Status of Belle

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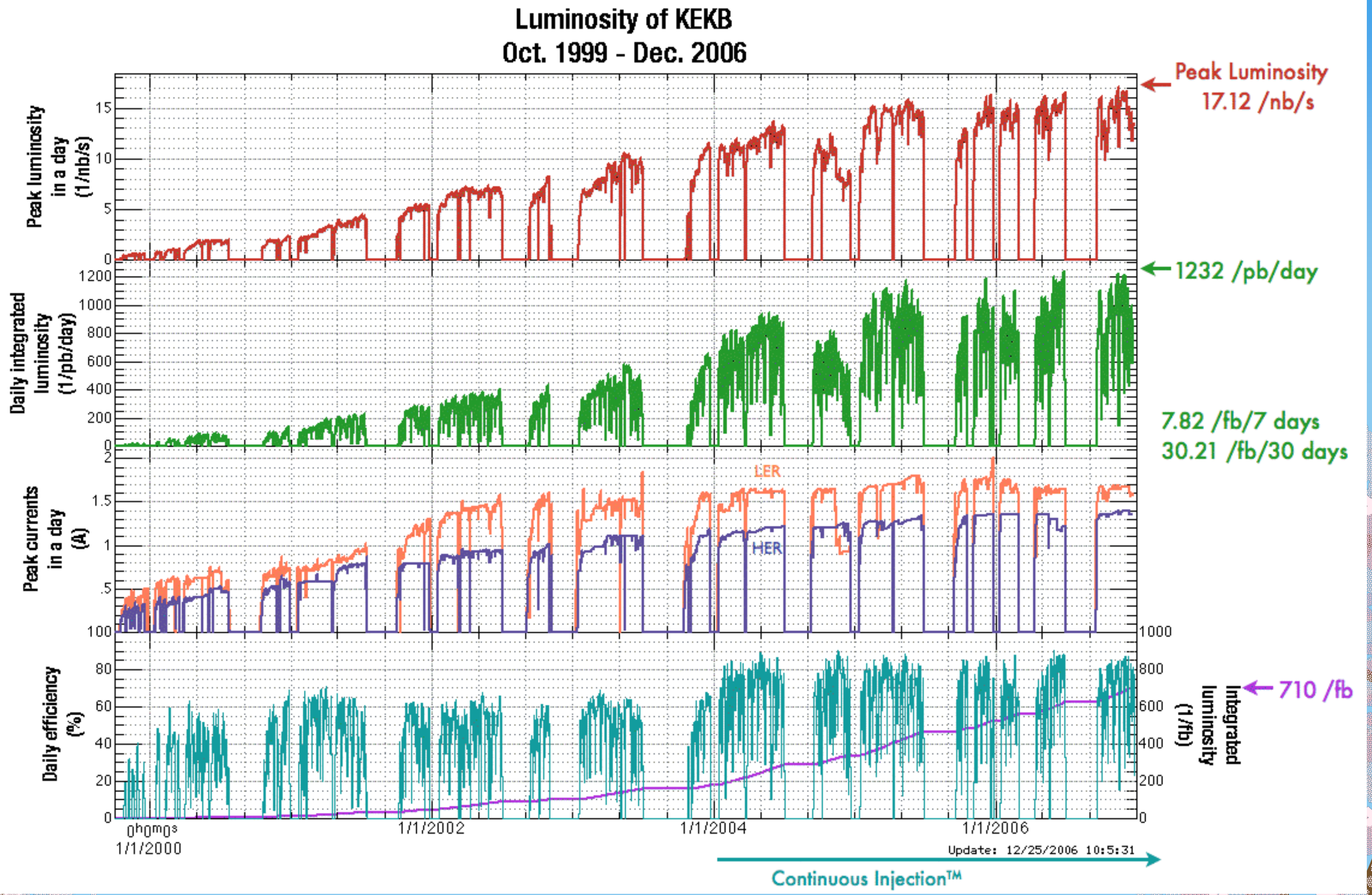
KEKB review, Mar.19, 2007

Outline

- **News on the Belle detector operation**
- Super-hot topics of physics
- Other topics of physics
- Summary & Conclusion



Luminosity of KEKB
Oct. 1999 - Dec. 2006
Peak Luminosity 17.12 /nb/s
1232 /pb/day
7.82 /fb/7 days
30.21 /fb/30 days
710 /fb
Peak luminosity in a day (1/nb/s)
Daily integrated luminosity (1/pb/day)
Peak currents in a day (A)
LER
HER
Daily efficiency (%)
Integrated luminosity (1/fb)
1/1/2000
1/1/2002
1/1/2004
1/1/2006
Update: 12/25/2006 10:5:31
Continuous Injection™

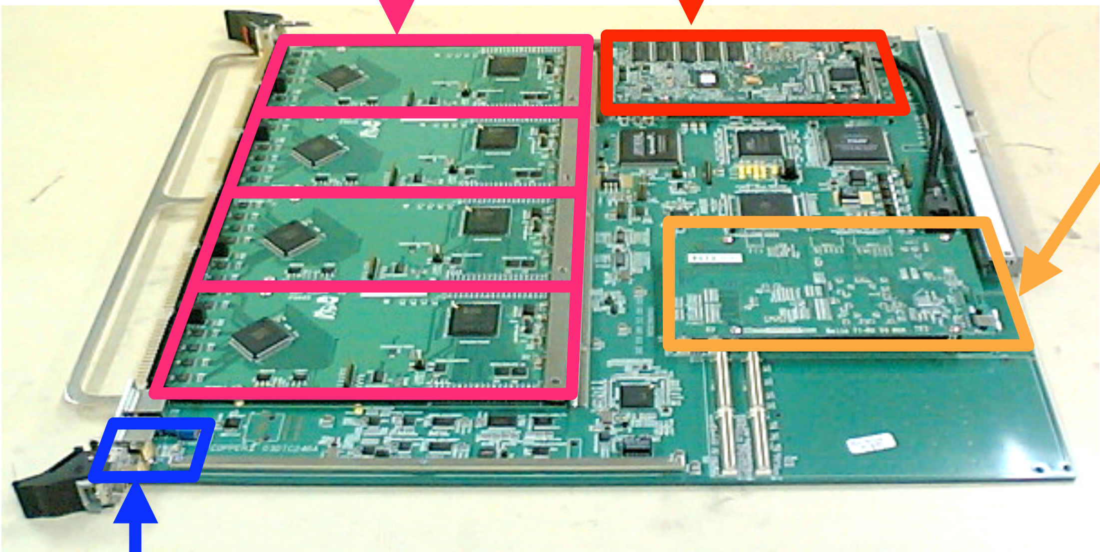
COPPER board

RadiSys EPC-6315
- **Intel P3 800 MHz**
- **256 MB memory**
- Network boot
- RedHat Linux 9

digitizer×4
(daughter board)

onboard CPU
(online data reduction, etc…)

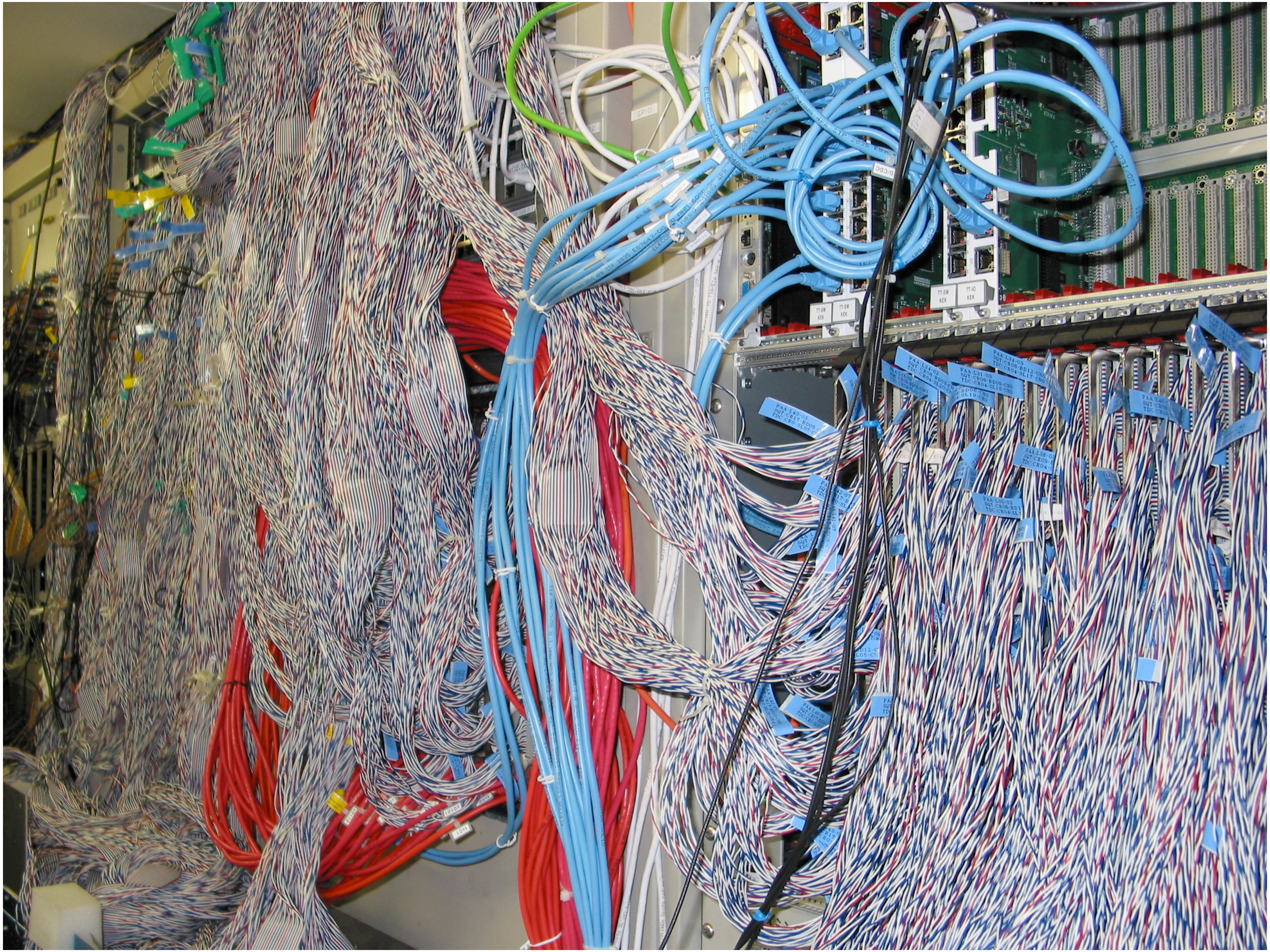
VME9U



Trigger module

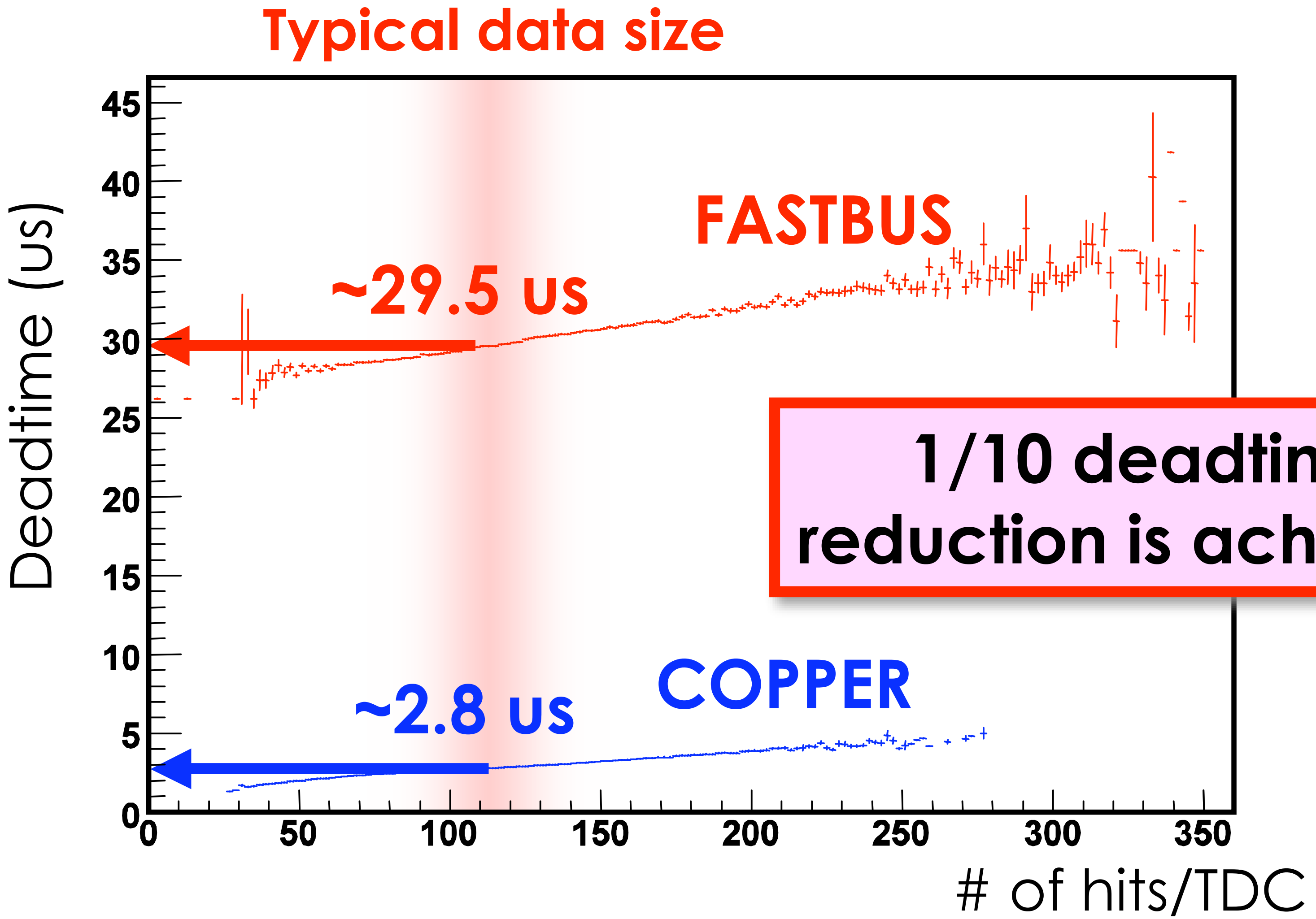
100BaseT port×2
boot/control, data transfer

First step for the pipelined readout
→ COPPER for the **CDC**



Performance: Deadtime Reduction

Yamagata



1/10 deadtime reduction is achieved

COPPERIZATION EFFORT CONTINUES…

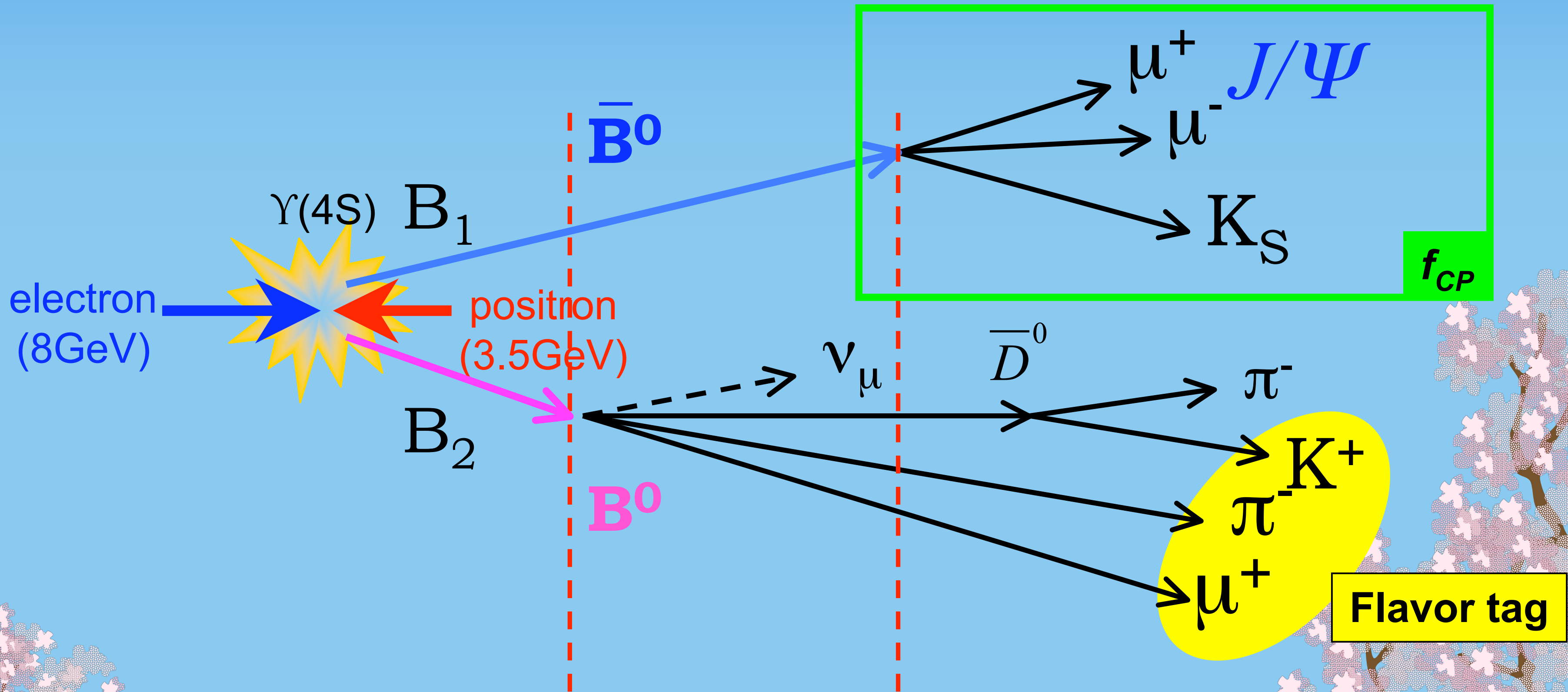
Will become COPPER in the coming summer
ACC, TRG, (part of) ECL

KLM, TOF, SVD, (rest of) ECL asap

Outline

- News on the Belle detector operation
- **Super-hot topics of physics**
  - **EPR Entanglement**
  - **D^0-D^0b mixing**
  - **Dark Matter Search**
- Other topics of physics
- Summary & Conclusion

Δt measurement at Belle

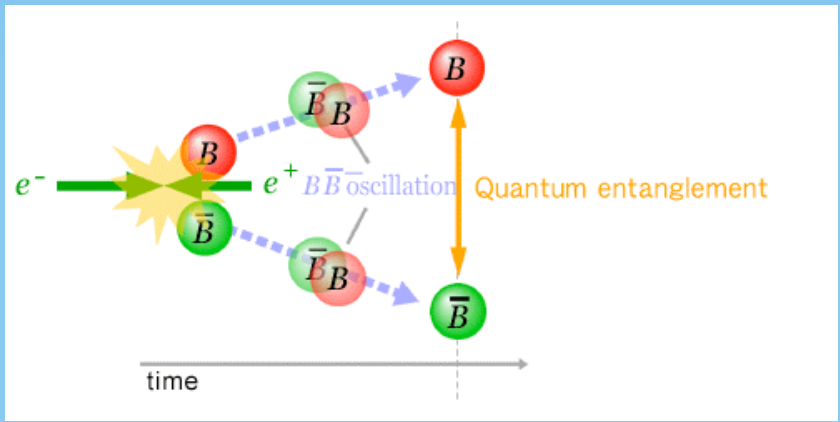


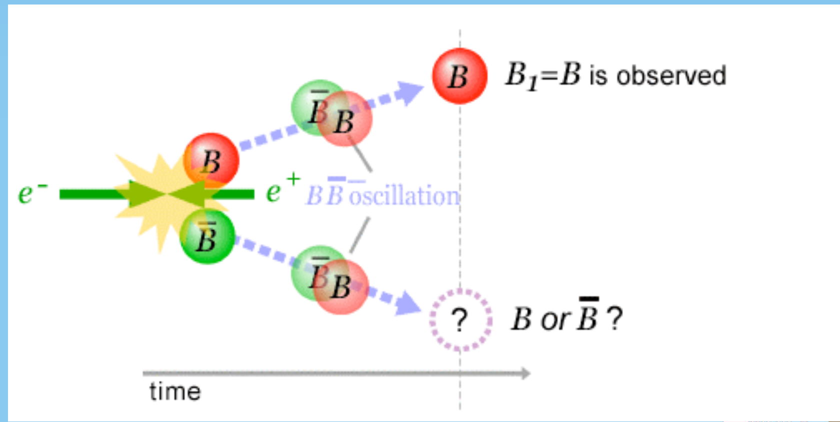
Δz ~ 200μm

$$\Delta t \approx \frac{\Delta z}{\langle \beta\gamma \rangle c}$$

Entangled state and EPR paradox

Entangled state cannot be described as product states of parts





Quantum Mechanics ↔ Local Realism

If one is B^0, the other is B^0b
at that moment

How can we know about the other B
before even light reaches?

