Asymmetric B Factories

"Beauty"

"the Beast"

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Outline

- Why B Factories?
- Requirements for B Factories & Detectors
- The present of B Factories
- Accelerator backgrounds
- *“Beauty”* and *“the Beast”*: Belle & BaBar
- The CP Physics
- Summary and prospects

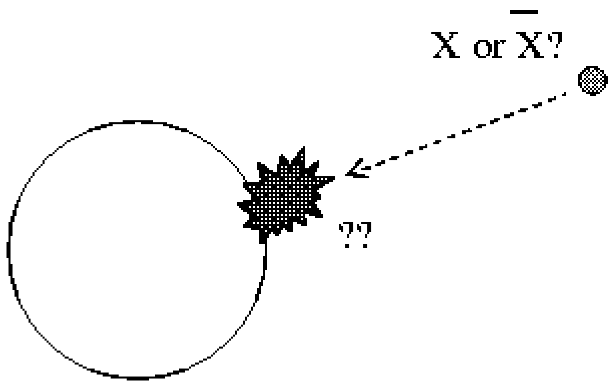
Why B Factories?

- In our model of fundamental interactions, the combined operations of C (charge conjugation) and P (parity) take matter into anti-matter
- In 1964, Cronin, Fitch *et al* discovered a small (~10^{-3}), but non-zero, violation of the CP symmetry in the neutral Kaon system
- CP violating process provides an absolute distinction between matter & anti-matter. But to date, only observed in Kaon system!
- Sakharov's 3 conditions for net excess of matter over anti-matter in evolution of Universe include CP Violation

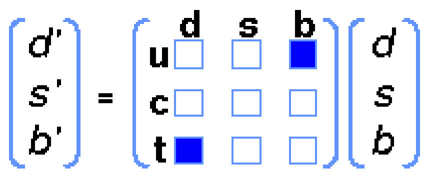
The Stanford Daily

CP Violation Saves Civilization!

People around the world are grateful to physicist today as a doomed visit from the Planet-X delegation was called off at the last minute. "I never thought this stuff was useful", one physicist was overheard saying...



- In the SM, CP violation is *accommodated* through an irreducible phase in the mixing matrix between quark weak interaction & mass eigenstates



CKM matrix
(■ = complex)

$d \cdot s^* = 0$ (K system)

$s \cdot b^* = 0$ (B_s system)

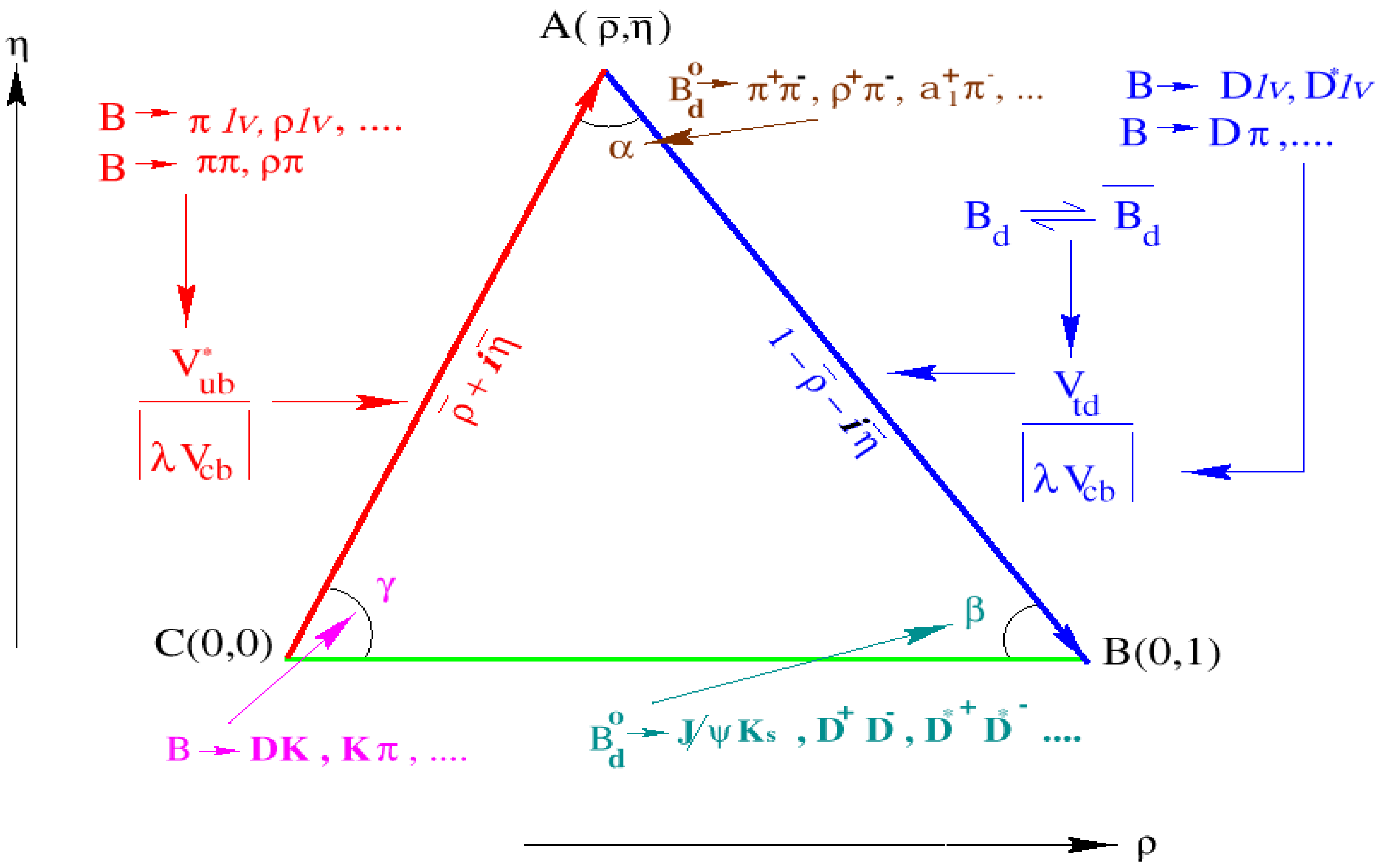
$d \cdot b^* = 0$ (B_d system)

- Because of the scale of the elements, it is often represented with the "Wolfenstein Parameterization" (A , λ , ρ , η)
- Unitarity imposes several constraints on the matrix, but one results in a triangle in the complex plane with sides of similar length ($\sim A\lambda^3$), which appears the most interesting for study

CP Violating Phase

The Unitarity Triangle

$$V_{ud} V_{ub}^* + V_{cd} V_{cb}^* + V_{td} V_{tb}^* = \mathbf{0}$$



- Direct CP Violation is the observation of a difference between the decay rates of matter & anti-matter

$$\Gamma(i\to f) \neq \Gamma(\bar{i}\to \bar{f})$$

- however, the amplitude for one process can in general be written

$$A=|A|\, e^{i\phi_w} e^{i\phi_s} \longrightarrow \bar{A} = |A| e^{-i\phi_w} e^{i\phi_s}$$

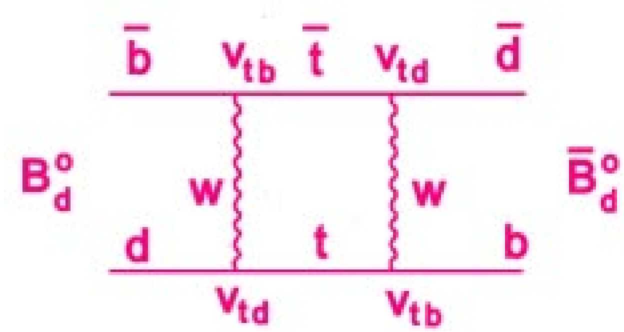
Weak phase changes sign

Strong phase does not

- since the observed rate is proportional to the amplitude, a difference would only be observed if there were an *interference* between two diagrams with different *weak and strong phases*

Rare and hard to interpret

- In the case of B-mixing



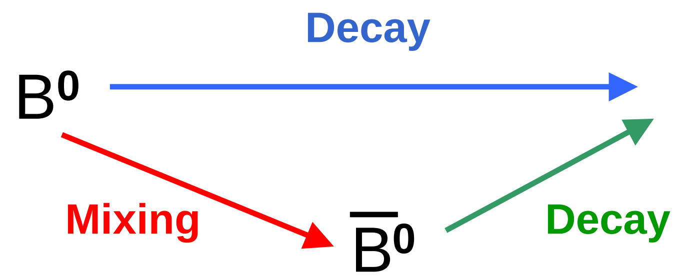
$$|B^0(t)\rangle = e^{-i(m-i\Gamma)/2} \, [\, \cos(\Delta m\, t/2)|B^0\rangle + i\sin(\Delta m\, t/2)\, e^{-2i\phi_m}|B^0\rangle]$$

Mixing phase = $\arg(V_{td}\, V^*_{tb})$

- if the final state cannot be produced by the flavor of the initial B^0, then we have <u>CP Violation in mixing</u> ⟶ T violation

Very small asymmetry ($\sim< 2\ 10^{-3}$)

- If both B^0 and $\bar{B}^0$ can decay to the same *CP eigenstate f,*



CP Violation from the interplay between decay and mixing

- there will be an *interference*,
- and a time-dependent asymmetry

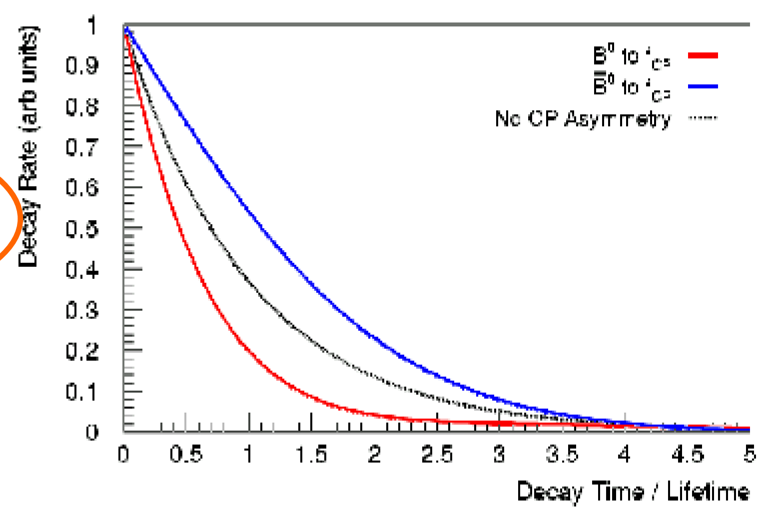
$$A_{CP}(t) = \frac{\Gamma(B^0 \longrightarrow f) - \Gamma(\bar{B}^0 \longrightarrow f)}{\Gamma(B^0 \longrightarrow f) + \Gamma(\bar{B}^0 \longrightarrow f)}$$

$$= -2\eta_f \sin(\Delta m\, \Delta t) \sin 2(\phi_m + \phi_D)$$

CP state of f

Mixing phase

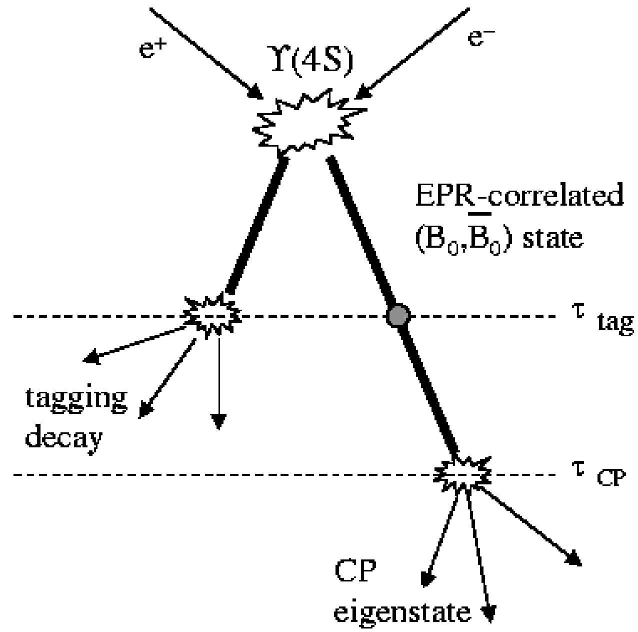
Decay phase



Access to the UT angles

- Run in “factory-mode” at the Υ(4S) resonance (10.6 GeV):
  - **Υ(4S) -> B^+B^-, $B^0\bar{B}^0$:**
    - **coherent production**
    - **high S/N ratio (~0.28)**
    - **clean (~11 tracks)**
    - **absence of fragmentation products**
    - **reconstruction of final states with π^0 and γ**
    - **kinematic constraints**
  - **off-peak backgr. subtraction**

Even though both B’s are mixing, if we tag the decay of one of them, the other must be the CP conjugate at that time. We therefore measure the time dependent decay of one B relative to the time that the first one was tagged (EPR “paradox”)

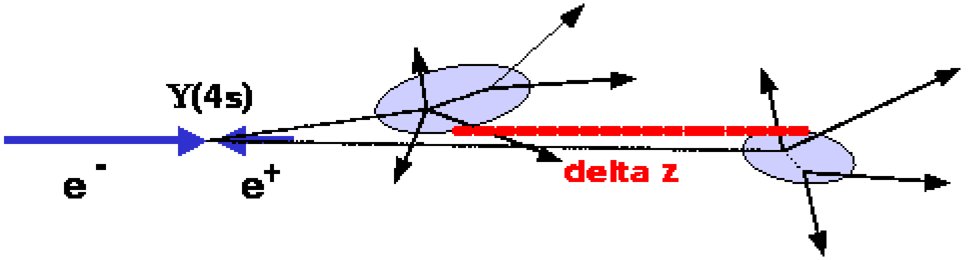


- Problem
  - at the Υ(4S) resonance, B’s only go about 30 μm in center of mass, making it difficult to measure time-dependent mixing
- The solution
  - if the **collider is asymmetric**, then the system is Lorentz boosted

Requirements of B Factories

- The primary goal of the asymmetric B factories is to make a systematic study of CP asymmetries in neutral B decays
  – redundant measurements of the sides and **angles** of the **UT**
- B decays modes expected to show observable CP asymmetries all have BR ~ 10^{-5}:
  – Need lots of data. Physics projections ~30-100 fb^{-1}/year, ~10 years
  – Can go home if we don't get 10^{33} cm^{-2} s^{-1}
- Difference in B decay times Δt~1 ps (rest frame)
  – boost (B^0,$\overline{B^0}$) system in lab frame and measure Δz

now the time measurement becomes a Δz position measurement



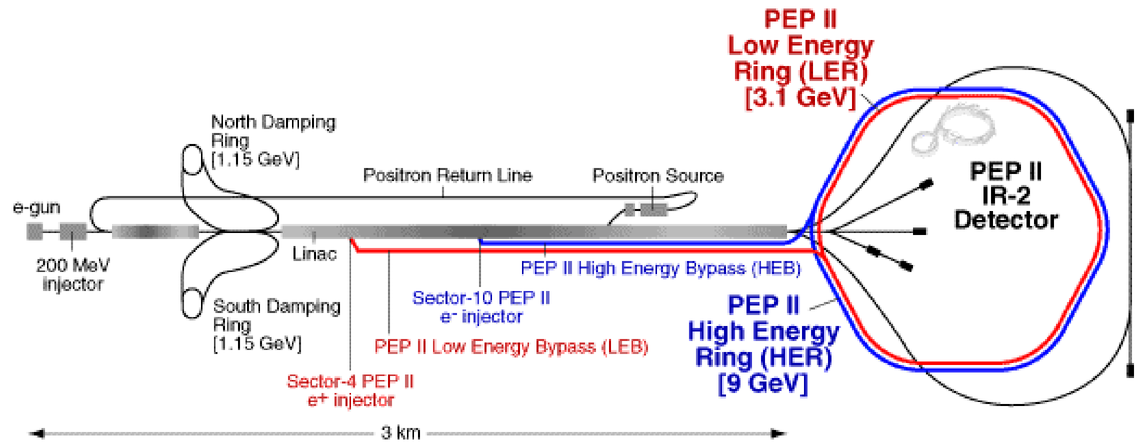
Detector requirements

- B Spectroscopy
  - Low branching fractions & potentially high backgrounds (accelerator-induced + physics)
    - Excellent momentum (~0.5%) & energy resolution
    - Good acceptance in forward direction (boost)
    - Track reconstruction down to 50 MeV/c P_t
    - K/π separation up to 4 GeV/c (B->$\pi\pi$/Kπ/KK decays)
    - Detection of π^0 and γ (20 MeV - 5 GeV)
    - $K^L{}_0$ detection capability
- Distinguish between b/$\bar{b}$ decays ("B tagging")
  - Mostly based on Lepton & Kaon Tagging
    - Lepton identification down to 500 MeV/c
    - Kaon identification below 2 GeV/c
- Vertexing
  - Δz ~ 260 μm, ~ 40% resolution required
    - Resolution dominated by multiple scattering

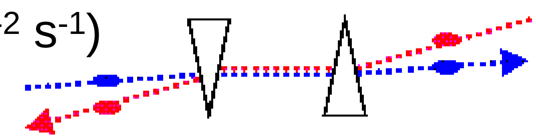
The present of B Factories

- Two collaborations have taken up this challenge:
  - BaBar + PEPII, SLAC (USA)
  - Belle + KEK-B, KEK (Japan)
- Symmetric B Factories (CLEO-III, Cornell, USA) are not in the game of time-dependent CP asymmetries, but lots of Physics can be done:
  - determination of V_{cb}
    - HQET in exclusive semi-leptonic decays B->D*(D) l ν
  - determination of V_{ub}
    - Inclusive decays
    - Exclusive decays
  - rare B decays (Penguin decays, Direct CP violation, non-Standard Physics,…)
  - Charm Physics, τ Physics, $\gamma\gamma$ Physics...

