determined: 4 ladders in 4 layers (0 deg. direction)
- **cables and space for service**
  - cables (SVD-Dockbox: polyolefin 0.635 pitch 34 pair twisted-parallel): 10 cables in FWD and 18 cables in BWD.
  - cooling pipes (1.6mm outer diameter SUS): 2 inlet-outlet pairs in BWD
- **readout system and DAQ**
  - FADC system (partial setup of phase-3), Belle II DAQ
- **request for dock boxes**
  - 1 box in FWD (2 junction boards), and 1 box in BWD (4 junction boards).
- **request for Belle II clock, trigger, injection timing?**
- **any other requests**
  - additional screw holes and alignment holes on FWD endflange



Junction boards

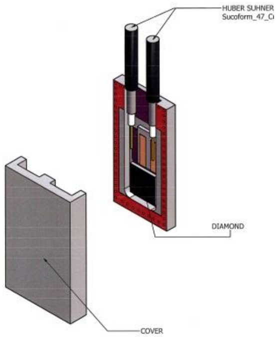


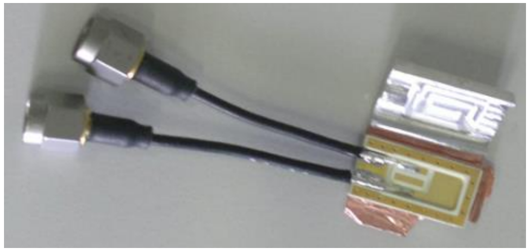
Dock box



diamond detector (+ PIN diode)

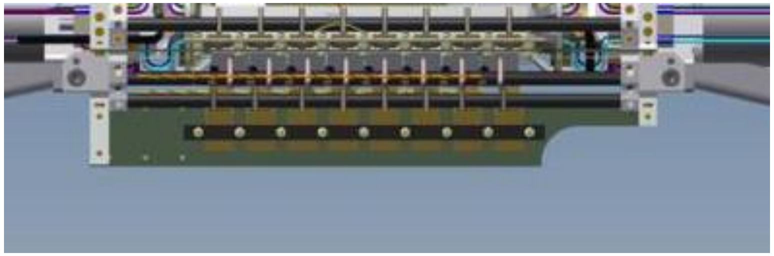
- **contact person**
  - L. Vitale
- **motivation and brief analysis plan**
  - spatial dependence of BG hits and injection BG
  - hit correlations with PXD and SVD
  - interlock system test
- **what kind of data to be stored on DAQ**
  - charge amount accumulated for ??? usec.
- **designs of sensor/package/support**
  - 12 x 10 x 3.3 mm^3
- **number and locations**
  - diamond: 4 sensors on the beam pipe. Orientation (parallel or perpendicular to the beam pipe) is under discussion.
  - PIN diode: 64 sensors. All the sensors will cover the VXD volume.
- **cables and space for service**
  - 2 cable for each sensor. In total, 4 cables for FWD and 4 cables for BWD.
    - 3m coaxial thin (HS SM47LSFH) from sensors to DOCKs + 22m? HS S_04162-B60, double shield
- **readout system and DAQ**
  - AH501 for test readout. A new electronics with FPGA will appear. where?, Data will be stored in Belle II VXD EPICS DB.
- **request for dock boxes**
  - ???
- **request for Belle II clock, trigger, injection timing?**
  - injection timing?
- **any other requests**





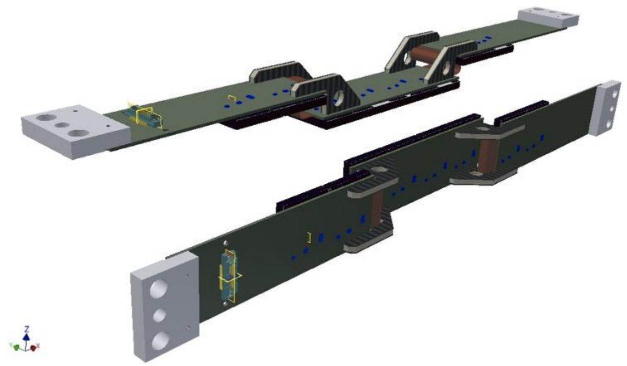
FE-I4 pixels

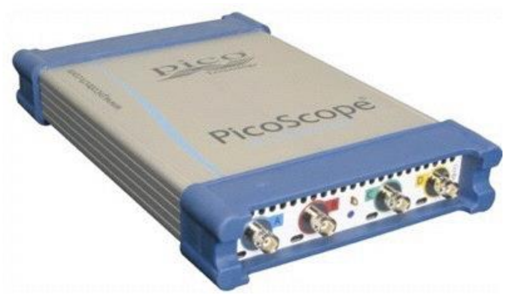
- **contact person**
  - C. Marinas
- **motivation and brief analysis plan**
  - hit occupancy under different machine configuration
  - spatial dependence of BG hits, injection BG
  - energy spectrum of SR hits
- **what kind of data to be stored on DAQ**
  - hit position, hit timing, energy deposit ???
- **designs of sensor/package/support**
  - arm design has to be fixed. how are they fixed on VXD structures ???
- **number and locations**
  - 3 arms are on 90, 180, and 270 deg.
- **cables and space for service**
  - ???
- **readout system and DAQ**
  - ???
- **request for dock boxes**
  - ???
- **request for Belle II clock, trigger, injection timing?**
  - How does it get injection timing (FTSW signals)???
- **any other requests**



CLAWS (Scintillator + SiPM)

- **contact person**
  - C. Marinas
- **motivation and brief analysis plan**
  - spatial dependence of BG hits, injection BG
- **what kind of data to be stored on DAQ**
  - energy deposit, hit timing
- **designs of sensor/package/support**
  - Are they already fixed???
- **number and locations**
  - 2 ladders on 135 and 225 deg.
- **cables and space for service**
  - cables ???
- **readout system and DAQ**
  - 6404D (PICOTECH) DAQ???
- **request for dock boxes**
  - no
- **request for Belle II clock, trigger, injection timing?**
  - **how does it get injection timing?**
- **any other requests**





Scintillator + PIN diode

- **contact person**
  - H. Nakayama, K. Nakamura
- **motivation and brief analysis plan**
  - spatial dependence of BG hits, injection BG
- **what kind of data to be stored on DAQ**
  - hit rate on scintillator, accumulated charge on PIN diode
- **designs of sensor/package/support**
  - design of sensor/package are almost fixed. PIN diode is under discussion.
- **number and locations**
  - under discussion (basically put around QCS)
- **cables and space for service**
  - ???
- **readout system and DAQ**
  - EASIROC (scintillator) and ??? (PIN diode). DAQ?
- **request for dock boxes**
  - ???
- **request for Belle II clock, trigger, injection timing?**
- **any other requests**

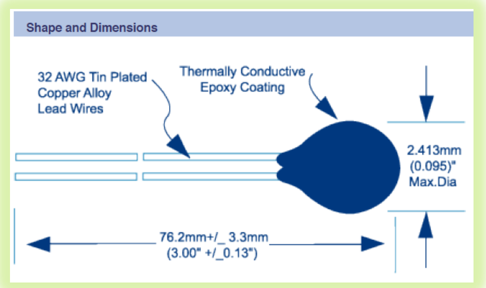
BGO

- **contact person**
  - J. Liau
- **motivation and brief analysis plan**
  - Bhabha scattering measurement (Luminosity measurement)
- **what kind of data to be stored on DAQ**
  - Energy deposits in crystals.
- **designs of sensor/package/support**
  - Sensor and package are determined. Support is under discussion.
- **number and locations**
  - 8 crystals (if space allows). Locations are under discussion. (Acceptance overlap issue with PXD cooling blocks.)
- **cables and space for service**
  - 1 fiber from each crystal. until where?
- **readout system and DAQ**
  - where? BEAST DAQ
- **request for dock boxes**
  - ???
- **request for Belle II clock, trigger, injection timing?**
- **any other requests**

Temperature and humidity sensors

- **contact person**
  - L. Vitale
- **motivation and brief analysis plan**
  - temperature and humidity measurement in the VXD volume
  - interlock system test
- **what kind of data to be stored on DAQ**
  - temperature and humidity values
- **designs of sensor/package/support**
  - NTC (temparature), Vaisala DMT242B (Dew point)
- **number and locations**
  - not determined
- **cables and space for service**
  - ???
- **readout system and DAQ**
  - where? Belle II VXD EPICS DB.
- **request for dock boxes**
  - ???
- **request for Belle II clock, trigger, injection timing?**
- **any other requests**

NTC sensors



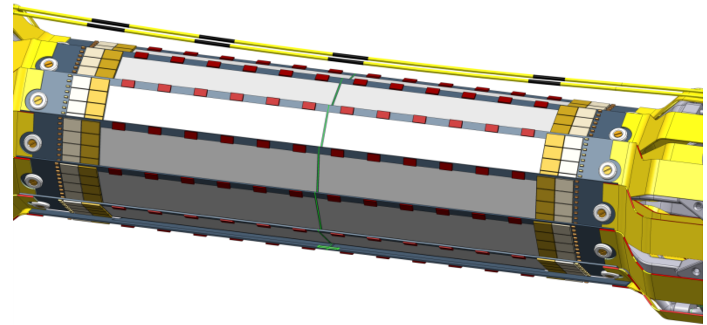
DMT242 Compact Dewpoint Transmitter for Desiccant Dryers

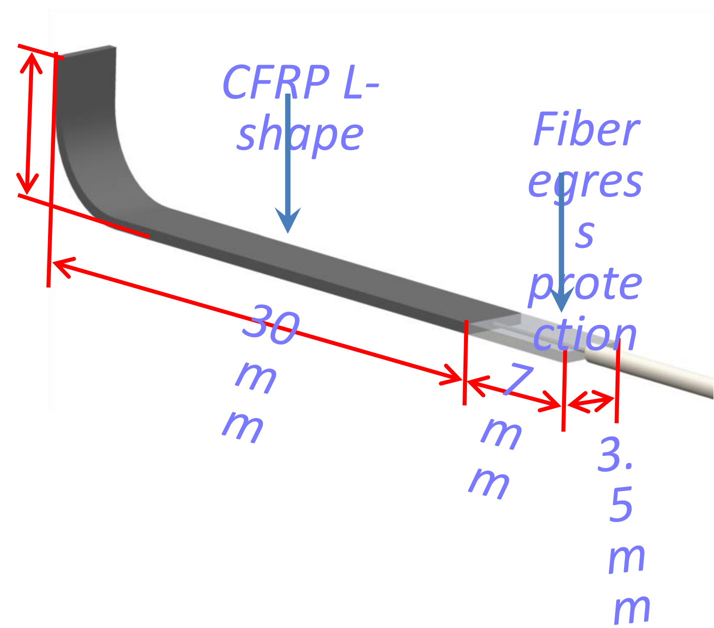
Vaisala DMT242B

Dew Point Transmitters

[-60, +60]°C dew point range

FOS + L-shape sensors

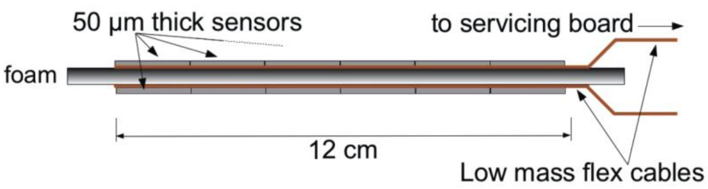


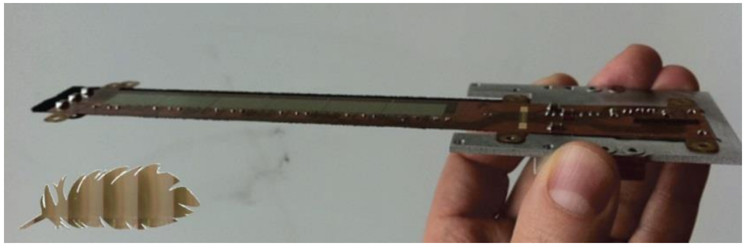


- **contact person**
  - I. Vila, D. Moya
- **motivation and brief analysis plan**
  - temperature and humidity in the VXD volume
  - interlock?
- **what kind of data to be stored on DAQ**
  - temperature, humidity, and deformation values
- **designs of sensor/package/support**
  - determined? (L-shape)
- **number and locations**
  - ???
  - Does L-shape need end-ring and CFRP cone? Can L-shape be put on SVD cartridge ?
- **cables and space for service**
  - ???
- **readout system and DAQ**
  - where? Belle II VXD EPICS DB.
- **request for dock boxes**
  - LC-LC connectors . (how many boxes???)
- **request for Belle II clock, trigger, injection timing?**
- **any other requests**