Was pointed out by Einstein for the first time

MAY 15, 1935 PHYSICAL REVIEW VOLUME 47

Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?

A. EINSTEIN, B. PODOLSKY AND N. ROSEN, *Institute for Advanced Study, Princeton, New Jersey*

(Received March 25, 1935)

Quantum Mechanics cannot be a complete theory!! (A.E)

Experimental Tests have been performed
in photon pairs, kaon pairs
→ QM confirmed

BB pair from Y(4S) decay is one of the few coherent system
much higher energy scale (~10GeV)

Time-dependent Flavor Asymmetry

QM: Time-dependent decay rate

Same Flavor ($B^0 B^0$, $\bar{B}^0 \bar{B}^0$): $\propto 1 - \cos(\Delta m \Delta t)$

Opposite Flavor ($B^0 \bar{B}^0$) : $\propto 1 + \cos(\Delta m \Delta t)$

$$A_{QM}(\Delta t) = \frac{OF - SF}{OF + SF} = \cos(\Delta m \Delta t)$$

Non-QM models: (example)

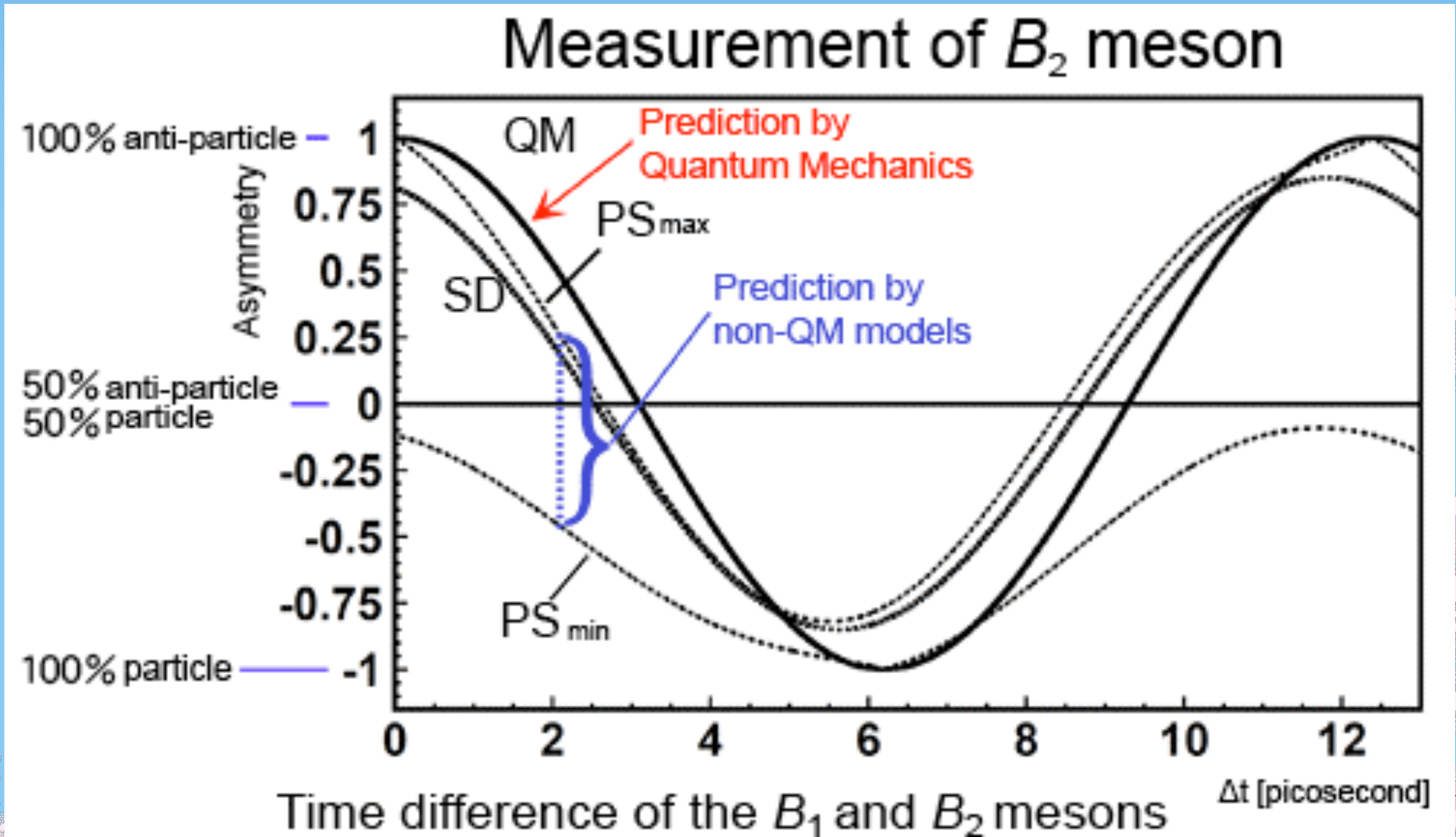
- **Local Realism: Pompili & Selleri (PS)**

  "elements of reality" = Flavor & mass ($B_H, B_L, \bar{B}_H, \bar{B}_L$)

  random flavor flip within pair

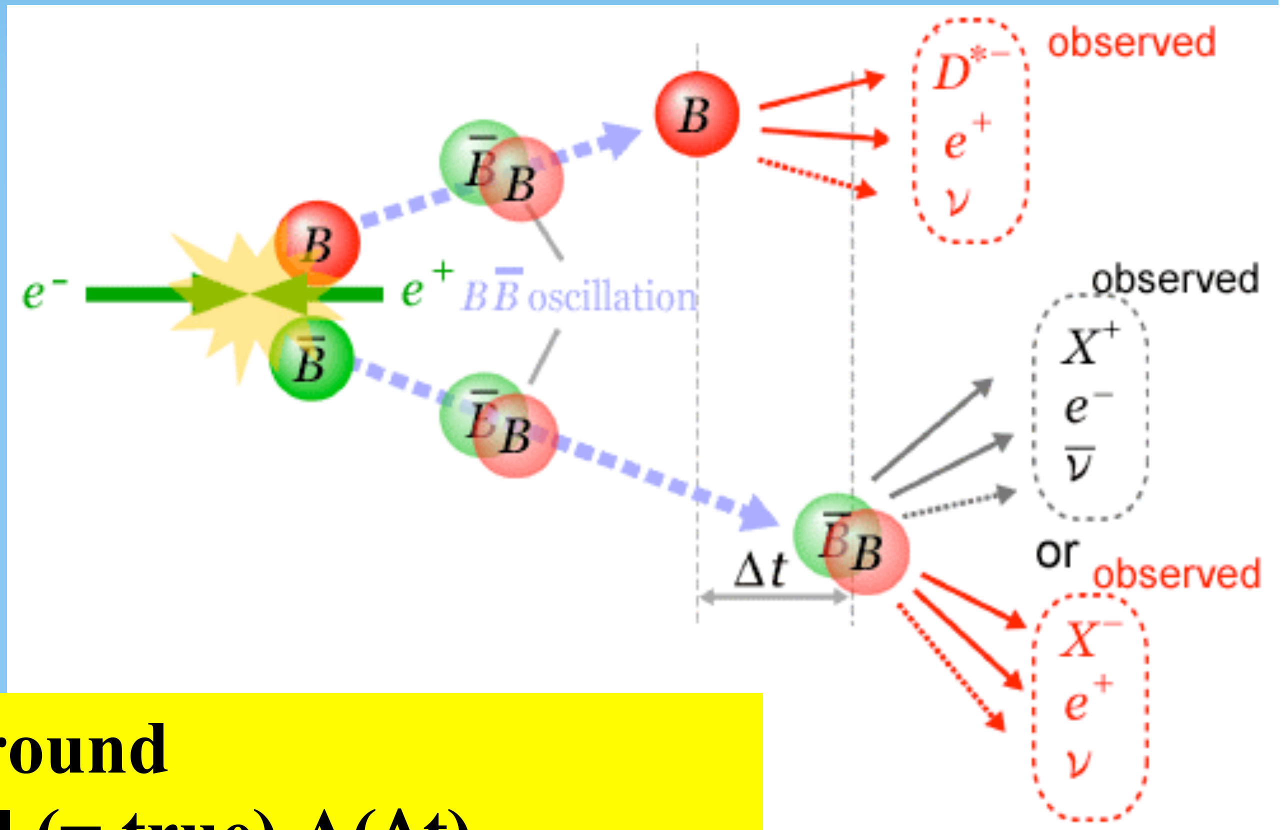
- **Spontaneous & immediate Decoherence (SD)**

Expectations



Analysis Method

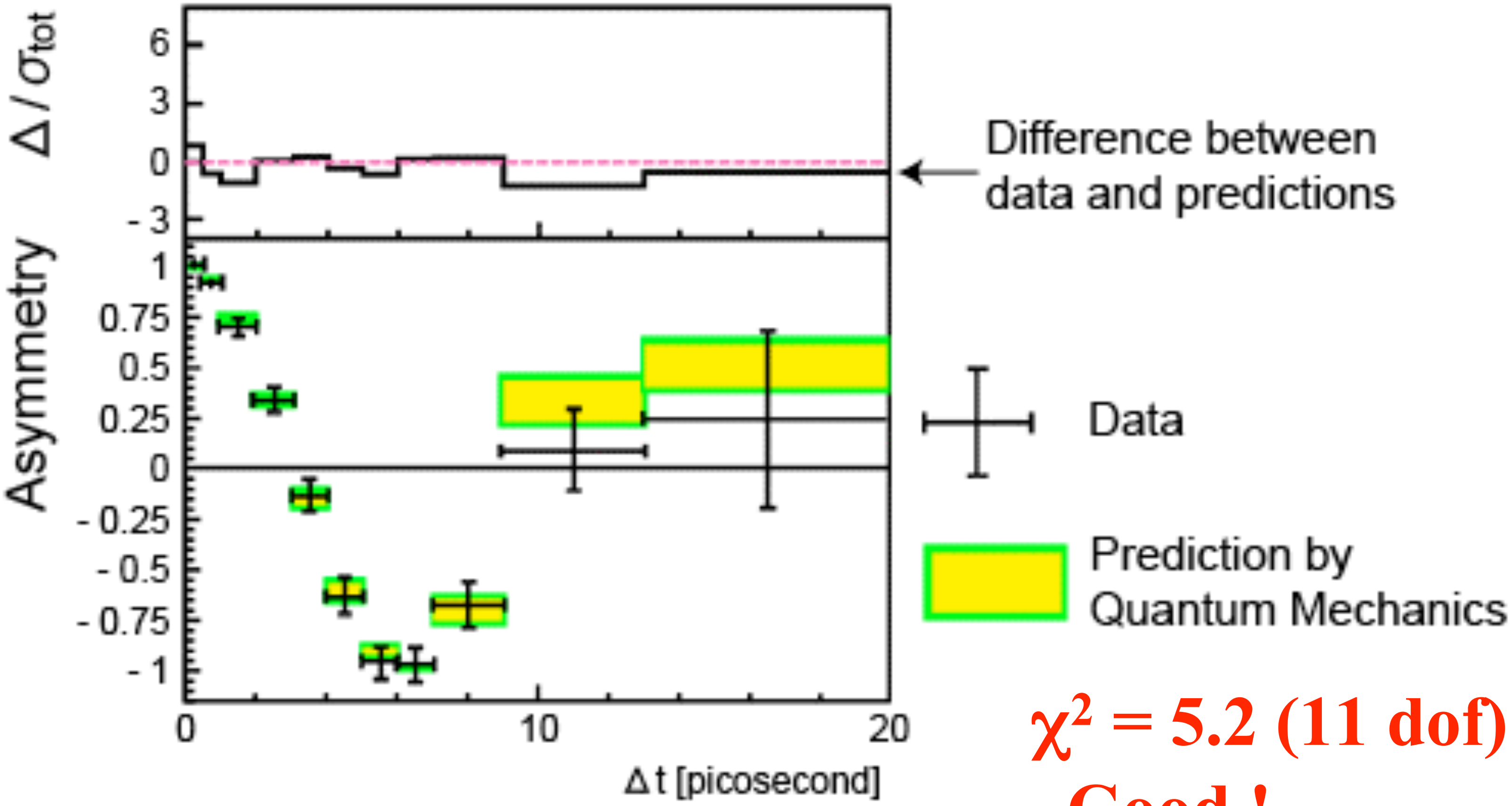
$B^0 \to D^*l\nu$ + High Quality (lepton) tag



- **Subtract Background**
- **Obtain Unfolded (= true) A(Δt)**

→ Direct comparison with (any) theories

Results & fit with QM



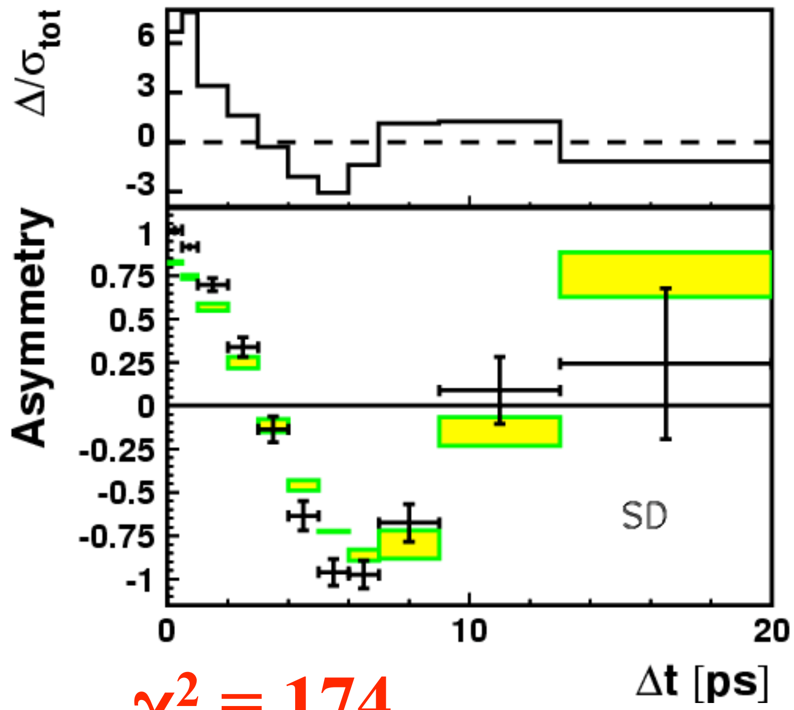
χ^2 = 5.2 (11 dof)

Good !