The PEP-II B Factory



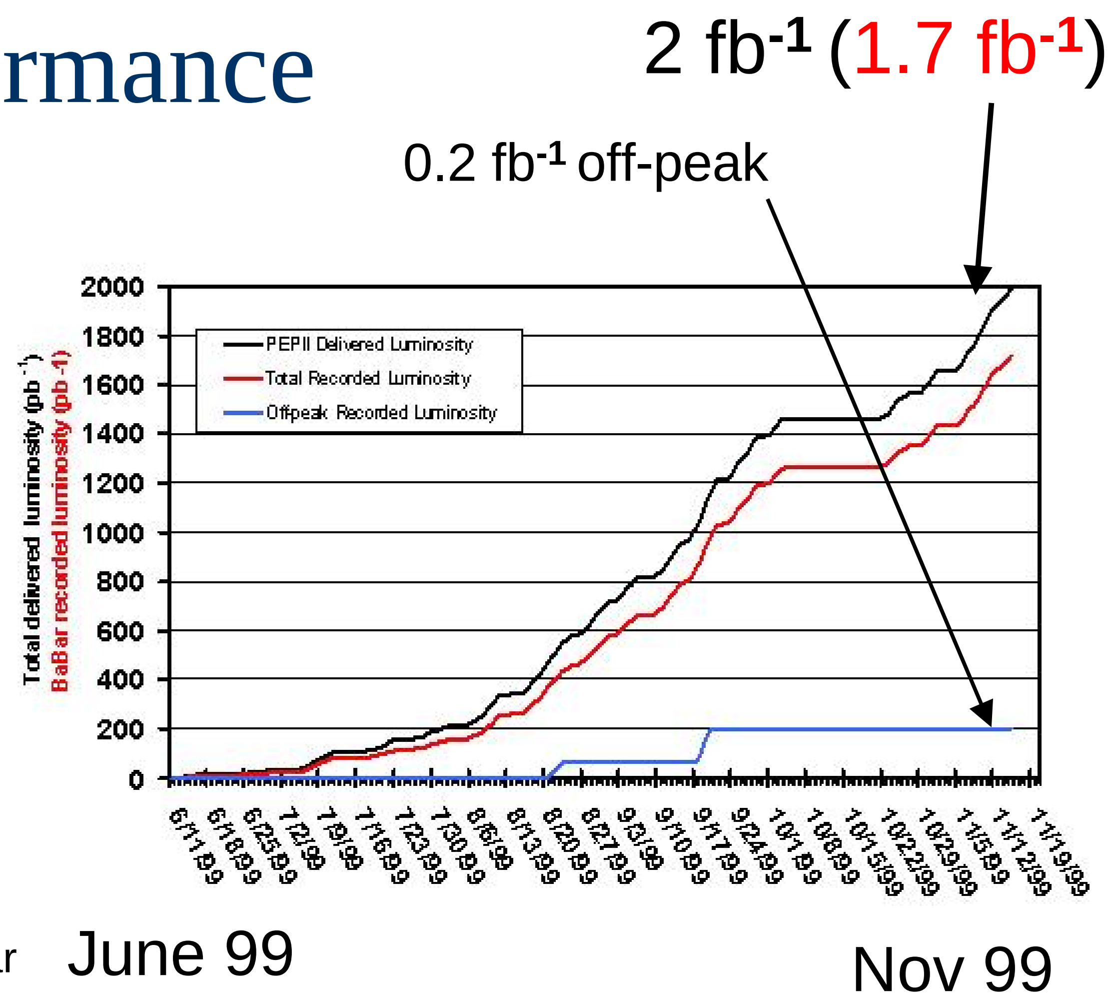
(design/achieved)	HER e-	LER e+
Beam energy (GeV)	9/9	3.1/3.1
Current/bunch (mA)	0.66/0.66	1.3/1.3
#bunches	1658/829	1658/829
Total current (A)	0.75/0.55	2.14/1.7
Bunch spacing (m)	1.26	
σ_z (cm)	1.0	1.15
σ_x @IP (µm)	155	
σ_y @IP (µm)	6.2	
Lifetime	4h@1A / 8h@0.5A	4h@2A / 2.7h@0.8A
1/2 Crossing angle(mr)	0 (head-on)	
Peak luminosity ($cm^{-2}\ s^{-1}$)	$3\ 10^{33}/1.4\ 10^{33}$	



PEP-II performance

Some milestones

May 97- HER commissioning begins
July 98- LER installation complete.
HER: 759 mA,
1222 bunches
Feb 99- LER: 1171 mA (WR)
March 99- Install BaBar
$L = 5.2\ 10^{32}$
786 bunches
HER: 350 mA
LER: 680 mA
May 99- First collisions with BaBar
Nov 99- $L=1.4\ 10^{33}$ (WR)

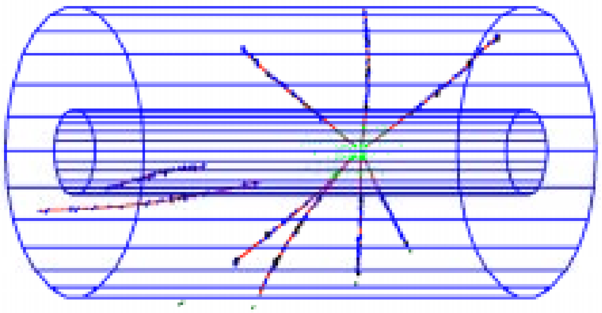


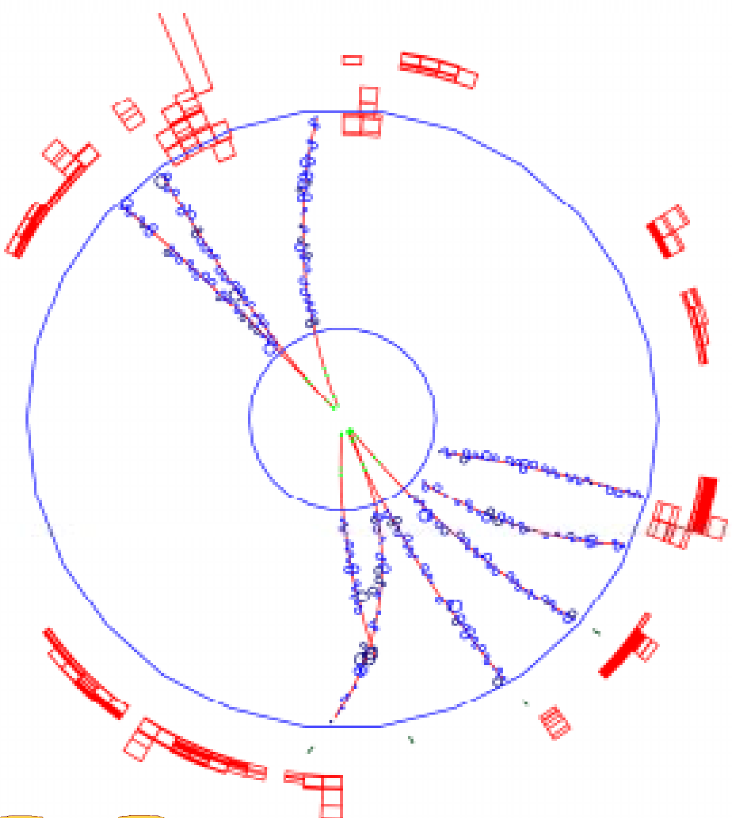
Always on or ahead schedule!

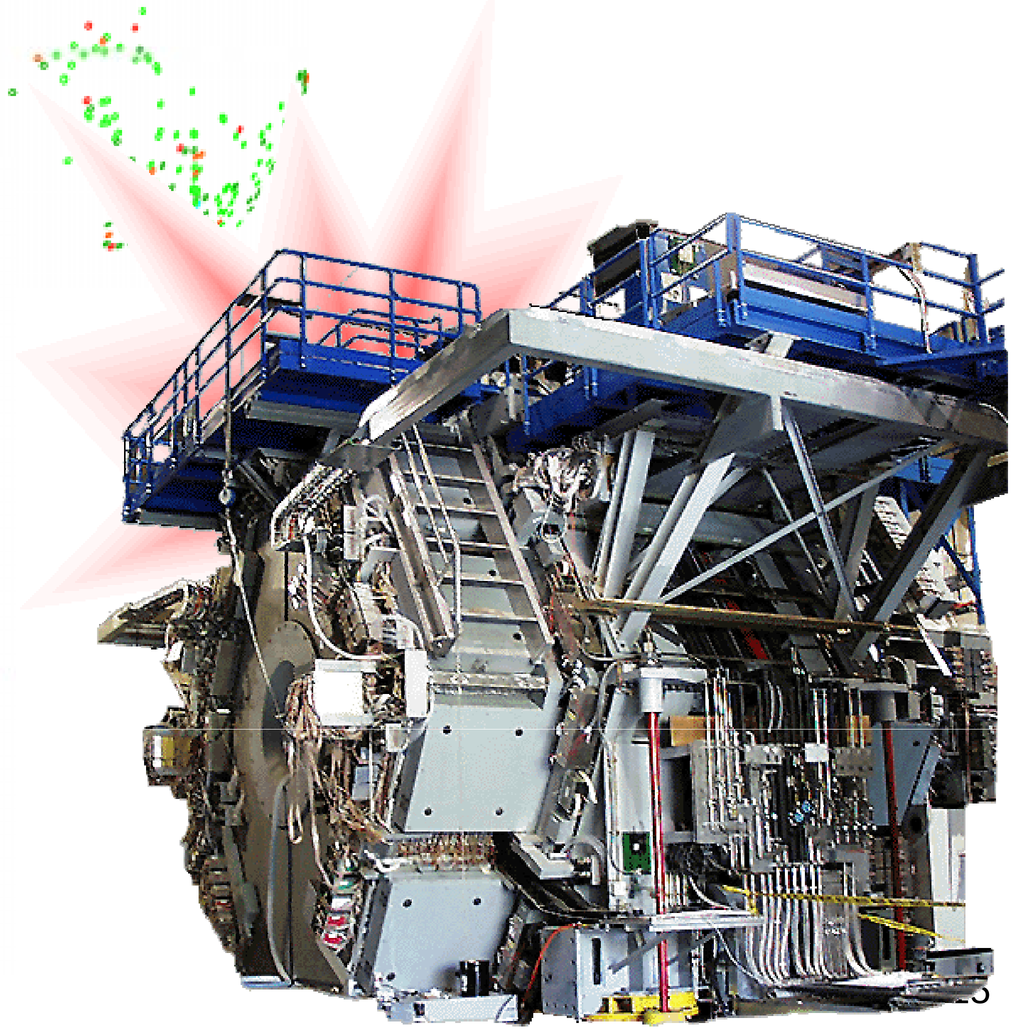
First Collisions in *BABAR*

Hadronic Event

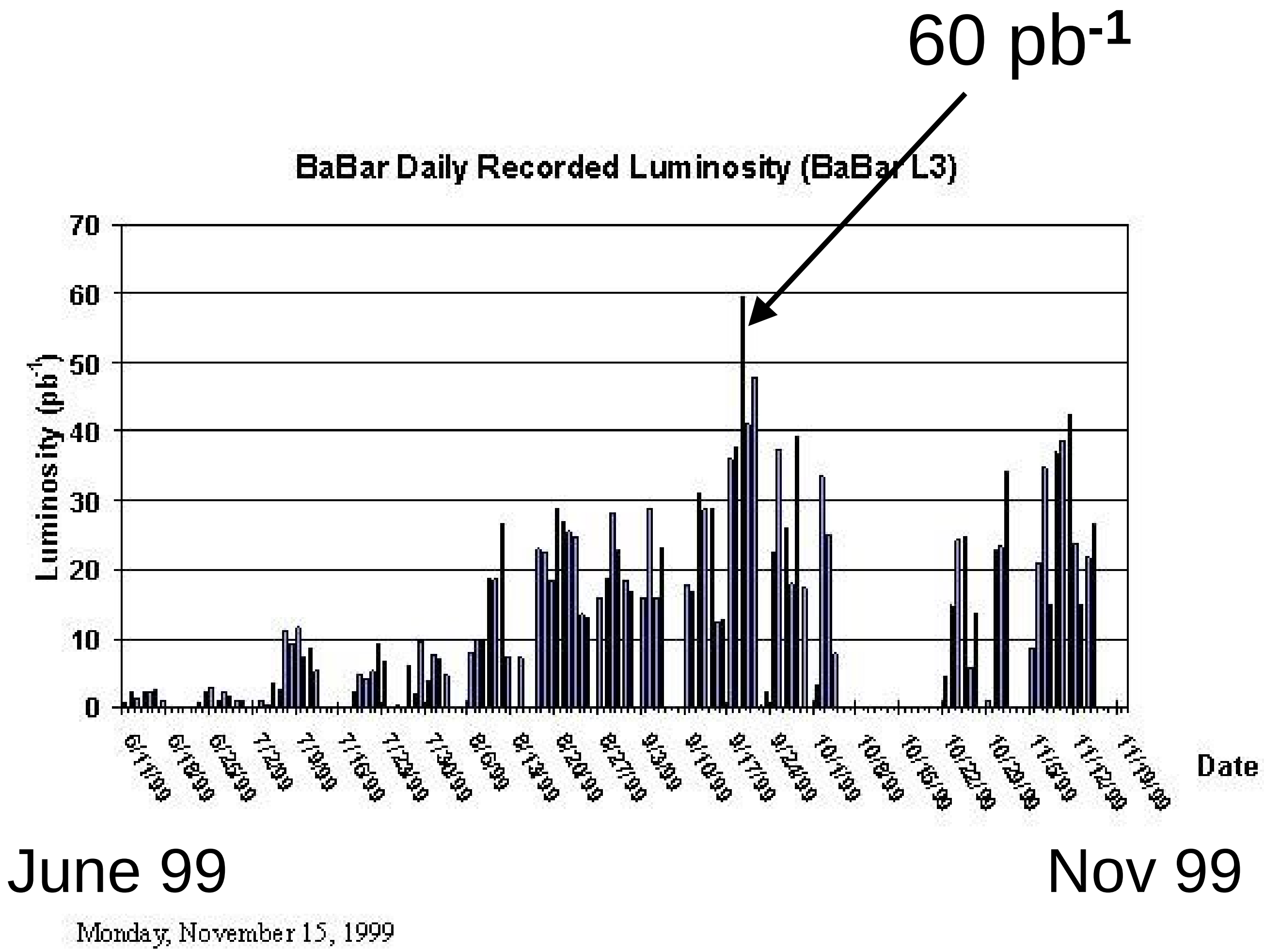
May 26, 1999





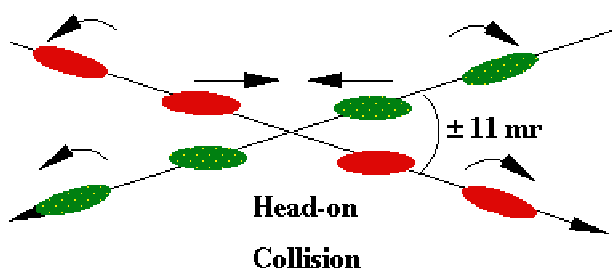


PEP-II performance



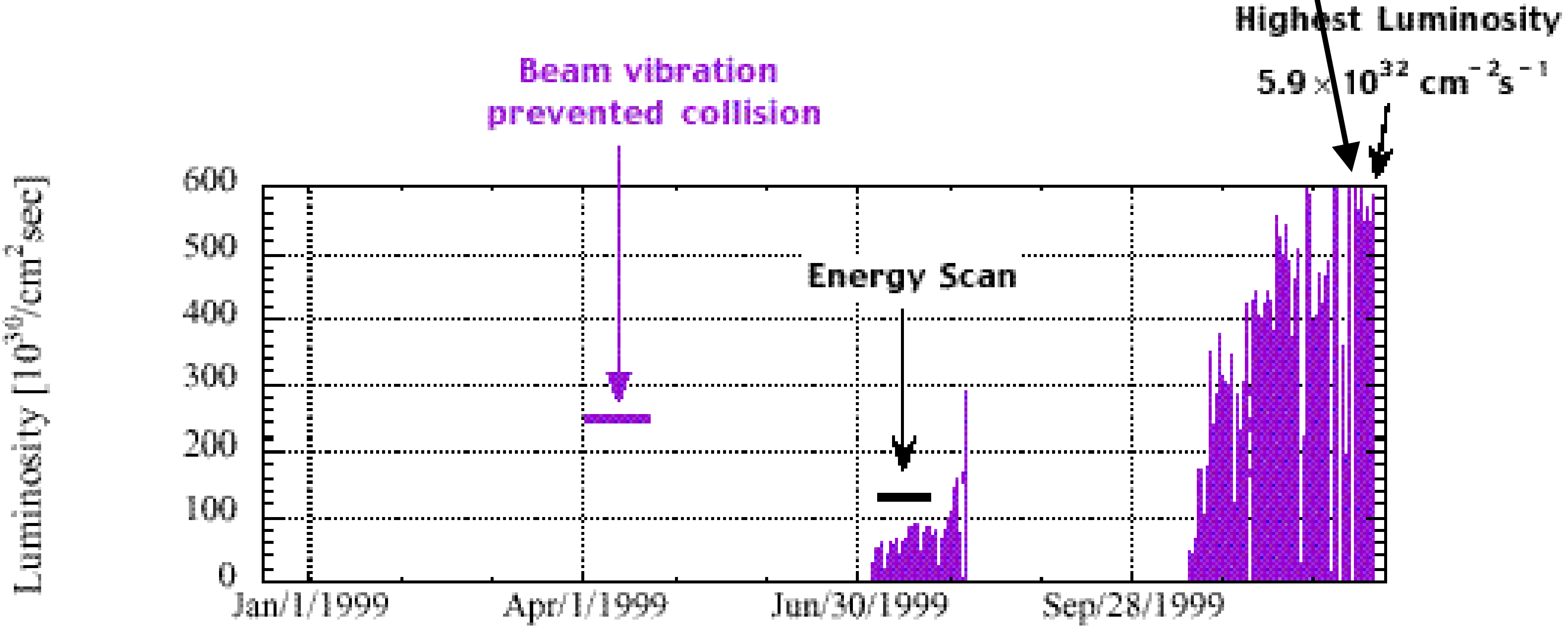
The KEK-B B Factory

(design/achieved)	HER e-	LER e+
Beam energy (GeV)	8.0/8.5	3.5/4.0
Current/bunch (mA)	0.22/4	0.52/2.3
#bunches	5000/800	5000/1024
Total current (A)	1.10/0.51	2.6/0.53
σ_z (cm)	0.40/0.56	0.40/0.56
σ_x @IP (μm)	77/170	
σ_y @IP (μm)	1.9/2	
Lifetime	4.2h@0.27A	1.7h@0.43A
1/2 Crossing angle(mr)	11	
Peak luminosity ($cm^{-2}\ s^{-1}$)	$1\ 10^{34}$ / $5.9\ 10^{32}$	
Recorded luminosity (Dec'99)	300 pb^{-1}	



