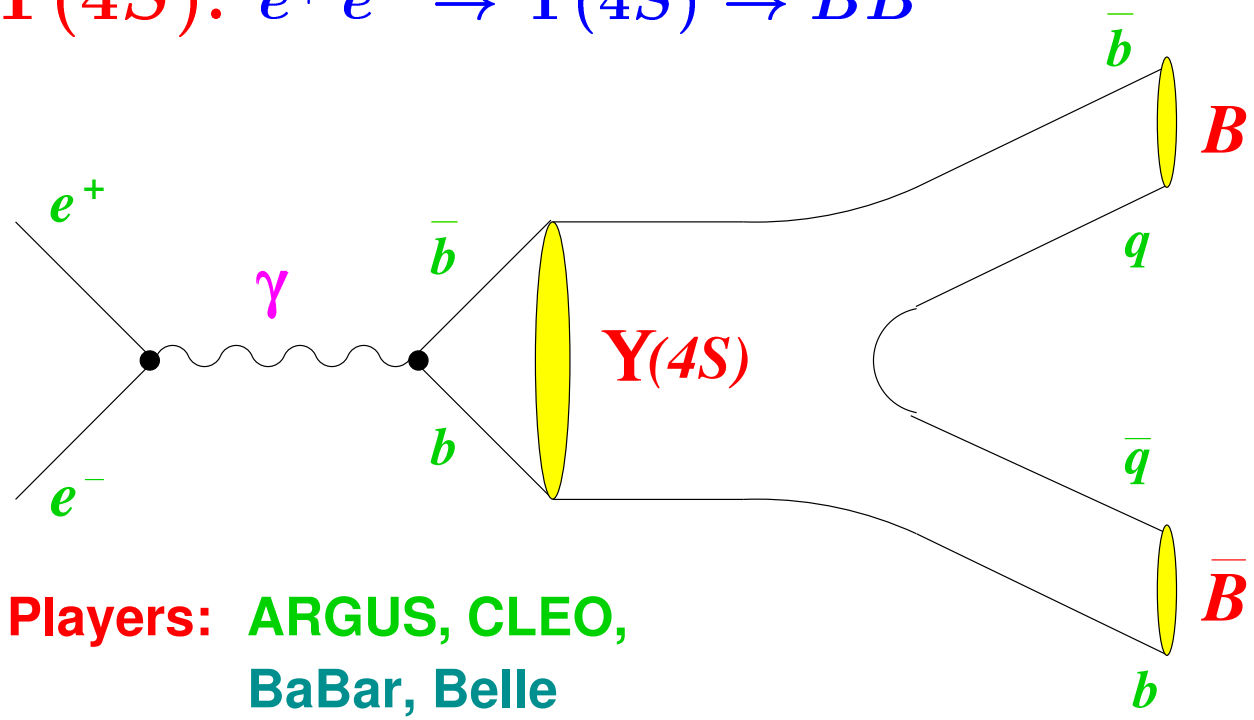
Experimental Environment

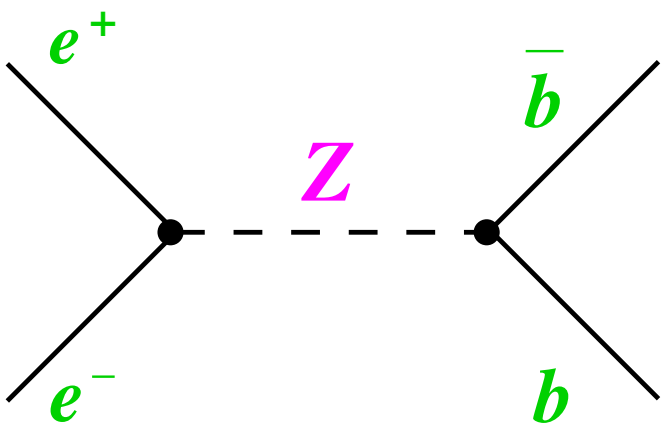
Overview of B Hadron Producers:

$\Upsilon(4S)$: $e^+ e^- \to \Upsilon(4S) \to B\bar{B}$



Players: ARGUS, CLEO, BaBar, Belle

Z^0: $e^+ e^- \to Z^0 \to b\bar{b}$

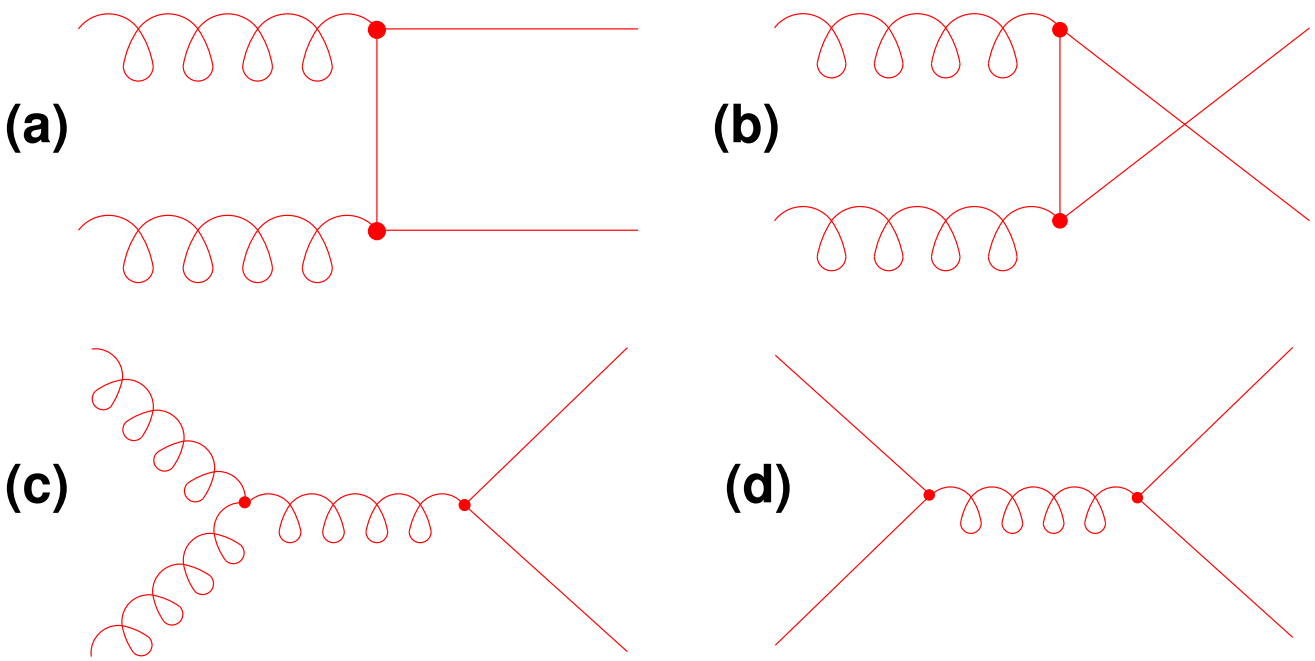


Players: ALEPH, DELPHI, L3, OPAL SLD

B Hadron Producers

Tevatron: $p\bar{p} \to b\bar{b}X$

- Lowest order $\mathcal{O}(\alpha_s^2)$ diagrams for $b\bar{b}$ production
  - (a)-(c) gluon-gluon fusion
  - (d) quark-antiquark annihilation



Players: CDF, D0

Other B producers: Hera-B, NuSea, FNAL fixed target

Future: Atlas, CMS, LHC-b, BTeV

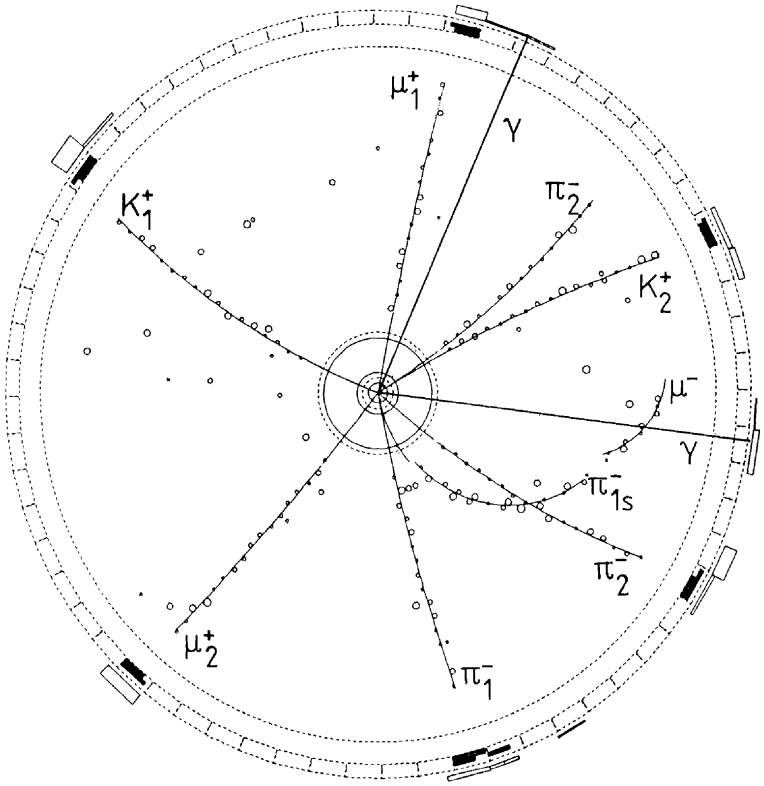
B Hadron Producers

Compare different colliders:

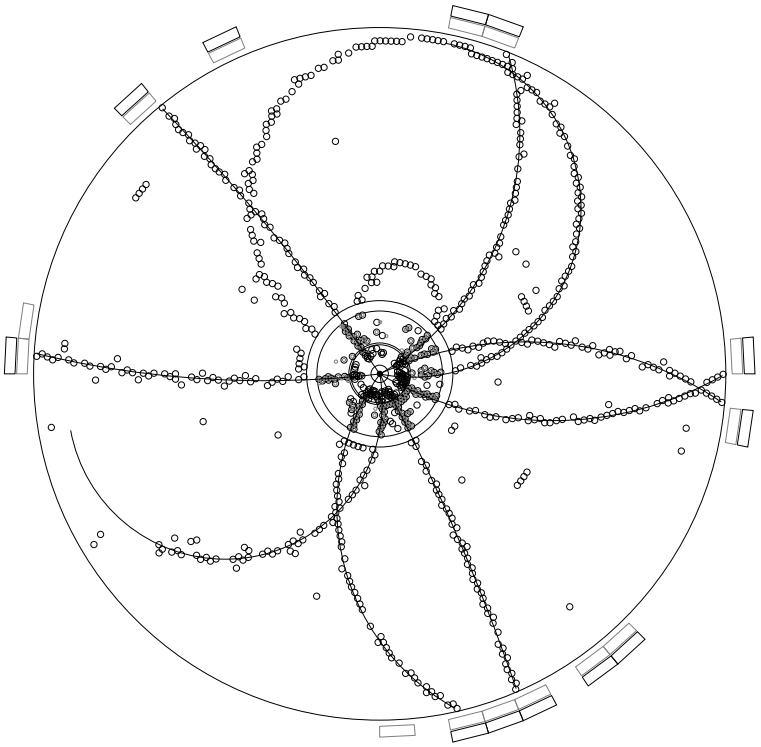
Luminosity	LEP	Tevatron	CESR	PEP II
First physics	e^+e^- 1989	$p\bar{p}$ 1987	e^+e^- 1979	e^+e^- 1999
Beam energy [GeV]	46 at Z^0	900	5.3	9.0×3.1
Luminosity $[10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	24 at Z^0	210	470	3000
Time between collisions	22 μs	396 ns	28 ns	4.2 ns
Partic./bunch $[10^{10}]$	30	p : 27 $\bar{p}$: 7.5	15	e^- : 2.7 e^+ : 5.9
Bunches/ring	4	36	9×2	1658
Bunch length [cm]	1.0	38	1.8	e^- : 1.1 e^+ : 1.0
Lumi lifetime	20 h	7-30 h	3-4 h	2 h
Filling time [min]	40	30	10	3
Interaction regions	4	2	1	1
Circumference [km]	26.7	6.28	0.77	1.46

Typical B Events at the Y(4S)

ARGUS:

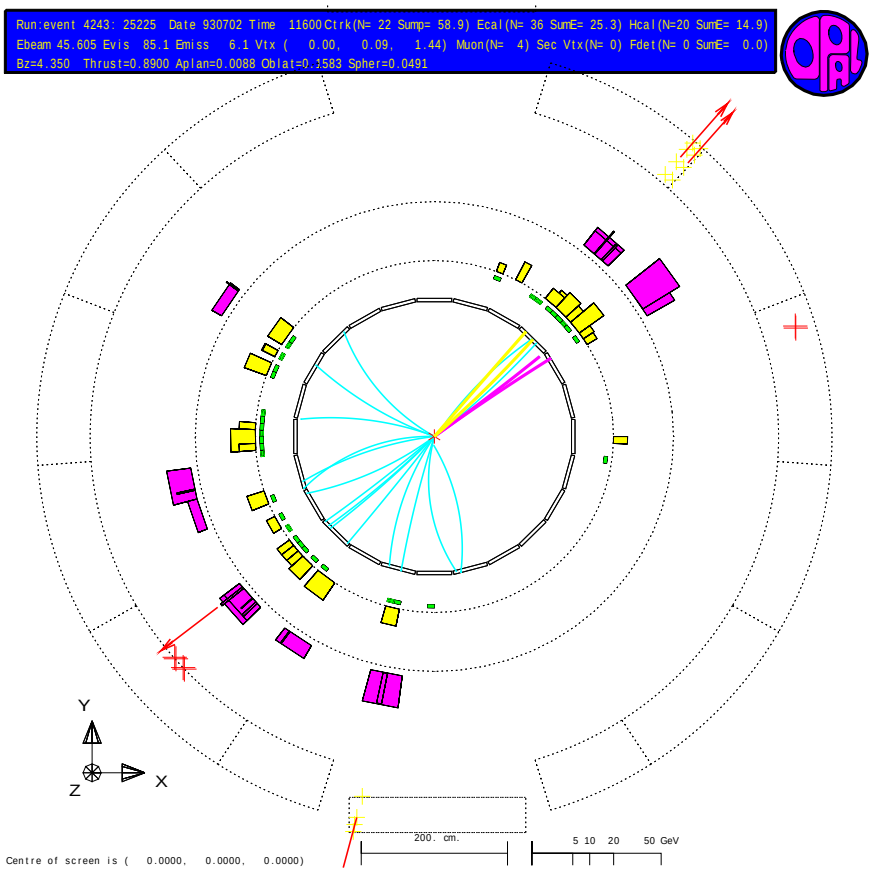


CLEO:

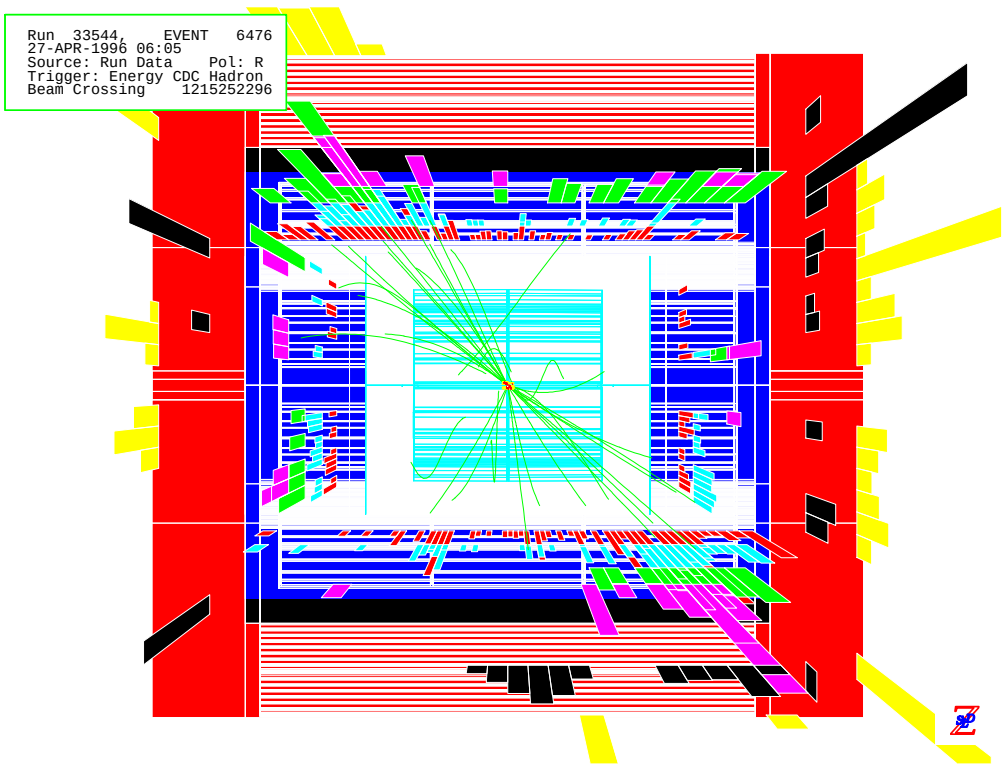


Typical B Events at the Z Pole

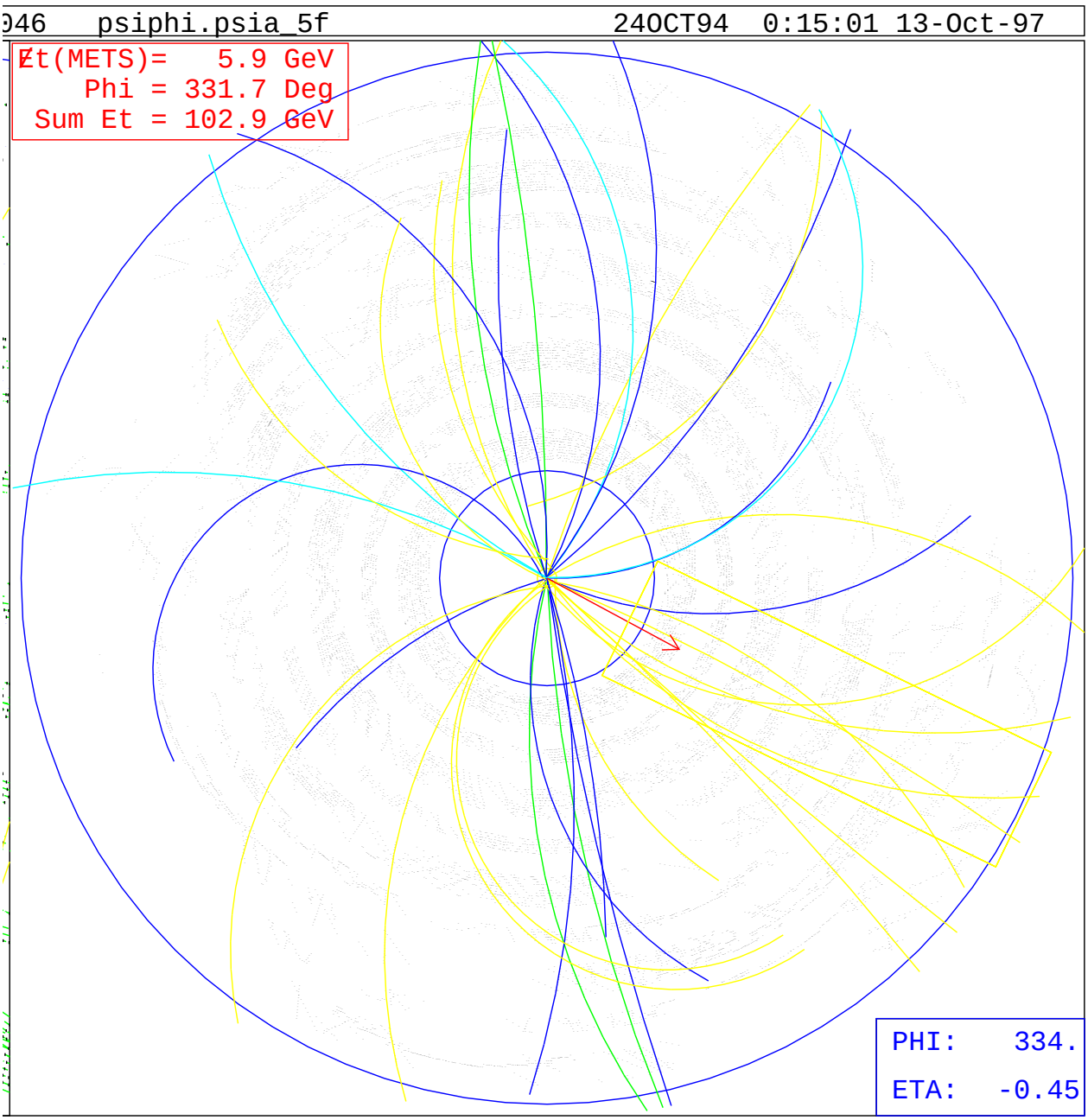
OPAL:



SLD:



Typical B Event at CDF



B Hadron Producers

Compare different colliders:

	$\Upsilon(4S)$	LEP (Z)	TeV ($p\bar{p}$)
$\sigma(b)$	≈ 1 nb	≈ 6 nb	≈ 50 μ b
$\sigma(b) : \sigma(\text{bg})$	1:3	1:4	1:1000
Production characteristics	at rest	back-to-back both b's in acceptance	not back-to-back in θ large η separation
Boost $< \gamma >$	1	6	2.5-3.5 trigger dependent B's produced just above threshold
Fragmentation	clean	clean 2 b's 1 colour string	messy proton remnants
B^0, B^+	yes	yes	yes
B_S^0, B_c, Λ_b	no	yes	yes
Underlying event	none	none	yes
Multiple events	no	no	yes
Trigger	inclusive	inclusive	lepton & hadron

Features of B Physics

Elements for successful B physics:

1. High rate B production

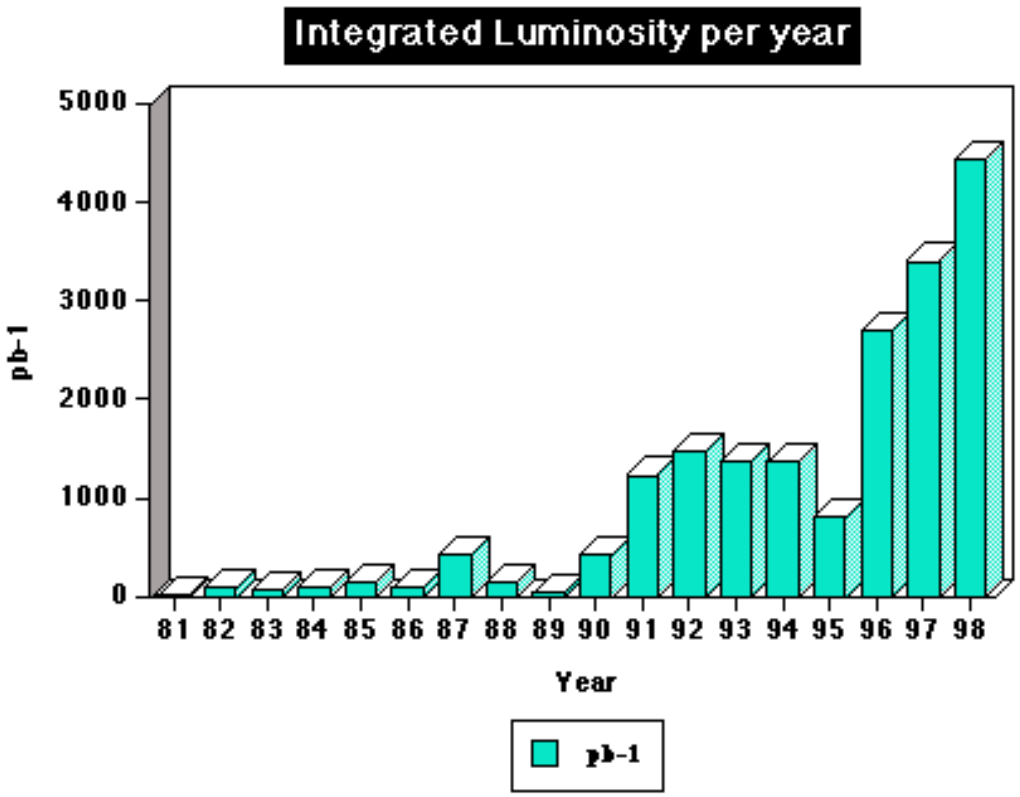
LEP:
$\sim 0.9 \cdot 10^6$ $b\bar{b}$ events per experiment (1991-1995)

CLEO:
$\sim 9.3 \cdot 10^6$ $B\bar{B}$ events (9.3 fb^{-1} / 1993-1999)

CDF:
$\sim 5 \cdot 10^9$ $b\bar{b}X$ events produced (100 pb^{-1} / 1992-1995)

BaBar:
$\sim 10 \cdot 10^6$ $B\bar{B}$ events (10/30 fb^{-1} in 9/12 months)

CESR :