[fit including WA Δm = (0.496 ± 0.014) ps^{-1} (excl. Belle/BaBar)]

Result: SD & PS

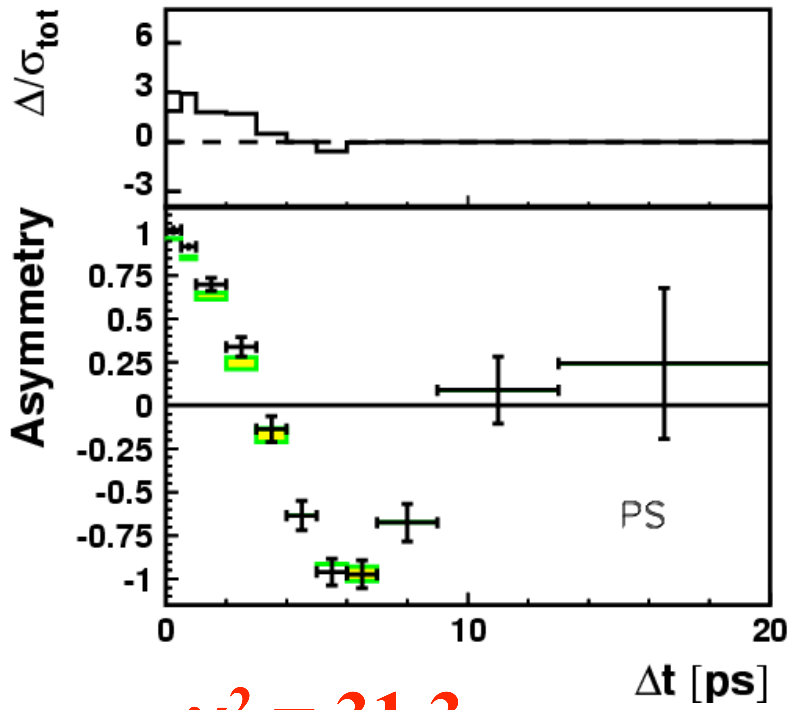
SD



$\chi^2 = 174$

disfavored 13σ over QM

PS



$\chi^2 = 31.3$

disfavored 5.1σ over QM

Decoherence fraction: $\lambda = 0.029 \pm 0.057$

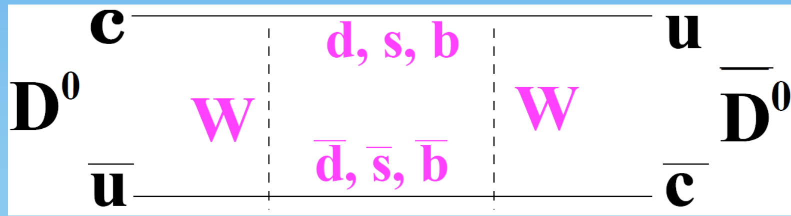
Conclusion

- QM is valid at E~10GeV
- SD, PS models are disfavored

D0-D0b mixing

Mixing observed in K^0, B^0_d and B^0_s, not yet in D^0 system

D^0 mixing in the SM governed by box diagrams



$$
\begin{aligned}
A &= \sum_{i,j=d,s,b} V_{ci}^{*} V_{ui} V_{cj} V_{uj}^{*} S\left(m_i^2, m_j^2\right) \\
&\approx \sum_{i,j=d,s} V_{ci}^{*} V_{ui} V_{cj} V_{uj}^{*} S\left(m_i^2, m_j^2\right) \\
&\approx \left(V_{cd}^{*} V_{ud} V_{cd} V_{ud}^{*} + V_{cd}^{*} V_{ud} V_{cs} V_{us}^{*} + V_{cs}^{*} V_{us} V_{cd} V_{ud}^{*} + V_{cs}^{*} V_{us} V_{cs} V_{us}^{*}\right) \cdot S \\
&= \left(-V_{cs}^{*} V_{us} V_{cd} V_{ud}^{*} - V_{cs}^{*} V_{us} V_{cs} V_{us}^{*} + V_{cs}^{*} V_{us} V_{cd} V_{ud}^{*} + V_{cs}^{*} V_{us} V_{cs} V_{us}^{*}\right) \cdot S \qquad (\because \text{CKM unitarity}) \\
&= 0
\end{aligned}
$$

Effective GIM suppression ($m_d \approx m_s$)

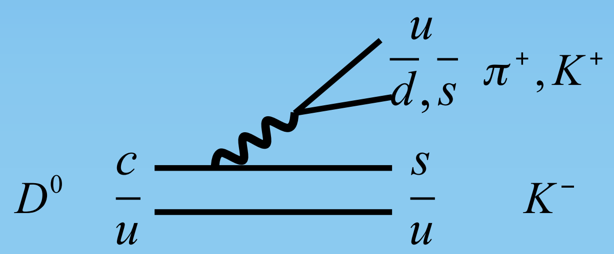
→ mixing in D^0 system is rare process

→ difficult to measure

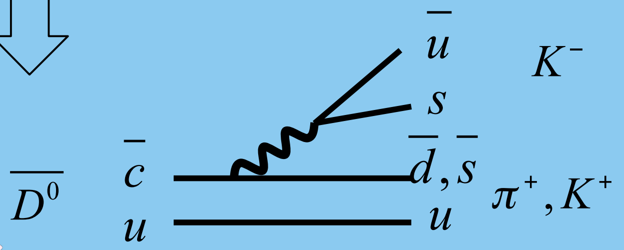
→ sensitive to the new physics

What to measure?

Lifetime difference between $D^0 \to K^-\pi^+$ and $D^0 \to K^-K^+$(, $\pi^-\pi^+$)



CF, CS



DCS, CS

No mixing → effective lifetimes are equal

$$A_{\pi^+K^-} \propto e^{-\Gamma t}$$
$$A_{K^+K^-} \propto e^{-\Gamma t}$$

mixing → effective lifetimes are different

$$A_{\pi^+K^-} \propto e^{-\Gamma\left(1+y_{K^-\pi^+}\right)}$$
$$A_{K^+K^-} \propto e^{-\Gamma\left(1+y_{K^+K^-}\right)}$$

non-zero $y_{CP} \equiv \dfrac{1+y_{K^+K^-}}{1+y_{K^-\pi^+}} - 1 \approx \dfrac{\Delta\Gamma}{2\Gamma}$

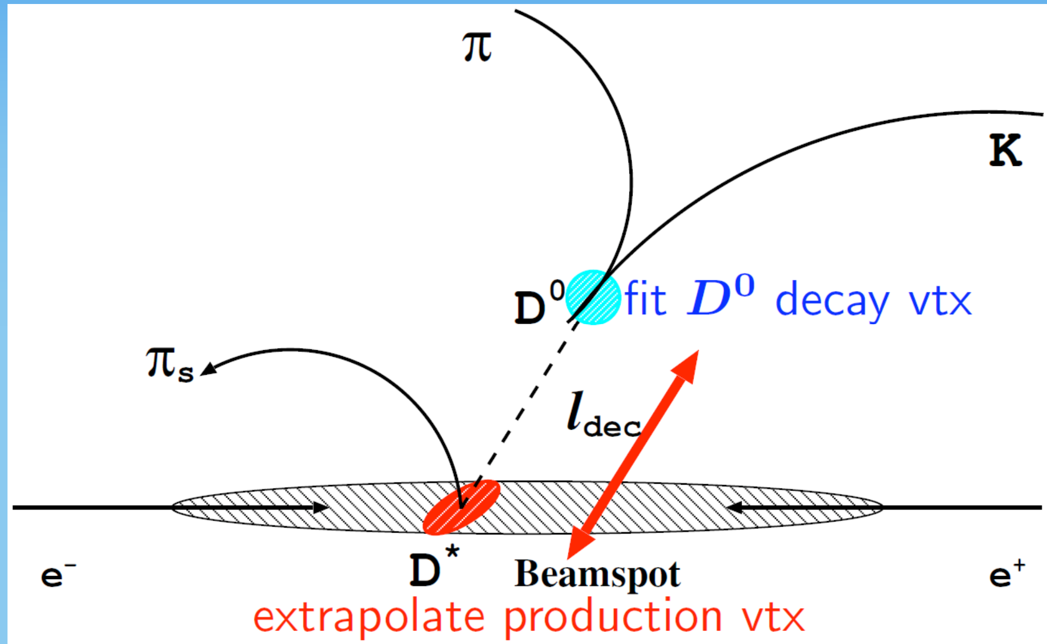
is a manifestation of D^0 mixing

Experimental Technique

Flavor tag at production

$$D^{*+} \to \pi^+ D^0$$

$$D^{*-} \to \pi^- \overline{D}^0$$



Proper-time measurement

$$t = \frac{l_{dec}}{c\beta\gamma}, \ \beta\gamma = \frac{p_{D^0}}{M_{D^0}}$$

D mesons from charm pair production $e^+e^- \to c\overline{c}$

to reject D* from B decays

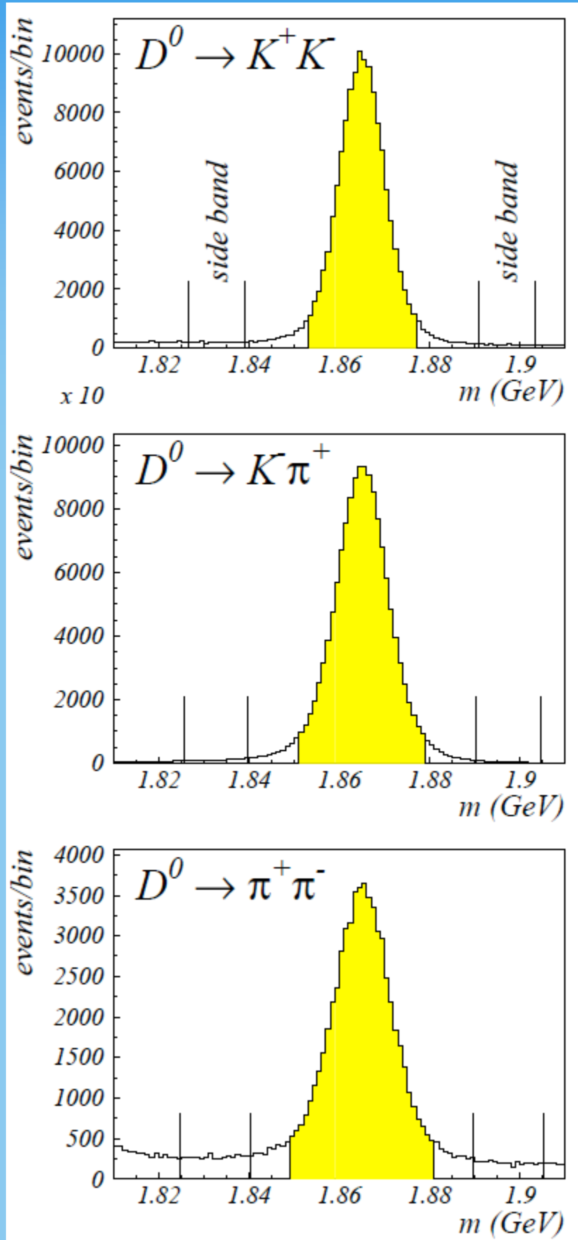
$$p_{D^{*+}}^{CMS} > 2.5GeV/c$$

signal events for fit

110K signal, purity = 98%

1.2M signal, purity = 99%

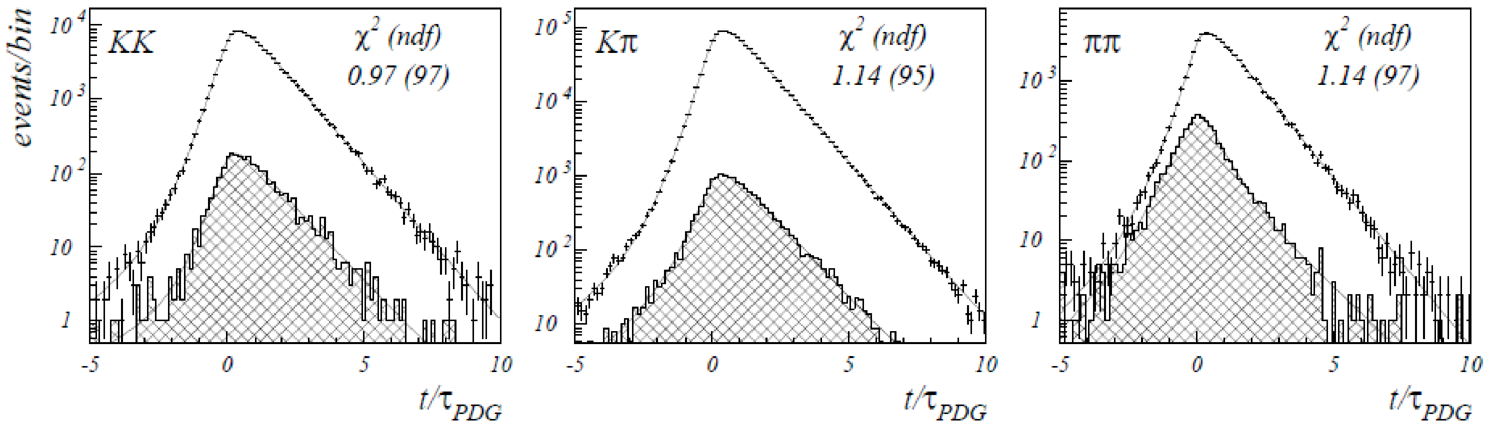
50K signal, purity = 92%



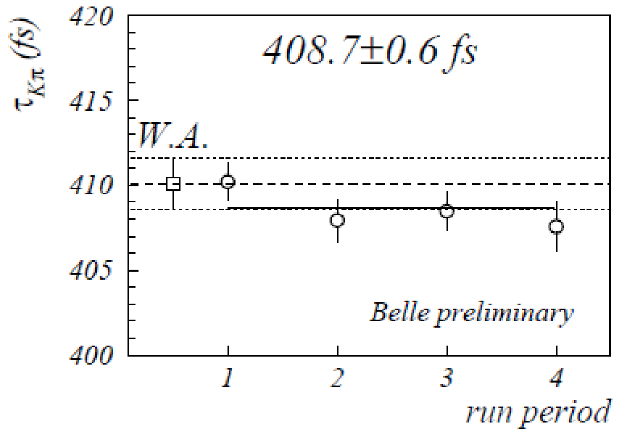
$D^0 \to K^+K^-,\ \pi^+\pi^-$ (Belle, 540 fb^{-1})

Simultaneous $KK/\pi\pi/K\pi$ binned likelihood fit

quality of fit: $\tilde{\chi}^2 = 1.084$ (289)



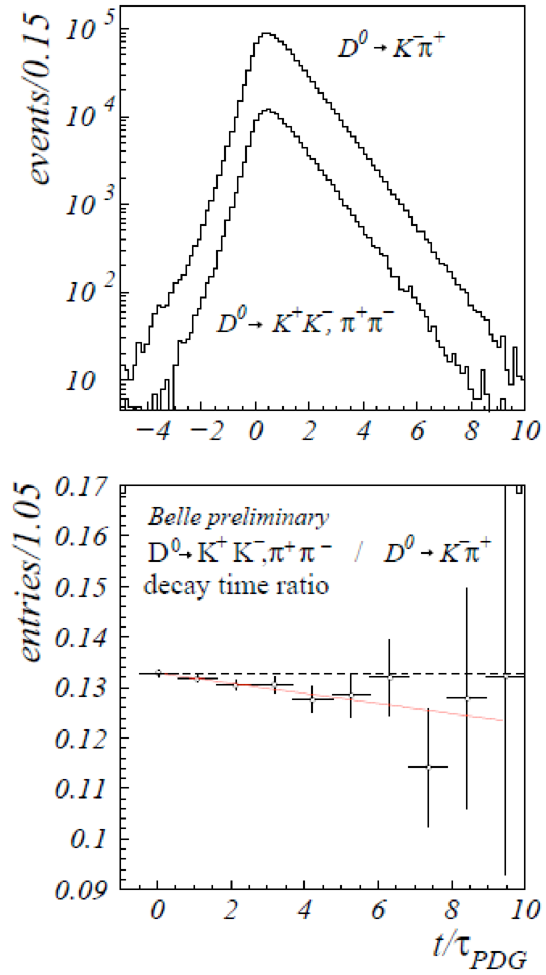
$D^0 \to K\pi$ lifetime very stable in slightly different running periods



$D^0 \to K^+K^-,\ \pi^+\pi^-$ (Belle, 540 fb^{-1})

Results (preliminary)

	y_{CP} (%)	A_Γ (%)
KK	1.25±0.39±0.28	0.15±0.34±0.16
$\pi\pi$	1.44±0.57±0.42	-0.28±0.52±0.30
$KK+\pi\pi$	1.31±0.32±0.25	0.01±0.30±0.15



Belle preliminary (540 fb^{-1})

$$y_{CP} = 1.31 \pm 0.32 \pm 0.25\ \%$$

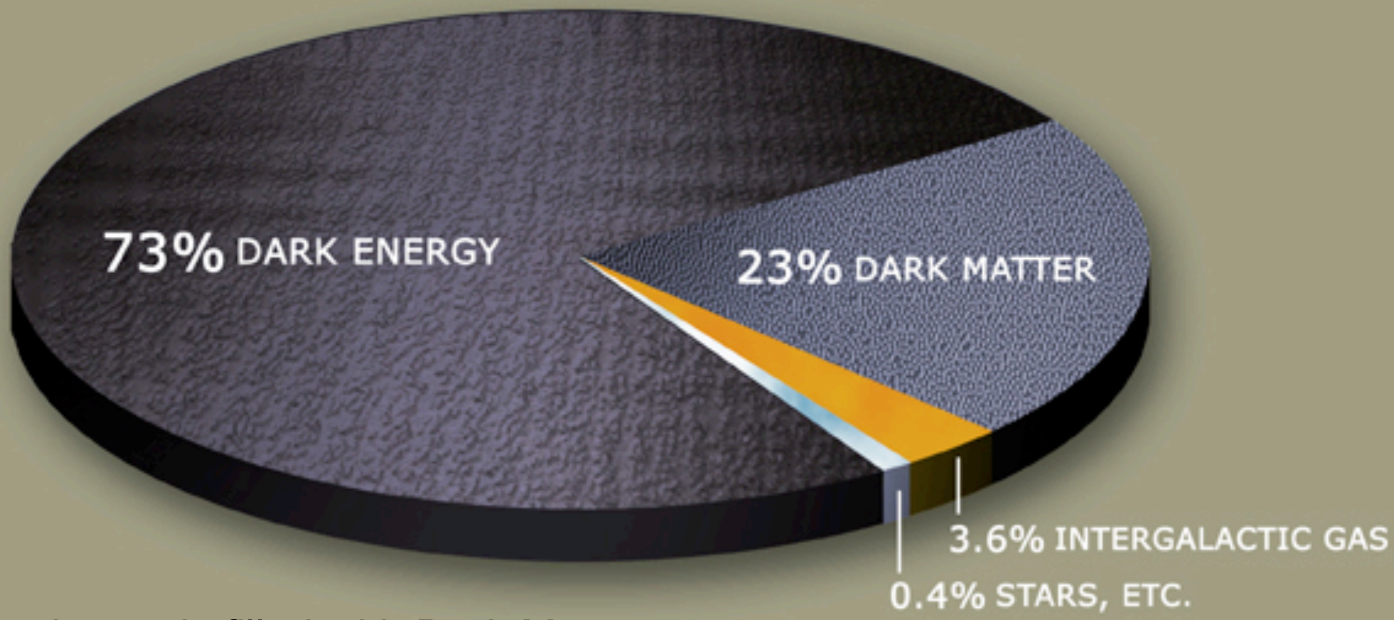
$> 3\sigma$ above zero
(4.1σ stat. only)
first evidence for $D^0 - \bar{D}^0$ mixing !!