KEK-B performance

300 pb^{-1}

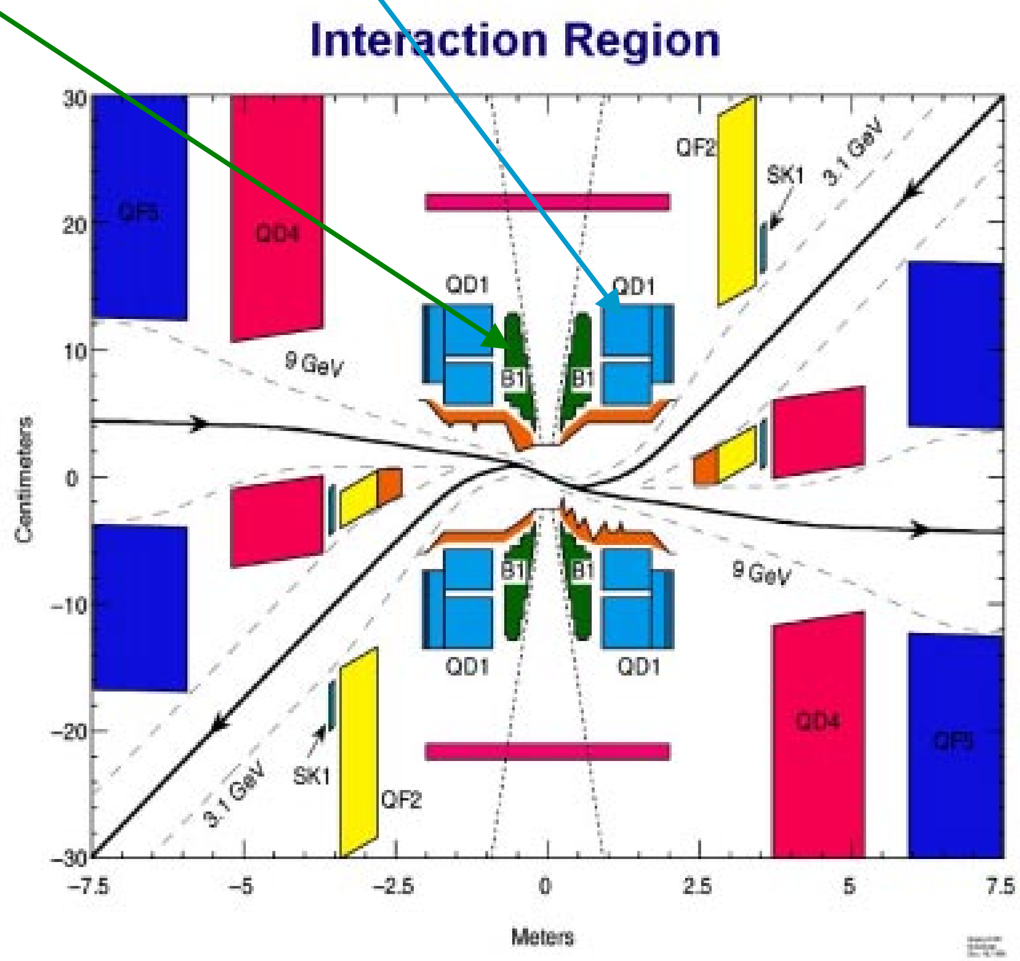


Accelerator backgrounds

- Backgrounds are an important challenge for B Factories:
  - high occupancies stress pattern recognition algorithms and saturate DAQ & storage capacity
  - ionizing radiation damages detector elements and electronics (SVT/SVD)
- Main sources are:
  - synchrotron X-rays from magnets
  - beam scattering off residual vacuum (Coulomb, Bremsstrahlung)
  - optics miss-tuning (injection loss, ...)
  - crossing angle - no parasitic collisions
- Shielding, masking, collimators, vacuum pumping, continuous radiation monitoring and beam dump interlock systems are the key for the safety, data quality and the useful lifetime of the experiment
- learn to live with them

- e.g. PEP-II bunch spacing (1.26 m) with head-on collisions requires binding and strong focusing inside the detector

• permanent magnets reach in to |z|=21 cm
• collision axis rotated ~20mr with respect to BaBar ("tilt")
• 1% X_0 water-cooled Be beam-pipe

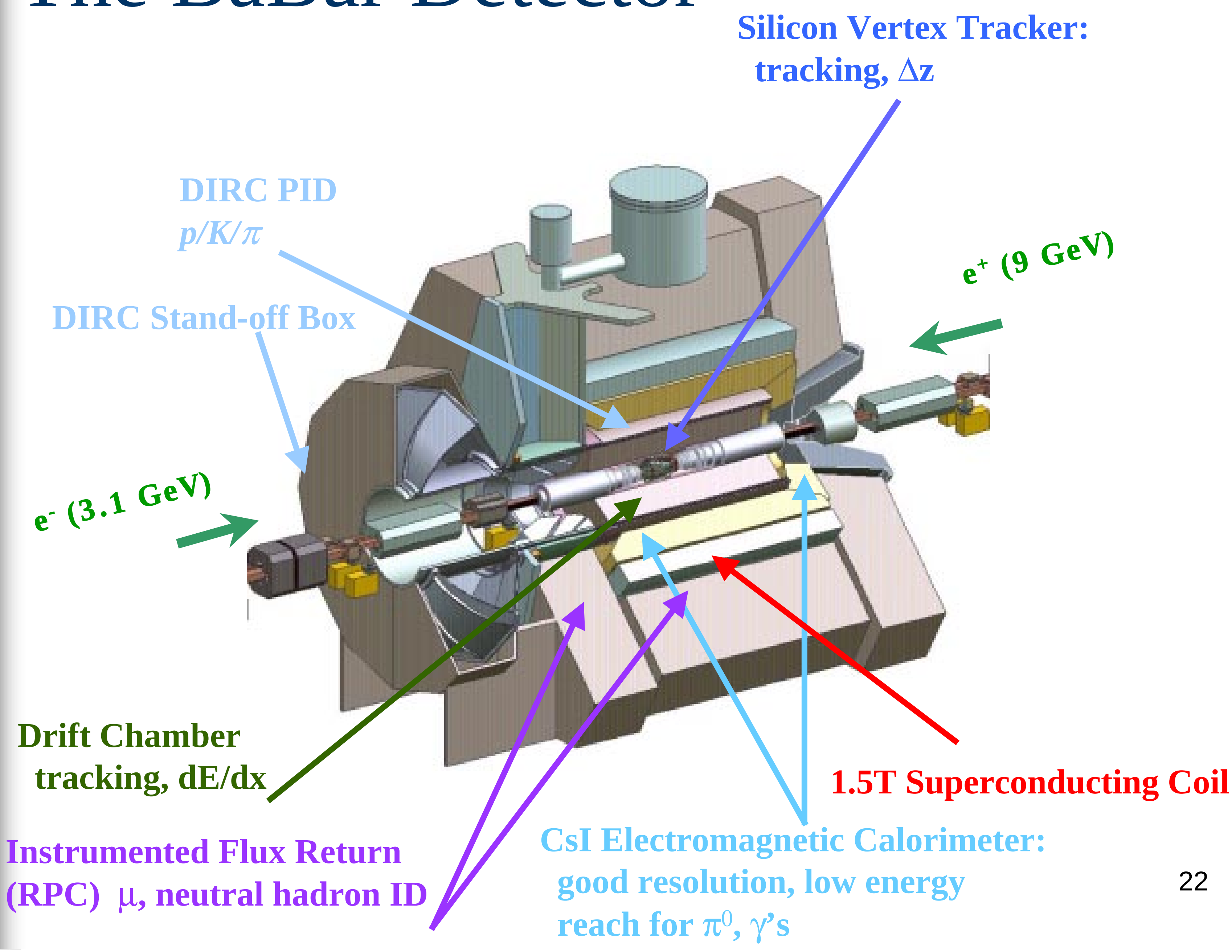


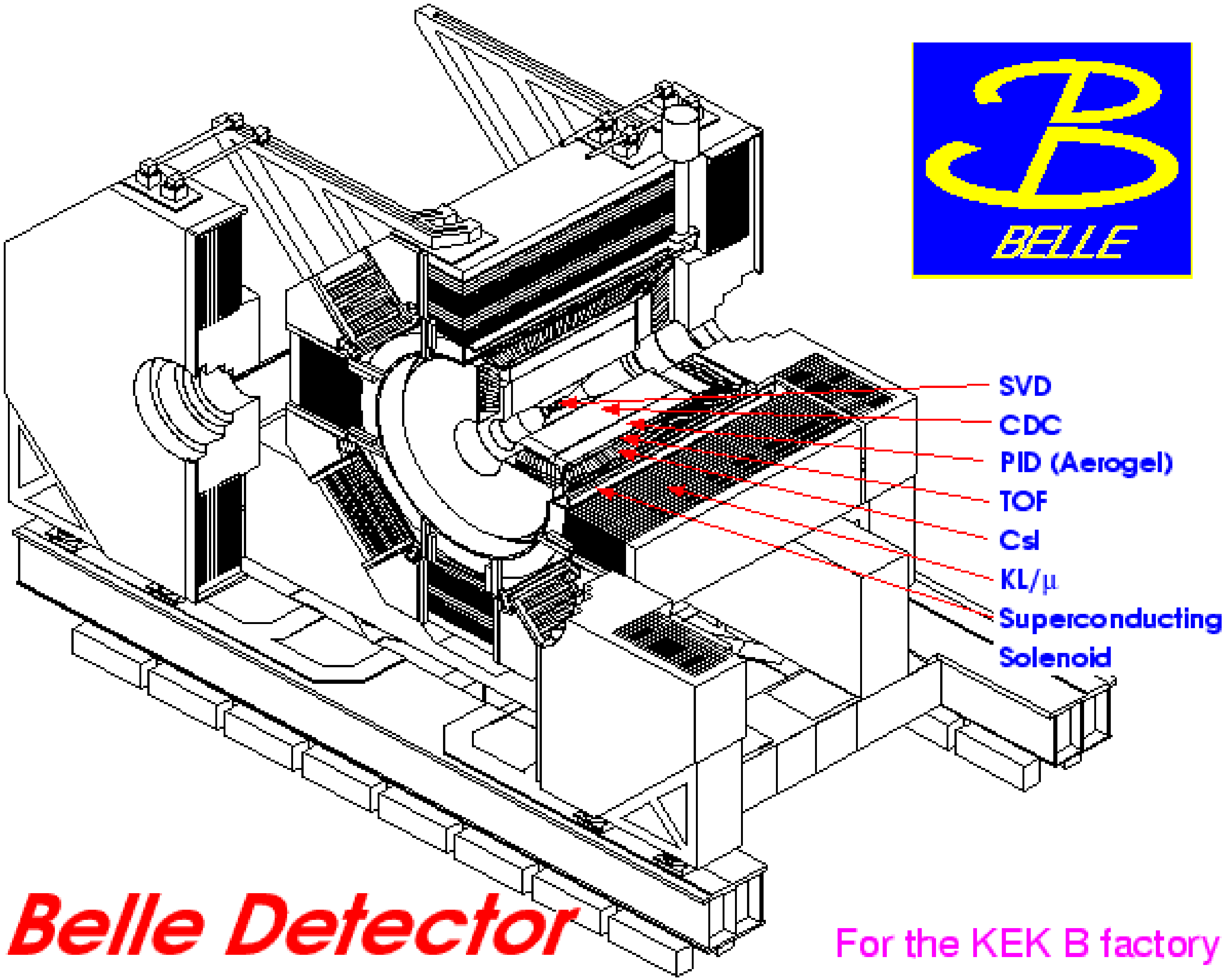
- this also imposes strong mechanical constraints to the detector

BaBar and Belle subsystems

	BaBar	Belle
Silicon Vertex Detector	SVT 5 double sided rad hard layers	SVD 3 double sided layers
Drift Chamber	DCH 22.5-80 cm, 40 layers (axial/stereo)	CDC 8-87 cm, 50 layers (18 stereo)
Particle ID	DIRC Detector of Internally Reflected Cherenkov light 144 Quartz bars	ToF+ACC 4 cm-thick scint., 128 ϕ segmentation 960+228 silica aerogel cells (threshold Cherenkov, n=1.01 - 1.03)
γ-detector (E_γ>20 MeV)	EMC 5760+820 CsI(Tl) Xtals in in barrel and forward endcap	CsI 6624+1152+960 CsI(Tl) Xtals 30 cm long
SC Magnet	1.5 T	1.5T
μ/K_L-detector (p_T>0.6 GeV/c)	IFR 19 RPC layers, 65 cm iron (barrel) 18 RPC layers, 60 cm iron (endcaps) 2 double-layer RPC inside the coil	KLM 14 layers RPC superlayer and 4.7 iron

The BaBar Detector

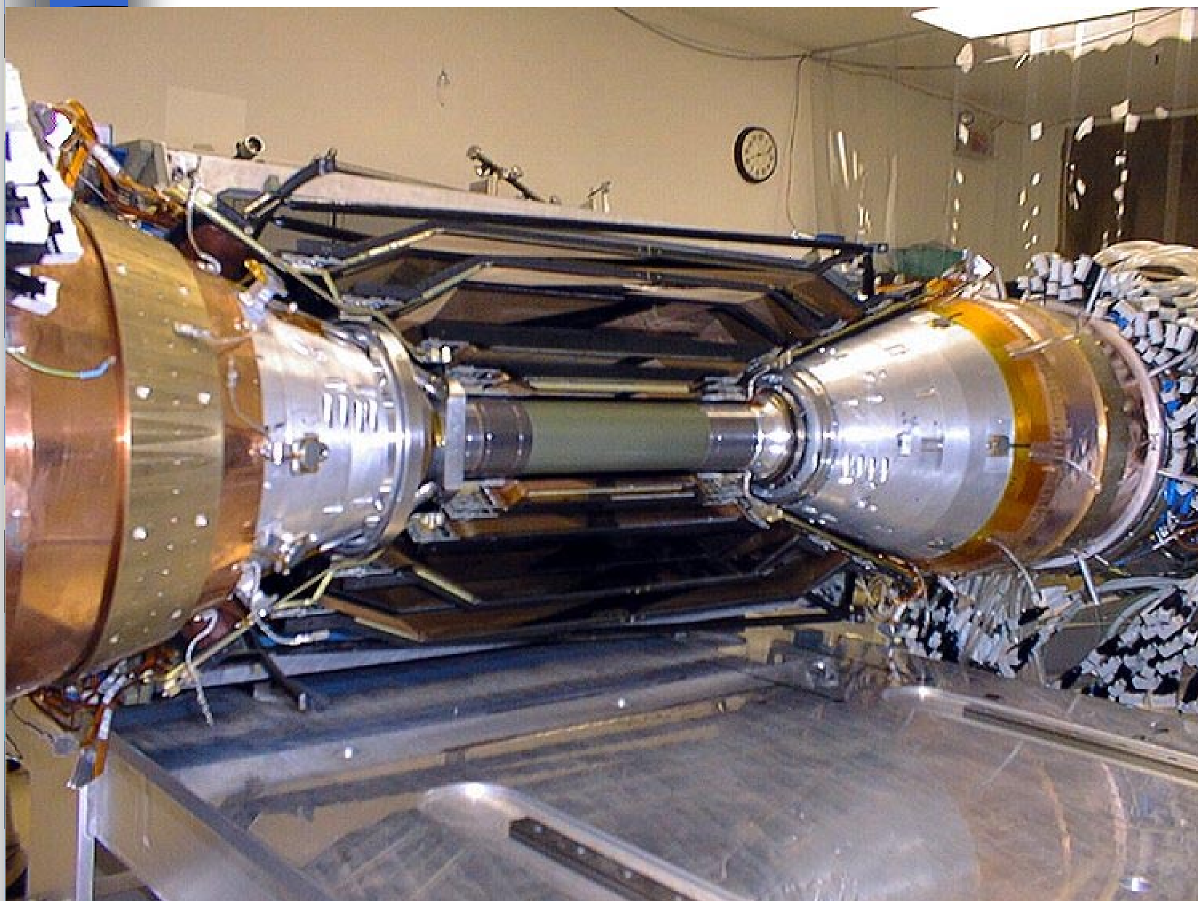




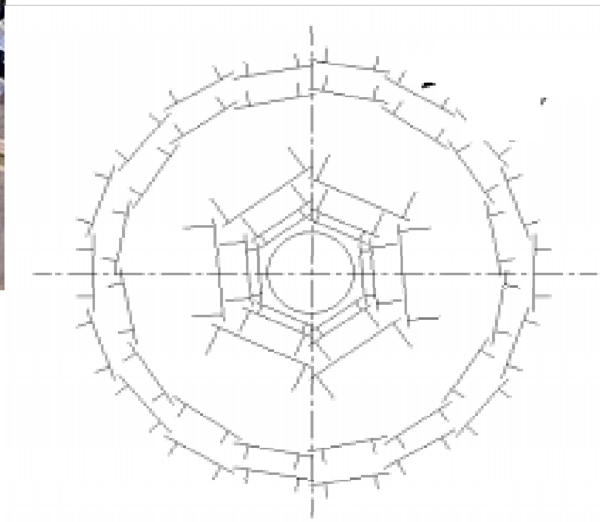
Belle Detector

For the KEK B factory

The BaBar Silicon Vertex Tracker

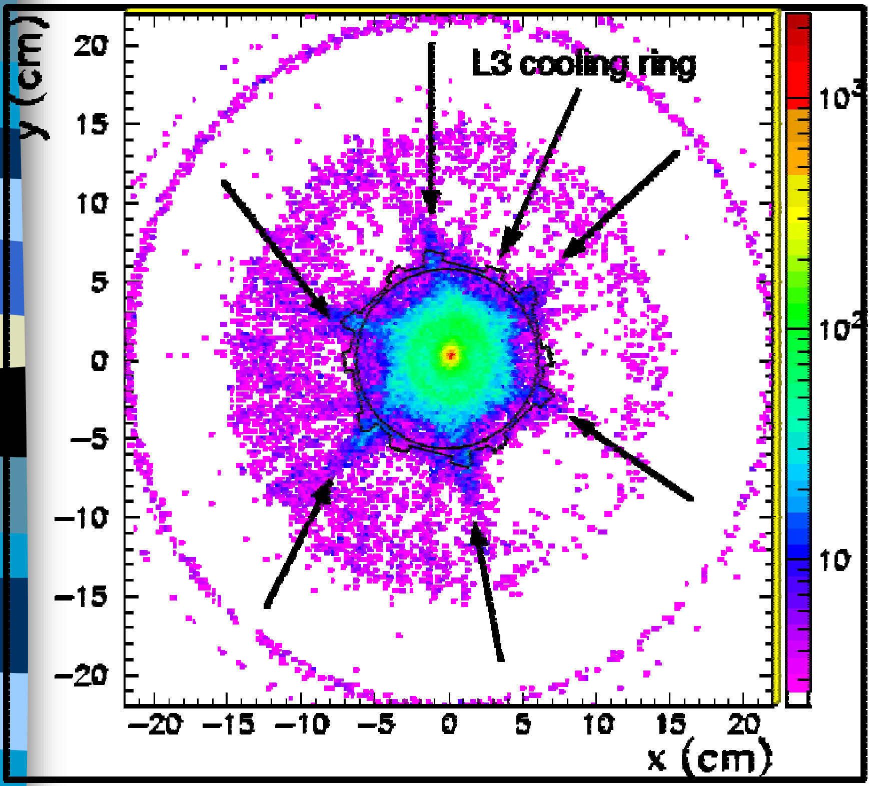


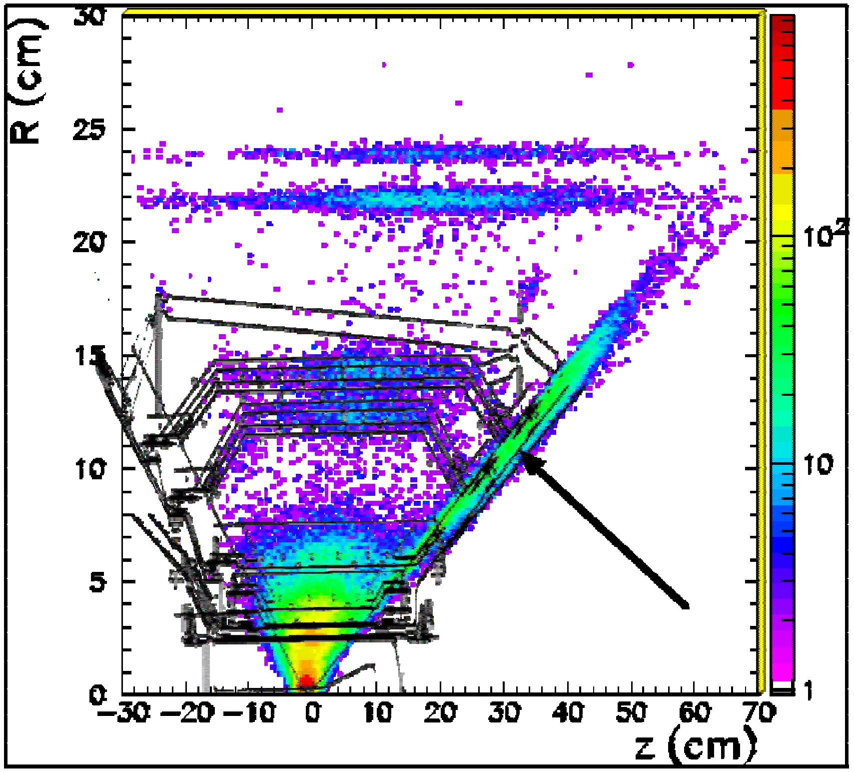
- 5 double-sided layers
- 143K channels (0.94 m^2)
- r=3.2 cm to 14.4 cm
- 15µm (ϕ) to 19µm (z) resolution for cosmics
- 60 µm z vertex resolution
- radiation hard to 2MRad
- tracker for p_T<100 MeV/c ($D^* \rightarrow D^0 \pi$)