PLUME

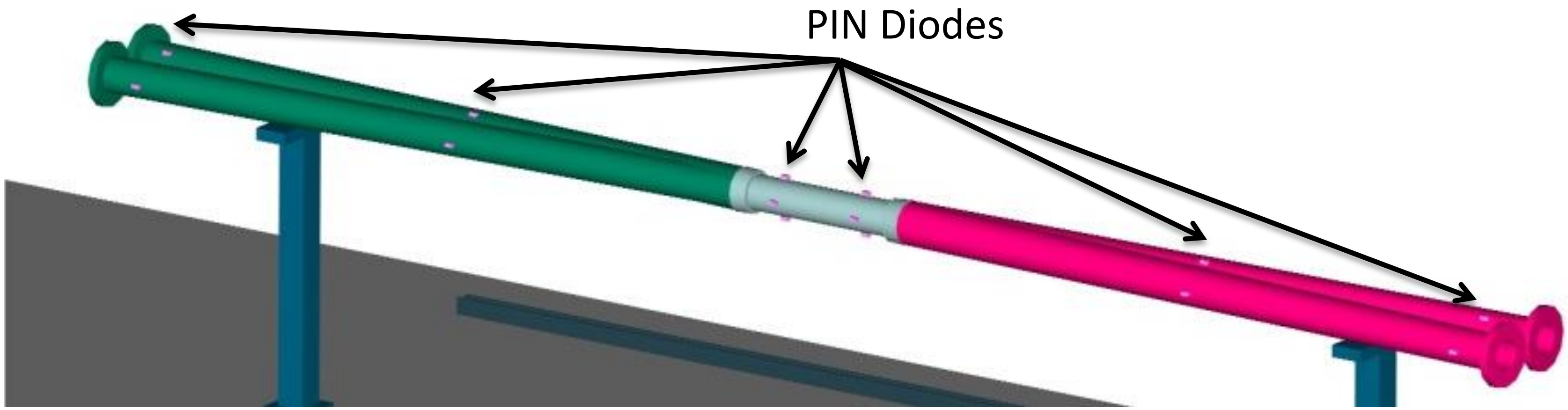
- **contact person**
  - I. Ripp-Baudot
- **motivation and brief analysis plan**
  - spatial dependence of beam BG hits
- **what kind of data to be stored on DAQ**
  - ???
- **designs of sensor/package/support**
  - Mimosa-26 2 x 6 x 0.7 x 10^6 pixels
  - baseline: PLUME-2
- **number and locations**
  - 1 ladder.
  - baseline plan: behind CROWS, at r ~ 4-5 cm, but still under discussion.
- **cables and space for service**
  - under discussion
- **readout system and DAQ**
  - VXD EPICS DB is preferable.
  - BEAST DAQ?
- **request for dock boxes**
  - ???
- **request for Belle II clock, trigger, injection timing?**
  - injection timing, timestamp
- **any other requests**





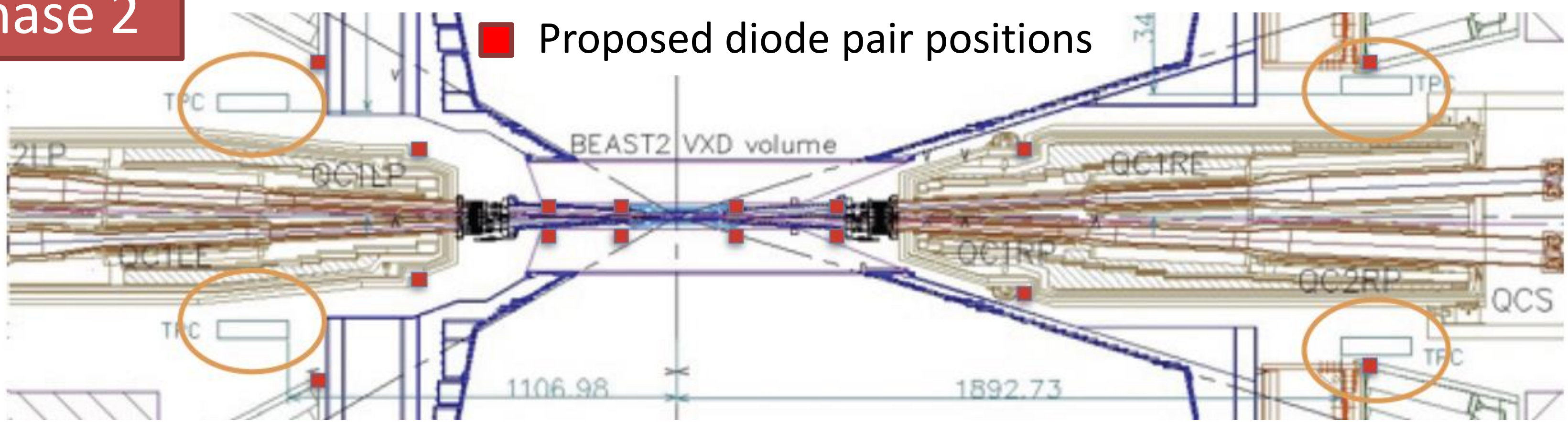
PIN Diode System

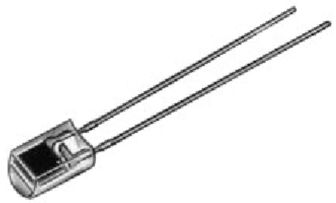
Phase 1



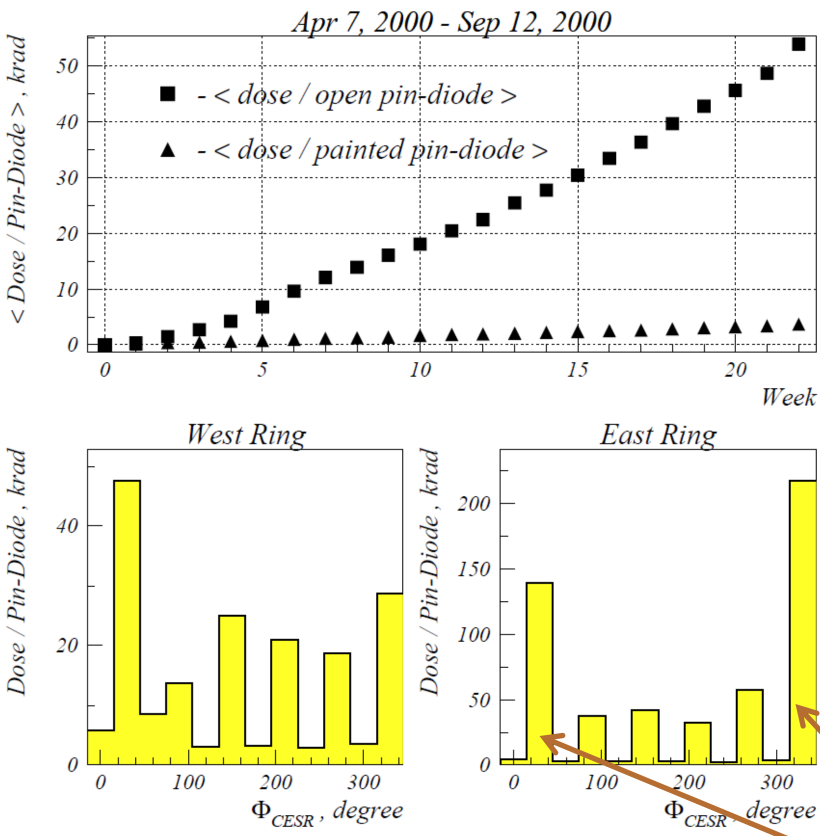
64 channels: 8 z-positions X 4 phi positions X 2 diodes (shielded+unshielded)

Phase 2





PIN Diodes System II



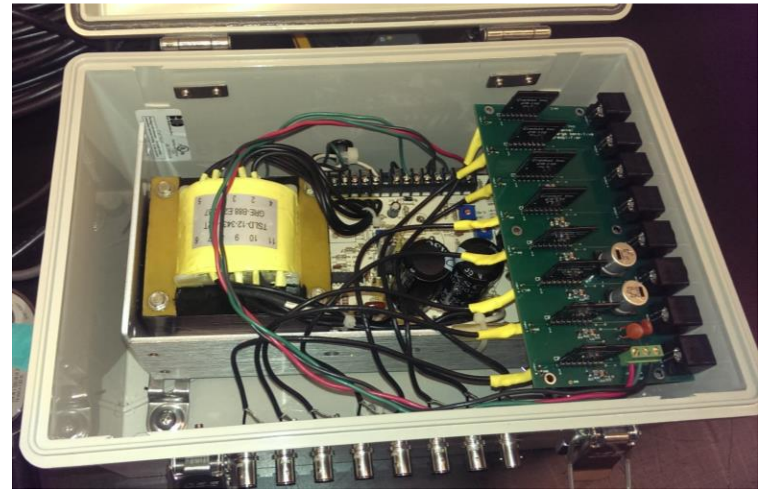
CLEO Measurements

Figure 5: Week-by-week integrated dose and their angular distribution.