$$A_\Gamma = 0.01 \pm 0.30 \pm 0.15\ \%$$

no evidence for CP violation

Marko Starič
J. Stefan Institute, Ljubljana, Slovenia

Dark Matter Search

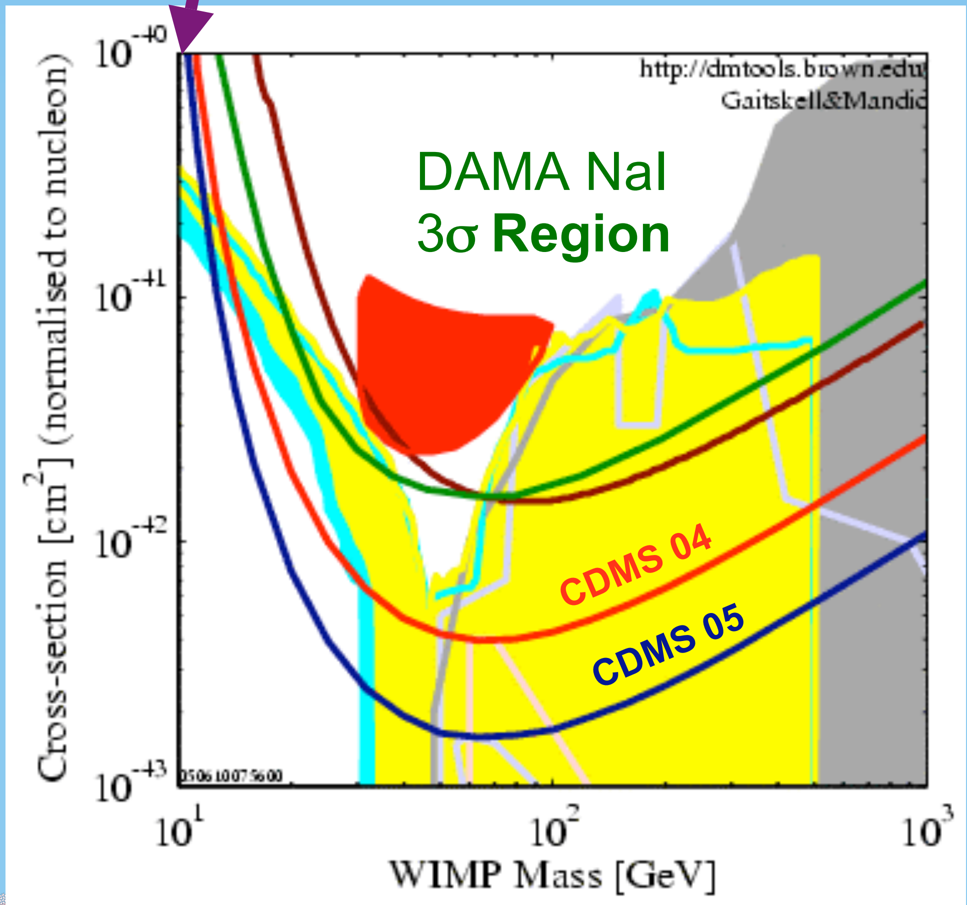


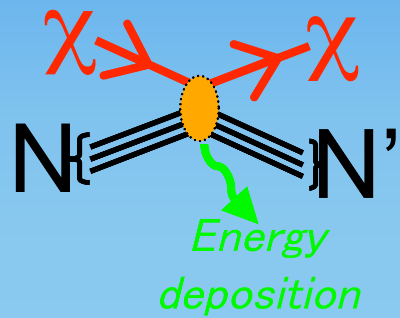
o% antimatter

¼ of our universe is filled with Dark Matter
WIMPs are good candidates of DM
(Weakly Interacting Massive Particle)

Experimental Situation

No sensitivity in direct searches
in low mass (O(1GeV)) region





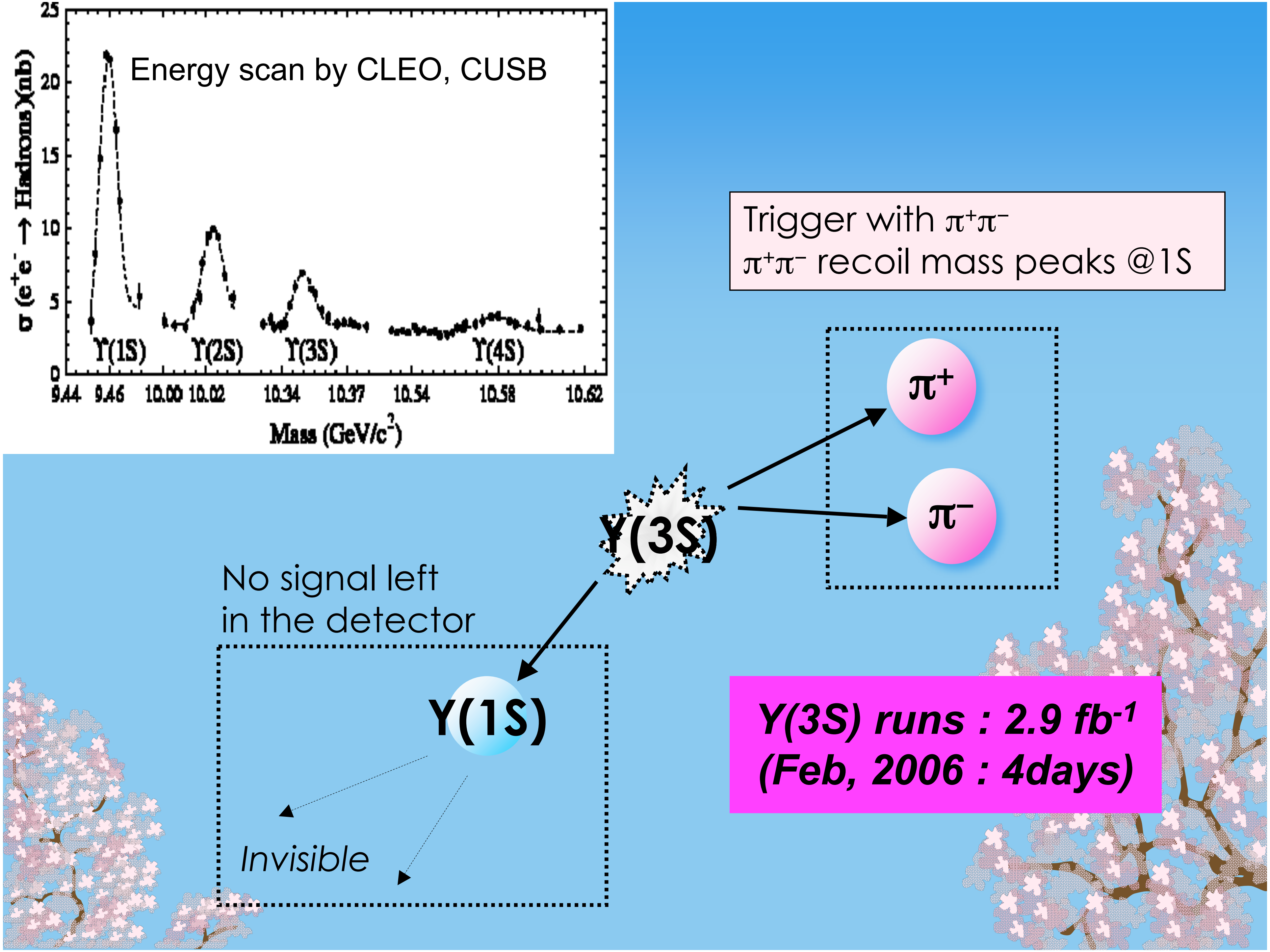
Theory Prediction in low mass region

$B(\Upsilon(1S) \rightarrow \chi\chi) \sim 6\times10^{-3}$ ($m_\chi < 4.73\,GeV/c^2 \sim m_b$)

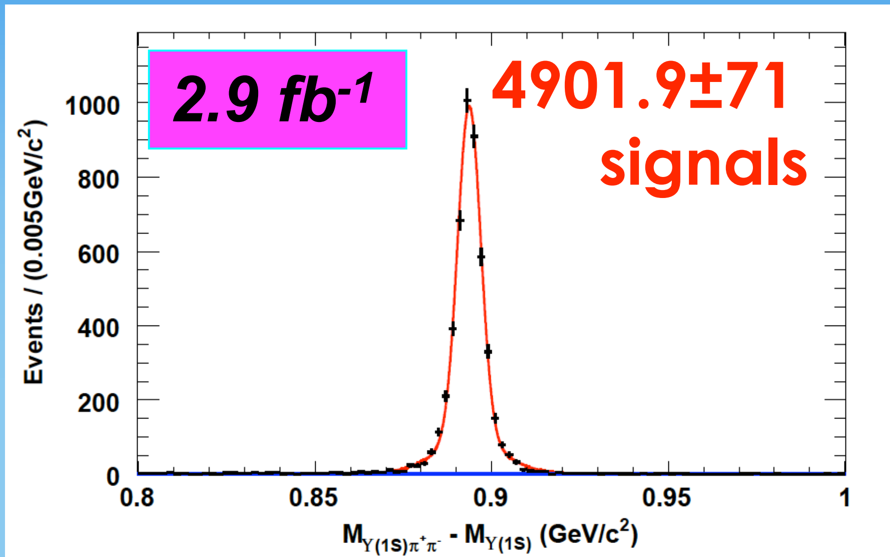
PRD 72, 103508 (2005) "Invisible quarkonium decays as a sensitive probe of dark matter"
Presented by B. McElrath in BNM-I in KEK Sep, 2006

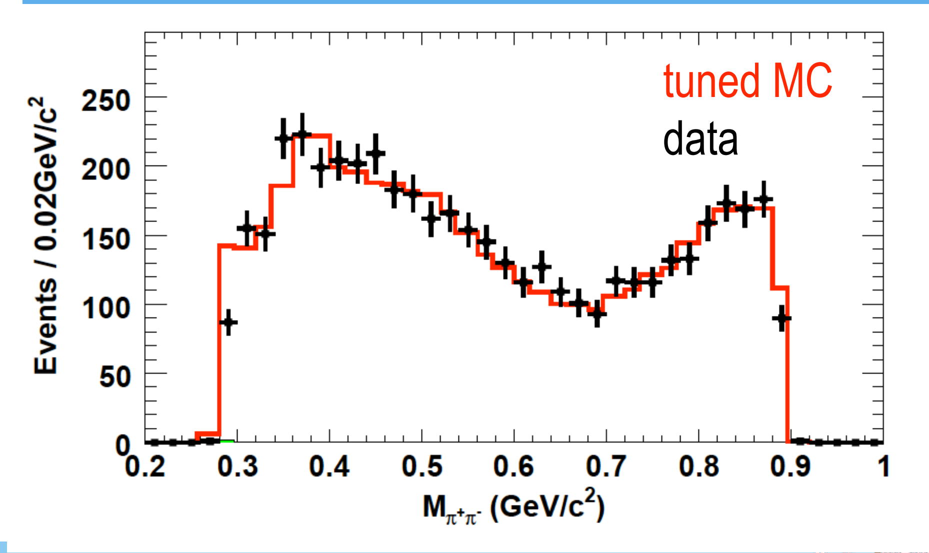
Previous Upper Limit : $< 23\times10^{-3}$ (90% CL) by ARGUS (1986)

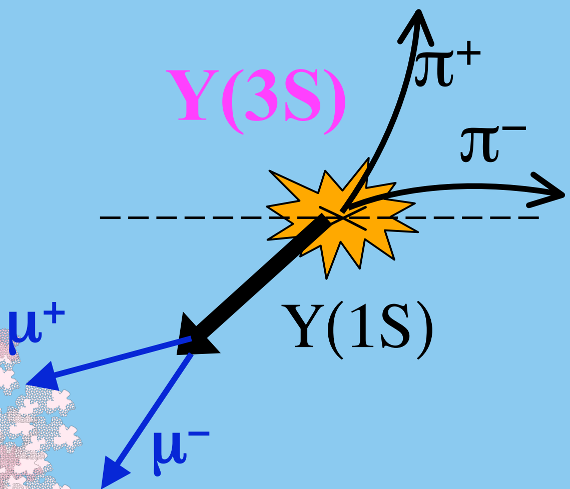
→ Why don't we measure this at Belle?

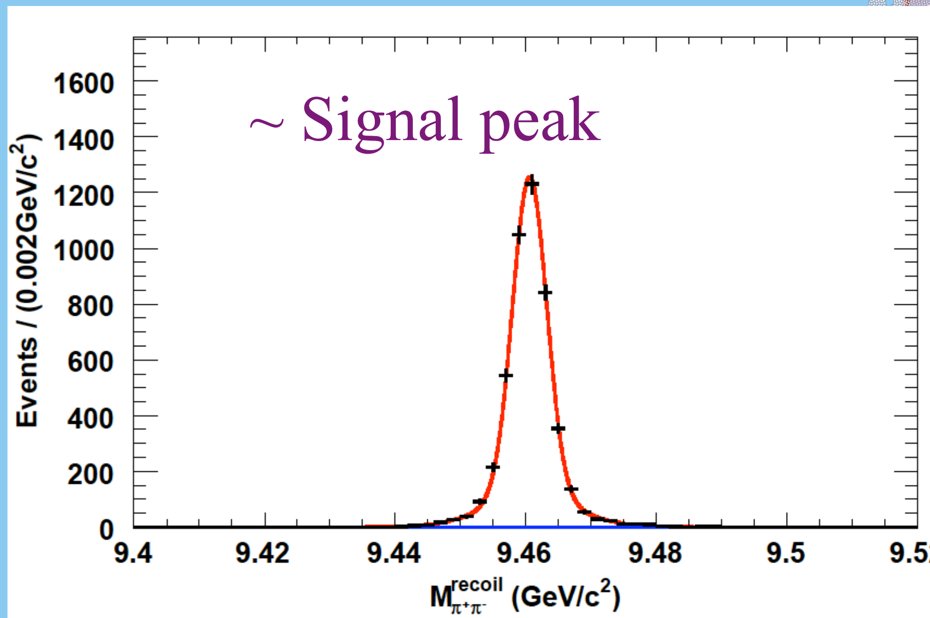

Energy scan by CLEO, CUSB
σ (e⁺e⁻ → Hadrons)(nb)
Mass (GeV/c²)
Υ(1S)
Υ(2S)
Υ(3S)
Υ(4S)
Trigger with π⁺π⁻
π⁺π⁻ recoil mass peaks @1S
π⁺
π⁻
Y(3S)
No signal left
in the detector
Y(1S)
Invisible
Y(3S) runs : 2.9 fb⁻¹
(Feb, 2006 : 4days)

Control Sample

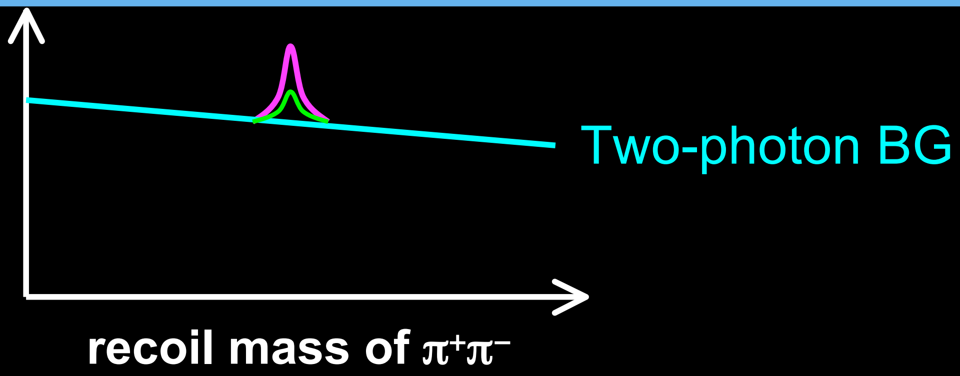






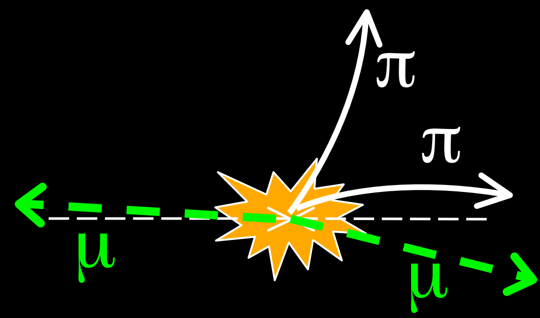


Background Expectation



$\Upsilon(1S) \rightarrow \mu^+\mu^-, e^+e^- \ldots$ (outside of acceptance)

$\Upsilon(1S) \rightarrow \nu\bar{\nu}$	$0.4 \pm$	0.1
$\Upsilon(1S) \rightarrow \mu^+\mu^-$	$77.3 \pm$	12.0
$\Upsilon(1S) \rightarrow e^+e^-$	$50.3 \pm$	8.2
$\Upsilon(1S) \rightarrow \tau^+\tau^-$	$5.2 \pm$	1.0
Other $\Upsilon(1S)$ decay modes	$0.0 +$	2.8
Other possible contributions	$0.0 +$	12.9
Total	133.2	$^{+19.7}_{-14.6}$



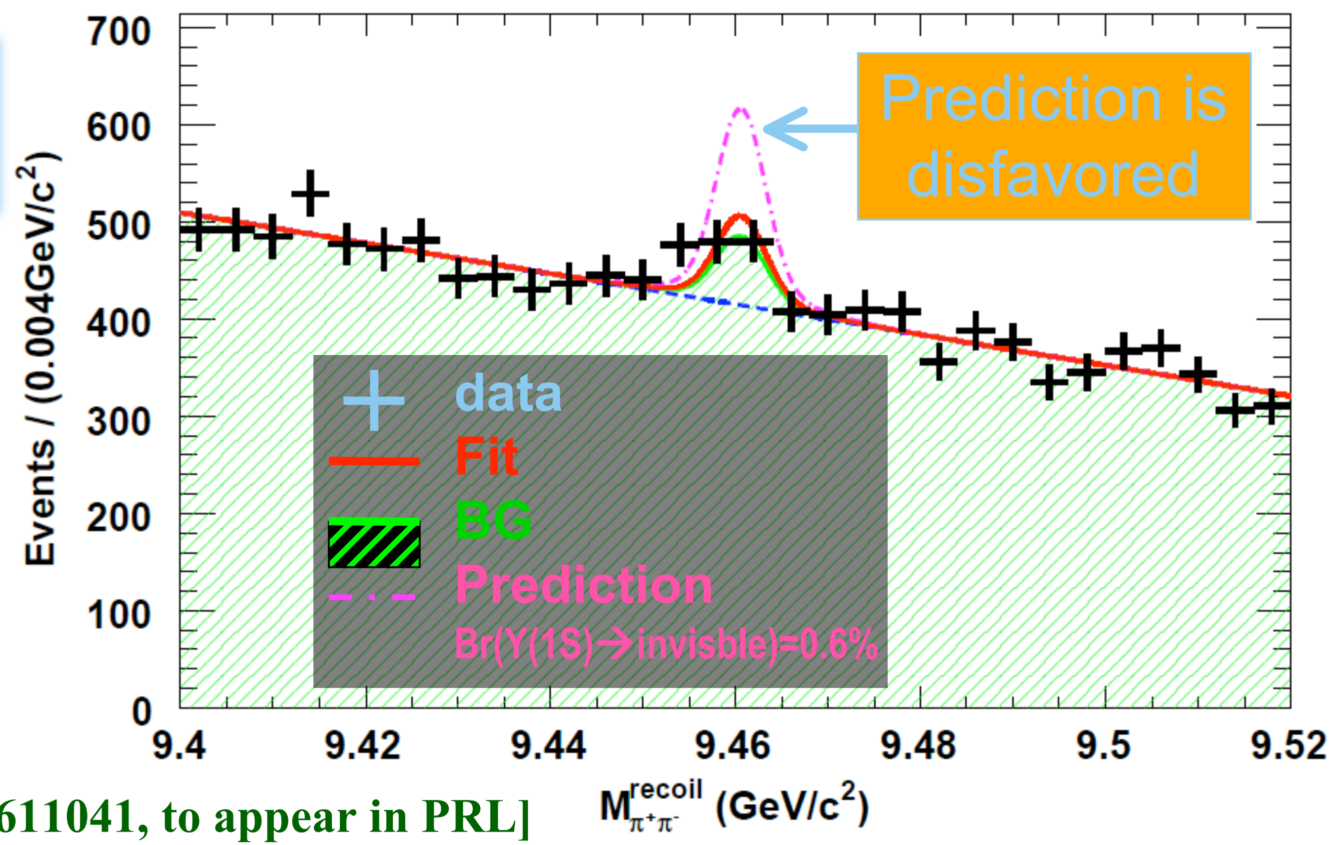
Cf. 244 signal events if $Br(\Upsilon(1S) \rightarrow invisible) = 6 \times 10^{-3}$

Result and Conclusion

$N_{signal} = 38 \pm 39 \Leftrightarrow 0$ consistent

$B\,(\Upsilon(1S)\rightarrow \text{invisible}) < 2.5\times10^{-3}$ (90%C.L.)