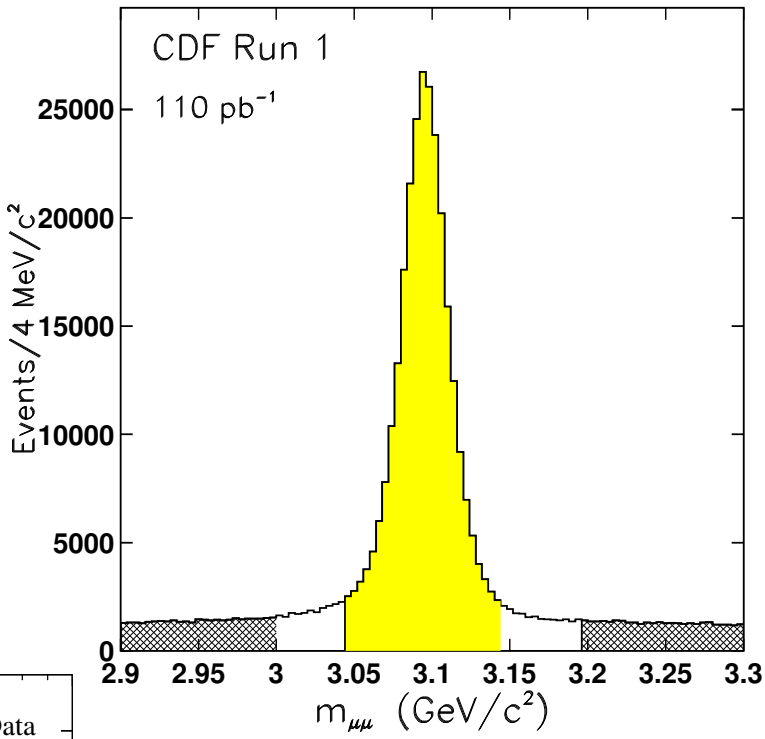


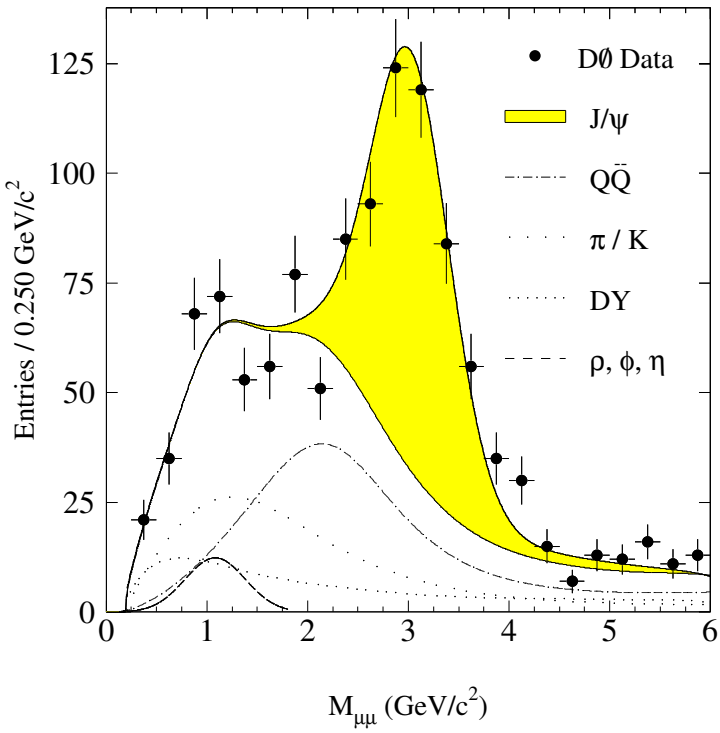
Features of B Physics

2. Excellent tracking with tracking chambers

Excellent momentum resolution translates into excellent invariant mass resolution

CDF: dimuon mass resolution ~ 16 MeV





D0: no tracking chamber muon momentum from muon chambers

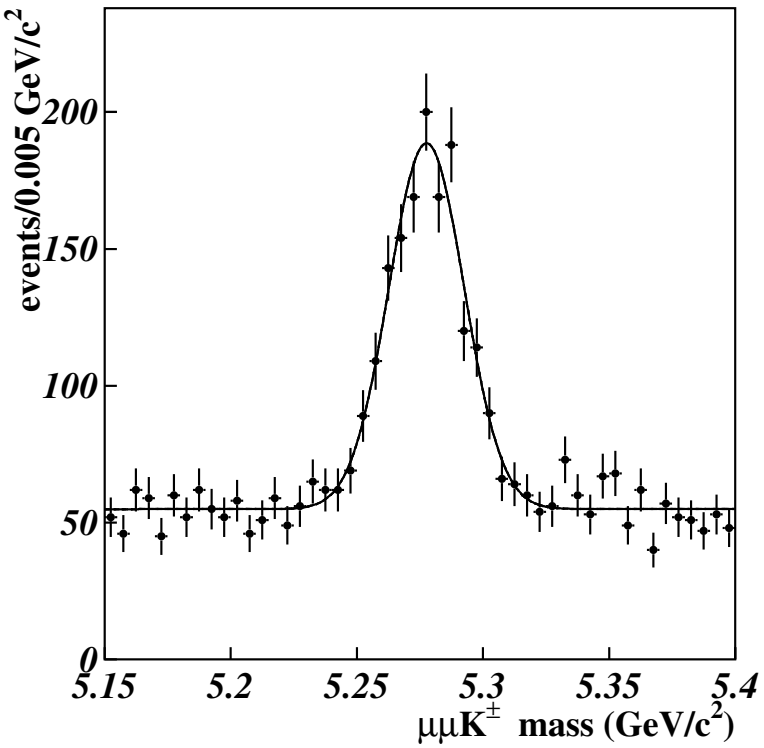
Features of B Physics

2. Excellent tracking with tracking chambers

Reconstruction of B mesons:

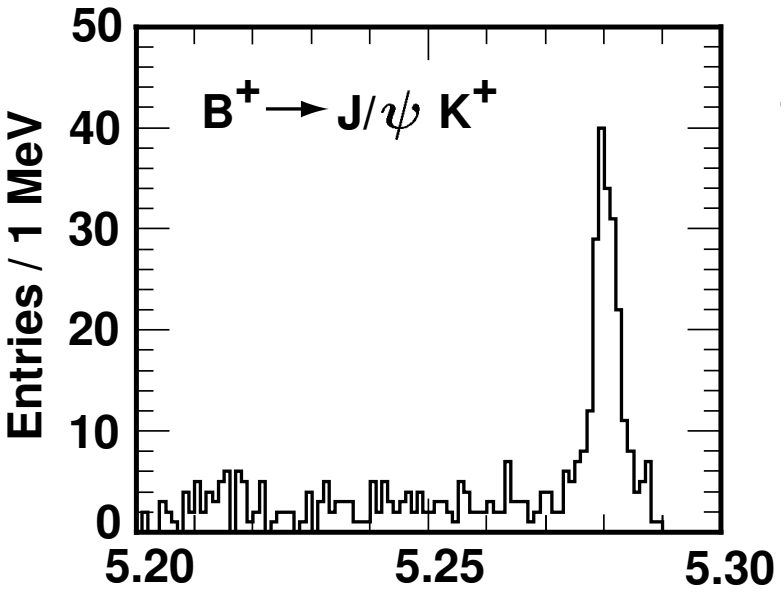
CDF: $B^+ \to J/\psi K^+$

- Typical B mass resolution:
  $\sim 20 - 30$ MeV$/c^2$
- $\mathcal{L} = 110$ pb^{-1}
  $\mathrm{N}(B^+) = 998 \pm 51$



CLEO: $B^+ \to J/\psi K^+$

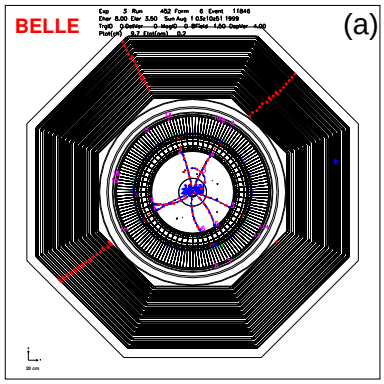
- Beam constraint
  $m_B = \sqrt{E^2_{\mathrm{beam}} - p^2_B}$
- Typical B mass resolution:
  $\sim 2 - 3$ MeV$/c^2$
- $\mathcal{L} = 3100$ pb^{-1}
  $\mathrm{N}(B^+) = 198 \pm 15$

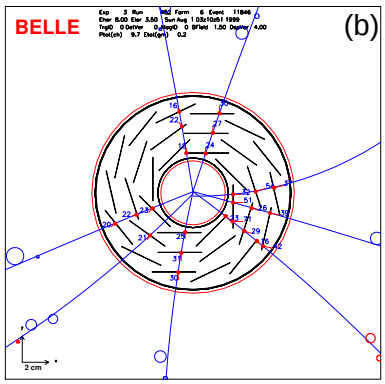


Features of B Physics

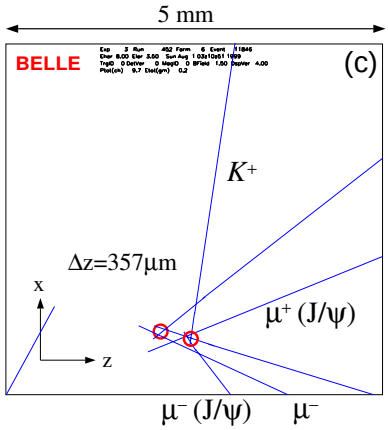
3. Superb vertexing with silicon vertex detector