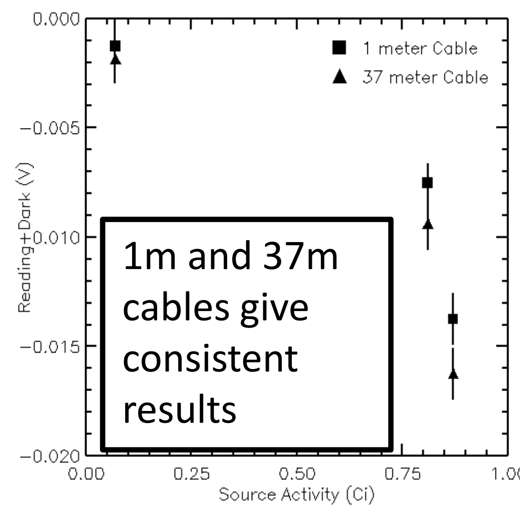
- Lead: David Cinabro (Wayne State)
- Use PIN diodes, Siemens SFH 206K PIN to measure ionizing radiation dose
- Inexpensive & robust
- Successfully used in CLEO for ~10 years and integrated a dose of < 3 Megarads
- Every 2nd diode (in phi) coated with gold-paint
- Allows separating dose from charged particles and x-rays

PIN Diode Status

- 8 channel prototype delivered, good good performance with final cables
- 64 channels in rack-mount enclosure being assembled at Wayne State
  - parts procured
  - assembly behind original schedule due to lack of manpower, but compatible with new KEK schedule
- Temperature monitoring essential - order placed for commercial system
- New Wayne State postdoc, now resident in Hawaii, to integrate & test
- Ship to send to Hawaii by February 2015, to KEK August 2015

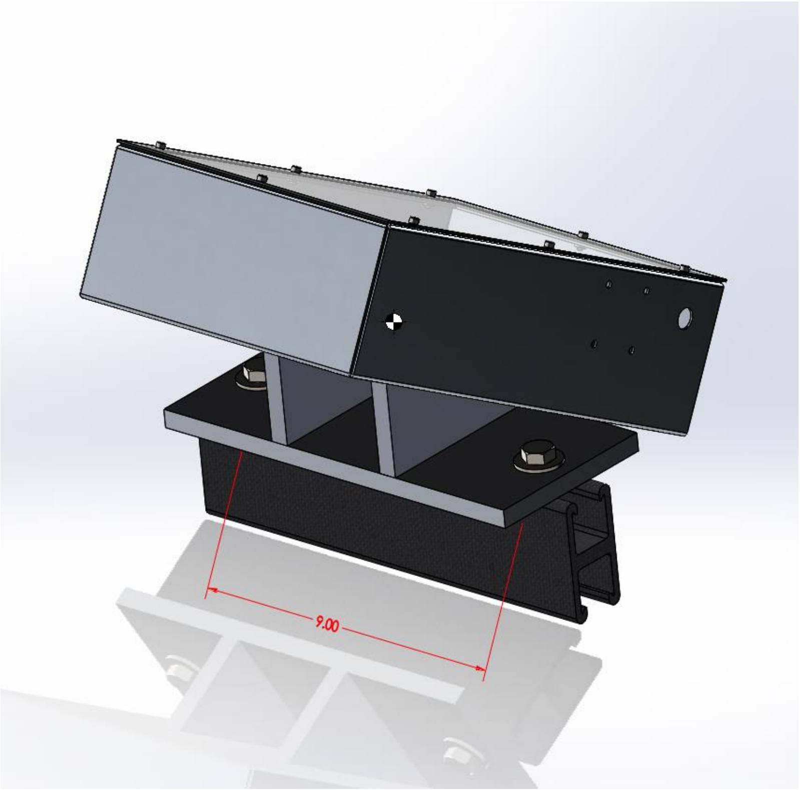


8 channel prototype



CsI Crystals

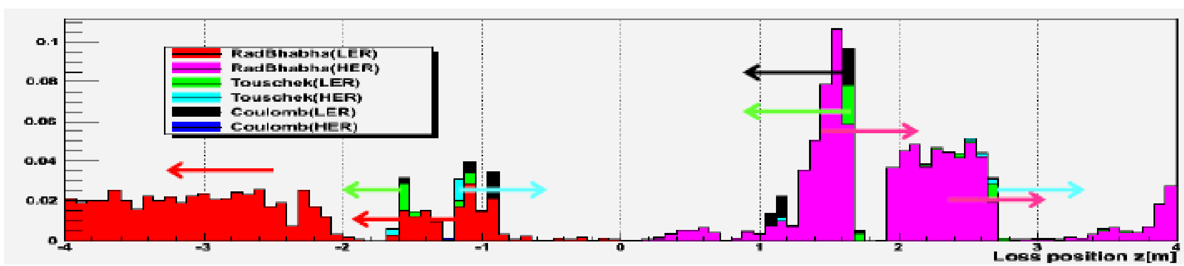
- Plan to measure CsI BGs using 4 pure CsI & 4 CsI(Tl) crystals in ECL location
- BEAST DAQ
- Beam-gas & Touschek only, unfocused beams
  - Checks whether simulation can predict these two background reliably
  - Provides data on pure CsI advantage, needed for Canadian calorimeter funding proposals

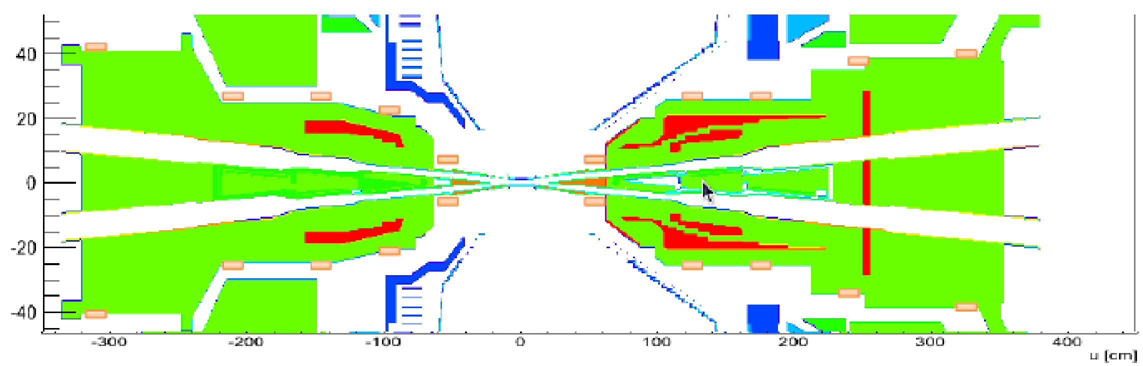


Holder for pair of crystal, preliminary mechanical design by U. of Victoria.

Motivation for Neutron Measurements

- Neutron backgrounds highly penetrating; difficult to predict & measure accurately, caused problems already at Belle and Babar
- Will be critical for Belle-II operation and lifetime
  - KLM deadtime, ECL electronics lifetime, TOP PMT lifetime
- Idea: neutrons produced at specific loss-positions along the beam-line. Fast neutrons preserve directional information and can be directionally reconstructed. Use them to “image” loss spots.

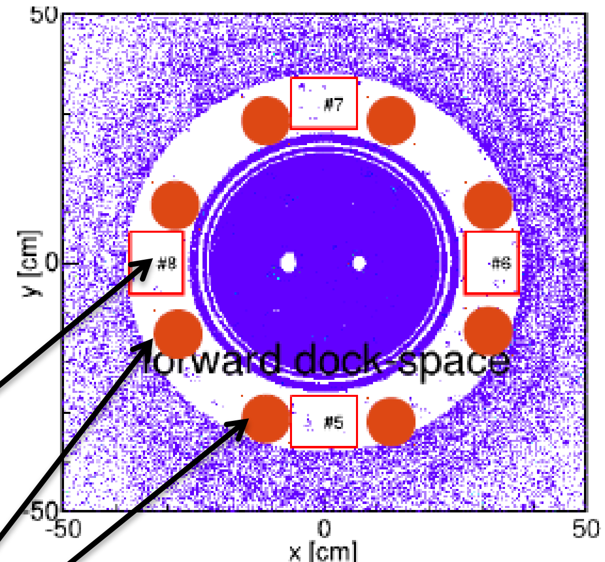


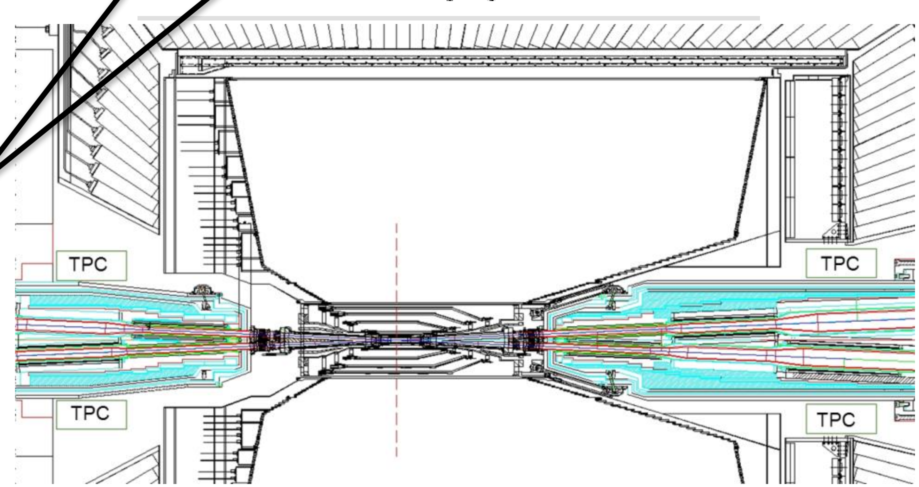


Phase 2

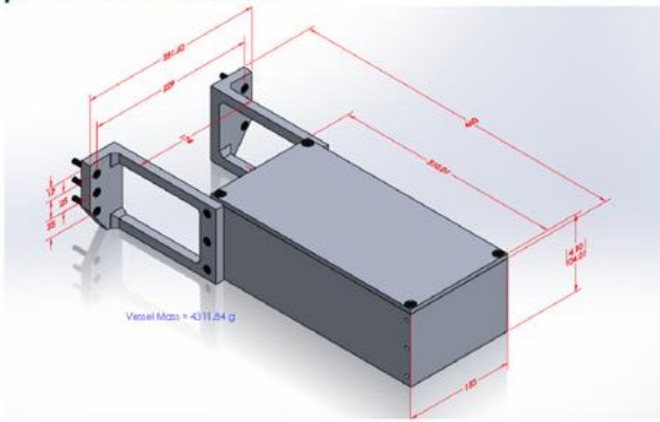
Neutron Detectors

- He-3 tubes and micro-TPCs in dock space
- Complimentary detectors
  - TPCs image direction of incoming fast neutrons, but detected rate is low
  - He-3 tubes measure rate of thermal neutrons, which is high