2.9 f b^{-1}
at Y(3S)



[hep-ex/0611041, to appear in PRL]

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Physics Publications in FY2006

http://belle.kek.jp/belle/publications.html

206. **Search for Lepton Flavor Violating tau^- Decays into l^- eta, l^- eta' and l^- pi^0**
Y. Miyazaki et al. (The Belle collaboration), to appear in PLB
(Belle preprint 2007-13, KEK Preprint 2006-61, hep-ex/0703009)
[Fig.1] [Fig.2] [Fig.3] [Fig.4] [Fig.5a | 5b | 5c | 5d] [Fig.6e | 6f | 6g | 6h | 6i | 6j] [Fig.7]

205. **Measurement of EPR-type flavor entanglement in Y(4s)->B0B0bar decays**
A. Go, A. Bay et al. (The Belle collaboration), submitted to PRL
(Belle preprint 2006-40, KEK Preprint 2006-61, quant-ph/0702267)
[Fig.1] [Fig.2]

204. **Evidence for CP Violation in B^0 -> D^+D^- Decays**
S. Fratina et al. (The Belle collaboration), submitted to PRL
(Belle preprint 2007-11, KEK Preprint 2006-75, hep-ex/0702031)
[Fig.1a | 1b] [Fig.2a | 2b] [Fig.3a | 3b]

203. **Improved Measurements of Branching Fractions and CP Asymmetries in B-> eta h Decays**
P. Chang et al. (The Belle collaboration), submitted to PRD(RC)
(Belle preprint 2007-10, KEK Preprint 2006-74, hep-ex/0608033)
[Fig.1] [Fig.2] [Fig.3]

202. **Measurement of charmless B Decays to eta K* and eta rho**
C.H. Wang et al. (The Belle Collaboration), submitted to PRD
(Belle preprint 2007-8, KEK Preprint 2006-71, hep-ex/0701057)
[Fig.1] [Fig.2] [Fig.3] [Fig.4] [Fig.5]

201. **Measurement of the mass of the tau lepton and an upper limit on the mass difference between tau+ and tau-**
M. Shapkin, K. Belous, A. Sokolov et al. (The Belle Collaboration), submitted to PRL
(Belle preprint 2007-9, KEK Preprint 2006-72, hep-ex/0608046)
[Fig.1] [Fig.2] [Fig.3]

200. **Search for B decays into eta' rho, eta' K*, eta' phi, eta' omega and eta' eta(') at Belle**
J. Schuemann et al. (The Belle Collaboration), submitted to PRD
(Belle preprint 2007-7, KEK Preprint 2006-70, hep-ex/0701046)
[Fig.1a | 1b | 1c | 1d | 1e | 1f | 1g | 1h] [Fig.2a | 2b | 2c | 2d | 2e | 2f | 2g | 2h]

199. **Measurement of the near-threshold e+ e- -> D(*) D*-bar cross section using initial state radiation**
G.Pakhlova et al. (The Belle Collaboration), published in PRL 98, 092001 (2007)
(Belle preprint 2007-5, KEK Preprint 2006-66, hep-ex/0608018)
[Fig.1] [Fig.2]

198. **Experimental Constraints on the Spin and Parity of the Lambda_c(2880)**
R. Mizuk et al. (The Belle Collaboration), submitted to PRL
(Belle preprint 2007-2, KEK Preprint 2006-63, hep-ex/0608043)
[Fig.1] [Fig.2] [Fig.3]

197. **Measurement of CP Asymmetry in a Time Dependent Dalitz Analysis of B0 -> (rho pi)0 and a Constraint on the CKM Angle phi2**
A. Kusaka, C. C. Wang, H. Ishino et al. (The Belle Collaboration), submitted to PRL
(Belle preprint 2007-4, KEK Preprint 2006-65, hep-ex/0701015)
[Fig.1] [Fig.2] [Fig.3]

196. **High statistics study of th…**
T. Mori et al. (The Belle C…
(Belle preprint 2007-3, KE…
[Fig.1] [Fig.2a | 2b]

195. **Observation of the decay…**
M. C. Chang et al. (The Be…
(Belle preprint 2007-1, KE…
[Fig.1] [Fig.2] [Fig.3]

194. **Observation of B decays t…**
S.-W. Lin, P. Chang et al. (…
(Belle preprint 2006-39, K…
[Fig.1] [Fig.2] [Fig.3]

193. **Study of B0-bar -> D0 pi+…**
A.Kuzmin et al. (The Belle…
(Belle preprint 2006-38, K…
[Fig.1] [Fig2a, b, c] [Fig3a, …

192. **A Search for the Rare Le…**
N. Satoyama et al. (The Be…
(Belle preprint 2006-36, K…
[Fig.1a, b] [Fig.2a, b] [Fig.3…

191. **Moments of the Hadronic…**
C. Schwanda et al. (The Be…
(Belle preprint 2006-37, K…
[Fig.1] [Fig.2]

190. **Search for Invisible Deca…**
O. Tajima, H. Hayashii, M…
(Belle preprint 2006-35, K…
[Fig.1] [Fig.2] [Fig.3] [Fig.4…

189. **Observation of the decay…**
A. Sokolov, M. Shapkin et…
(Belle preprint 2006-34, K…
[Fig.1] [Fig.2] [Fig.3] [Fig.4…

188. **Time-Dependent CP Asy…**
Y. Ushiroda, K. Sumisawa…
(Belle preprint 2006-32, K…
[Fig.1a, b] [Fig.2a, b, c]

187. **Observation of Direct CP…**
H. Ishino et al. (The Belle C…
(Belle preprint 2006-33, KEK Preprint 2006-50, hep-ex/0608035)
[Fig.1a, b] [Fig.2] [Fig.3] [Fig.4]

186. **Study of decay m…** N.Gabyshev et al. (Belle preprint 20…) [Fig.1a, b] [Fig.2a, …

185. **Dalitz Analysis o…** A. Garmash et al. (Belle preprint 20…) [Fig.1a, b, c] [Fig.…

184. **Search for B^{+}…** Q. L. Xie et al. (T… (Belle preprint 20…) [Fig.1a, b, c] [Fig.…

183. **Measurement of … resonance** A. Drutskoy et al. (Belle preprint 20…) [Fig.1a] [Fig.2a, b]

182. **Moments of the …** P. Urquijo, E. Bar… (Belle preprint 20…) [Fig.1a, b] [Fig.2a, …

181. **Observation of t… and B0 -> J/psi K…** K.-F. Chen, K.Ha… in PRL 98, 03180… (Belle preprint 20…) [Fig.1a-i, j-m] [Fig…

180. **Study of the cha…** K.S.Park and H.K… (Belle preprint 20…) [Fig.1a, b] [Fig.2]

179. **Improved measu…** Chun-Min Jen, P. … (Belle preprint 20…) [Fig.1a, b, c, d] [F…

178. **First Observatio…** K. Inami et al. (Th… (Belle preprint 20…) [Fig.1a, b] [Fig.2a, …

177. **Improved Mea…** S. Blyth et al. (… (Belle preprint …) [Fig.1a, b] [Fig.…

176. **Observation o…** R.Kumar, J.B.S… (Belle preprint …) [Fig1] [Fig2] [F…

175. **Observation o…** G.Gokhroo, G.… (Belle preprint …) [Fig1] [Fig2]

174. **Observation o…** Ruslan Chistov… (Belle preprint …) [Fig1] [Fig2] [F…

173. **Study of J/psi…** C.-H. Wu, M.-… (Belle preprint …) [Fig1] [Fig2] [F…

172. **Search for lep…** Y.Miyazaki et … (Belle preprint …) [Fig1] [Fig2] [F…

171. **Measurement…** P.Krokovny et … (Belle preprint …) [Fig1] [Fig.2a, …

170. **Search for the…** F. Fang, T.E. B… (Belle preprint …) [Fig.1a, b] [Fig.…

169. **Measurement…** A. Poluektov et … (Belle preprint …) [Fig.1ab, cd, ef]

168. **Measurement of D0 -> pi lnu (K l nu) Form Factors and Absolute Branching Fractions**
L. Widhalm et al. (The Belle Collaboration), published in PRL 97, 061804 (2006)
(Belle preprint 2006-12, KEK Preprint 2006-6, hep-ex/0604049)
[fig1] [fig2]

167. **Evide…** K. Ika… (Belle…) [fig1] [

166. **Measu…** T.Hok… (Belle…) [fig1] [… d]

165. **Measu…** F.J. R… (Belle…) [fig1a, …

Physics Publications in FY2006

http://belle.kek.jp/belle/publications.html

206. **Search for Lepton Flavor Violating tau^- Decays into l^- eta, l^- eta' and l^- pi^0**
Y. Miyazaki et al. (The Belle collaboration), to appear in PLB
(Belle preprint 2007-13, KEK Preprint 2006-61, hep-ex/0703009)
[Fig.1] [Fig.2] [Fig.3] [Fig.4] [Fig.5a | 5b | 5c | 5d] [Fig.6e | 6f | 6g | 6h | 6i | 6j] [Fig.7]

205. **Measurement of EPR-type flavor entanglement in Y(4s)->B0B0bar decays**
A. Go, A. Bay et al. (The Belle collaboration), submitted to PRL
(Belle preprint 2006-40, KEK Preprint 2006-61, quant-ph/0702267)
[Fig.1] [Fig.2]

204. **Evidence for CP Violation in B^0 -> D^+D^- Decays**
S. Fratina et al. (The Belle collaboration), submitted to PRL
(Belle preprint 2007-11, KEK Preprint 2006-75, hep-ex/0702031)
[Fig.1a | 1b] [Fig.2a | 2b] [Fig.3a | 3b]

203. **Improved Measurements of Branching Fractions and CP Asymmetries in B-> eta h Decays**
P. Chang et al. (The Belle collaboration), submitted to PRD(RC)
(Belle preprint 2007-10, KEK Preprint 2006-74, hep-ex/0608033)
[Fig.1] [Fig.2] [Fig.3]

202. **Measurement of charmless B Decays to eta K* and eta rho**
C.H. Wang et al. (The Belle Collaboration), submitted to PRD
(Belle preprint 2007-8, KEK Preprint 2006-71, hep-ex/0701057)
[Fig.1] [Fig.2] [Fig.3] [Fig.4] [Fig.5]

201. **Measurement of the mass of the tau lepton and an upper limit on the mass difference between tau+ and tau-**
M. Shapkin, K. Belous, A. Sokolov et al. (The Belle Collaboration), submitted to PRL
(Belle preprint 2007-9, KEK Preprint 2006-72, hep-ex/0608046)
[Fig.1] [Fig.2] [Fig.3]

200. **Search for B decays into eta' rho, eta' K*, eta' phi, eta' omega and eta' eta(') at Belle**
J. Schuemann et al. (The Belle Collaboration), submitted to PRD
(Belle preprint 2007-7, KEK Preprint 2006-70, hep-ex/0701046)
[Fig.1a | 1b | 1c | 1d | 1e | 1f | 1g | 1h] [Fig.2a | 2b | 2c | 2d | 2e | 2f | 2g | 2h]

199. **Measurement of the near-threshold e+ e- -> D(*) D*-bar cross section using initial state radiation**
G.Pakhlova et al. (The Belle Collaboration), published in PRL 98, 092001 (2007)
(Belle preprint 2007-5, KEK Preprint 2006-66, hep-ex/0608018)
[Fig.1] [Fig.2]

198. **Experimental Constraints on the Spin and Parity of the Lambda_c(2880)**
R. Mizuk et al. (The Belle Collaboration), submitted to PRL
(Belle preprint 2007-2, KEK Preprint 2006-63, hep-ex/0608043)
[Fig.1] [Fig.2] [Fig.3]

197. **Measurement of CP Asymmetry in a Time Dependent Dalitz Analysis of B0 -> (rho pi)0 and a Constraint on the CKM Angle phi2**
A. Kusaka, C. C. Wang, H. Ishino et al. (The Belle Collaboration), submitted to PRL
(Belle preprint 2007-4, KEK Preprint 2006-65, hep-ex/0701015)
[Fig.1] [Fig.2] [Fig.3]

196. **High statistics study of th**
T. Mori et al. (The Belle Co
(Belle preprint 2007-3, KE
[Fig.1] [Fig.2a | 2b]

195. **Observation of the decay**
M. C. Chang et al. (The Be
(Belle preprint 2007-1, KE
[Fig.1] [Fig.2] [Fig.3]

194. **Observation of B decays t**
S.-W. Lin, P. Chang et al. (
(Belle preprint 2006-39, K
[Fig.1] [Fig.2] [Fig.3]

193. **Study of B0-bar -> D0 pi**
A.Kuzmin et al. (The Belle
(Belle preprint 2006-38, K
[Fig.1] [Fig2a, b, c] [Fig3a,

192. **A Search for the Rare Le**
N. Satoyama et al. (The Be
(Belle preprint 2006-36, K
[Fig.1a, b] [Fig.2a, b] [Fig.3

191. **Moments of the Hadroni**
C. Schwanda et al. (The Be
(Belle preprint 2006-37, K
[Fig.1] [Fig.2]

190. **Search for Invisible Deca**
O. Tajima, H. Hayashii, M
(Belle preprint 2006-35, K
[Fig.1] [Fig.2] [Fig.3] [Fig.4

189. **Observation of the decay**
A. Sokolov, M. Shapkin et
(Belle preprint 2006-34, K
[Fig.1] [Fig.2] [Fig.3] [Fig.4

188. **Time-Dependent CP Asy**
Y. Ushiroda, K. Sumisawa
(Belle preprint 2006-32, K
[Fig.1a, b] [Fig.2a, b, c]

187. **Observation of Direct CP**
H. Ishino et al. (The Belle (
(Belle preprint 2006-33, KEK Preprint 2006-50, hep-ex/0608035)
[Fig.1a, b] [Fig.2] [Fig.3] [Fig.4]

186. **Study of decay m**
N.Gabyshev et al.
(Belle preprint 20
[Fig.1a, b] [Fig.2a,

185. **Dalitz Analysis o**
A. Garmash et al.
(Belle preprint 20
[Fig.1a, b, c] [Fig.

184. **Search for B^{+}**
Q. L. Xie et al. (T
(Belle preprint 20
[Fig.1a, b, c] [Fig.

183. **Measurement of resonance**
A. Drutskoy et al.
(Belle preprint 20
[Fig.1a] [Fig.2a, b]

182. **Moments of the**
P. Urquijo, E. Bar
(Belle preprint 20
[Fig.1a, b] [Fig.2a,

181. **Observation of t and B0 -> J/psi K**
K.-F. Chen, K.Ha
in PRL 98, 03180
(Belle preprint 20
[Fig.1a-i, j-m] [Fig

180. **Study of the cha**
K.S.Park and H.K
(Belle preprint 20
[Fig.1a, b] [Fig.2]

179. **Improved measu**
Chun-Min Jen, P.
(Belle preprint 20
[Fig.1a, b, c, d] [F

178. **First Observatio**
K. Inami et al. (T
(Belle preprint 20
[Fig.1a, b] [Fig.2a,

177. **Improved Mea**
S. Blyth et al. (
(Belle preprint
[Fig.1a, b] [Fig.

176. **Observation o**
R.Kumar, J.B.S
(Belle preprint
[Fig1] [Fig2] [F

175. **Observation o**
G.Gokhroo, G.
(Belle preprint
[Fig1] [Fig2]

174. **Observation o**
Ruslan Chistov
(Belle preprint
[Fig1] [Fig2] [F

173. **Study of J/psi**
C.-H. Wu, M.-
(Belle preprint
[Fig1] [Fig2] [F

172. **Search for lep**
Y.Miyazaki et
(Belle preprint
[Fig1] [Fig2] [F

171. **Measurement**
P.Krokovny et
(Belle preprint
[Fig1] [Fig.2a, b

170. **Search for the**
F. Fang, T.E. B
(Belle preprint
[Fig.1a, b] [Fig.