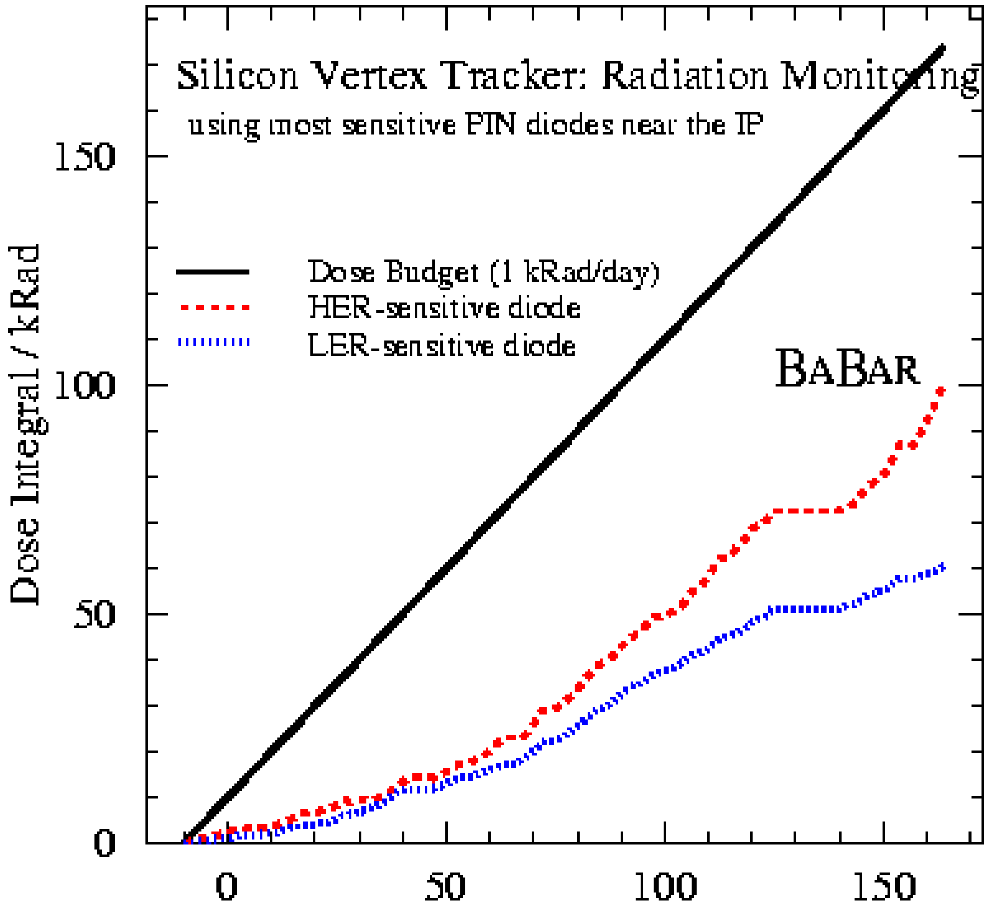


Monitoring the material

BaBar



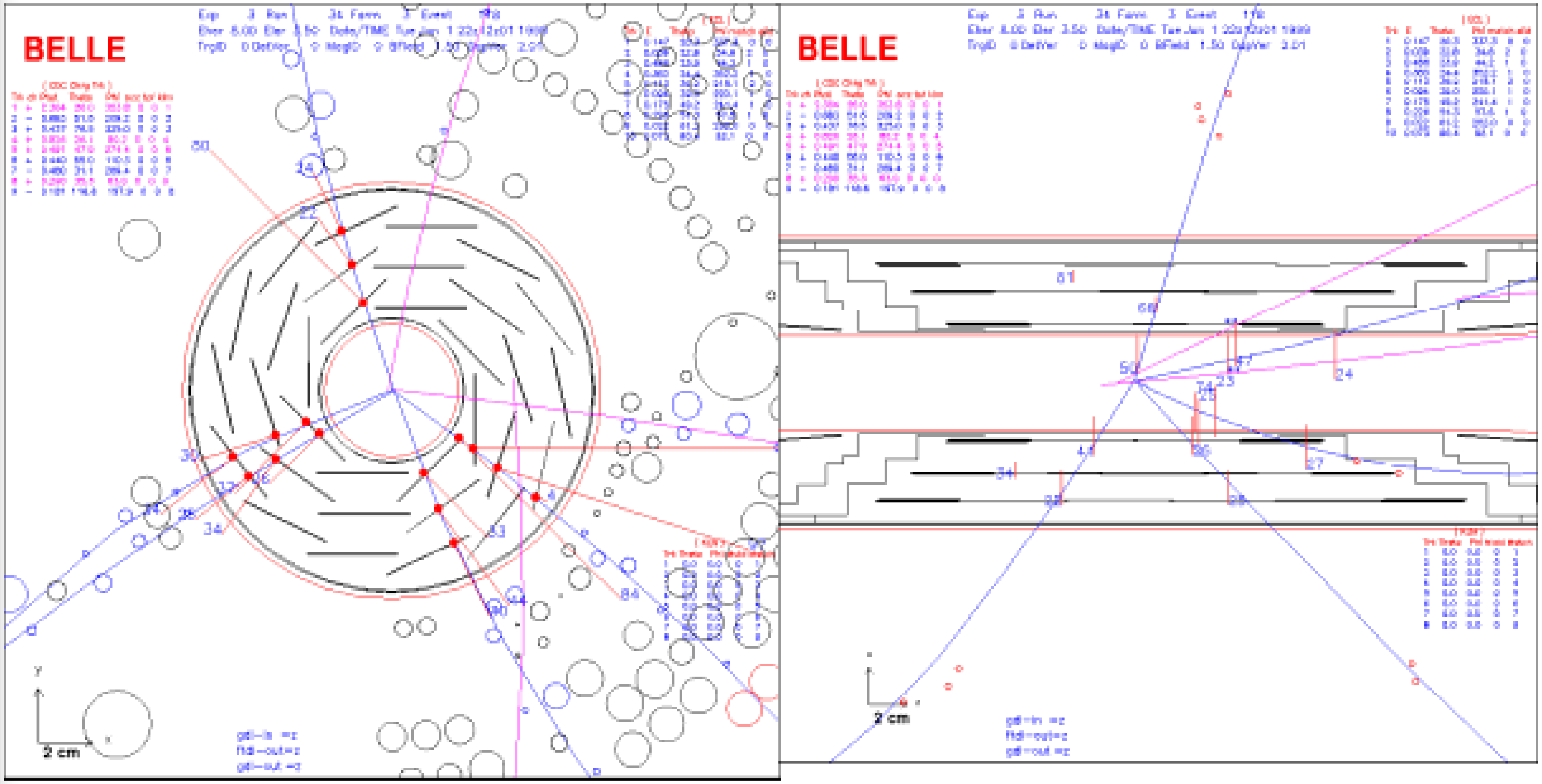




Days of running

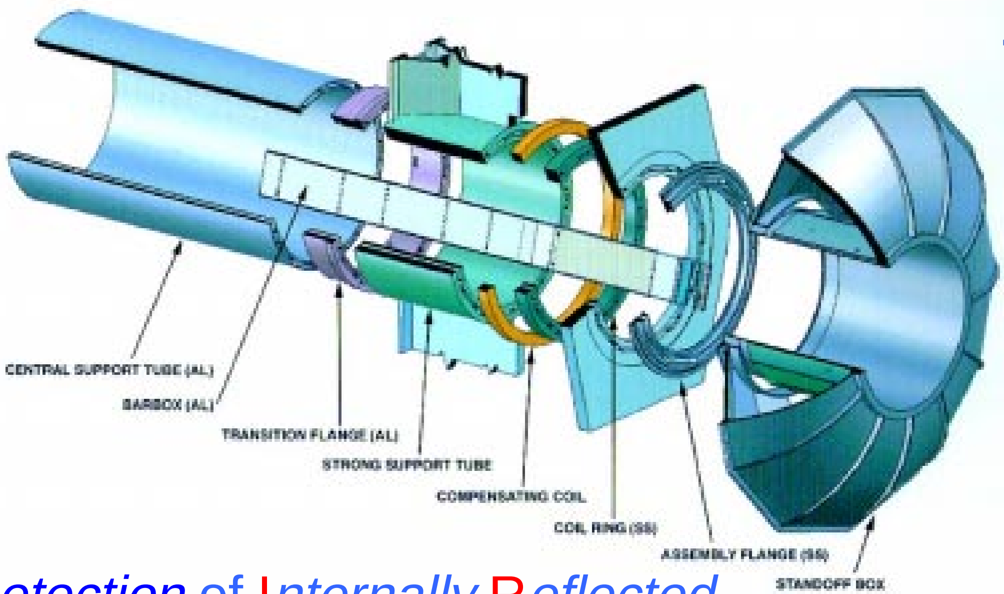
- PEP-II is providing clean beams
- The radiation dose received by the detector is well below the "budget" (240 kRad/year)

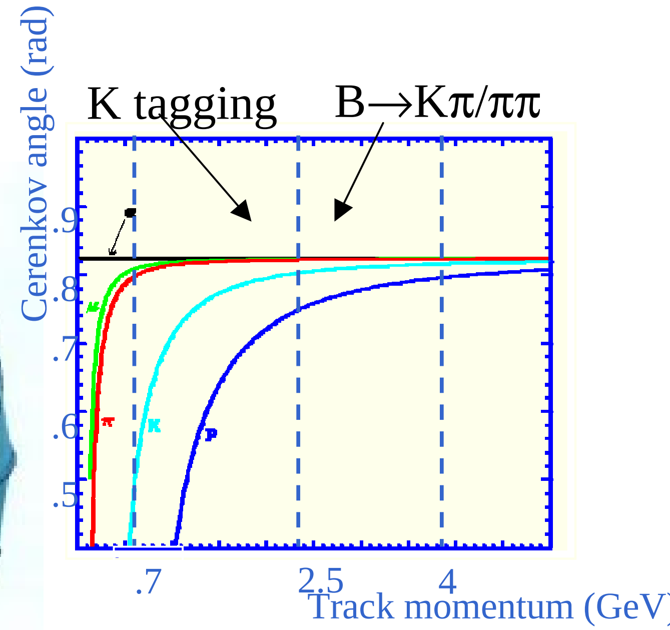
The Belle SVD



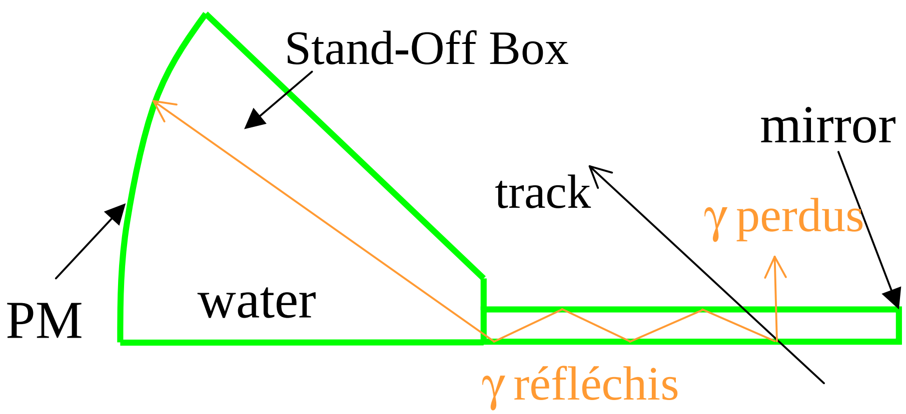
- 300 μm thick Si
- 3 layers of double-sided strips
- r = 3.0-5.8 cm
- σ_z ~ 45 μm

The BaBar DIRC





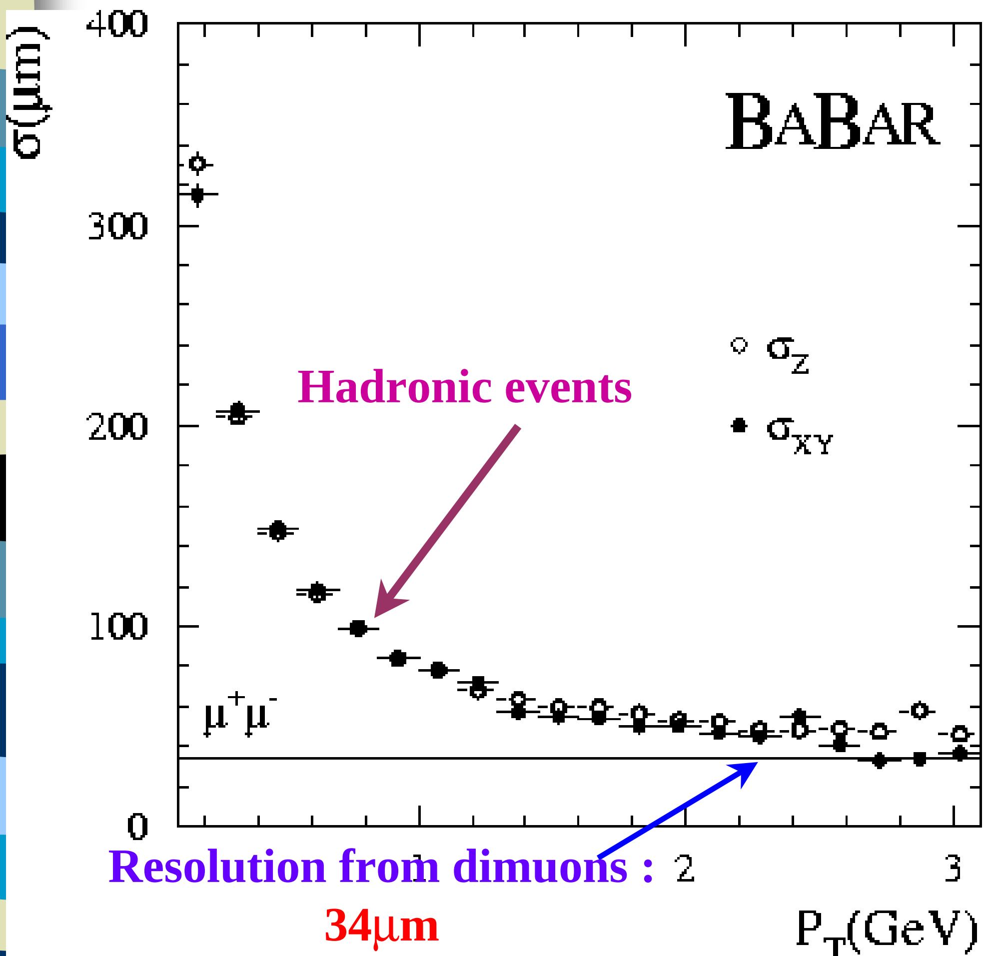
D*etection* of **I***nternally* **R***eflected* **C***herenkov* light



- Cherenkov light produced in 144 quartz bars transported to water standoff box with 10572 PMT's
- 12 sectors, 5 with quartz installed
- π/K separation from 0.7-4 GeV
- Complete since October
- Challenge: surface polish RMS 5-10 angstroms! Nearly too challenging for vendor