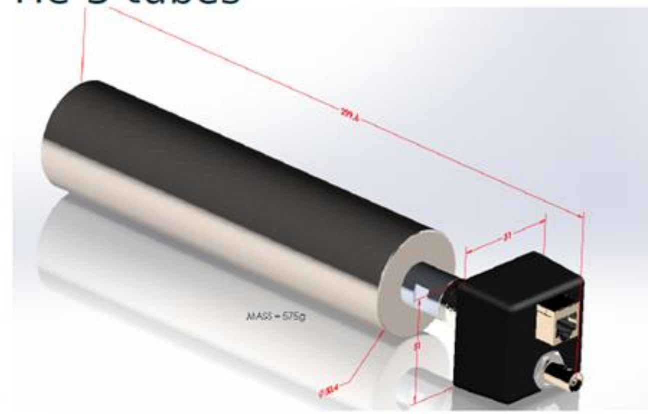




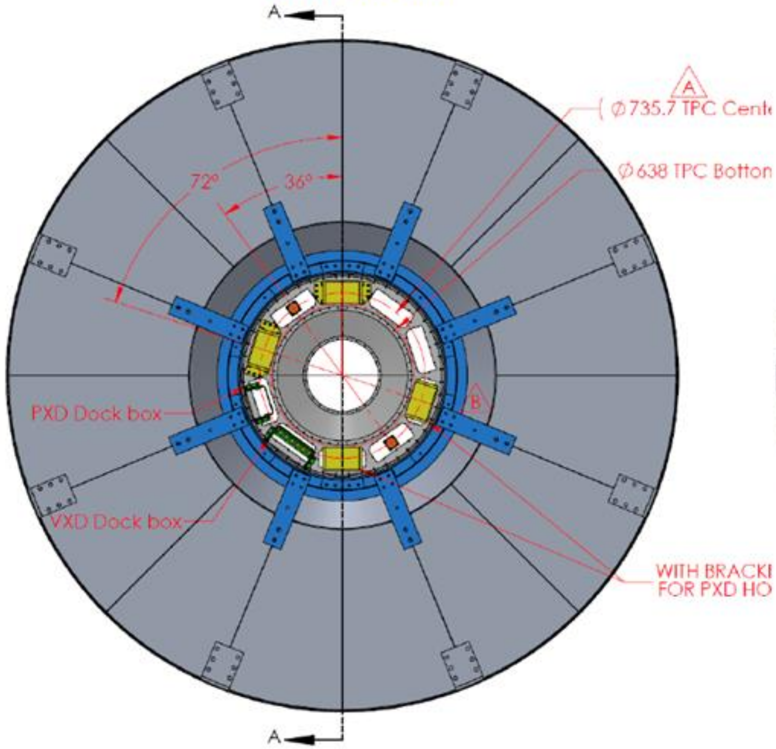
- μ-TPC vessels



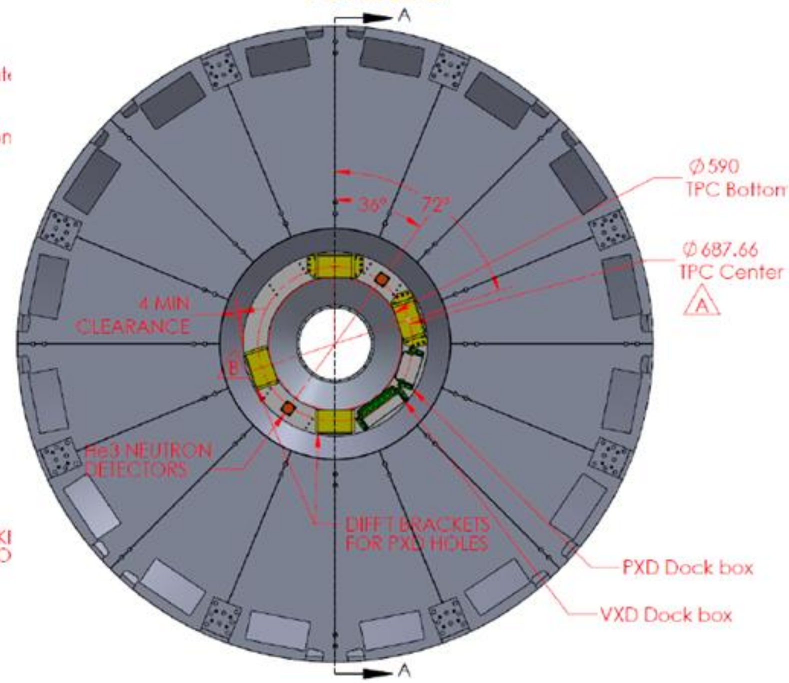
- He-3 tubes



Backward



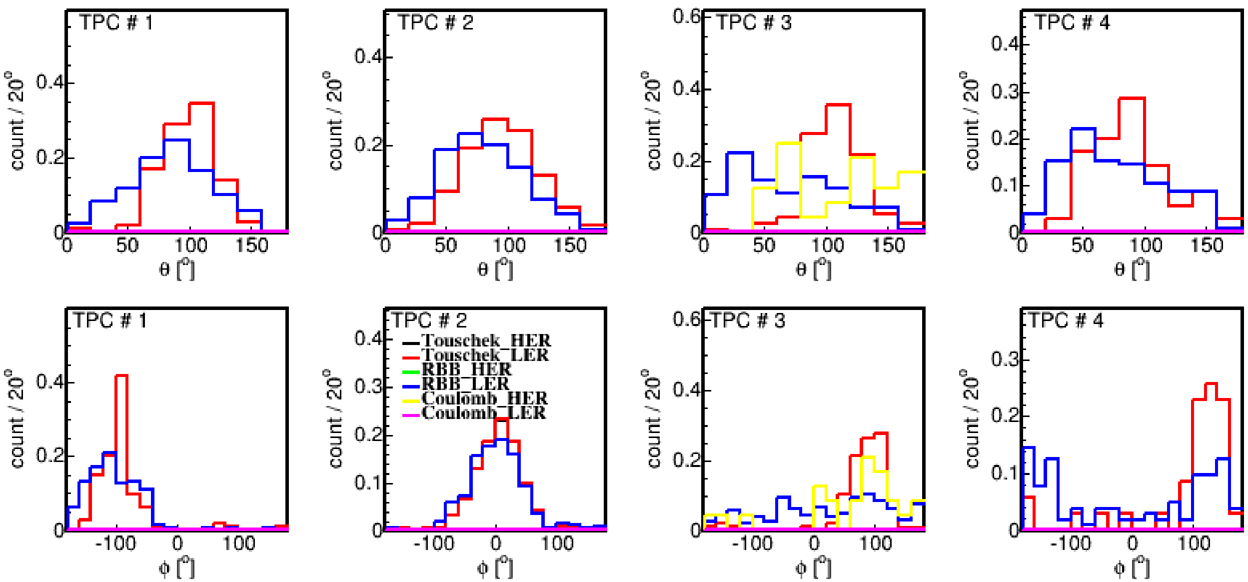
Forward



Jan 15th: Heroic CAD effort by Alexandre Beaulieu (Victoria) confirmed detectors fit into VXD docks.

Measuring Individual Neutron BGs w/ TPCs

I. Jaegle (Hawaii)



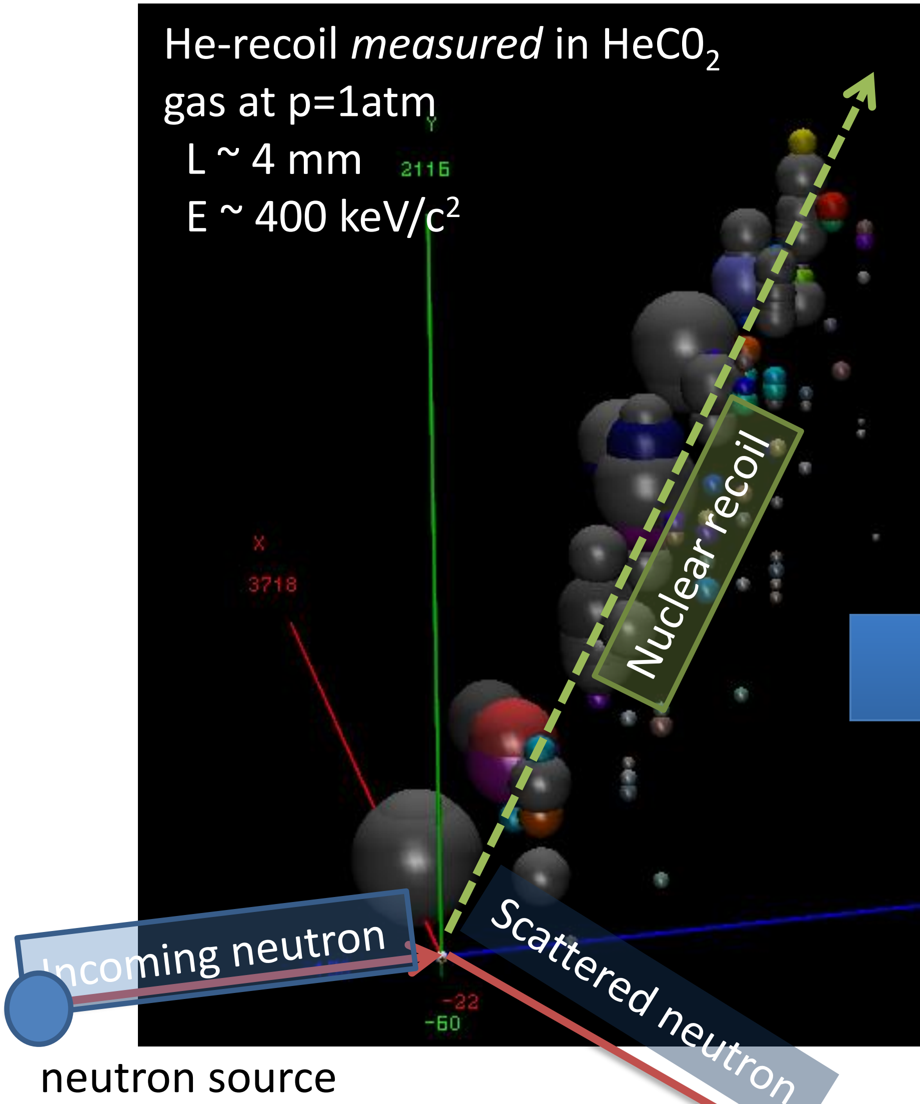
(note: Distributions normalized to same area)

Directional detection motivation

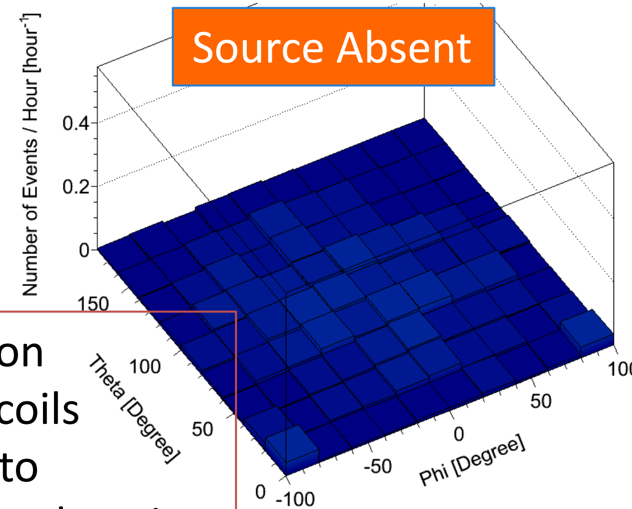
1. Isolate neutrons coming directly from beam lines (rather than re-scattered)
2. Measure neutron flux versus polar angle (beam line position) → validate/tune simulation

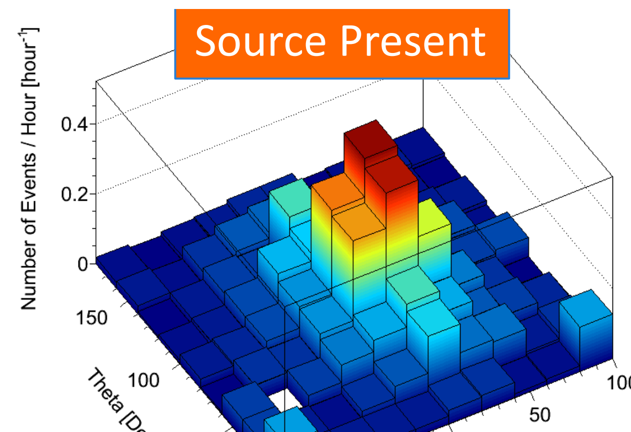
- nominal beams: RBB HER dominates
  → measure
- Run single beams
  - no RBB
  - measure Touchek
  - vacuum bump
    → measure Coulomb

micro-TPC Detector Prototyping



Mean direction of nuclear recoils corresponds to neutron source location





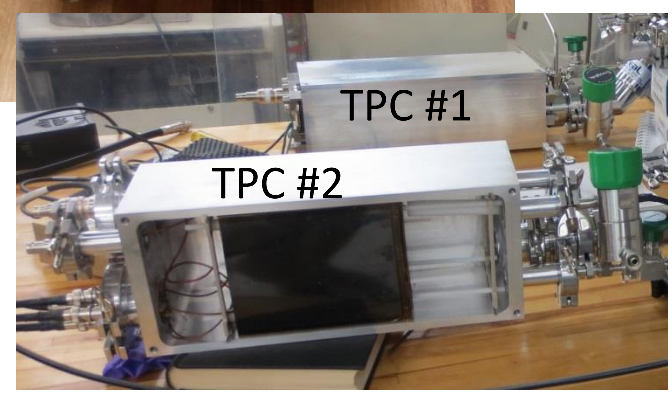
Clear excess & peaks in expected direction!