169. **Measurement**
A. Poluektov et
(Belle preprint
[Fig.1ab, cd, ef]

168. **Measurement of D0 -> pi lnu (K l nu) Form Factors and Absolute Branching Fractions**
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167. **Evide**
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166. **Meas**
T.Hok
(Belle
[fig1] [
d]

165. **Meas**
F.J. R
(Belle
[fig1a,

Prospects of $B \to K_S \pi^0 \gamma$ TCPV analysis

Phys. Rev. Lett. **94**, 231601 (2005)		275MBB
Phys. Rev. D **74**, 111104(R) (2006)		535MBB
?	(200x)	~1000MBB

(*) If no drastic improvement in analysis

…………………

$5ab^{-1}$: the error be compatible with the (largest estimation of) SM polution

$\delta S = 0.1$ @ 5/ab

Hope prompt increase of luminosity
Success of Crab is desired

Summary & Conclusion

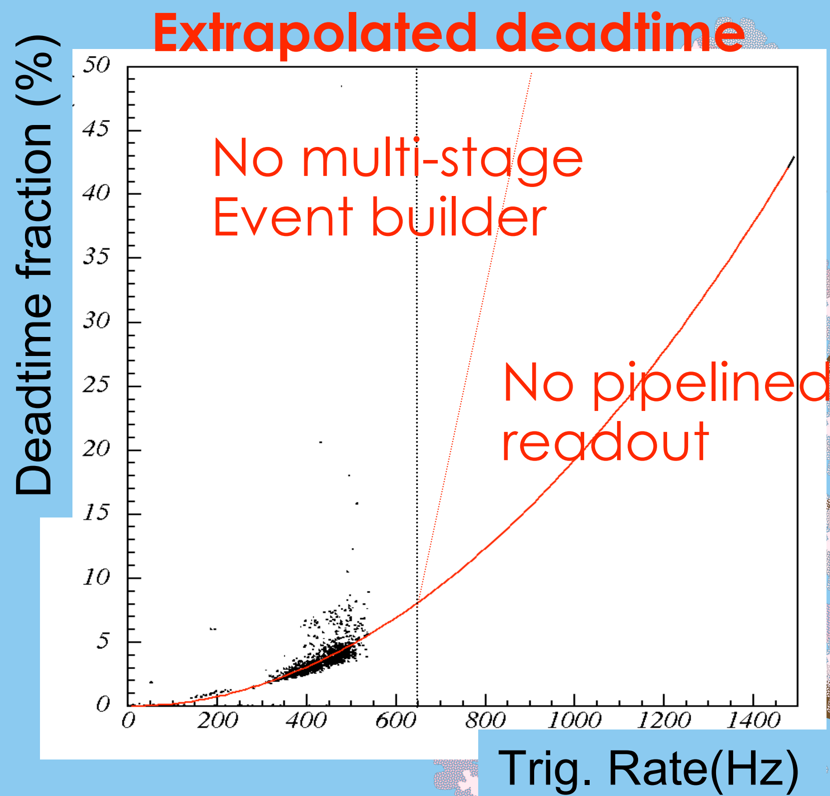
- Belle DAQ Upgrade is going on
- For an entangled system (B^0-B^0b), again Quantum Mechanics is supported
- Evidence of D^0-D^0b mixing is found for the first time
- Dark Matter search is performed. One theory rejected
- Sincerely anticipating a success of Crab Cavity operation

Limit of the current readout system

- The luminosity of KEKB will increase drastically due to the crab cavity installation.
- Trigger rate will be >1kHz and deadtime fraction will be ~20% with the current readout system.

→ We need a pipelined readout system.

COPPER



$D^0 \to K^+K^-,\ \pi^+\pi^-$ (Belle, 540 fb^{-1})

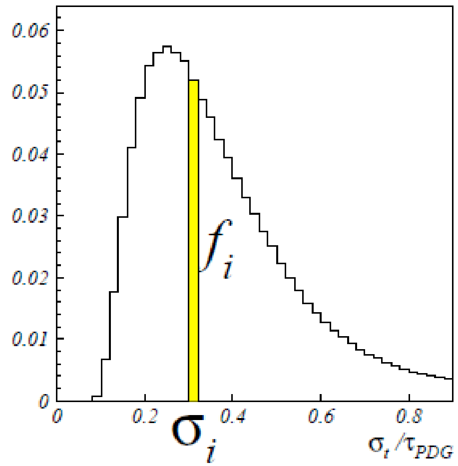
Lifetime fit

- Parameterization of proper decay time distribution

$$\frac{dN}{dt} = \frac{N}{\tau} e^{-t/\tau} * R(t) + B(t)$$

- Resolution function
  - ▷ constructed from normalized distribution of event proper time uncertainty σ_t
  - ▷ ideally, σ_t of event represents uncertainty with Gaussian p.d.f
  - ▷ examining pulls → p.d.f.=sum of 3 Gauss.

σ_t distribution



$$R(t) = \sum_{i=1}^{n} f_i \sum_{k=1}^{3} w_k G(t; \sigma_{ik}, t_0)\ , \qquad \sigma_{ik} = s_k \sigma_k^{pull} \sigma_i$$

- $R(t)$ studied in details with $D^0 \to K\pi$ and special MC samples - also in changing running conditions (two different SVD, small misalignments)

$D^0 \to K^+K^-,\ \pi^+\pi^-$ (Belle, 540 fb^{-1})

Cross-checks

- MC: y_{CP}(out) - y_{CP}(input) $< 0.04\%$ for large range of input values
- y_{CP} independent of resolution function parameterization:
  $R(t)$ = single Gaussian: $\Delta\tau$ = 3.5%, Δy_{CP} = 0.01%
- Exchanging data side band with signal window background from tuned MC:
  Δy_{CP} = -0.04%

Systematics

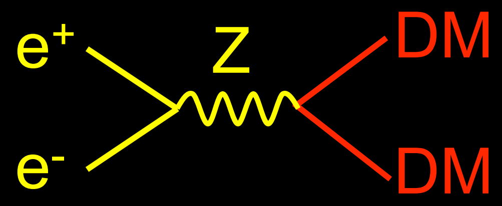
source	y_{CP}	A_Γ
acceptance	0.12%	0.07%
equal t_0 assumption	0.14%	0.08%
mass window position	0.04%	0.003%
difference btw. background and side bands	0.09%	0.06%
difference btw. final states in opening angle	0.02%	
background parameterization	0.07%	0.07%
resolution function	0.01%	0.01%
analysis cuts	0.11%	0.05%
binning	0.01%	0.01%
total	0.25%	0.15%

これまでの探索結果（つづき）

LEP

Invisible width of Z

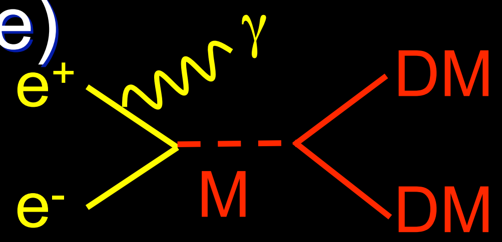
Zにカップルするものに対するリミット



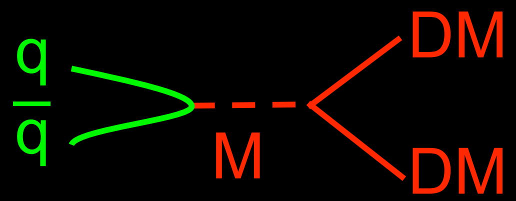
LEP

single photon counting ($e+e- \rightarrow \gamma$ invisible)

e^+e^-にカップルするものに対するリミット



$q\bar{q}$にカップルするものに対するリミットは？



実はまだ十分に探索されていない

単純なMSSMなら上記のリミットが適用可

が、しかし…

Next-to-MSSM等々$q\bar{q}$がfavorされるモデルはいくらでも作れる

PRD 72, 103508 (2005) “Invisible quarkonium decays as a sensitive probe of dark matter”

hep-ph/0510147 “Probing MeV Dark Matter at Low-Energy e+e- Colliders”

hep-ph/0509024 “Light neutralino dark matter in the next-to-minimal”

hep-ph/0601090 “Dark matter pair-production in b→s transitions”

実験の役目: 無数にある理論の可能性を一つ一つ排除する

もし見つけてしまったらラッキー（ダークホース狙いで万馬券）

じゃあ、どのくらい期待されるか？

Relic density is denoted as follows

$$\Omega h^2 \cong \frac{0.1\ \text{pb}\cdot c}{\langle \sigma(\chi\chi \rightarrow SM)\, v \rangle}$$

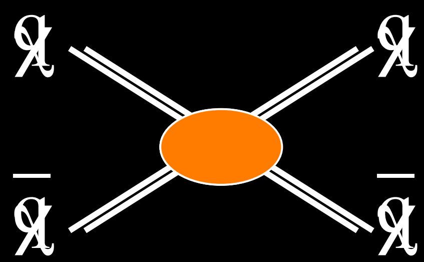
Ω : relic density

h : Hubble constant

v : 1/20 ~ 1/25

$$\Omega h^2 = 0.113 \leftarrow \text{WMAP}$$

$$\sigma(\chi\chi \rightarrow SM) \sim 18\ \text{pb}$$



ここまではPDGより抜粋

$$\sigma(SM \rightarrow \chi\chi) \cong \sigma(\chi\chi \rightarrow SM),\quad \Gamma(\Upsilon(1S) \rightarrow \chi\chi) = f_\Upsilon^2 M_\Upsilon \sigma(bb \rightarrow \chi\chi)$$

$Br(\ \Upsilon(1S) \rightarrow \chi\chi\ ) \sim 6\text{x}10^{-3}$ $(m_\chi < 4.73\text{GeV}/c^2 \sim m_b)$

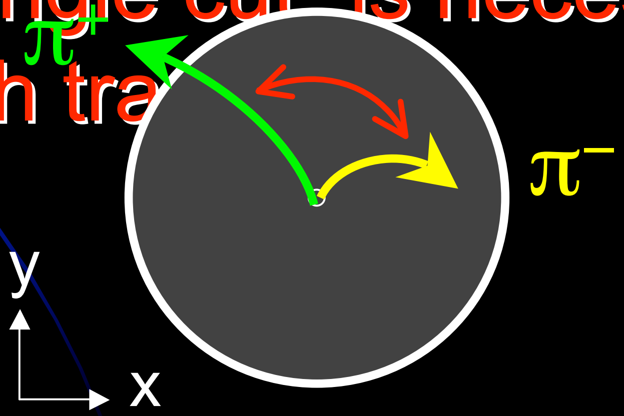
PRD 72, 103508 (2005) "Invisible quarkonium decays as a sensitive probe of dark matter"

これまでのベストリミットは < $23\text{x}10^{-3}$ (90% CL) by ARGUS (1986)

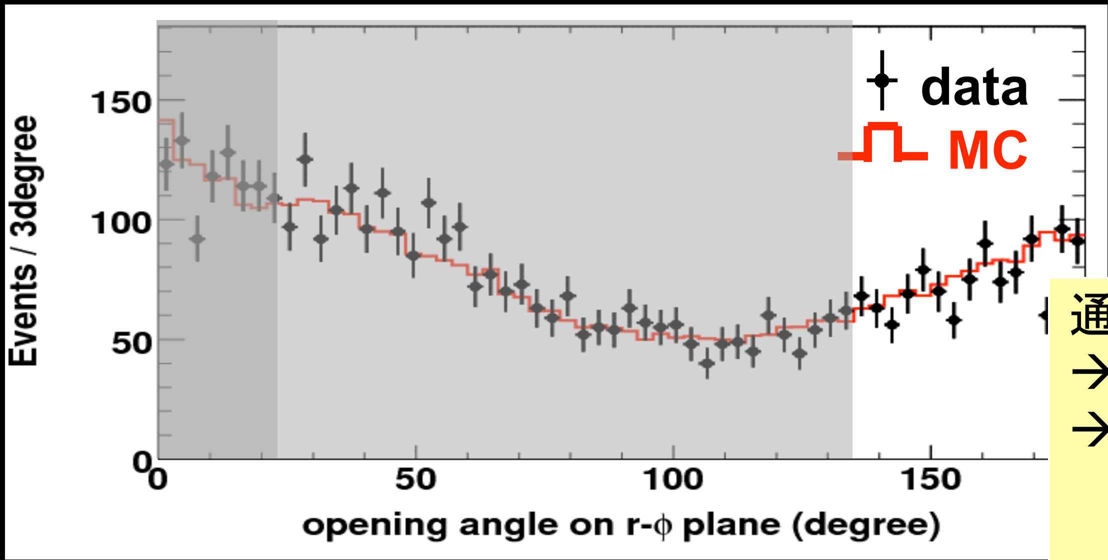
Trigger logic is important

For trigger issue, we need two charged tracks

- Reach to outer most layer of CDC (pt ~250 MeV/c)
- Reach to middle layer of CDC (pt ~120 MeV/c)
- "Opening angle cut" is necessary to distinguish tra

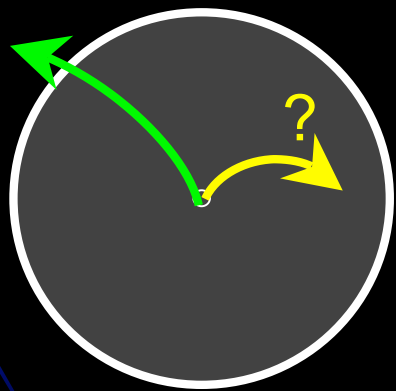


Special Trigger for $\Upsilon(3S) \to \pi^+\pi^-\Upsilon(1S)^{invisible}$



Control sample
$\Upsilon(3S) \to \pi^+\pi^-\Upsilon(1S)$
$\Upsilon(1S) \to \mu^+\mu^-$

通常のトリガー条件(>135°)では効率悪い
→ 出来るだけ、ゆるいカット条件が良い
→ トリガーレート ~850Hz(通常の2倍のレート)までゆるめた、特別トリガーを実装して、データを取得した。

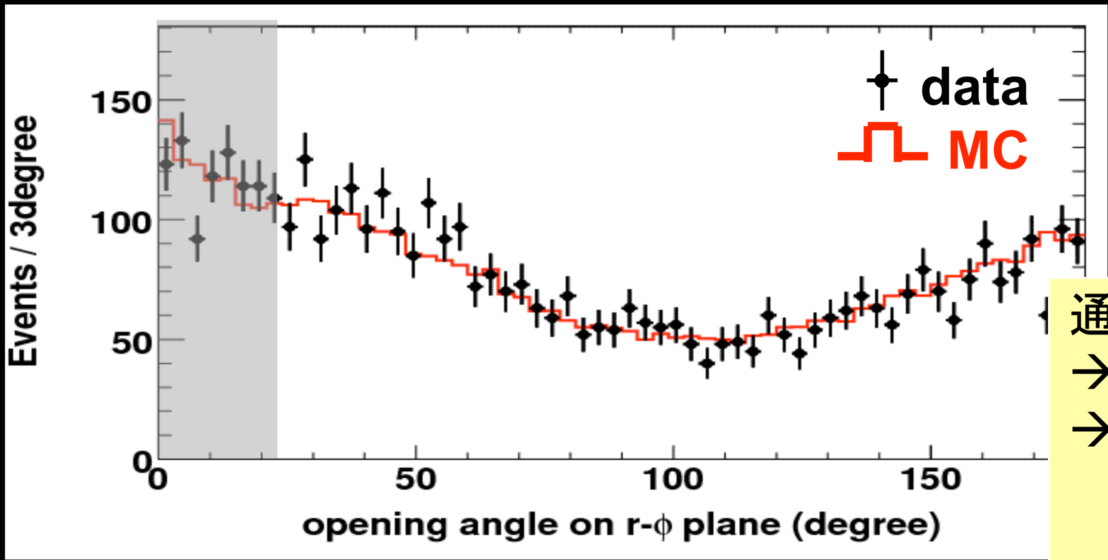


実は1トラック(pt>250)トリガーをプリスケール1/500で実装したので

$$\frac{\text{2-track trigger \& 1-track trigger}}{\text{1-track trigger}}$$

トリガー効率をモニターできる

Special Trigger for $\Upsilon(3S) \rightarrow \pi^+\pi^-\Upsilon(1S)^{invisible}$



Control sample
$\Upsilon(3S) \rightarrow \pi^+\pi^-\Upsilon(1S)$
$\Upsilon(1S) \rightarrow \mu^+\mu^-$

通常のトリガー条件(>135°)では効率悪い
→ 出来るだけ、ゆるいカット条件が良い
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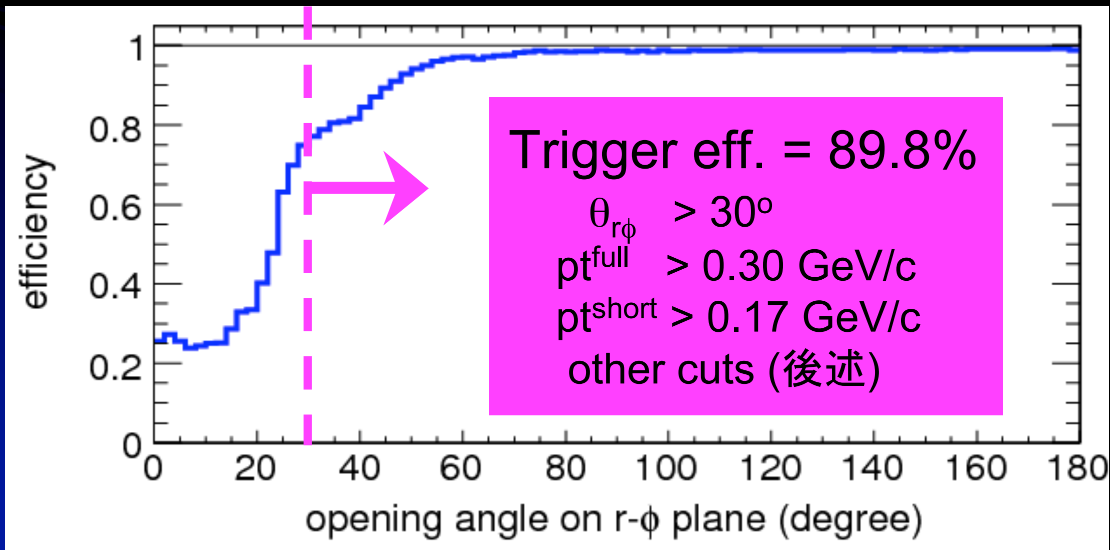