Performances: BaBar tracking

Resolution on distance of closest approach



P_t resolution

– for $P_T > 1$ GeV/c

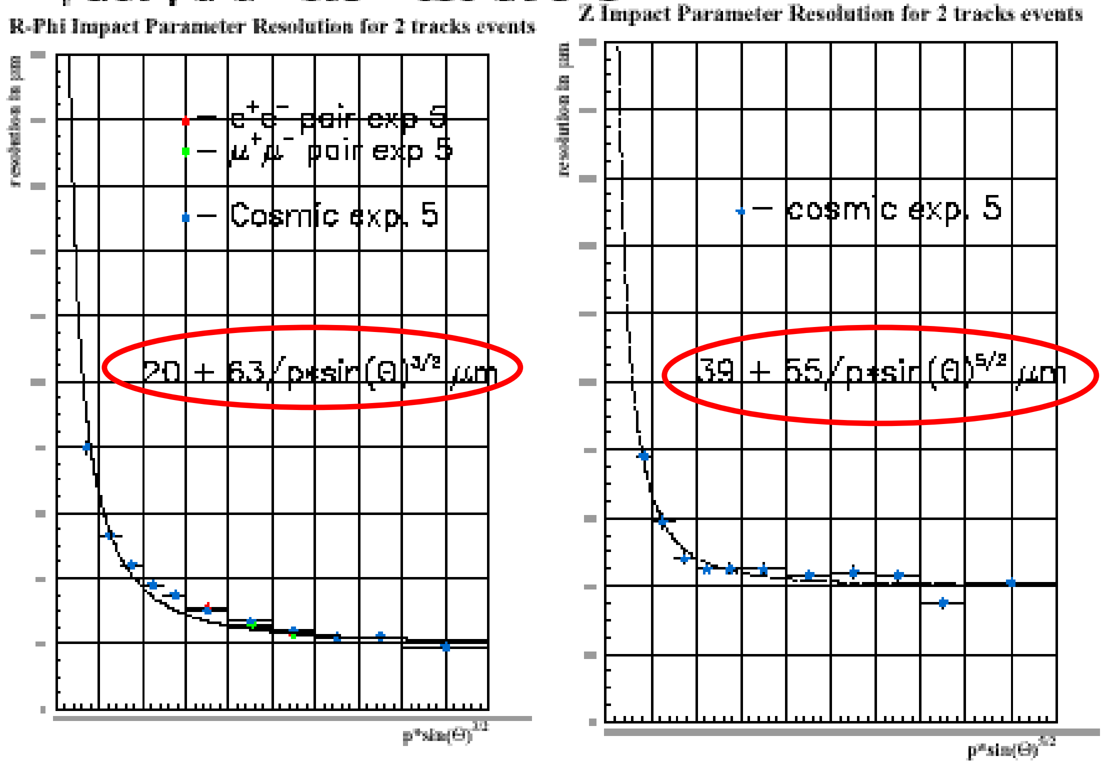
$$\frac{\sigma_{Pt}}{Pt} = 0.30\% Pt$$

– for DCH only

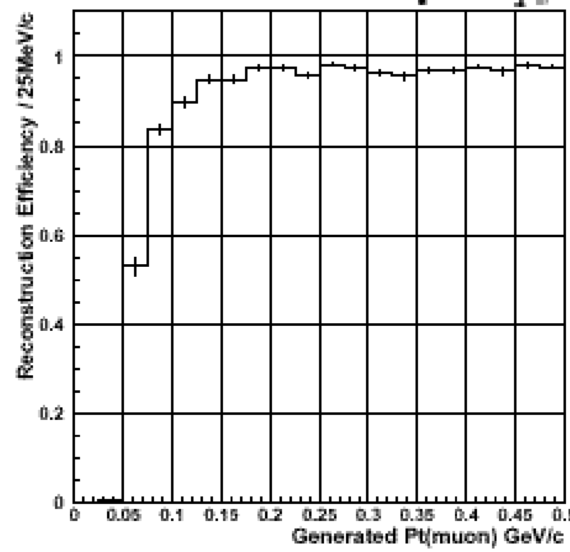
$$\frac{\sigma_{Pt}}{Pt} = 0.45\% Pt$$

Performances: Belle tracking

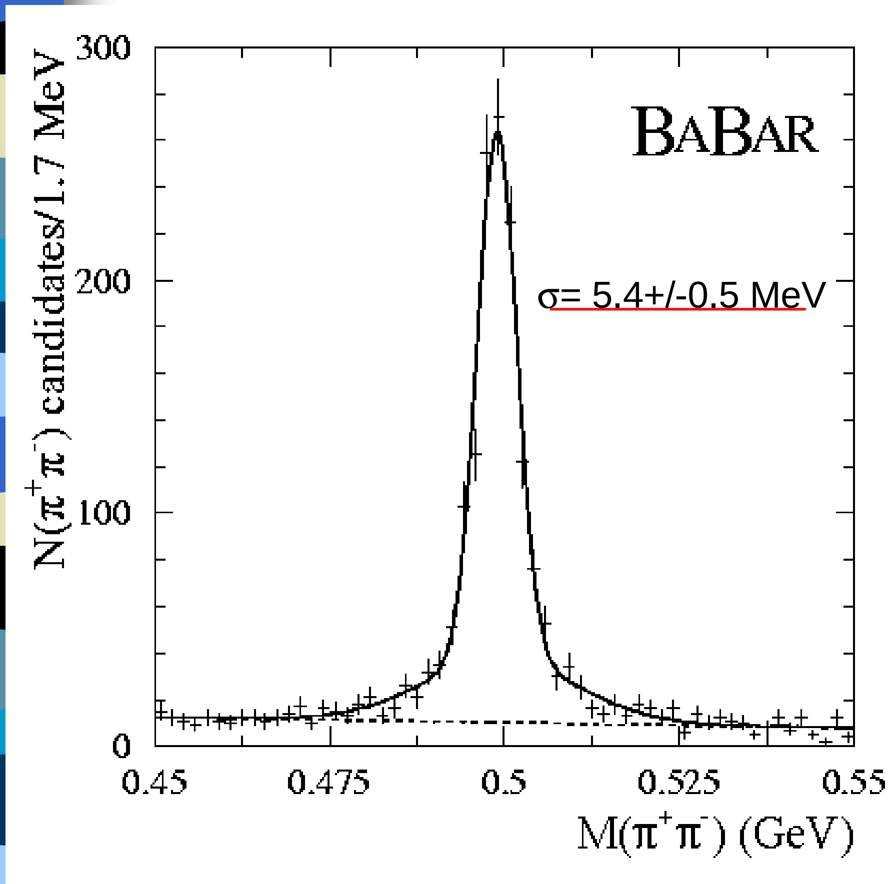
Impact parameter resolutions

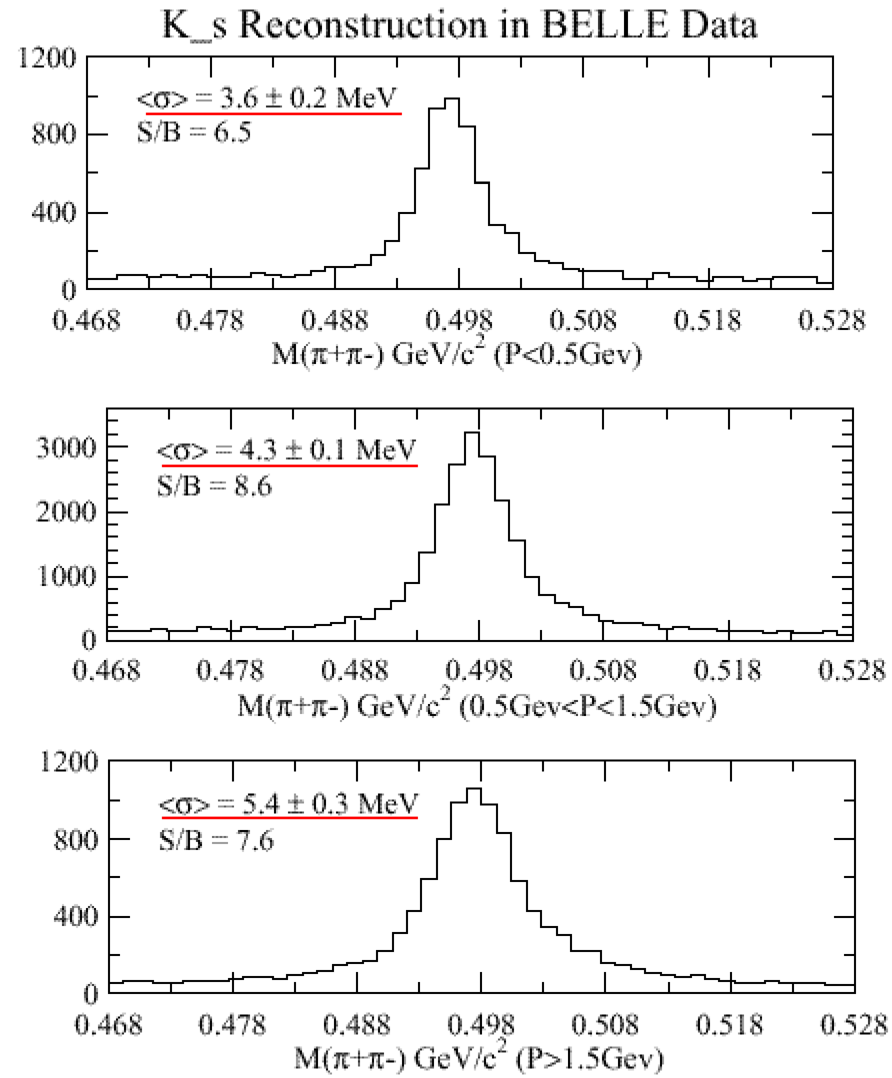


Track-find efficiency vs p_t



Performances: $K^0_s \longrightarrow \pi^+\pi^-$



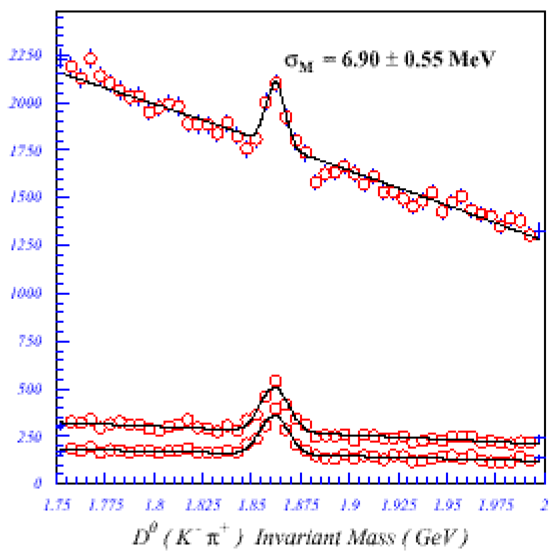


Performances: D mesons

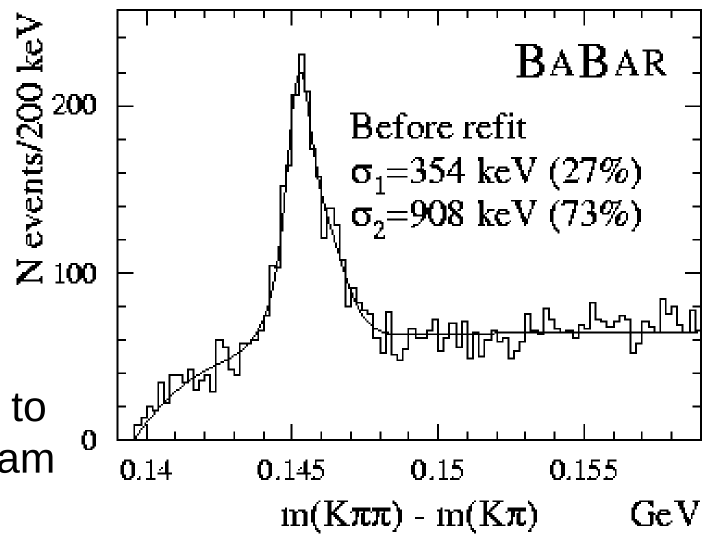
$D^{*+} \rightarrow D^0 \pi^+$

$D^0 \rightarrow K^- \pi^+$

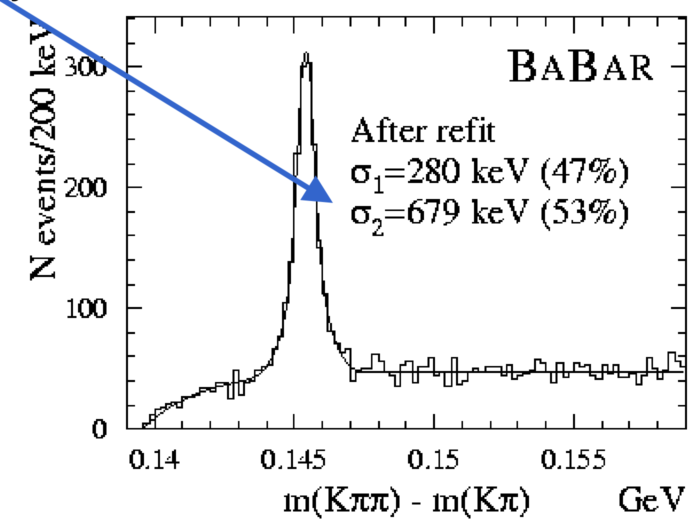
Belle



σ_M=6.9+/-0.6 MeV
(SVD hits required)

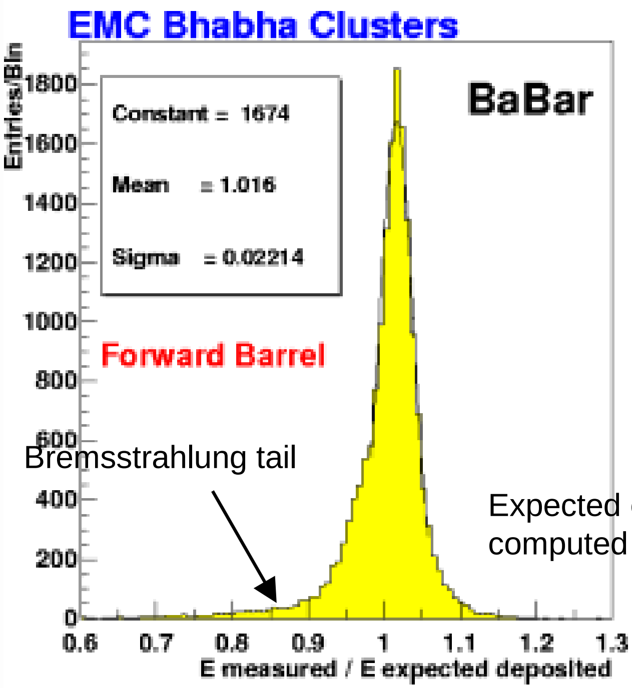


Constraint vertex to originate from beam spot improves resolution and purity



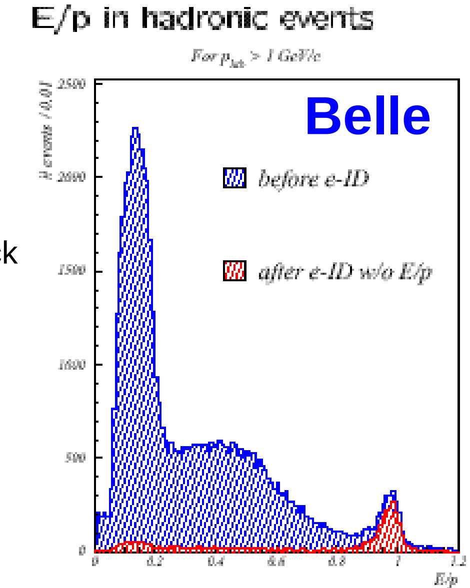
BaBar (not final alignment)
σ_M=7.9+/-0.4 MeV
(no SVT hits required)

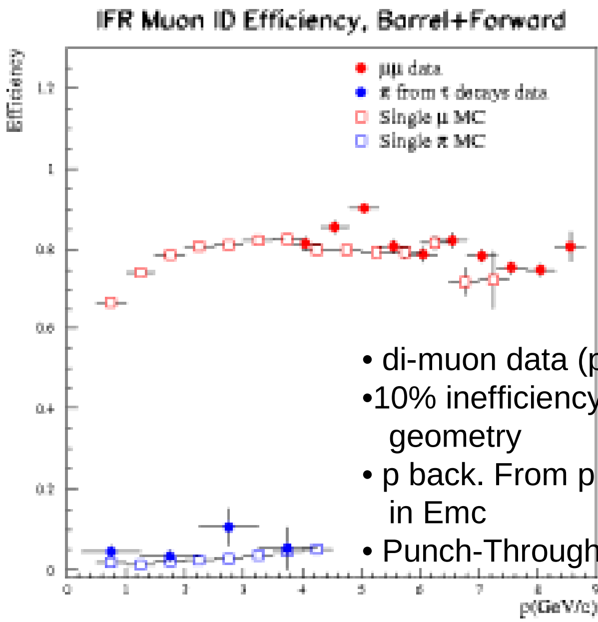
Performances: lepton identification



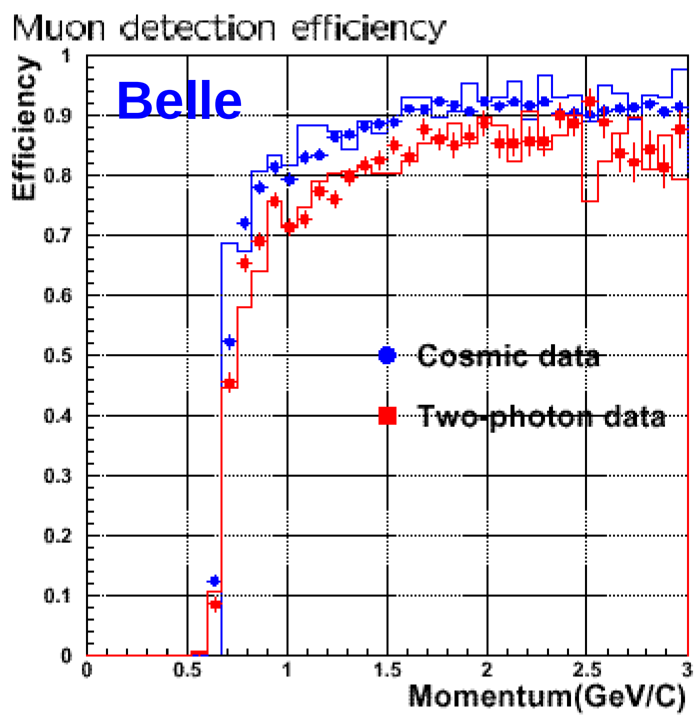
Expected e^- (e^+) energy computed from track angle

- E/p
- association with CDC track
- dE/dx in CDC
- Aerogel hit and ToF

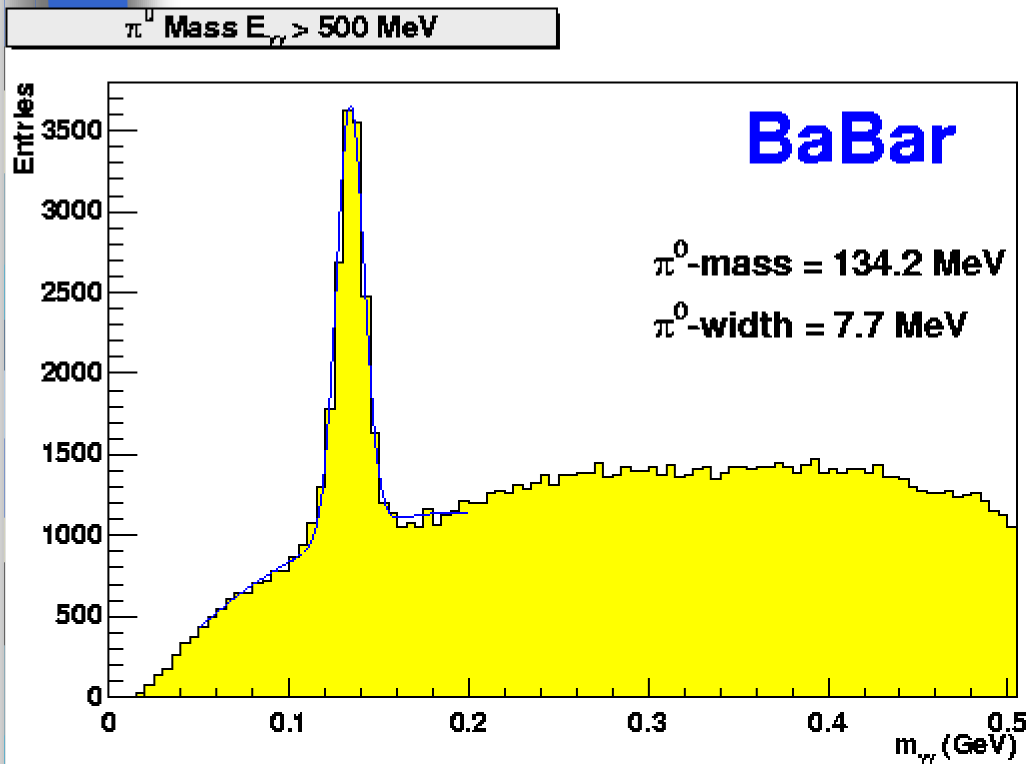




- di-muon data (p>~4 GeV/c)
- 10% inefficiency due to detector geometry
- p back. From p decay in DCH or in Emc
- Punch-Through: 1.2%