Tiny pre-prototype demonstrated detection principle.

micro-Time Projection Chambers

Hawaii

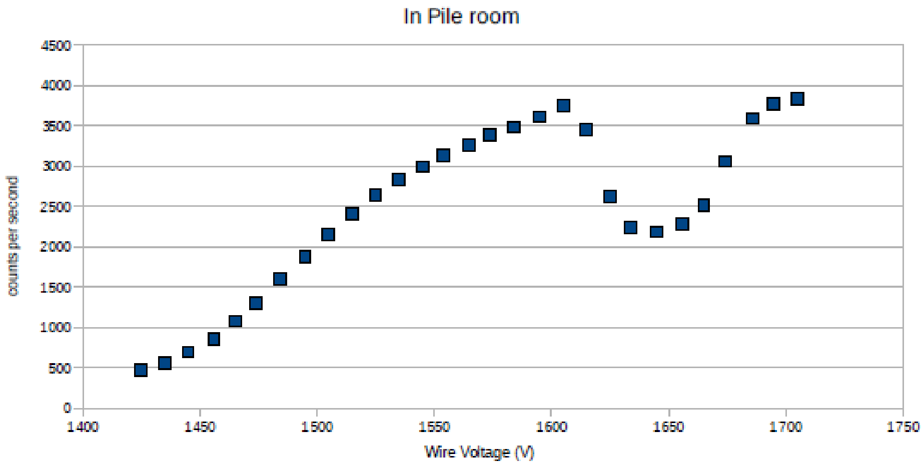
- Two constructed (for phase 1)
  - Excellent performance in lab tests
  - Working on improved x-ray rejection and better cable shielding to be ready for the tough commissioning environment
- Eight remaining (for phase 2)
  - Construct in 2015, to KEK March 2016 (needed approx. January 2017)

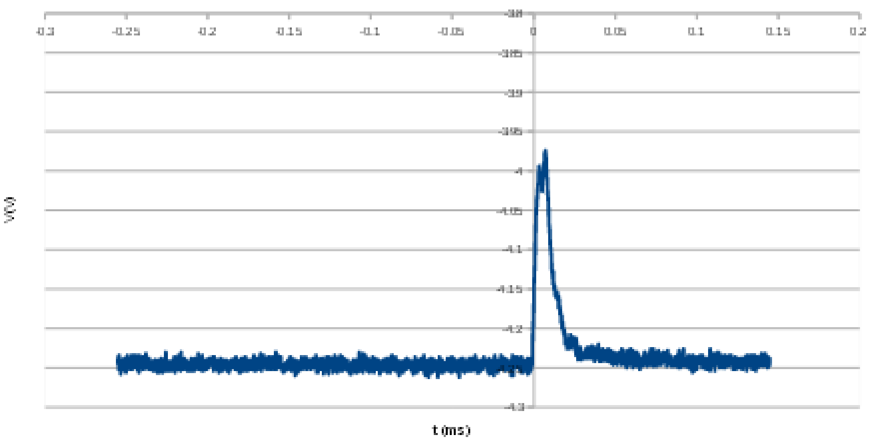


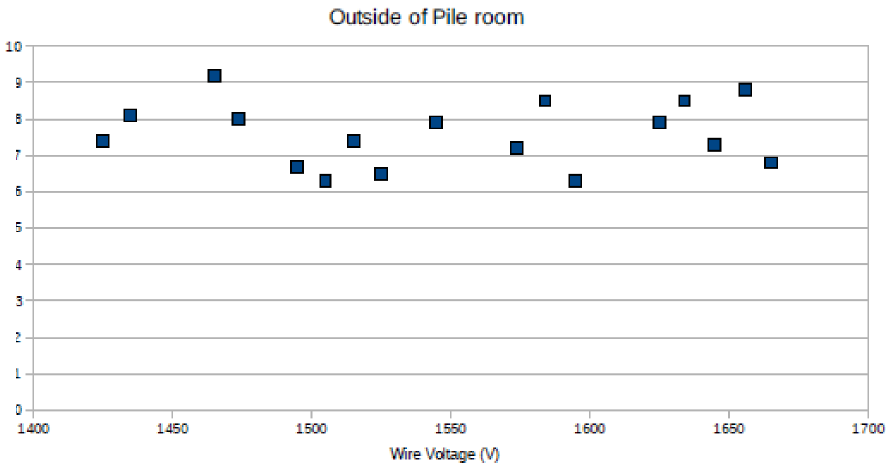
Phase 2

He-3 Tubes

Victoria





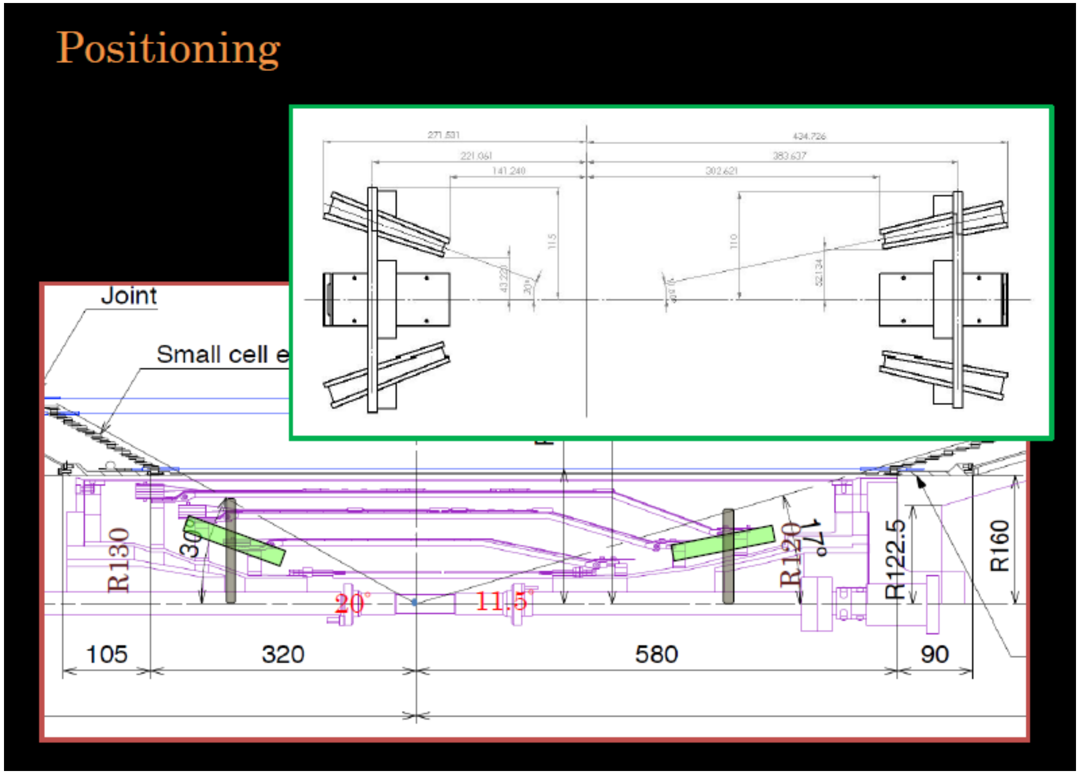


Clear response to neutron source observed. First tube being shipped to Hawaii *now*.

Phase 2

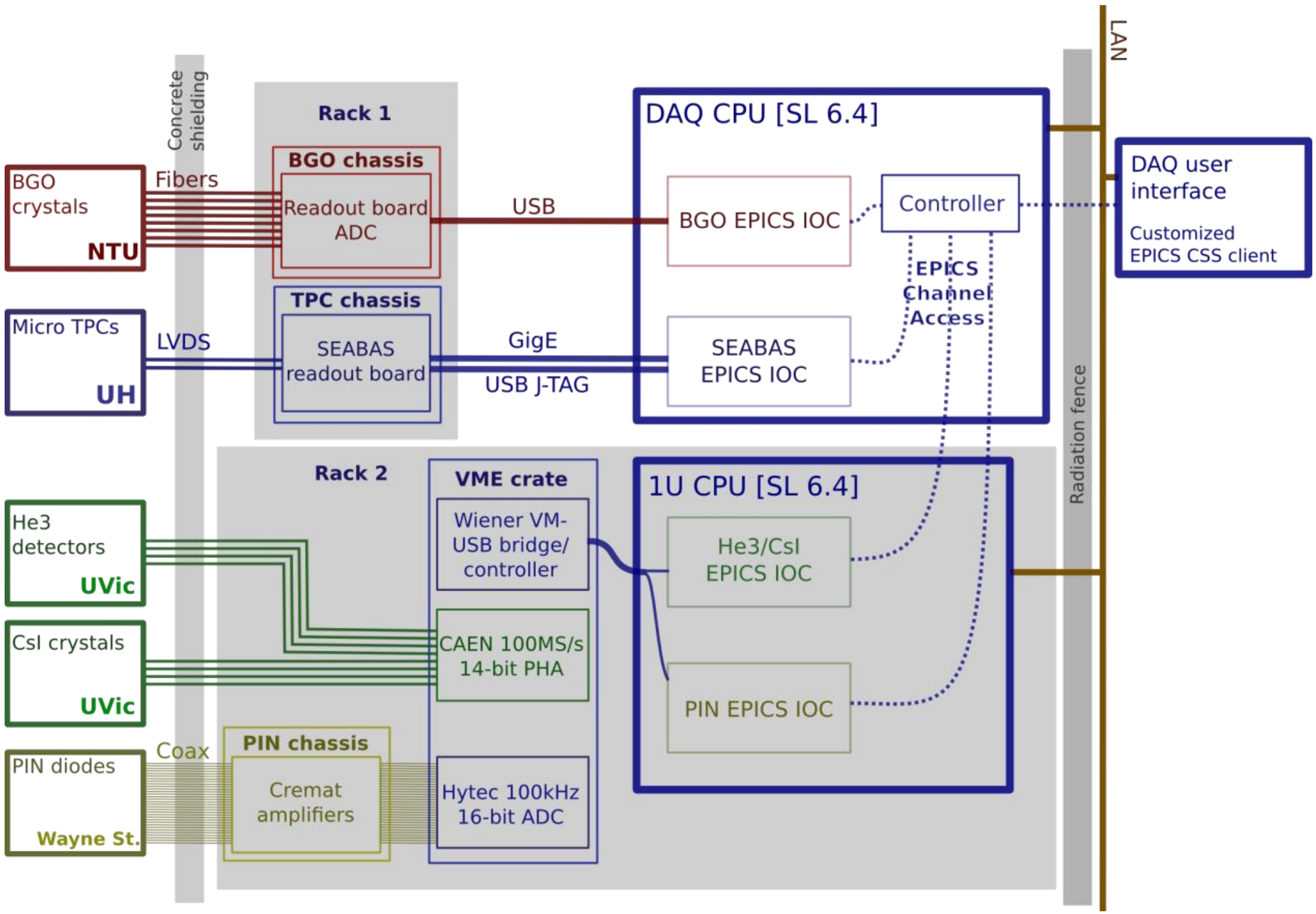
BGO luminosity monitors

NTU



- Eight BGO crystals (from Belle Extreme forward Calorimater)
- To provide independent luminosity measurement via electron coincidence, radiative Bhabha events
- Also can provide analog (real-time) back-ground level to SuperKEKB
- Working prototype w/ electronics exists
- NTU student visiting Hawaii *tomorrow* for integration first two BGO crystals into MiniBEAST
- Need to finalize phase II mechanical mounts (SVD endrings)