実は1トラック(pt>250)トリガーをプリスケール1/500で実装したので

$$\frac{\text{2-track trigger \& 1-track trigger}}{\text{1-track trigger}}$$

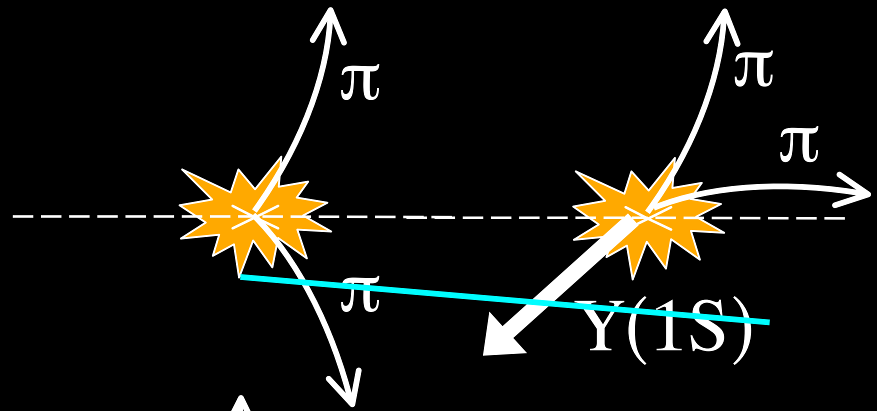
トリガー効率をモニターできる

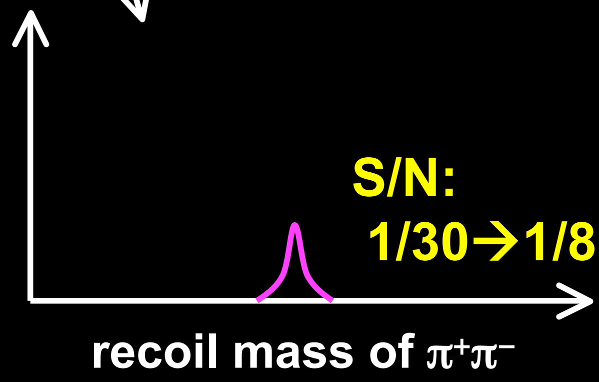
244 events predicted

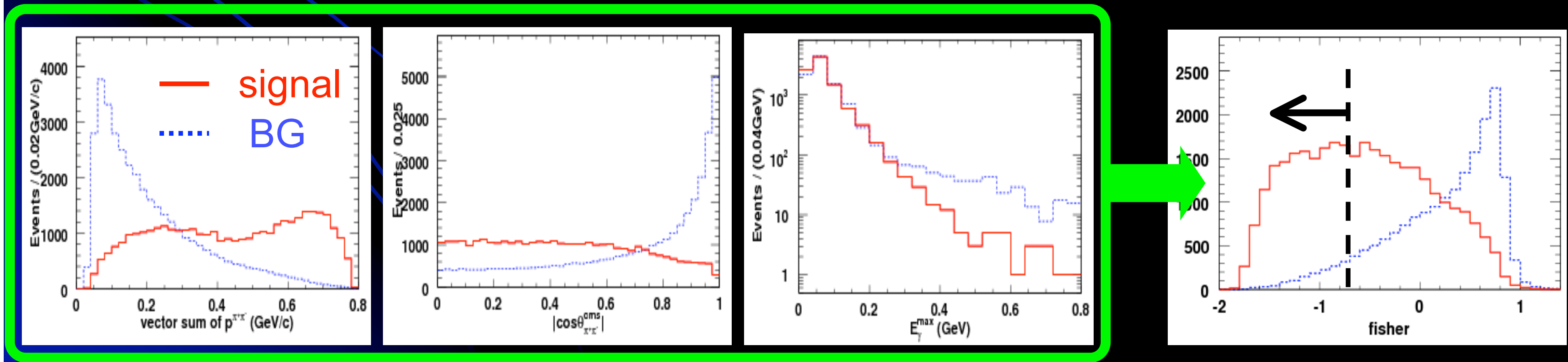
$Br(\Upsilon(1S) \rightarrow invisible) = 6 \times 10^{-3}$

$\Upsilon(3S) \to \pi^+\pi^- \Upsilon(1S)^{invisible}$

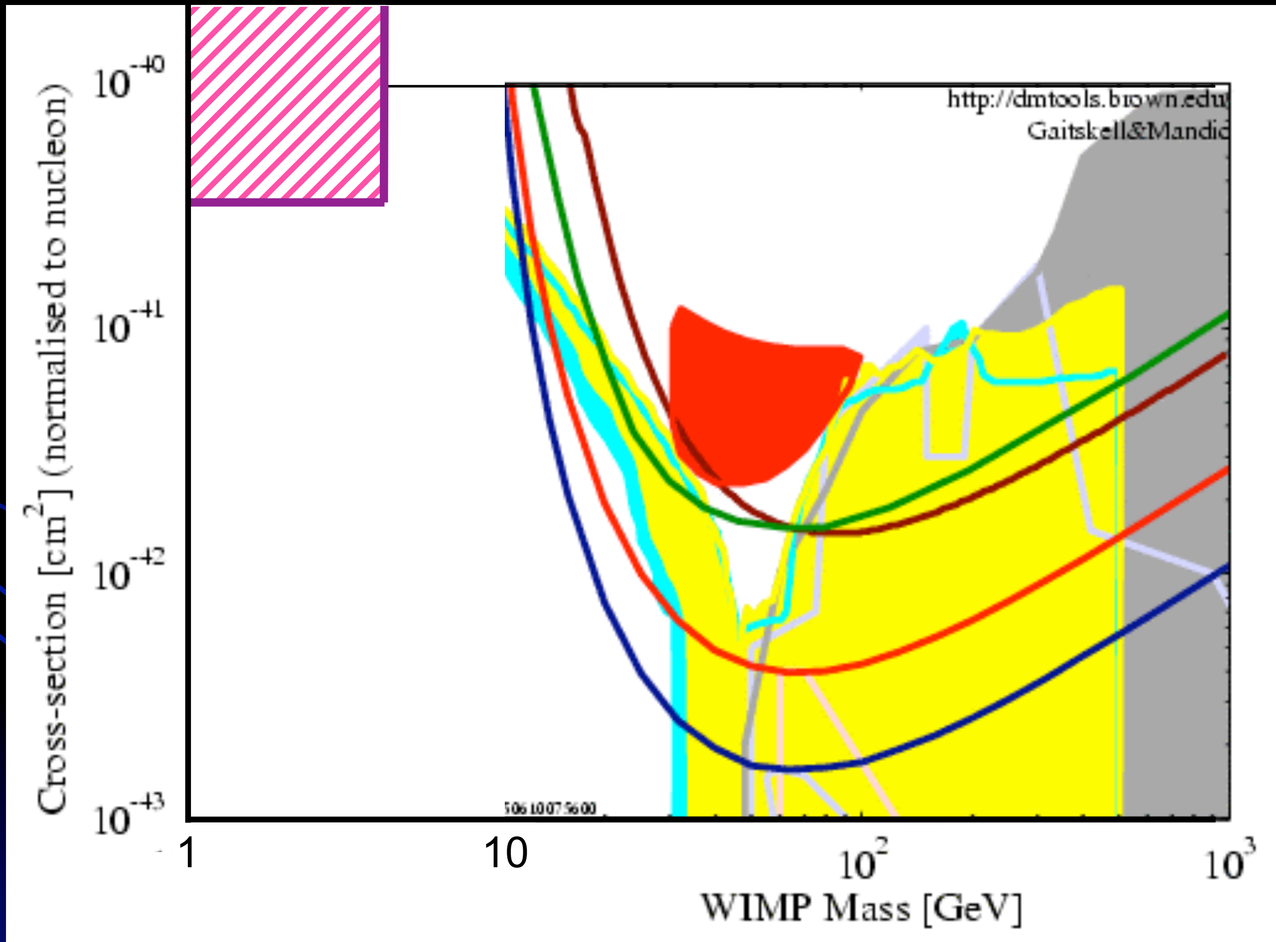
- **Two-photon**
  - 2 prong $\pi\pi$, ee, $\mu\mu$ …
    - → p_t is balanced
    - → Boosted (θ distribution)
  - $\pi^+\pi^-\pi^0$ …
    - → π^0 veto, γ energy cut







- 今後の宿題 -
例えばこんな感じで直接探索と一緒のプロットは描けないのか？



その他、結果が与えるインパクト

Physics Letters B 269 (1991) 213–219
North-Holland

PHYSICS LETTERS B

Can the upsilon decay into cosmions?

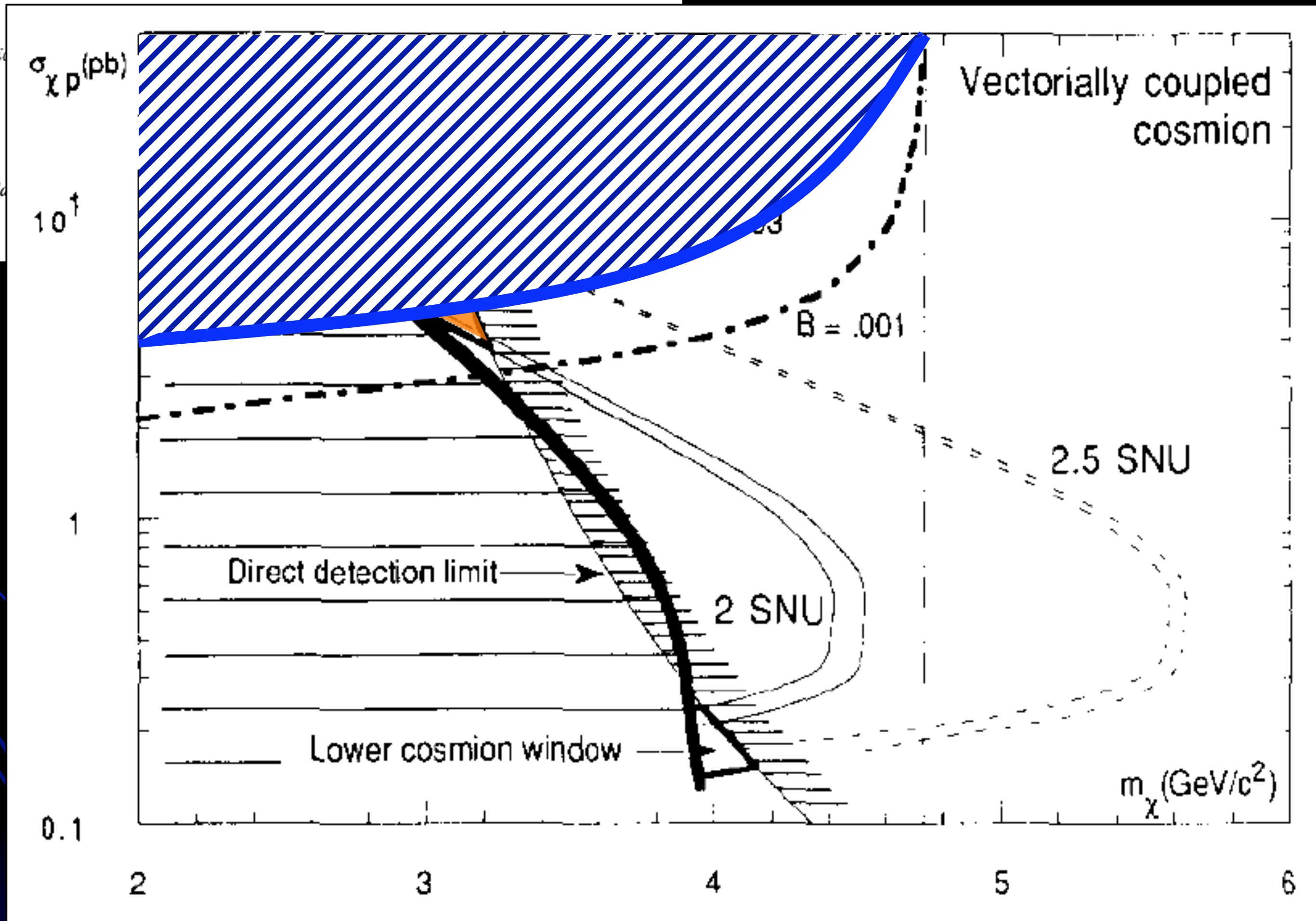
Pierre Fayet
Laboratoire de Physique Théorique de l'E

and

Jean Kaplan
LPTHE, Université PARIS VI–VII ², 2 pl

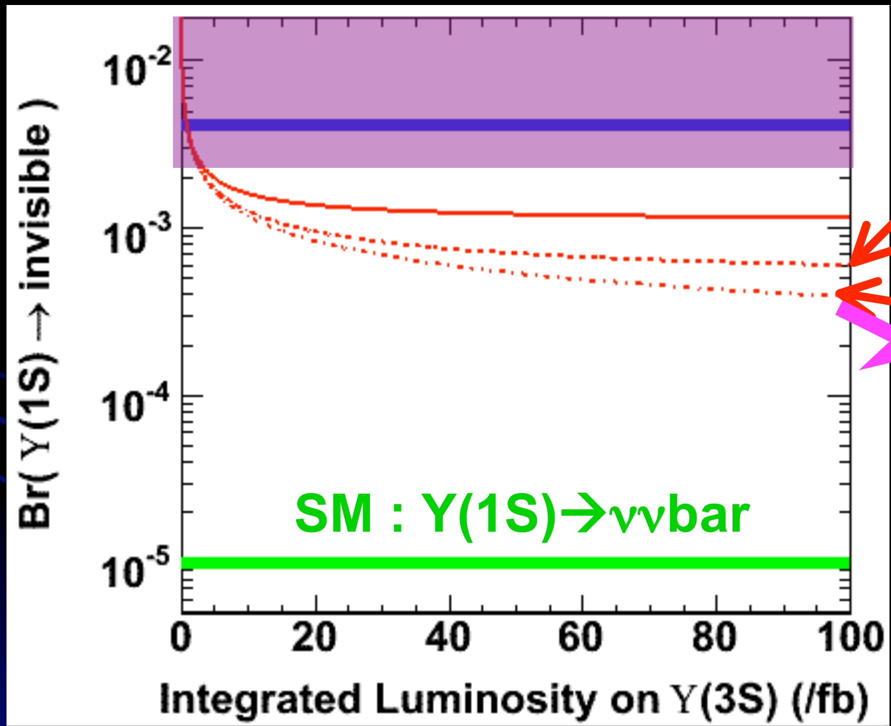
Received 25 July 1991

もう死んでるも同然の
理論みたいだが



Prospects

90 %C.L



Super-forward μ-detector

and Super-forward cal.

To be reach 2×10^{-4}

~500 fb^{-1}

まとめ

- Y(1S)の見えない(invisible)崩壊の発見は、
軽いダークマター(m_b以下)を示唆する(かもしれない)
  - 直接探索実験では探索できない領域
  - Br(Y(1S)→invisible) ~ $6x10^{-3}$ が理論期待値
  - 従来の探索リミットは < $23x10^{-3}$ (90%CL) by ARGUS
- **特別なトリガーでY(3S)のデータを$2.9fb^{-1}$取得
Y(1S)の見えない崩壊の探索をした。**
- **残念ながら見つからなかったが、理論期待値に到達する探索が行えた。**
  - Br(Y(1S)→invisible) < $2.5x10^{-3}$ (90%CL)
  - 結果の論文はPRLに投稿した (hep-ex/0611041)

その他、結果が与えるインパクト (2)

PHYSICAL REVIEW D **74**, 054034 (2006)

Constraints on light dark matter and U bosons, from ψ, Υ, K^+, π°, η and η' decays

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Laboratoire de Physique Théorique de l'ENS, UMR 8549 CNRS, 24 rue Lhomond, 75231 Paris Cedex 05, France

(Received 29 July 2006; published 27 September 2006)

によると

$$\Gamma(\Upsilon \to \text{gravitino} + \text{photino}) \propto \frac{G_{\text{Newton}}\alpha}{m_{3/2}^2}, \qquad (3)$$

という式が出てきて、これより

gravitino mass, $m_{3/2}$, に与えるインパクト

$m_{3/2} > 1.5\text{x}10^{-7}$ eV

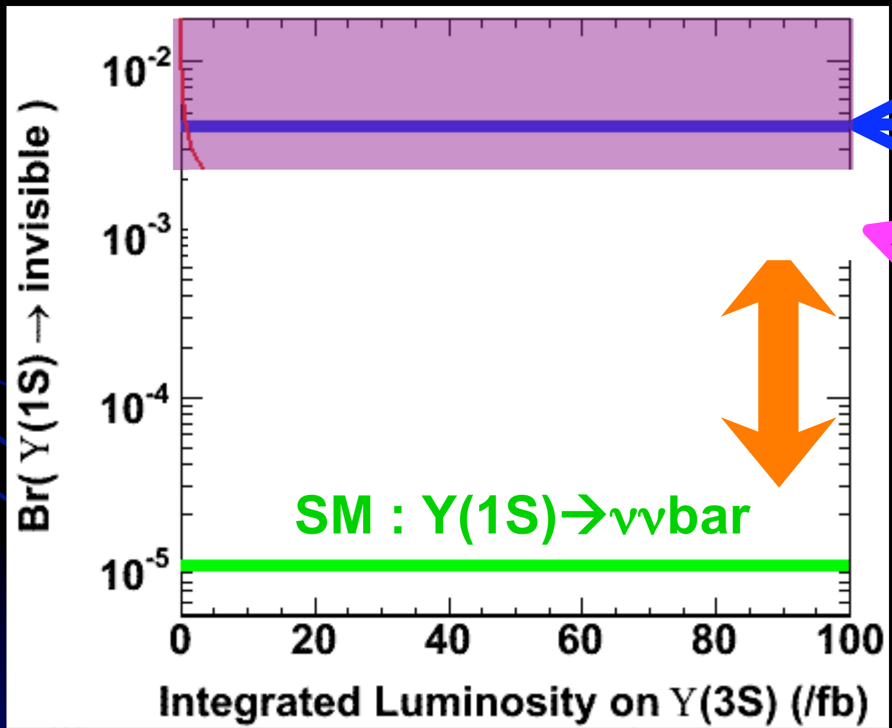
これまでは $m_{3/2} > 0.3\text{x}10^{-7}$ eV だった

が得られる

Prospects with more data

この論文の著者によれば、
「SM予想値までは、
探索するが価値ある」
らしい…

90 %C.L. limit



Prediction of
PRD 72, 103508 (2005)