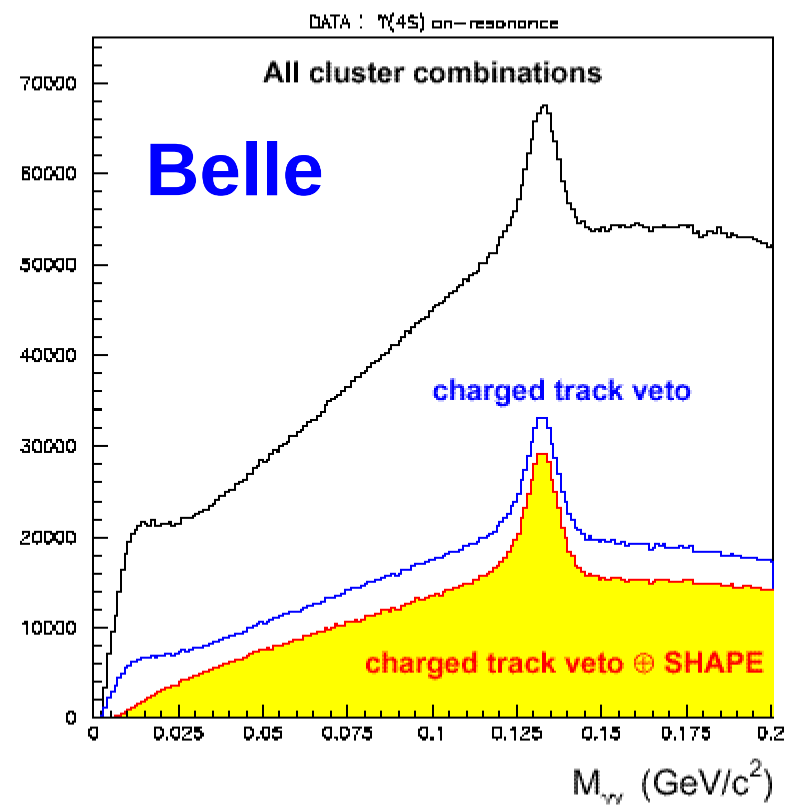


Performances: photons and π^0s



- E_γ>100 MeV
- E_π >500 MeV
- Improvements expected by reducing noise
- BaBar expects to achieve a resolution of ~5.5%

- E_γ>50 MeV for barrel, 100 MeV for endcap
- E_π >500 MeV
- Resolution ~ 4%



Summary of detector performances

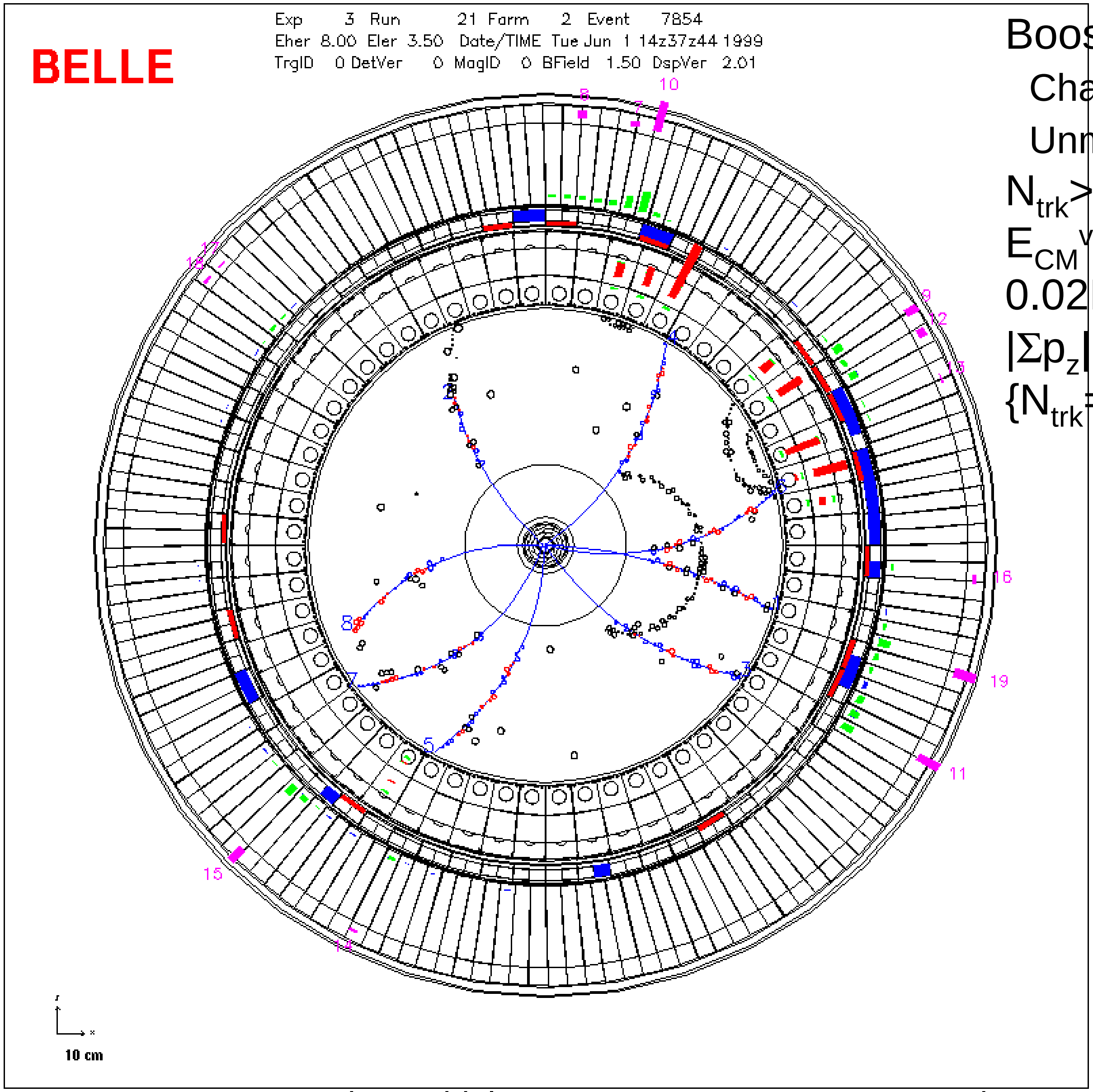
BaBar

- σ_{hit}(DCH)=125 μm average for Bhabha. Exceeds spec of 140 μm
- σ(dE/dx)=7% for Bhabha
- $\sigma(\theta_c)$=3.0 mrad for Bhabha (2.0 spec)
- σ_z(SVT)=19 μm for cosmic tracks
- $\sigma_E/E=1\%\ E(GeV)^{-1/4} + 1.2\%$ at $\theta=90^o$
- $dp_T/p_T=0.30\%p_T$ for p_T>1 GeV/c
- $\sigma(\pi^0)$ ~ 5.7%
- $\sigma(K^0_s)$ ~ 1.0%
- $\sigma(D^0)$ ~ 0.42%
- "rolling" calibrations not yet used

Belle

- σ_{hit}(CDC)=149 μm for Bhabha
- σ(dE/dx)=9% for pions, 7% Bhabha
- σ(ToF)=100 ps for di-muons
- σ_z(SVT)=45 μm for cosmic tracks above $p\sin\theta^{5/2}$=2 GeV
- σ_E/E=2% for $e^+e^- \to \gamma\gamma$
- $dp_T/p_T=0.25\%p_T + 0.39\%$
- $\sigma(\pi^0)$ ~ 4%
- $\sigma(K^0_s)$ ~ 0.9%
- $\sigma(D^0)$ ~ 0.37%

Just to fun: first Belle Hadronic Event



Hadronic criteria

Boost to CMS:

- Charged track= π
- Unmatched neutral = γ

$N_{trk}>1$

$E_{CM}^{vis}>0.20E_{CM}$

$0.02E_{CM}<E_{cal}<0.90E_{CM}$

$|\Sigma p_z|<E_{CM}/2$

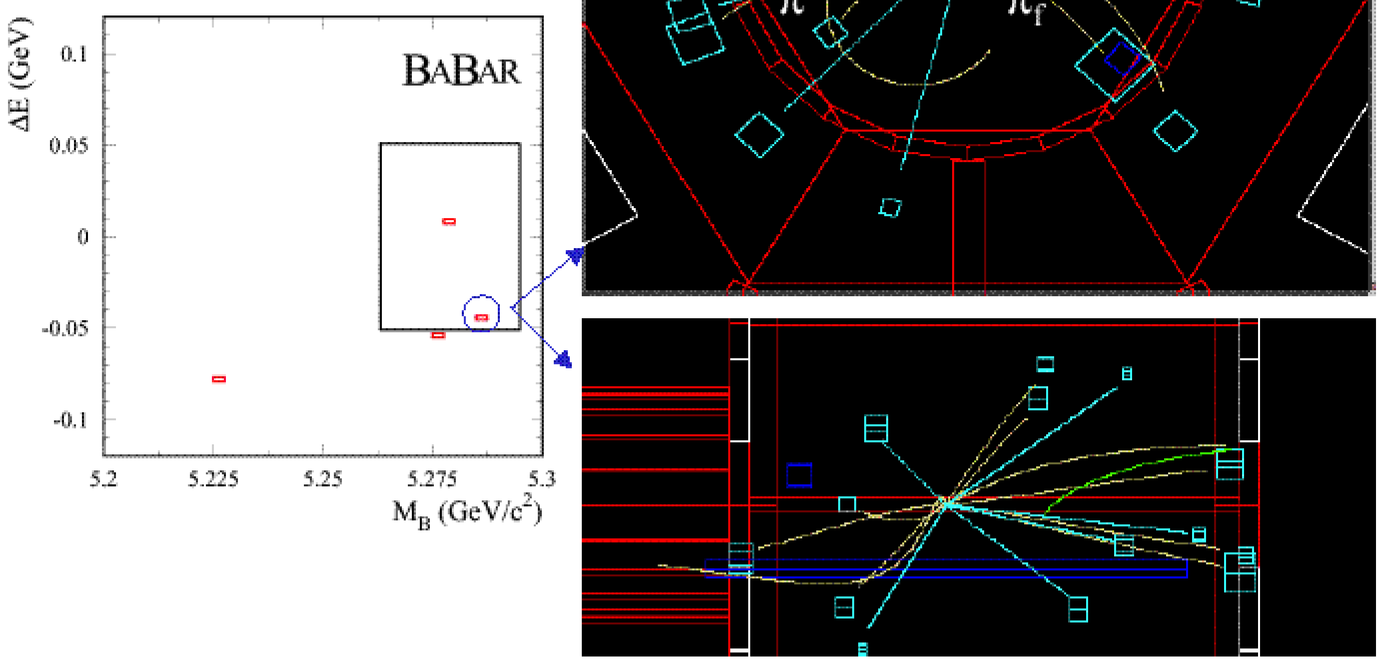
$\{N_{trk}=2:|\Sigma p|<0.90E_{CM}\}$

More fun: first fully reconstructed BaBar $B^0 \longrightarrow D^*\pi$ candidate

$B^0 \to D^{*-}\pi^+_f$

$\quad \hookrightarrow \overline{D^0}\,\pi^-_s$

$\quad\quad \hookrightarrow K^+\pi^-$



…not so fun

- Belle:
  - June - August run, harsh beam-background
    - radiation damage of innermost SVD-layer
    - innermost 3 CDC-layers had to be turned off
    - CDC occupancy very high
  - Upgrades during summer (backgrounds ➔ ~1/100):
    - HER vacuum chamber replacement
    - add new vacuum pumps and shielding near IP
    - SVD replacement
  - Since mid-October, 50% machine study/50% physics
- BaBar:
  - May - December run. Excellent machine operation, backgrounds from synchrotron X-rays and beam-gas scattering a bit high but inside operational limits
    - High DAQ occupancies. BaBar efficiency is ~90%
    - Full DIRC only since October. High LER backgrounds
    - add new shielding near IP
    - IFR: many RPC layers and 30% of electronics turned off due to cooling problems
    - 6z & 3ϕ SVT half-modules damaged
  - Y2K run, some PEP-II stability problems, but taking data
- Both: some discrepancies with Monte Carlo

Computing

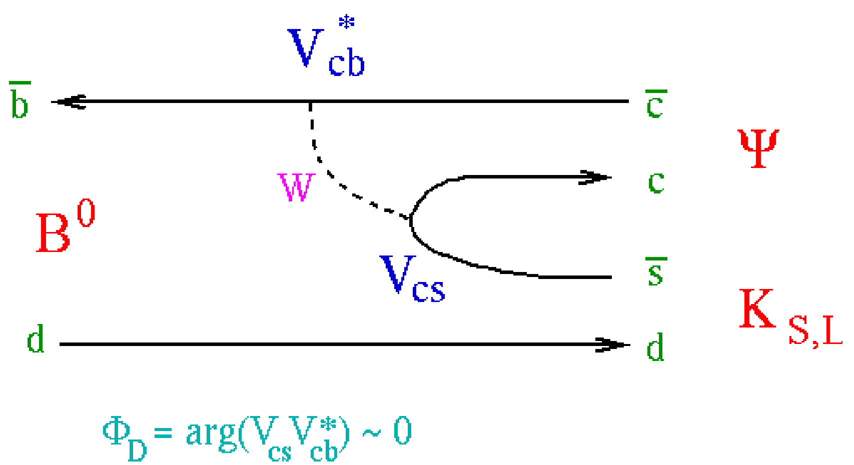
- Offline computing is also a challenge for B Factories
  - for 10 fb^{-1} (CP physics projections ~ 100 fb^{-1}):
    - e+ e- ➔ $\Upsilon(4S)$ **x 99% x 1.05 nb ~ 10 M**
    - e+ e- ➔ qqbar x 95% x 3.39 nb ~ 32 M
    - e+ e- ➔ e^+e^- x 20% x ~40 nb ~ 80 M
    - e+ e- ➔ $\mu^+\mu^-$ x 99% x 1.16 nb ~ 12 M
    - e+ e- ➔ $\tau^+\tau^-$ x 95% x 0.94 nb ~ 9 M
    - e+ e- ➔ $\gamma\gamma$ x 95% x ~1 nb ~ 10 M

~ 150 M / 10 fb^{-1}

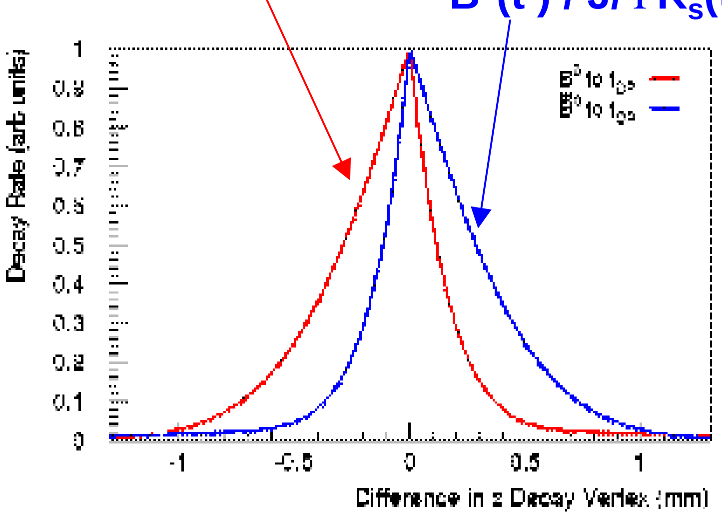
- B Factories are pushing hard for *Object Oriented* offline
- e.g. BaBar:
  - Two levels of trigger: L1 up to 2KHz, L3 up to 100 Hz. Then to tape
  - Fortran? What's Fortran? BaBar is first large HEP experiment to make OO commitment from day 1
  - being the first does not make life easy
  - 100 computer-node farm (Sun Ultra Sparc 5) -> prompt reconstruction
  - All databases, including the multi-Terabyte event store, use *Objetivity (TM).* Pushing Objetivity software harder than any previous customer
  - *"rolling"* calibrations in prompt reconstruction. E.g. SVT-DCH alignment produced for every run!
  - But analyses can also be done running over "skims" on your private desktop using *ROOT*

The CP Physics

- Too early for results
- As shown before, in process of tuning up and understanding detector performance, reconstruction code and analysis tools
- also tuning key ingredients for first CP measurement in the "gold plated" mode: $B^0 \rightarrow J/\Psi\ K^0_s$



Probes $\phi_M = \beta$



$\Delta z = \beta_z \gamma c(t-t')$

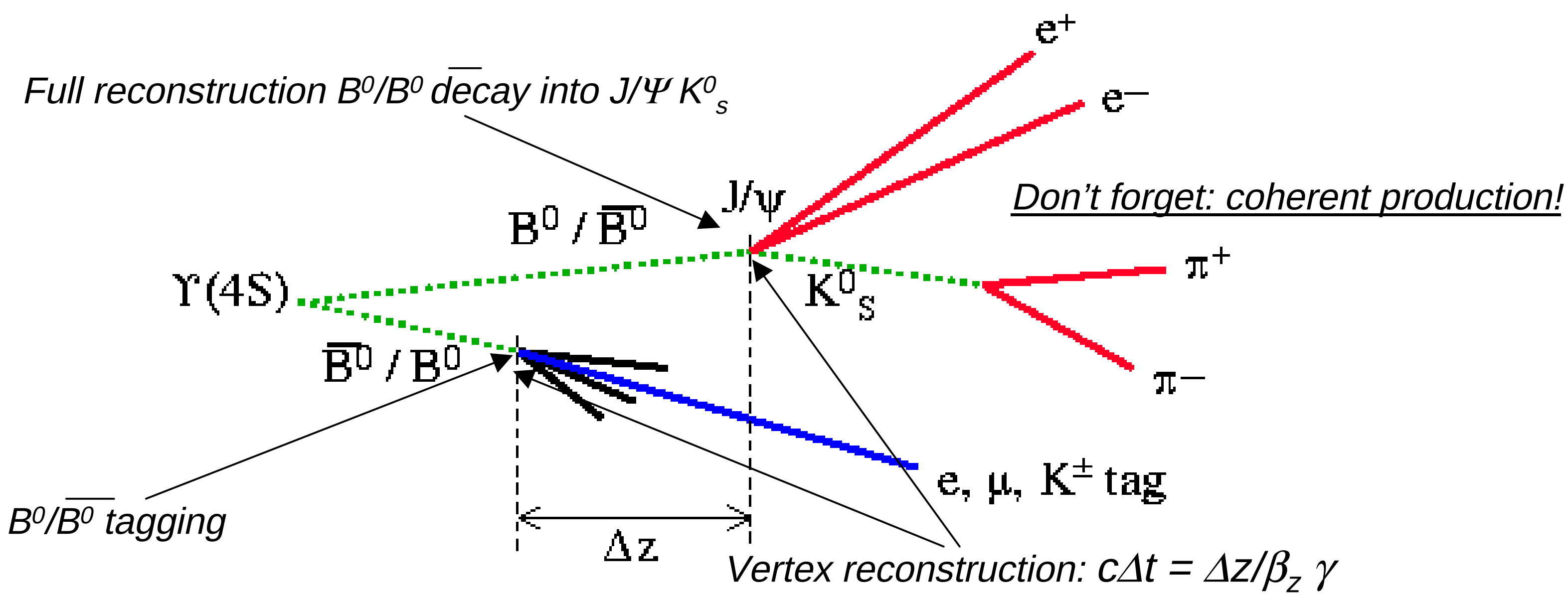
- Many experimental advantages:
  - clean signature, low background
  - low multiplicity, no neutrals: good reconstruction efficiency
  - relatively large rate