BEAST DAQ



P. Lewis (Hawaii)

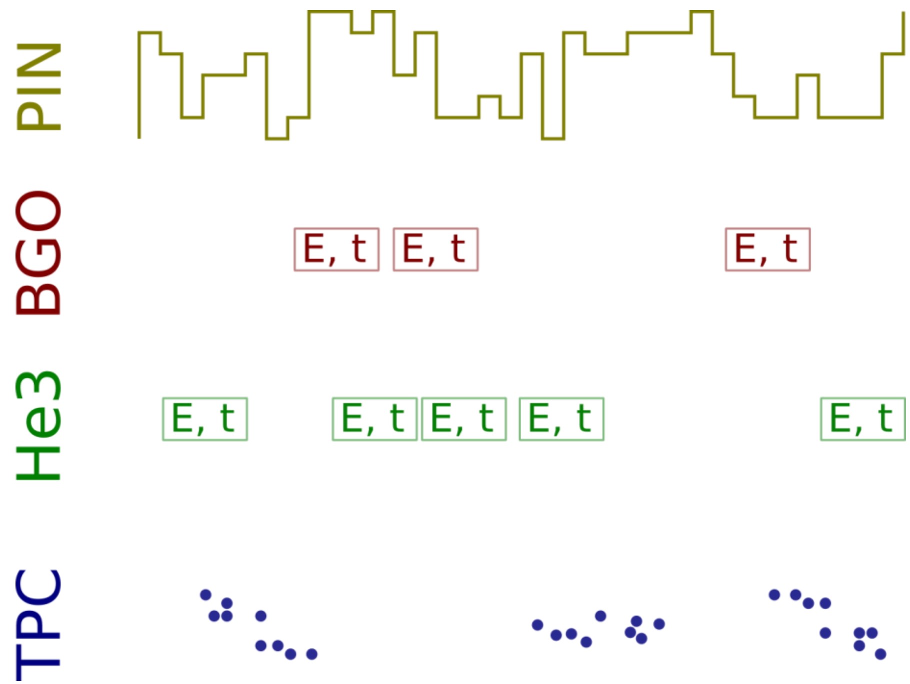
- Build pseudo-events *independently of Belle*
    - **to accelerator EPICs at 1Hz. Also to mask control?**
    - timestamp for off-line comparison with Belle/accelerator data

Raw and processed BEAST2 data

BEAST2 has **no trigger** and **no events**. DAQ is asynchronous and slow:

- **PIN**: raw ADC output **sampled** at 100kHz, averaged to ~1Hz
- **BGO**: fitted **event** peak amplitude with timestamps, ~0.1s-level timing
- **He3**: Pulses with time information, timing resolution unknown
- **TPC**: triggered **events** with pixel data (time, coordinates and charge), ms-level timing

P. Lewis (Hawaii)



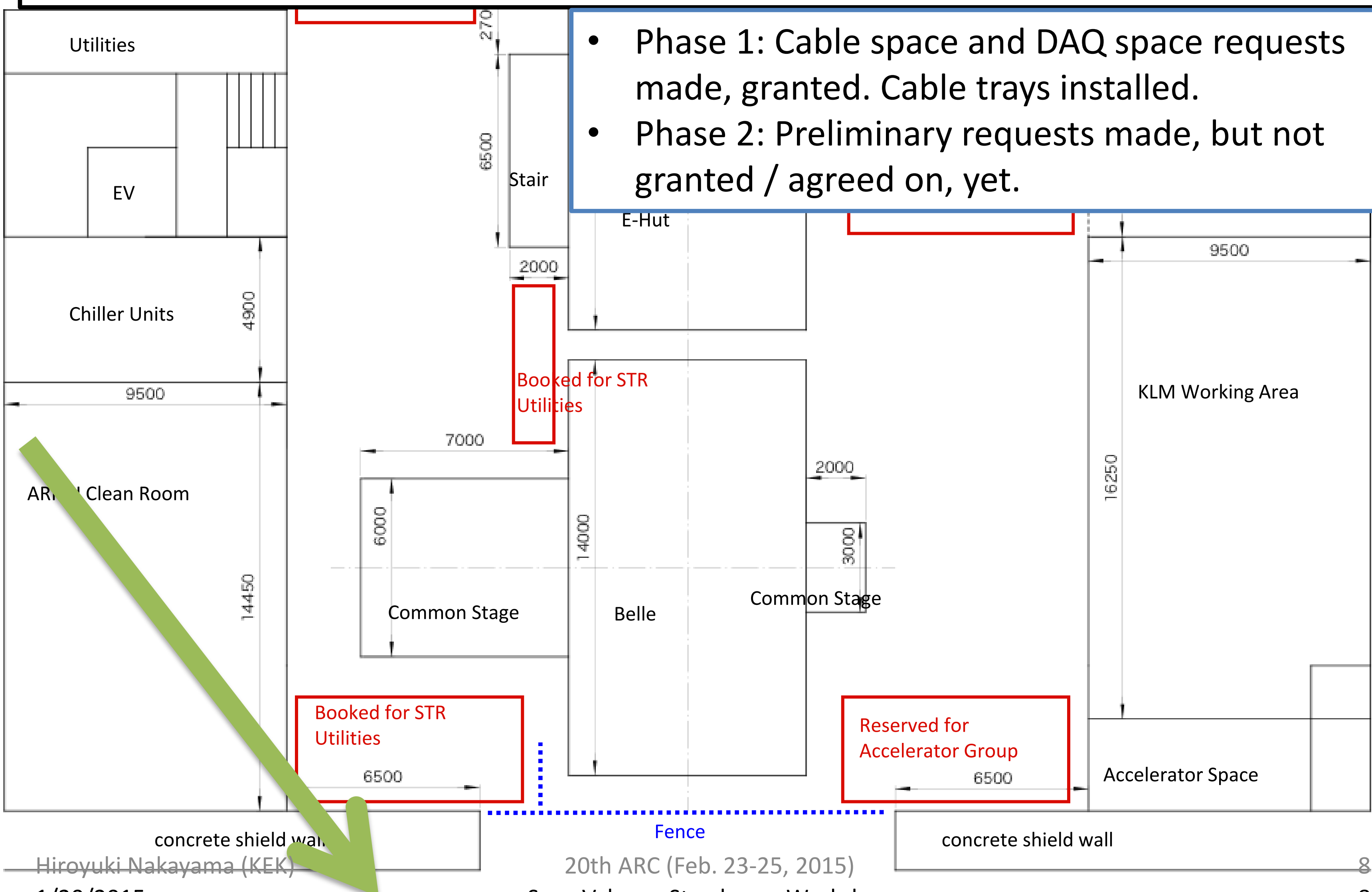
Consequently, BEAST2 data will consist of:

- Independent databases of raw detector data [ROOT files]
- Summaries and human-readable processed data in “pseudo-events” in a ROOT file
- Pseudo-events will summarize detector data for a fixed interval of time, i.e. 1 second

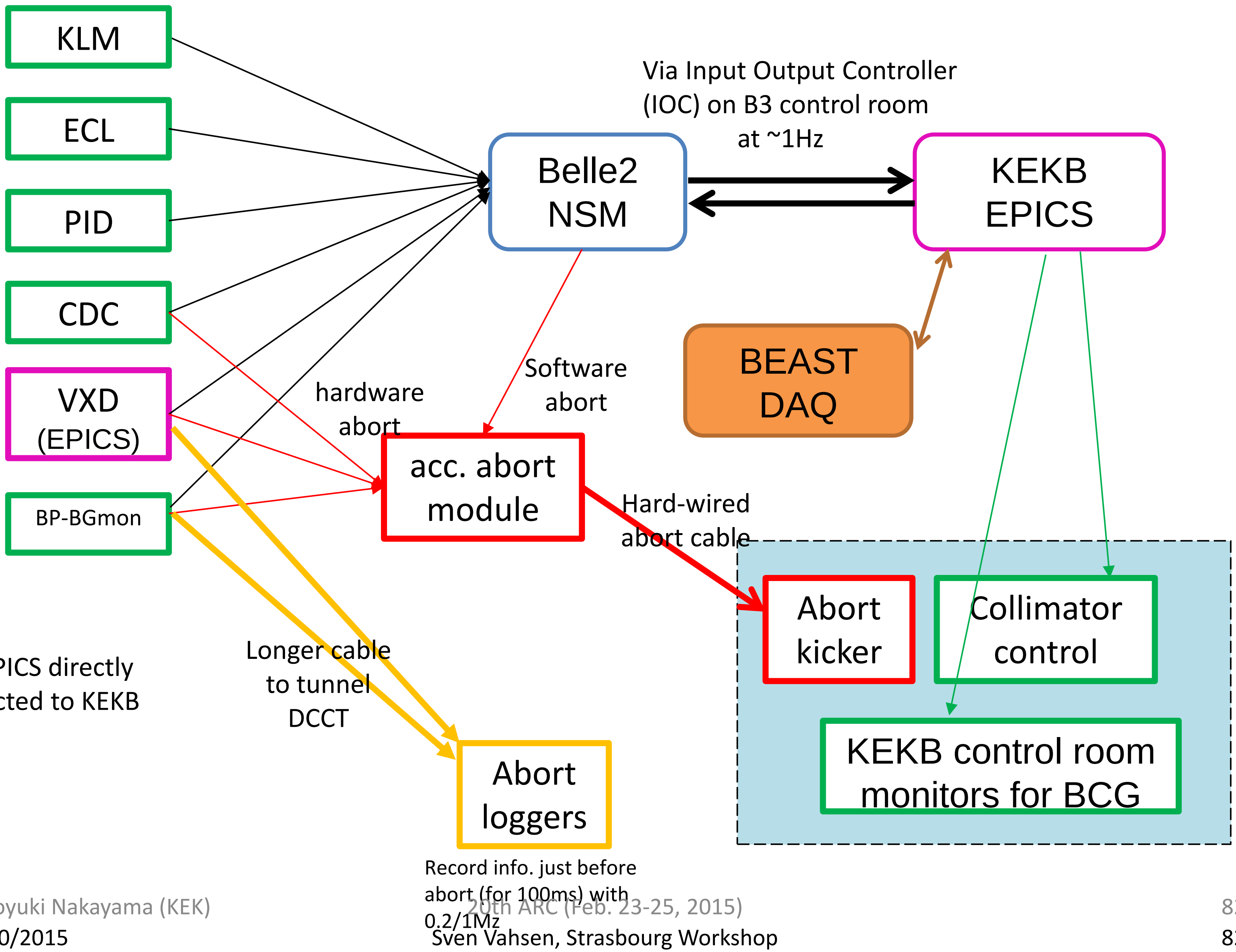
Note: **If we want MHz rate sensor data, e.g. to study injection backgrounds, it will need to go via a different DAQ path.** E.g. beam abort diamond sensors, ATLAS pixel modules.

BEAST DAQ Location – 20-30 m from IP

- Phase 1: Cable space and DAQ space requests made, granted. Cable trays installed.
- Phase 2: Preliminary requests made, but not granted / agreed on, yet.

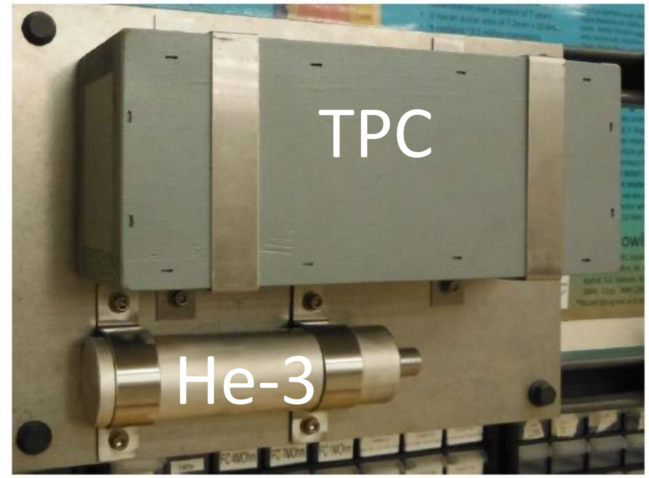


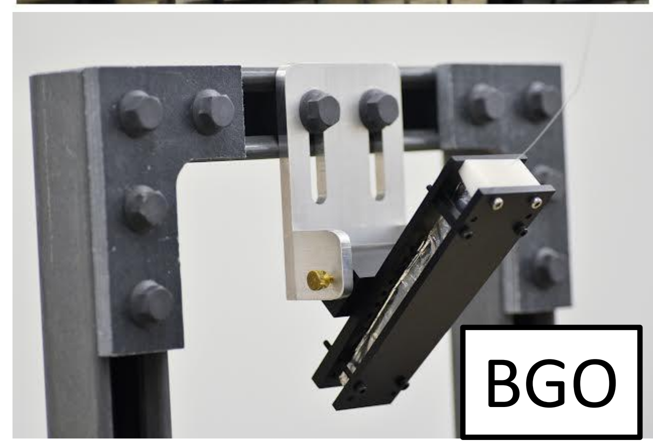
Monitor DAQ diagram (outdated?)