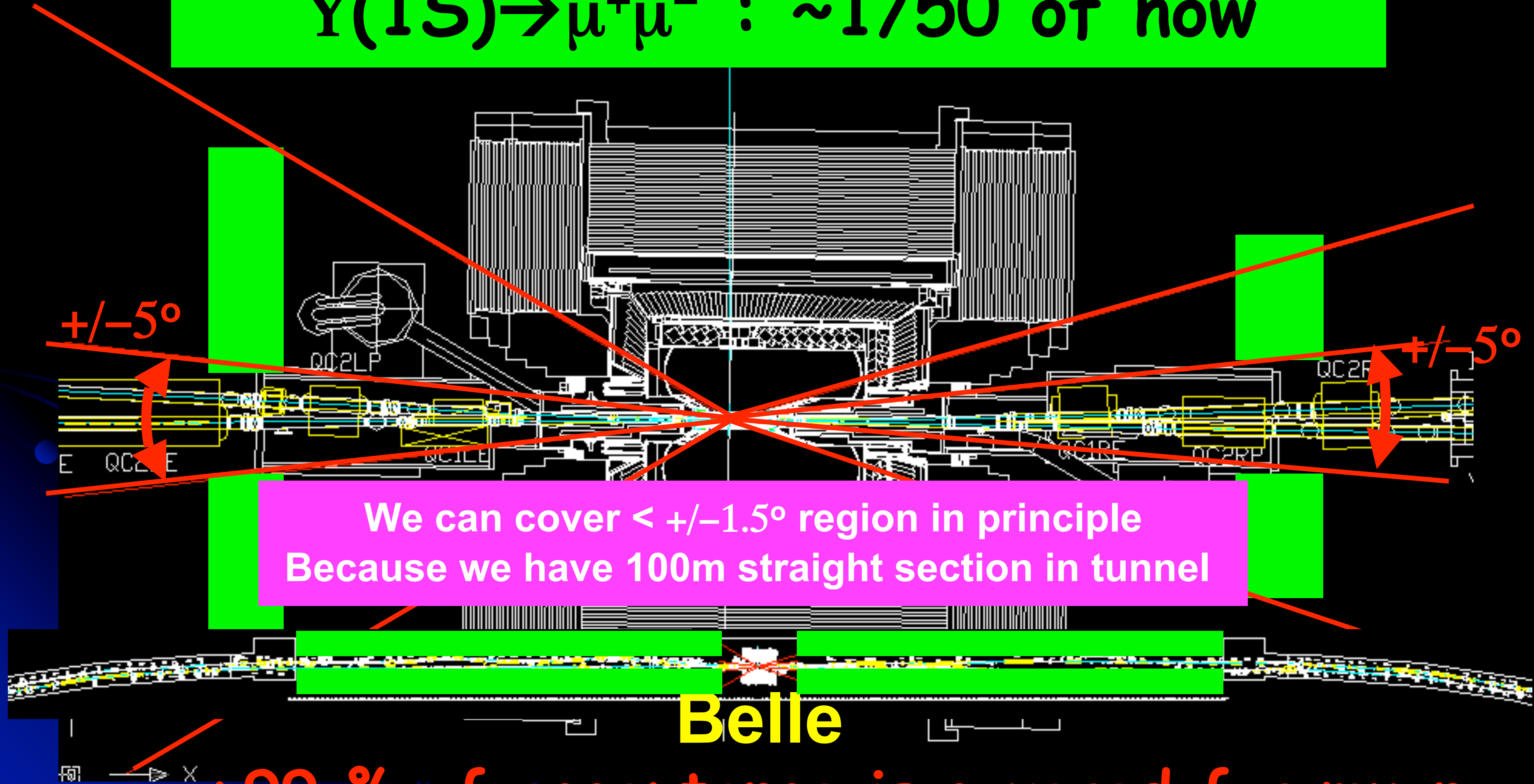
To be saturated ~20 fb^{-1}
due to “peaking BG”

２桁に及ぶ空白領域を
何とか探索できないのか？

敵は
Y(1S) → $\mu^+\mu^-$, e^+e^-
である。

FWD/BWD muon detectors

$\Upsilon(1S) \rightarrow \mu^+\mu^-$: ~1/50 of now



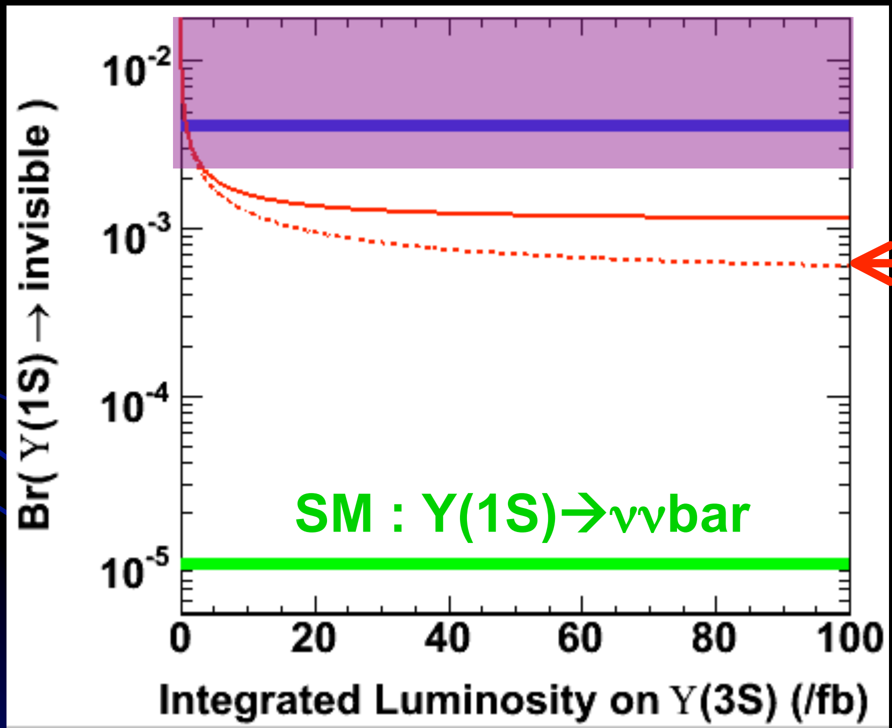
We can cover < +/−1.5° region in principle
Because we have 100m straight section in tunnel

Belle

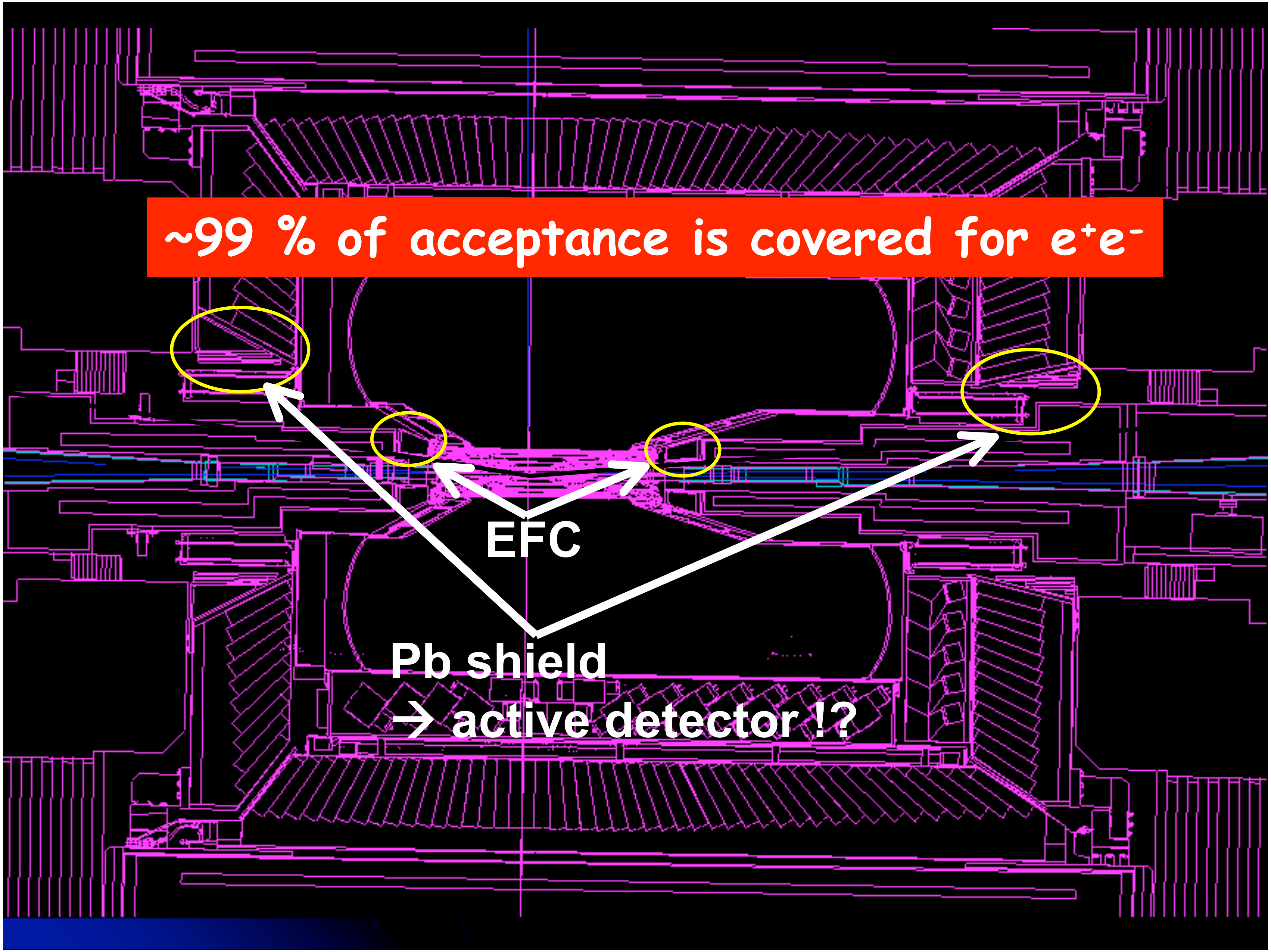
>99 % of acceptance is covered for muon

Sensitivity for Y(1S)^{invisible}

90 %C.L

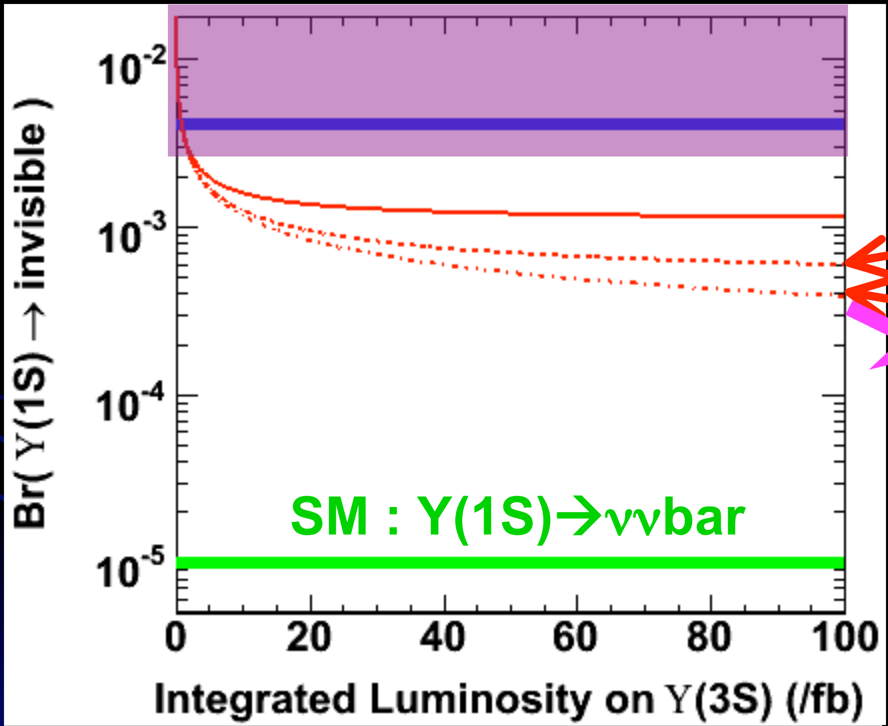


FWD/BWD μ-detector


~99 % of acceptance is covered for e⁺e⁻
EFC
Pb shield
→ active detector !?

Sensitivity for Υ(1S)^{invisible}

90 %C.L



FWD/BWD μ-detector

+ EFC

To be reach 2×10^{-4}

~500 fb^{-1}

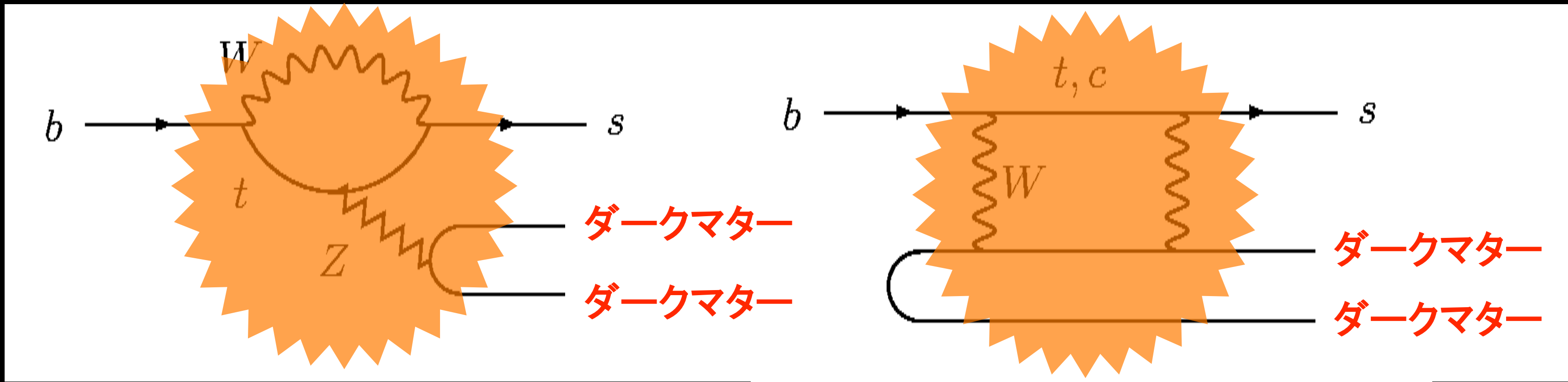
残り一桁を達成するための

アイデアは現在募集中

ダークマター探索に感度がある Super-KEKB の物理

例えば B→K xx

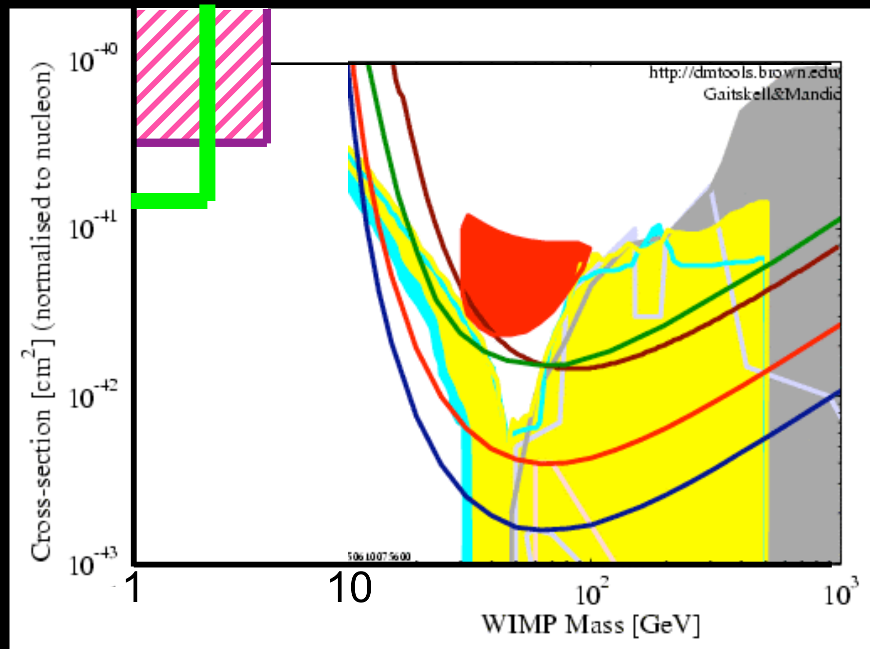
標準理論で記述される崩壊ダイアグラム



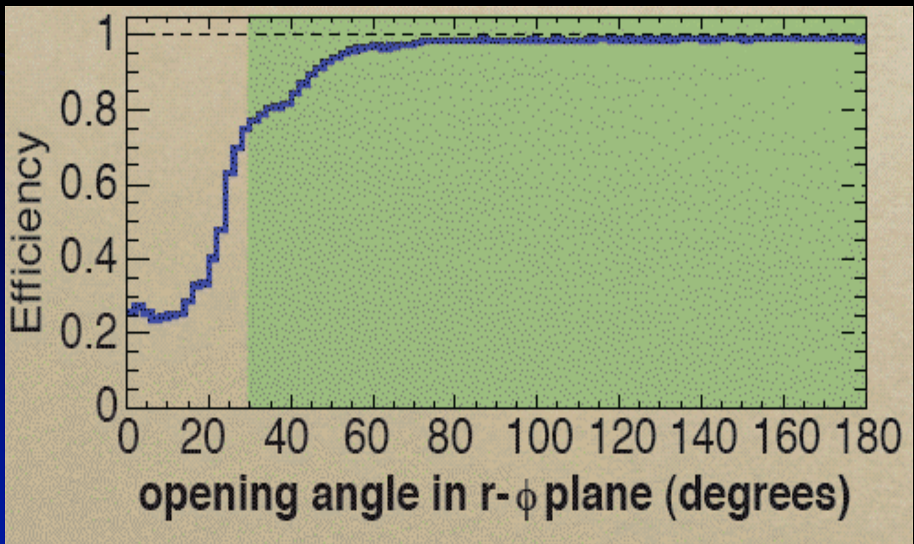
もし予想(Br~$4x10^{-6}$⇔$35ab^{-1}$)より高い分岐比で発見したら…

ダークマターである可能性もある

これは、
Y(1S)→invisible
よりさらに軽いものに
感度がある



Special: Loose 2-track Trigger



Trigger eff. 89.8%

Trig. effic.: monitored by prescaled 1-track Trrig.

$\Upsilon(3S) \rightarrow \pi^+\pi^-\Upsilon(1S)^{invisible}$

- **Two-photon**
  - 2 prong $\pi\pi$, ee, $\mu\mu$ …
    - → p_t is balanced
    - → Boosted (θ distribution)
  - $\pi^+\pi^-\pi^0$ …
    - → π^0 veto, γ energy cut