$B^0 \to J/\psi\, K^0_S$ (1/2 x 0.09%)

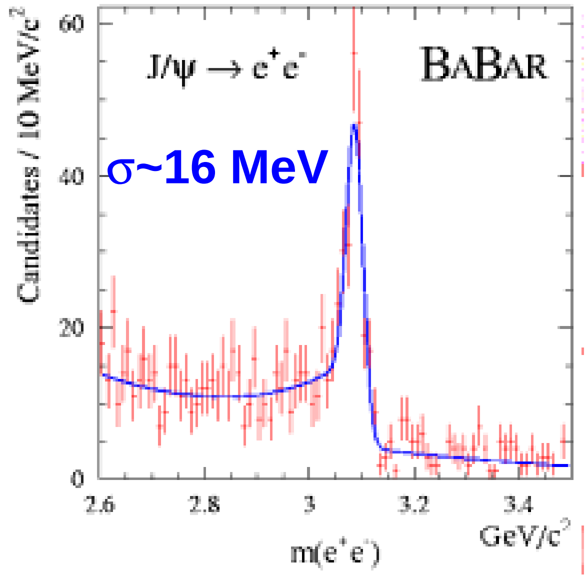
- $K^0_S \to \pi^+ \pi^-$ (69%)
- $J/\psi \to e^+ e^-$, $\mu^+ \mu^-$ (6%+6%)

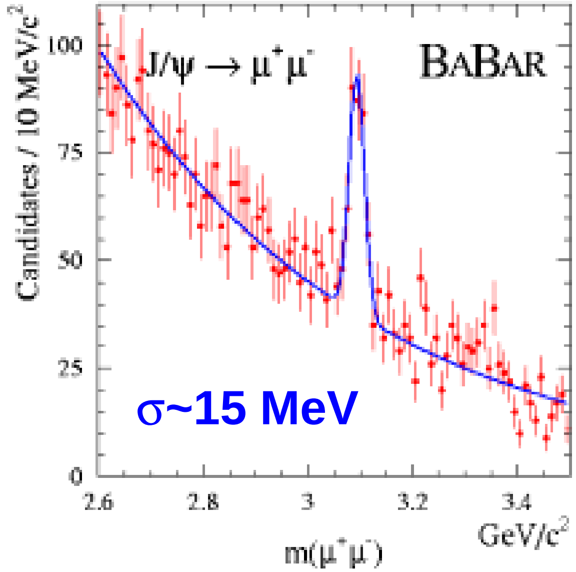
BR ≈ 3.7×10^{-5}

- The key ingredients for the measurement of sin2β:



Inclusive J/Ψ signal





e^+e^-:L~540 pb^{-1}

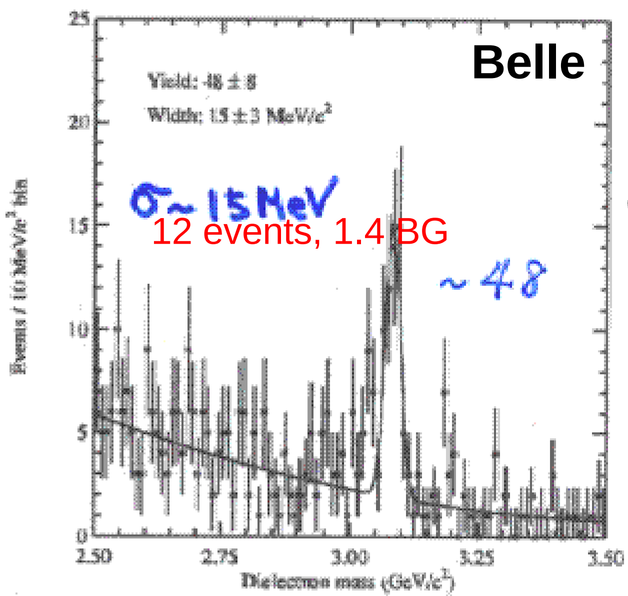
E/p

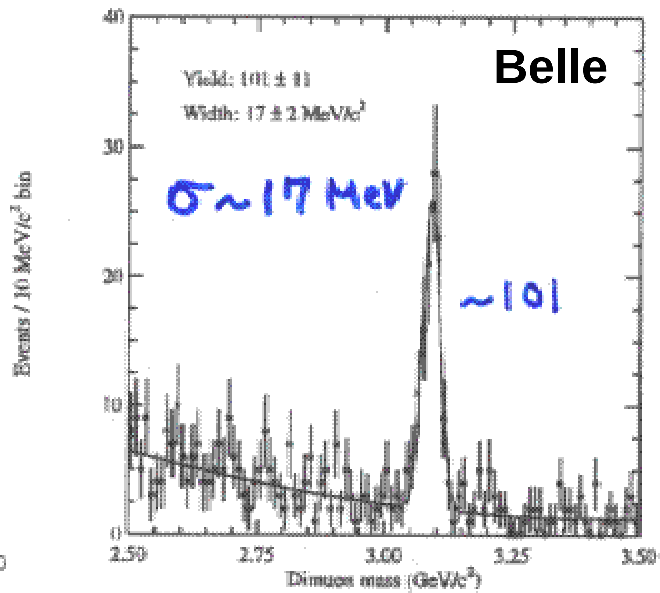
$\mu^+\mu^-$:L~380 pb^{-1}

MIP signature in calorimeter

Improvements are expected from:

- better alignment
- brem recovery
- full profit of IFR





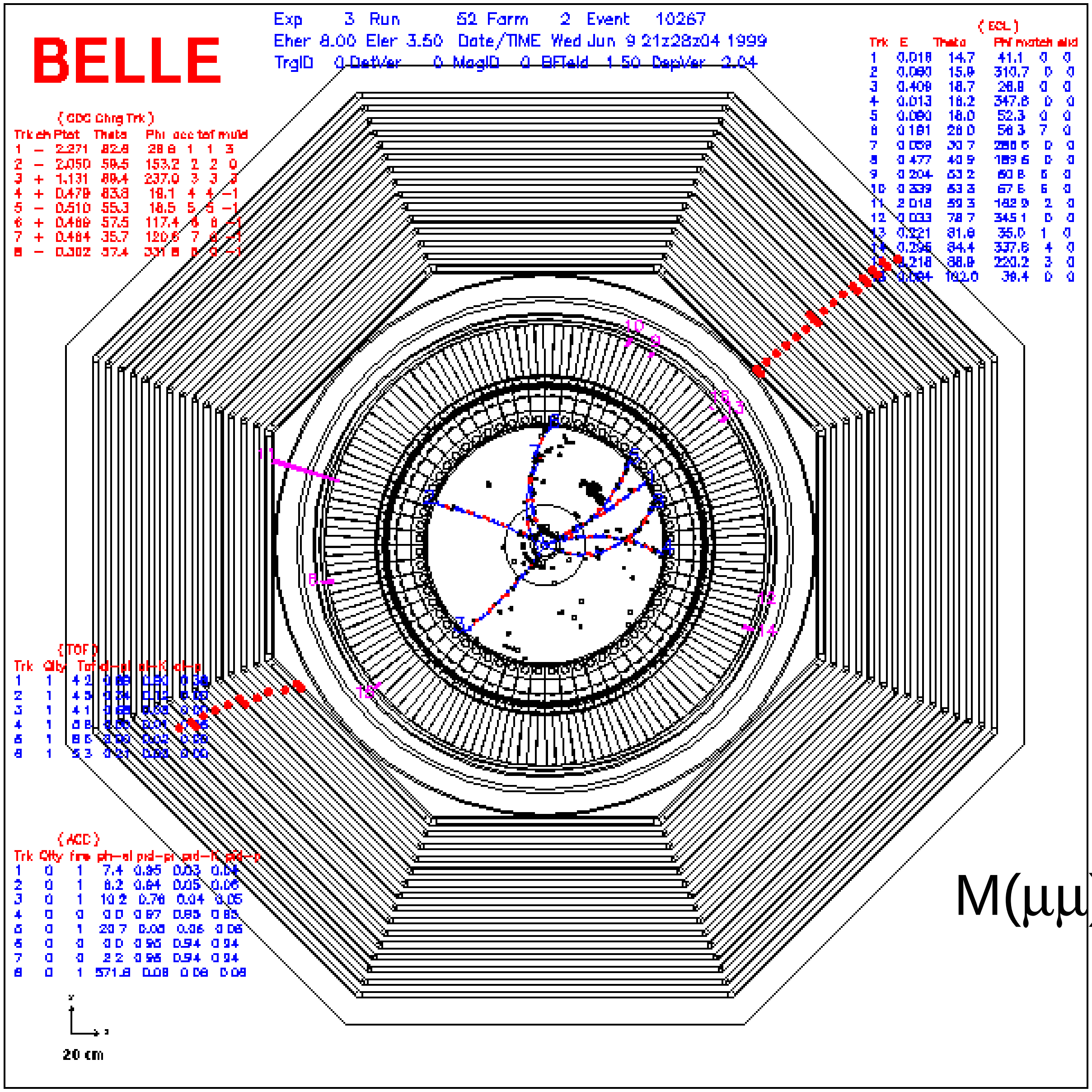
L~120 pb^{-1}

e^+e^-: E/p

$\mu^+\mu^-$: KLM

Yields in rough agreement with expectations

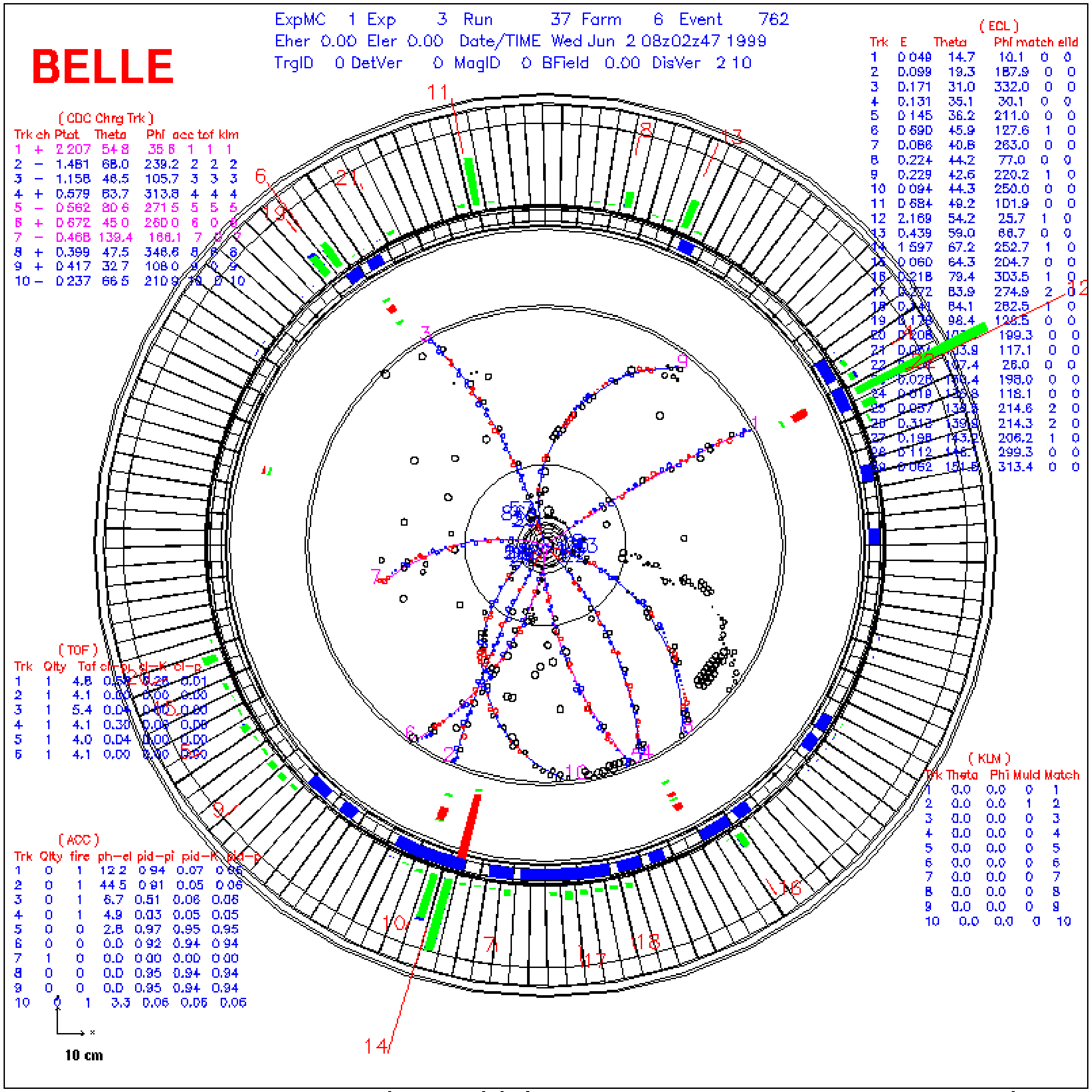
First Belle J/ψ(μμ) Candidate



$J/\psi \rightarrow \mu\mu$

$M(\mu\mu)$=3.1 GeV

First Belle J/ψ(ee) Candidate



J/ψ → ee

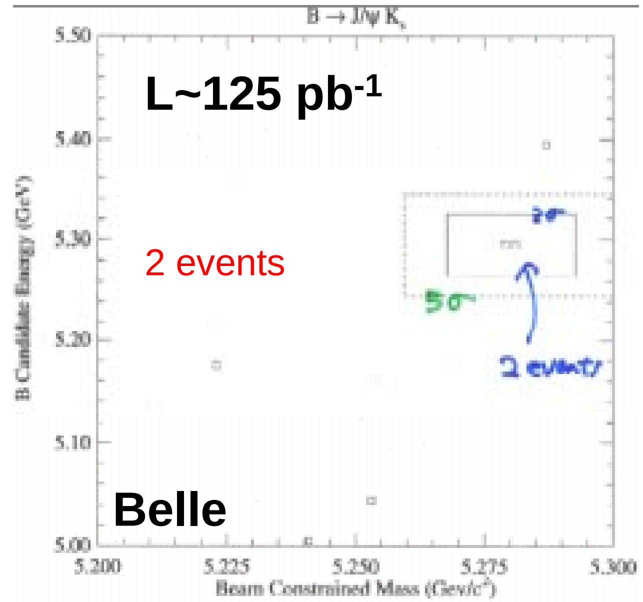
M(ee)=3.1 GeV

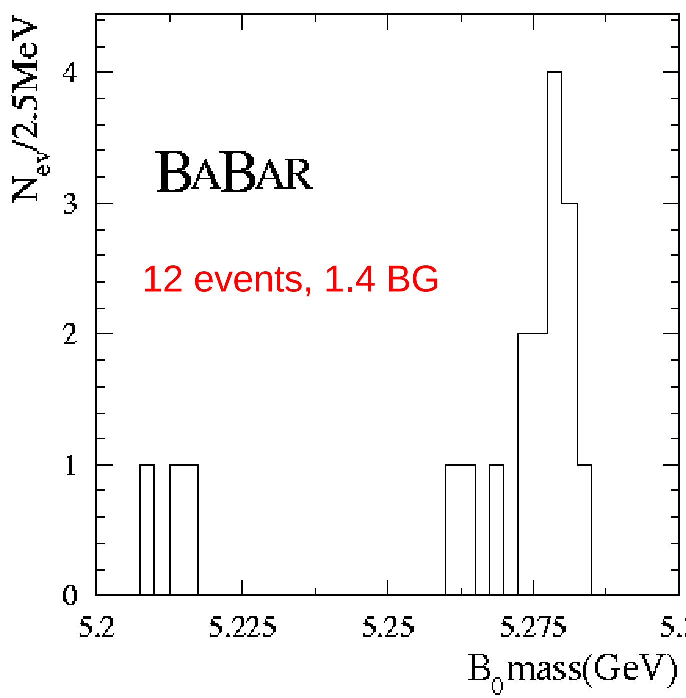
$B^0 \rightarrow J/\Psi\ K^0_s$ reconstruction

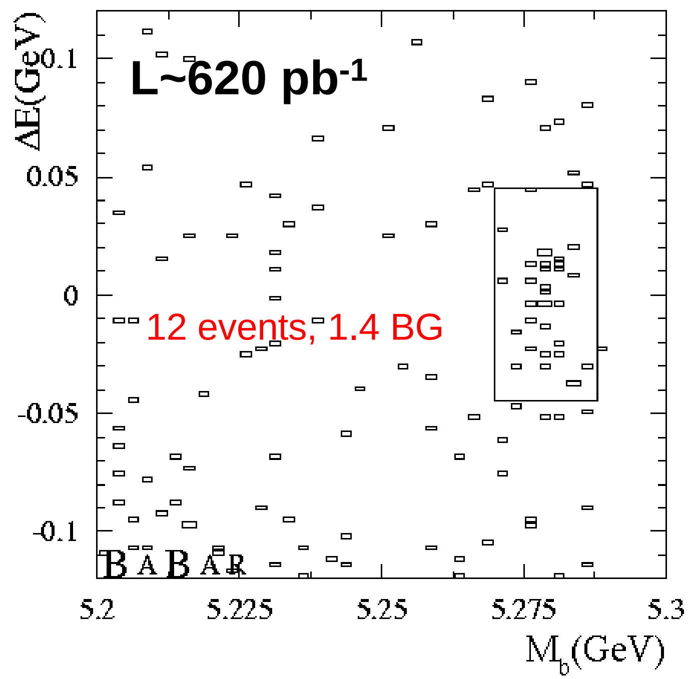
- Helicity angle $\theta(B,l)>18^o$ in J/Ψ frame
- Fit with constraints:
  - J/Ψ, K^0_s from common vertex
  - J/Ψ mass constraint
  - center-of-mass energy
- To calculate:

$\Delta E = E_B - s^{1/2}/2 \quad m_B = (E_B^2 - p_B^2)^{1/2}$

Yields in rough agreement with expectations



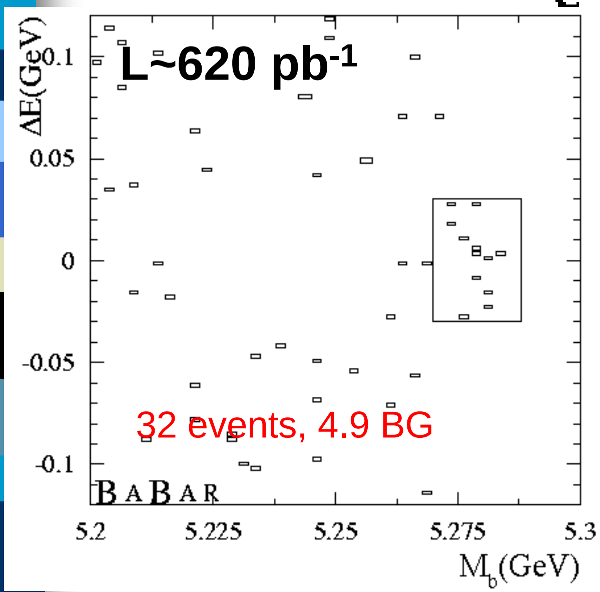




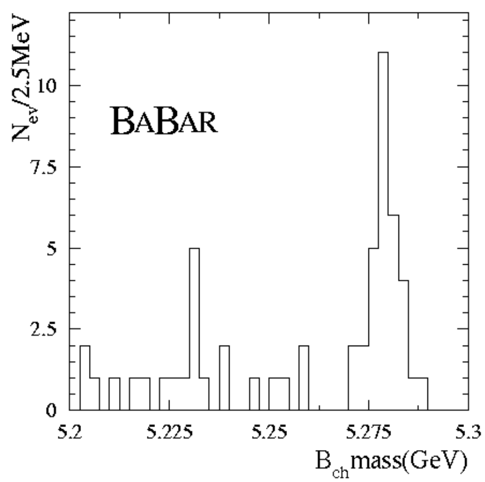
- $B^+ \rightarrow J/\Psi\ K^+$ reconstruction
  - Charged B equivalent of $B^0 \rightarrow J/\Psi\ K^0_s$
  - Control sample for developing *sin2β* analysis

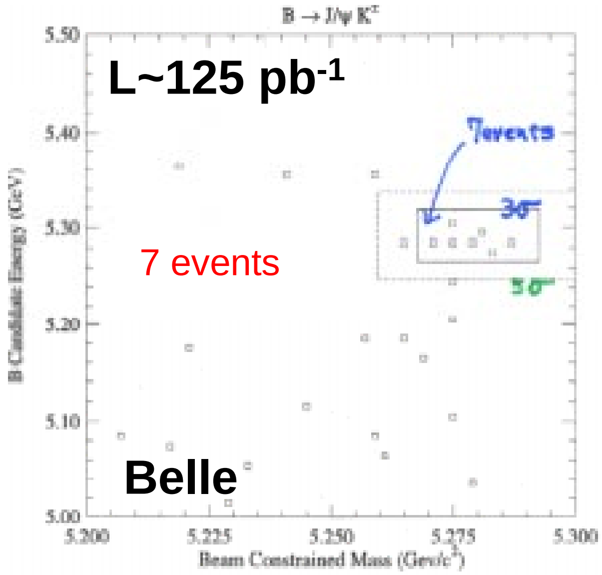
$$B^+ \rightarrow J/\psi\ K^+ \quad (0.1\%)$$
$$\hookrightarrow e^+ e^-,\ \mu^+ \mu^- \quad (6\% + 6\%)$$

$BR \approx 1.2 \times 10^{-4}$



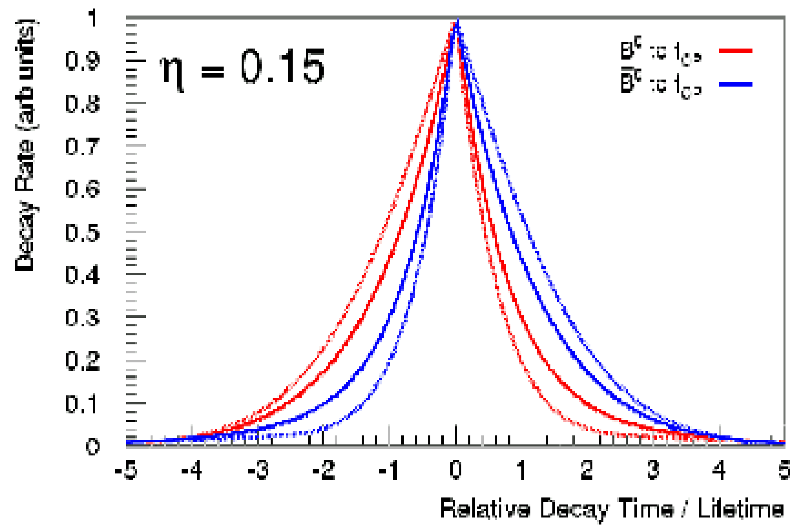
Yields in rough agreement with expectations





- Flavor tagging
  - Tagging exploits the correlation between the flavor of a B and the charge of its decay products (e, μ, K^{+-})
  - Multivariate methods suitable whenever possible
  - Tagging methods:
    - have some inefficiency ε
    - false rate η (due to reconstruction mistakes or physics events)
  - The measured CP asymmetry is diluted by incorrectly tagged decays. Miss-tagging limits the statistical precision of *sin2β*

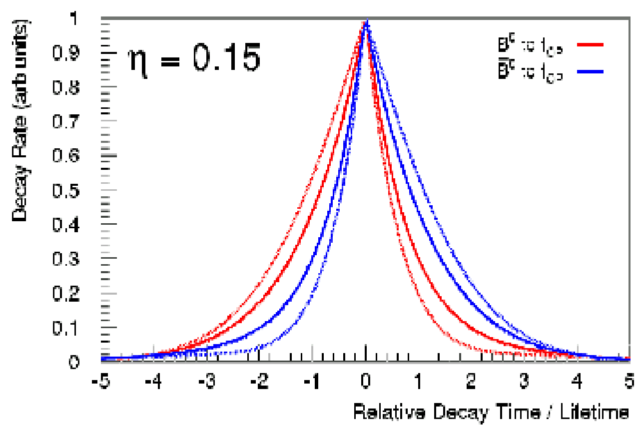
$$1/\sigma^2_{stat} \approx \varepsilon(1-2\eta)^2 N_{rec}/3$$



  - B mixing provides a calibration signal for measuring the miss-tag rate η from data

Mixing as miss-tag rate calibration

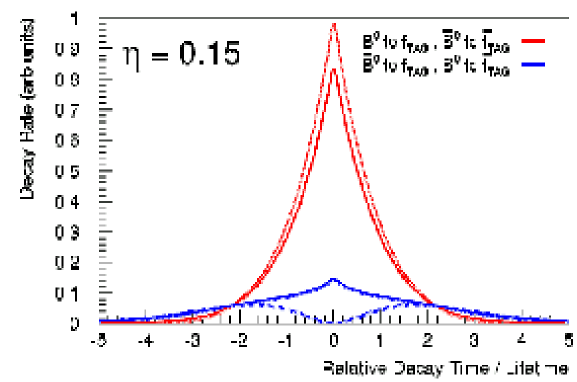
- <u>CP asymmetry</u>
- fully reconstructed f_{CP}
- use remaining tracks to tag flavor of f_{CP} parent
- measure $B^0 \to f_{CP}$ and $\bar{B}^0 \to f_{CP}$ rates vs Δt



- **assume $\eta_{CP} \sim \eta_{MIX}$**
- fit asymmetry to

$(1-2\eta_{CP})\sin 2\beta \sin(\Delta m \Delta t)$

- <u>Mixing asymmetry</u>
- fully reconstructed f_{TAG} or $\bar{f}_{TAG}$
- use remaining tracks to tag flavor of f_{TAG} or $\bar{f}_{TAG}$ parent
- measure $B^0 \to f_{TAG} + \bar{B}^0 \to \bar{f}_{TAG}$ and $B^0 \to f_{CP}$ + $B^0 \to f_{CP}$ rates vs Δt



- fit asymmetry to

$(1-2\eta_{MIX})\cos(\Delta m \Delta t)$

Effective only if the error on η_{MIX} is not a dominant syst error

<u>Challenge</u>: understand f_{TAG} reconstruction syst which can lead to incorrect tags

Example of flavor specific B^0 reconstruction

Aim for $N(f_{TAG}) > 3N(f_{CP})$

$B^0 \rightarrow D^{*-} l^+ \nu_e$ (4.6% + 4.6%)

  ↳ $D^0 \pi^+$ (68%)

    ↳ $K^- \pi^+$ (4%)

$BR \approx 0.25\%$

$B^0 \rightarrow D^{*-} \pi^+$ (0.28%)

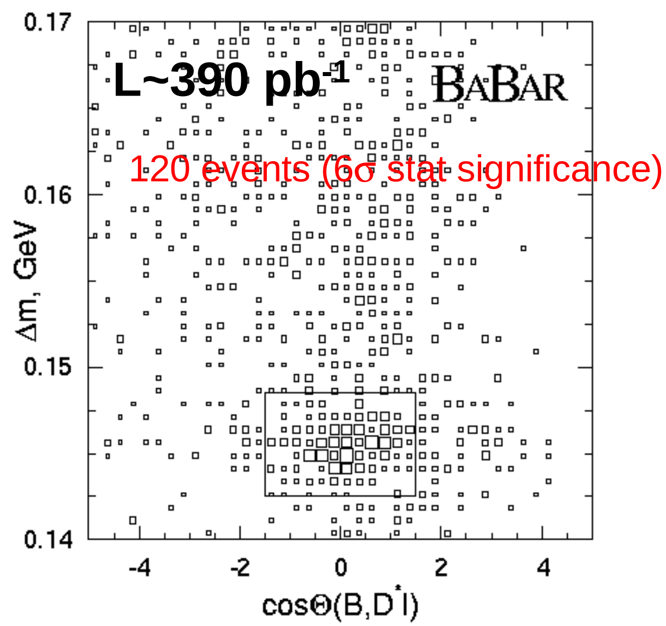
  ↳ $D^0 \pi^+$ (68%)

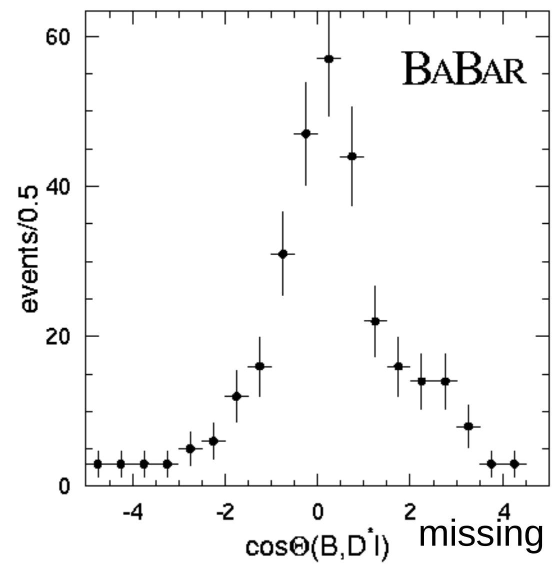
    ↳ $K^- \pi^+$ (4%)

    $K^- \pi^+ \pi^+ \pi^-$ (8%)

$BR \approx 2 \times 10^{-4}$

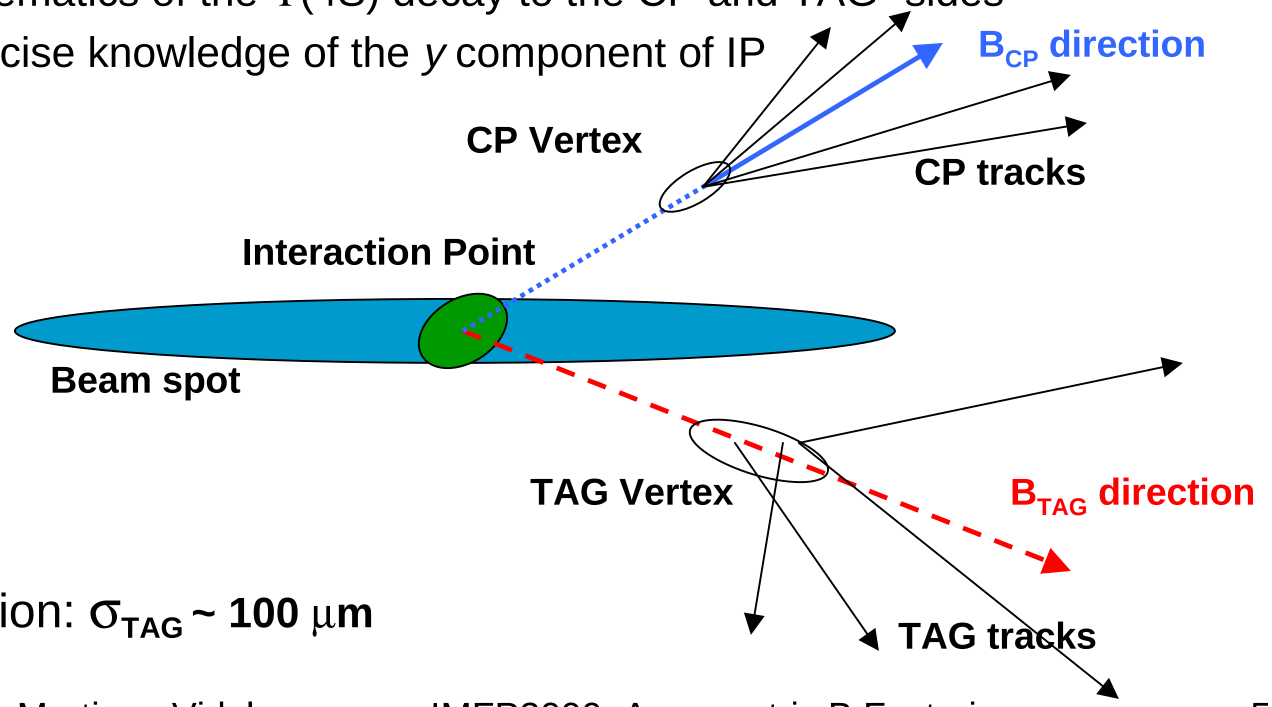
Identify electrons :
- using E(cal)/p(trk)
- p(CM)>1 GeV





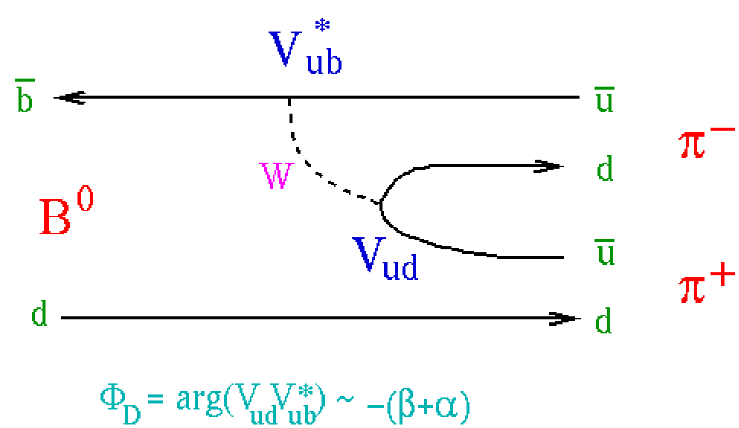
missing mass

- Tag vertex reconstruction
  - Finding the position of the CP vertex is fairly straightforward: σ_{CP} **~ 40 μm**
  - All non-CP tracks in the event come from the other B (absence of fragmentation products!)
  - More difficult than CP side vertex
    - contamination from secondary charm decays
  - But stringent constraints can be applied:
    - kinematics of the Υ(4S) decay to the CP and TAG "sides"
    - precise knowledge of the *y* component of IP



  - resolution: σ_{TAG} **~ 100 μm**

- B Factories will measure CP violation in many other channels (longer term)
- Other interesting channels for ***sin2β*** which "double" the CP sensitivity compared with $B^0 \rightarrow J/\Psi K^0_s$:
  - color suppressed modes:
    - $B^0 \rightarrow J/\Psi K_S^0$, $K_S^0 \rightarrow \pi^0 \pi^0$; $B^0 \rightarrow J/\Psi K_L^0$; $B^0 \rightarrow J/\Psi K^{*0}$
    - $B^0 \rightarrow \Psi' K_L^0$; $B^0 \rightarrow \chi_{c1} K_L^0$
  - Cabibbo suppressed modes:
    - $B^0 \rightarrow D \bar{D}$; $B^0 \rightarrow D^* \bar{D}^*$; $B^0 \rightarrow D^* \bar{D}$; $B^0 \rightarrow \bar{D}^* D$
  - penguin modes:
    - $B^0 \rightarrow \eta' K_S^0$; $B^0 \rightarrow \phi K_{S,L}^0$?
- And the measurement of α in the "tin plated" mode: $B^0 \rightarrow \pi^- \pi^+$
  - Probes $\phi_M + \phi_D = \beta - (\alpha+\beta) = -\alpha$
  - Complicated by "penguin pollution", but still promising
  - requires K/π separation. Difficult!



- And what about γ?

  That's another history...

Summary and Prospects

- More than 30 years after discovery of CP violation, we still do not know its origin
- The Standard Model includes CP violation, but it cannot account for the observed excess of matter over anti-matter
- …but the Era of *B Factories* has arrived!
- After almost a decade of preparations, two dedicated experiments, PEP-II+BaBar and KEK-B+Belle, are taking data to measure the CP asymmetries in neutral B mesons to test the consistency of the SM and search for evidence of New Physics
- Machine backgrounds a bit high, but still learning and making progress in reducing them
- Steady increase of luminosity to design value:
  - PEP-II is delivering luminosity in the 10^{33} cm^{-2} s^{-1} region (a factor 1/2 below design)
  - KEK-B is in the 10^{32} cm^{-2} s^{-1} region, but rapid progress during the last few months (a factor ~1/10 below design)

- Both detectors are now complete and they are performing well:
  - BaBar has accumulated ~2 fb^{-1} since during his first run (May-Dec'99)
  - Belle has on tape ~0.3fb^{-1} from his June-Dec'99 run
- Reconstruction/analysis codes are in good shape
- Physics analysis are on the way with the first data
- Both experiments can achieve their schedules. The decisive factors in doing the physics will probably be:
  - maintaining high operational efficiency (>=50% machine+detector overall efficiency)
  - reaching design luminosity
  - handling relatively high levels of accelerator backgrounds
- Projections for both experiments is to accumulate ~3 10^7 B^0/year
- Short term goal is to accumulate ~10 fb-1/experiment by the time the current run ends next summer

- Expect first physics results from tuning and validation studies by next summer
- Expect to perform first measurement of *sin(2β)* from 10 fb^{-1} of reconstructed and tagged $B^0 \rightarrow J/\Psi\, K^0_s$ decays
- MC studies predict an error on *sin(2β)*~0.7 of about 0.3 for this measurement
- With ~10 fb-1, we should be able to measure the miss-tag fraction η with an error of ~10%
- This talk has been devoted to CP asymmetries in asymmetric B Factories, but many other physics can be done:
  - B oscillations and B lifetimes
  - overall CKM contributions
  - Direct CP Violation
  - Charm Physics, τ Physics, $\gamma\gamma$ Physics
  - ...

- BaBar+Belle are just ready for lots and lots of more data!
- The good news: in this moment,

combined machine & detectors overall efficiencies >=50%

- This year promises to be an exciting one for CP Physics!

Stay tuned!