VXD EPICS directly connected to KEKB EPICS?

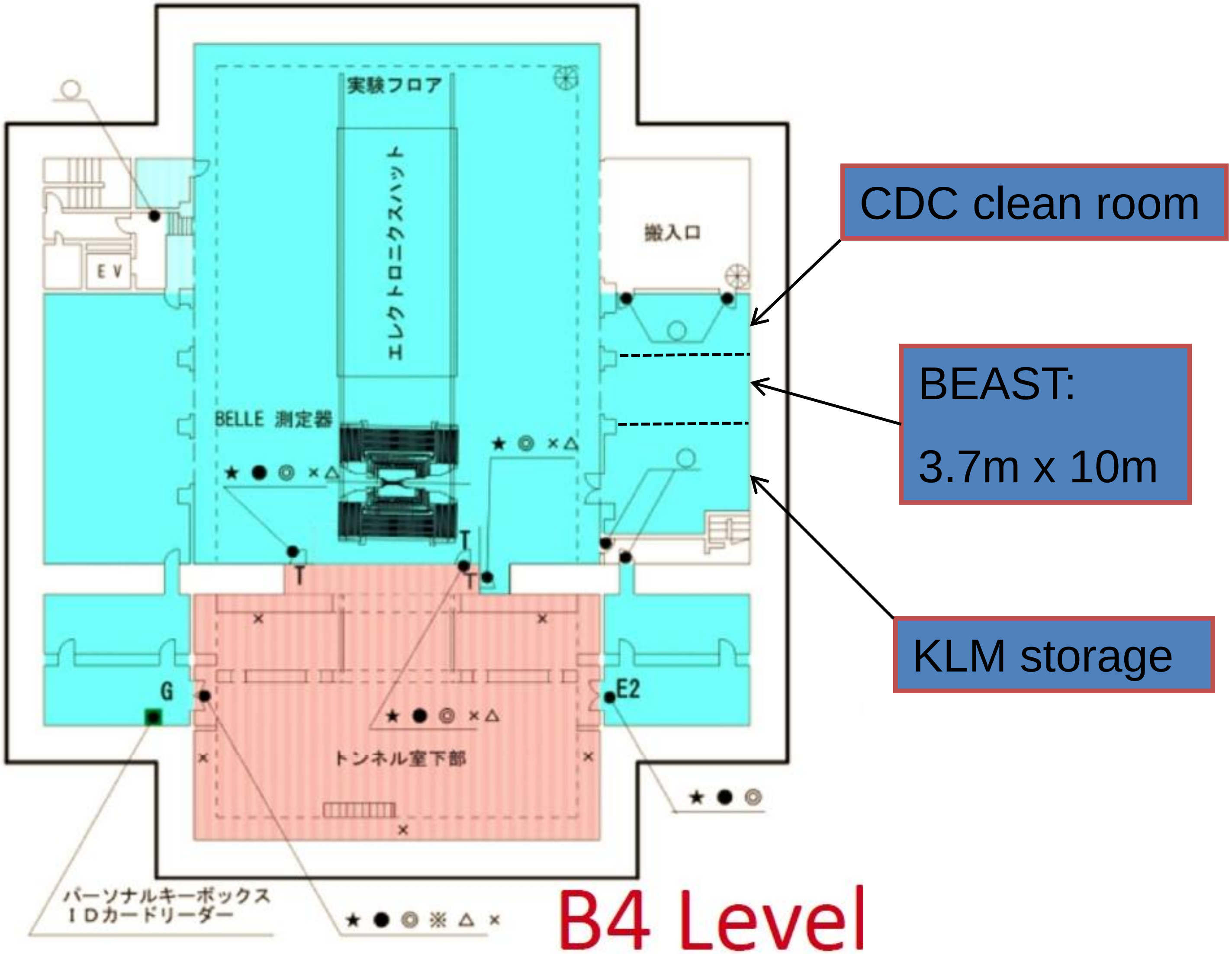
Mechanical Mockups





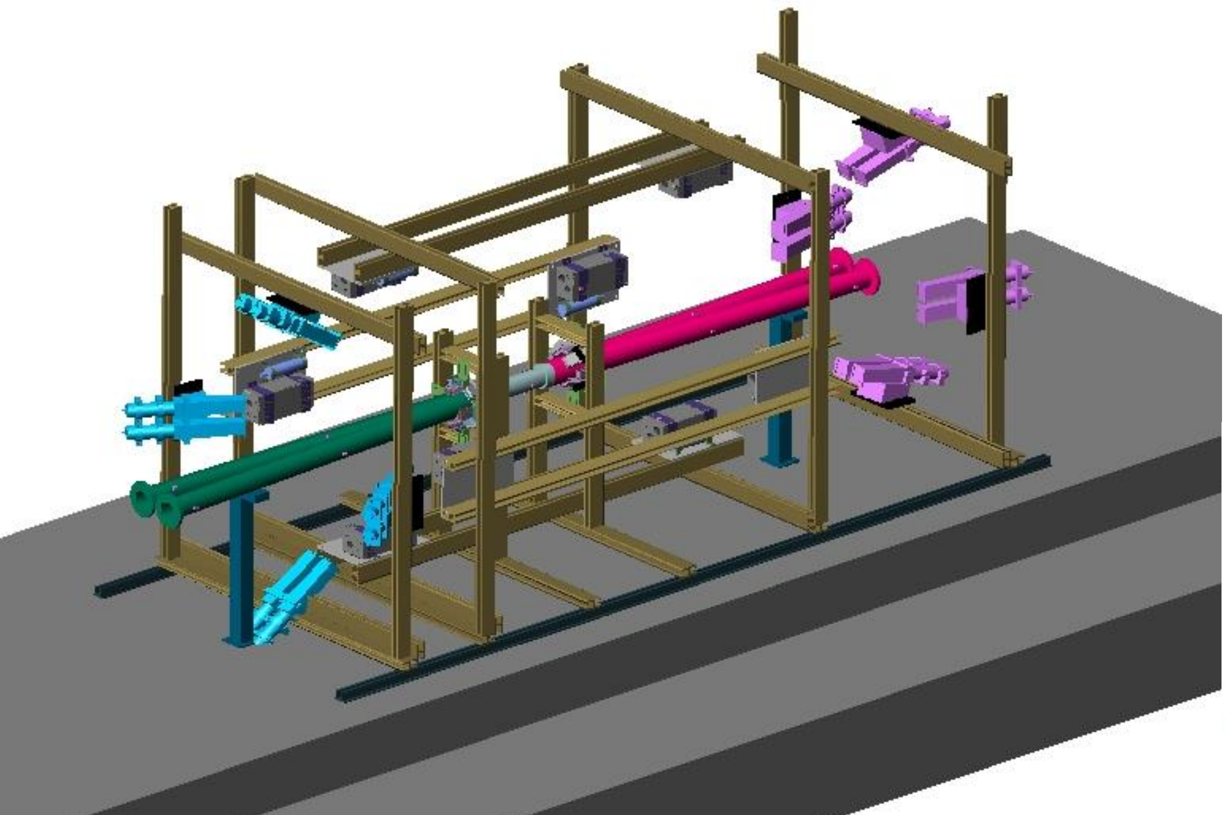
Small-scale mockups have been built to validate mechanical interfaces.

Phase 1 staging area in Tsukuba Hall B4 (“KLM side room”)

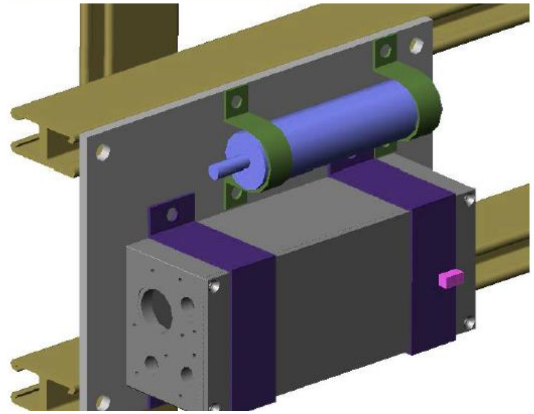


Proposing to skip phase 1 assembly in KLM side room. All mechanics & DAQ will already have been tested in Hawaii. **Still need KLM side room for receiving tests, repairs, staging.**

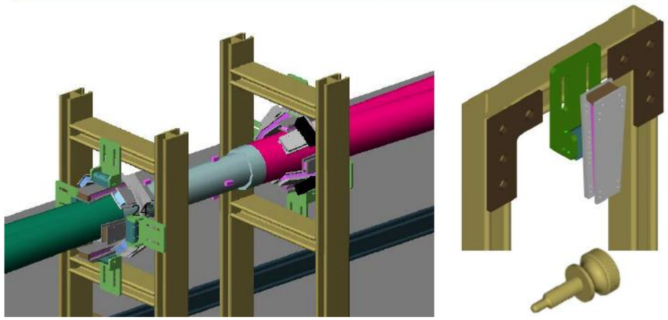
Phase 1 Mechanical Design (Rosen)



TPC Module with He3 proportional tube and diode.

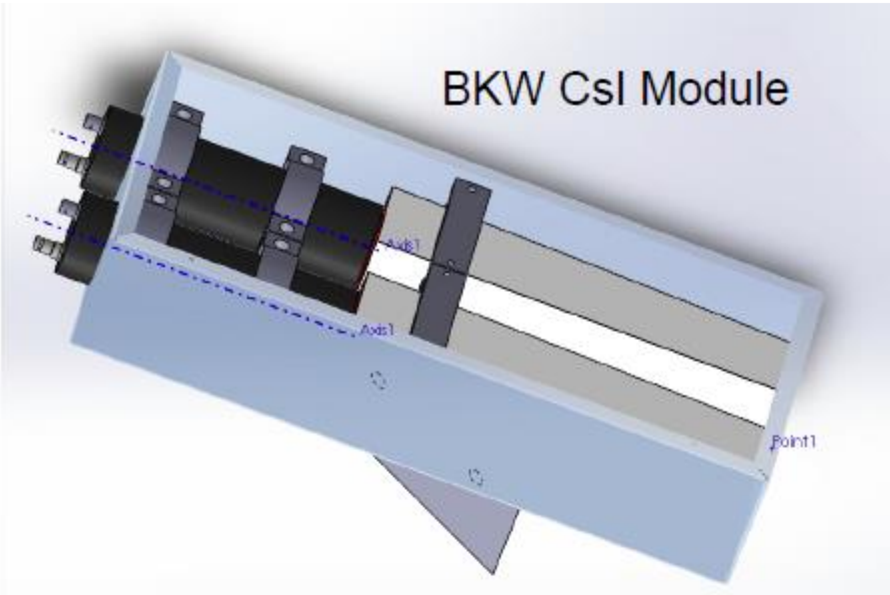


BKW and FWD BGO Modules: adjustable in X, Y, and Z.

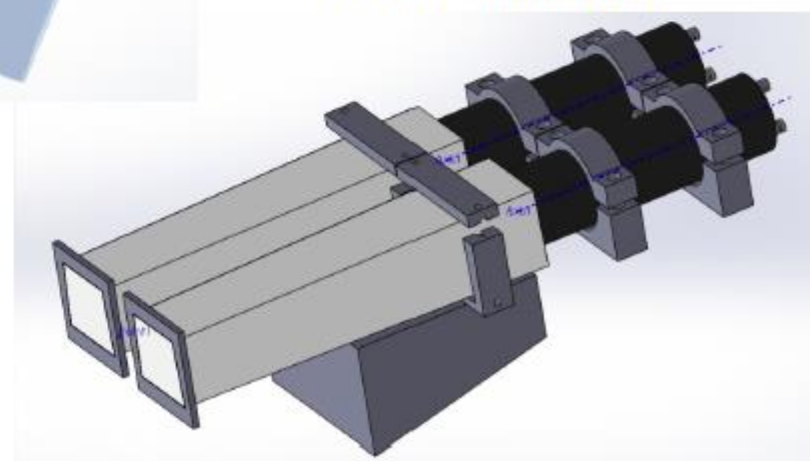


- Full 3D CAD exists (Rosen). Remaining work: Finalize CSI supports, cable strain reliefs
- Will use concrete anchors. Rosen will drill. Accelerator group has approved, will help survey
- Mockups of detector supports have been built (see previous B2GM)
- All parts purchased
- Will start cutting fiberglass and assemble in mockup “beast cave” at U. Hawaii next week

Phase 1 Mechanical Design (Beaulieu)



FWD CsI Module



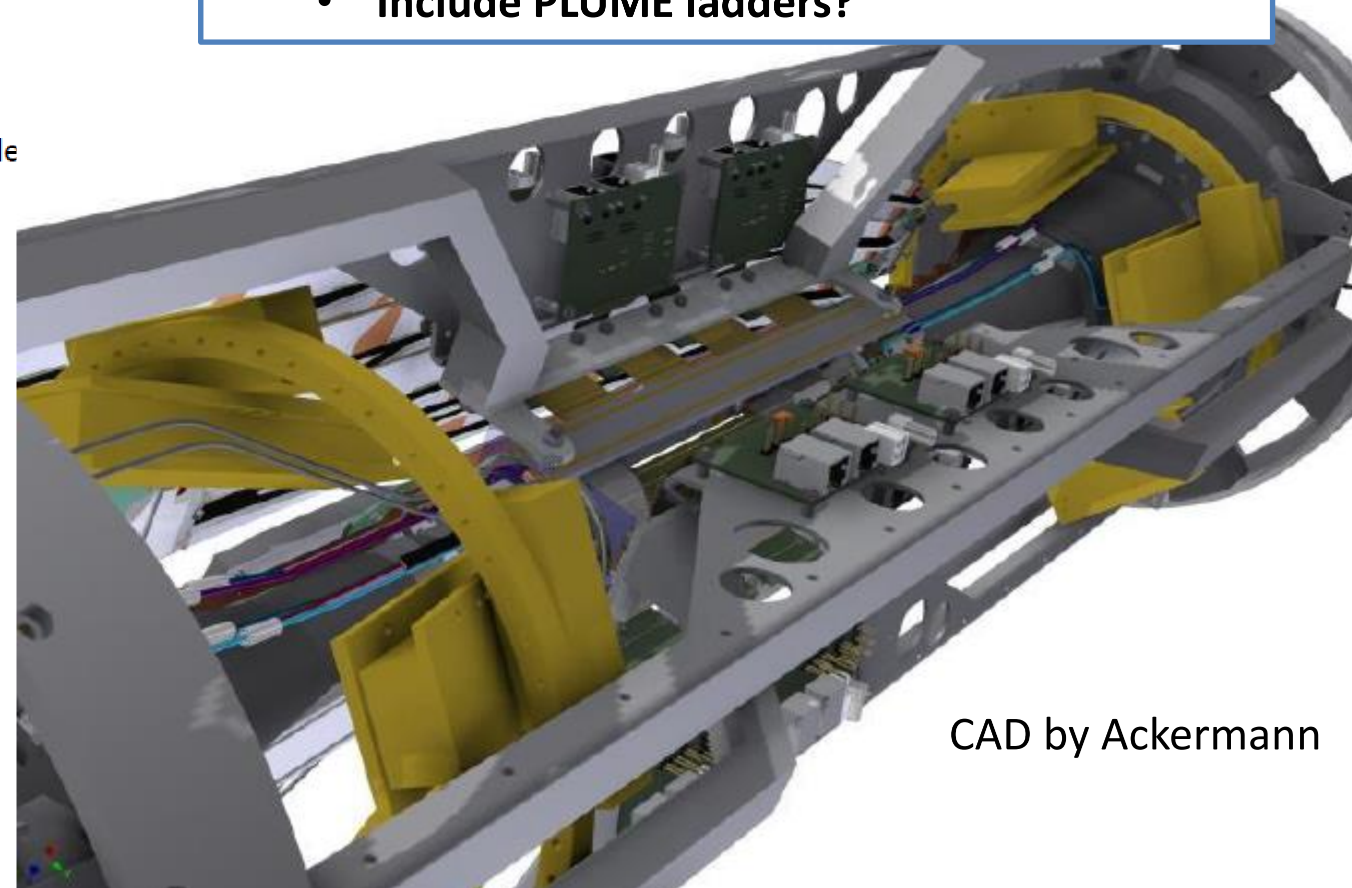
Each CsI module has a mass of ~15kg.

New addition to BEAST. Two crystals to Hawaii early 2015. Availability of crystals?

Phase 2 VXD Mechanics (Marinas talk)

- 2 PXD ladders (L1+L2)
- 4 SVD layers (L3-L6)
- Thermal envelope and cooling (dry air+CO_2)
- BEAST II specific monitoring
  → Synchrotron radiation (be
- Abort systems
  → Diamonds
- General monitoring (T and RH)
  → Fibers and commercial de

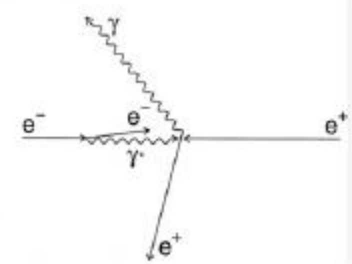
- Great progress on integrating VXD sensors, BGOs, and FE-I4 sensors (x-ray measurements)
- **Important open questions –*request EB guidance***
  - **Material (X_0) allowance?**
  - **Include PLUME ladders?**



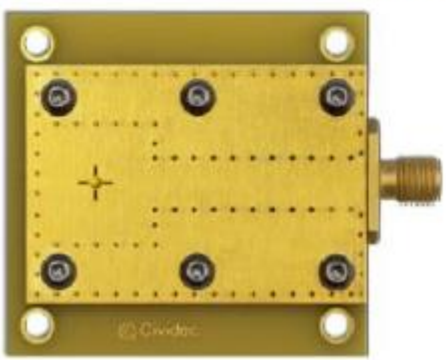
CAD by Ackermann

Fast Luminosity Monitoring

- Fast luminosity monitoring is required in the presence of dynamical imperfections, for feedback and optimization.
- Precision $\delta\mathcal{L}/\mathcal{L} = 10^{-3}$ in 1ms
- Lumi monitoring for each bunch crossing: 2500 bunches, collide each 4 ns
- Measurement: Radiative Bhabha process at zero photon scattering angle , Large cross-section ~ 0.2 barn
- Technologies: Sensors set immediately outside beam pipe



- 5x5 mm² diamond sensors (Radiation hardness, Fast charge collection)

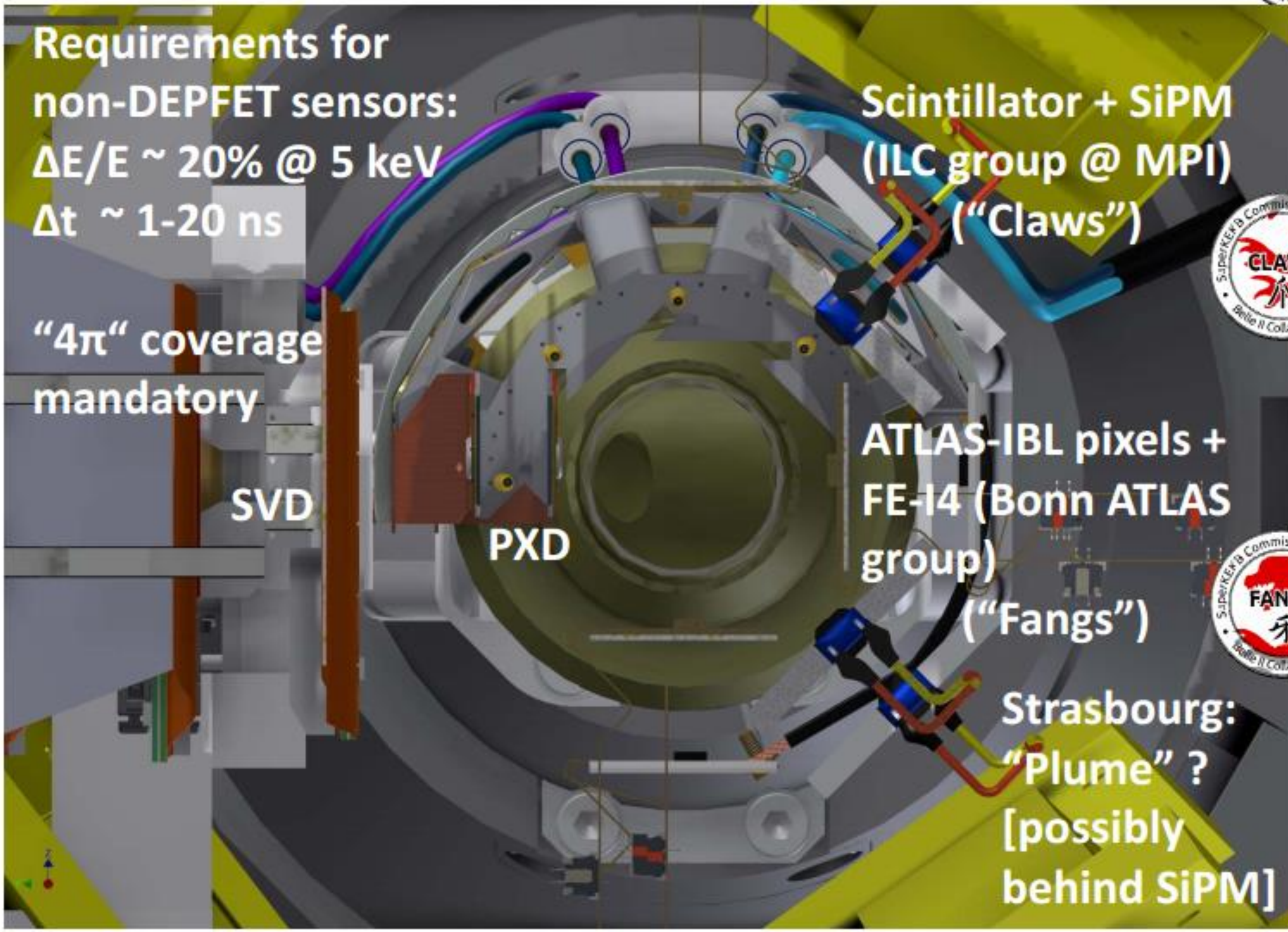


LAL group

-Scintillator + Cherenkov detector

ZDLM group at KEK, S.Uehara San

VXD Equipment during Phase 2



C. Kiesling, 9th Belle PAC, KEK, Feb. 9-11, 2015 8