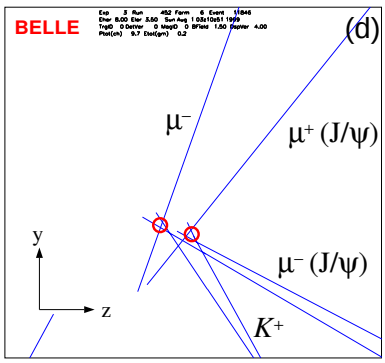
Exploit "long" lifetime of B hadrons





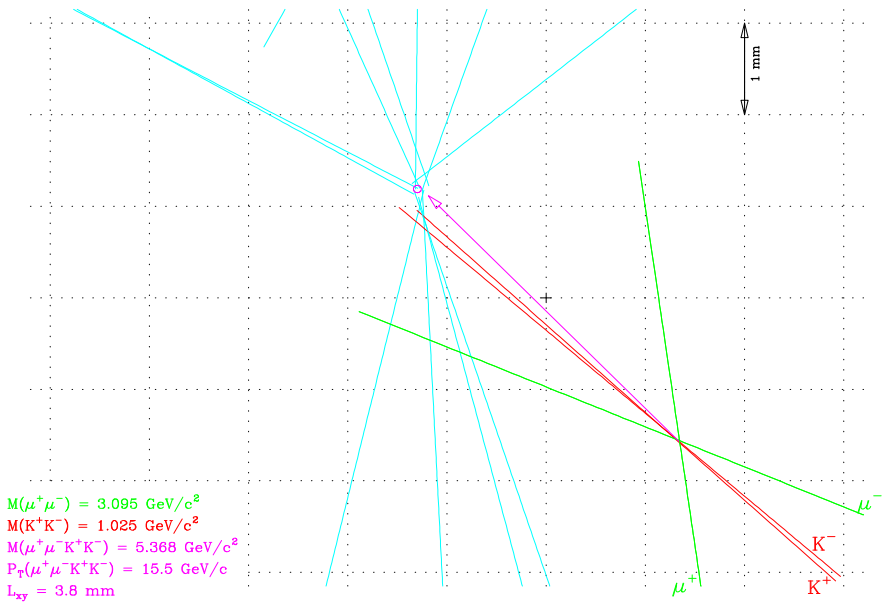
BELLE





Example of $B_s \to J/\Psi\ \phi \to \mu^+\mu^-\ K^+\ K^-$

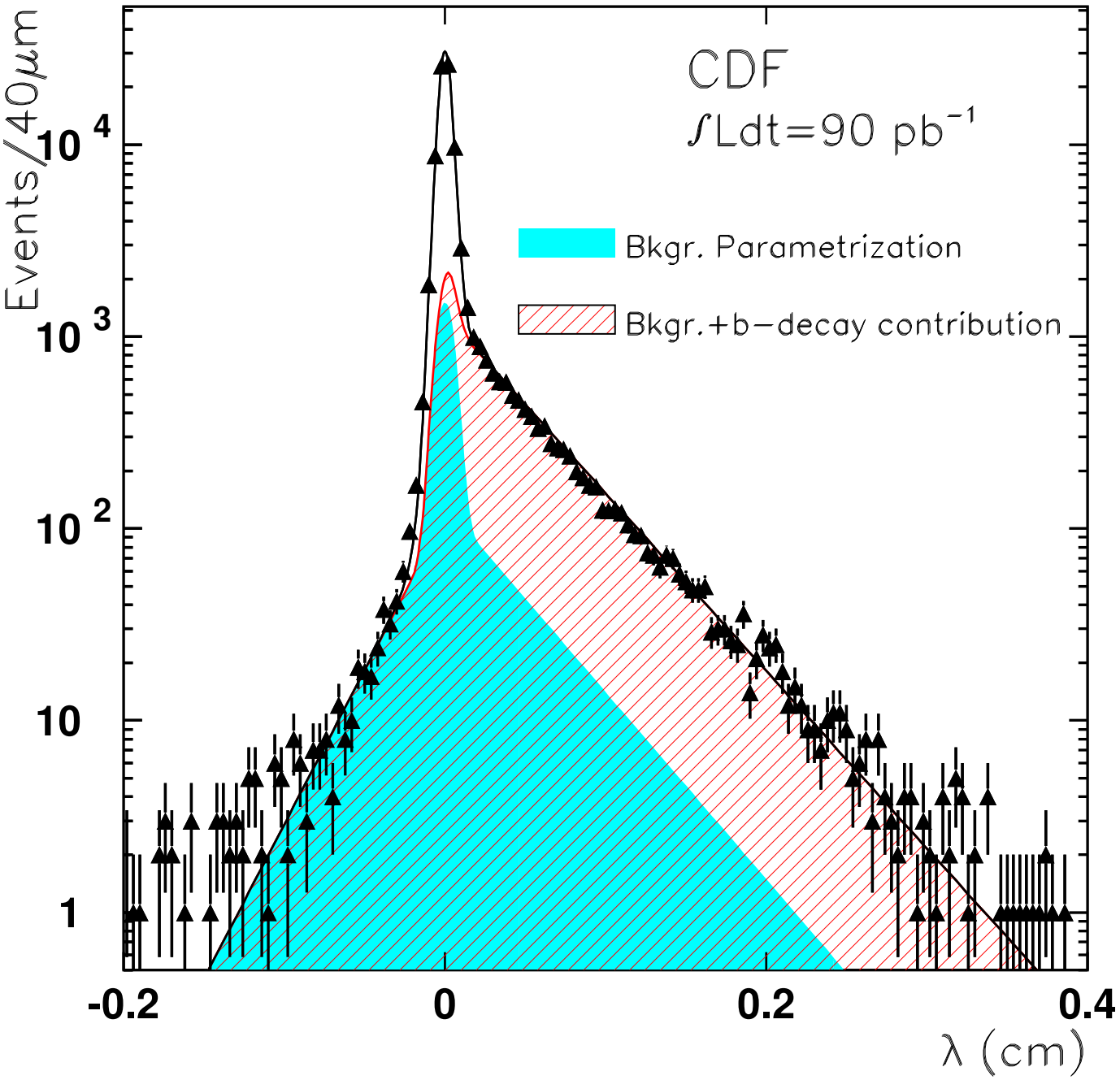
CDF



Features of B Physics

3. Superb vertexing with silicon vertex detector

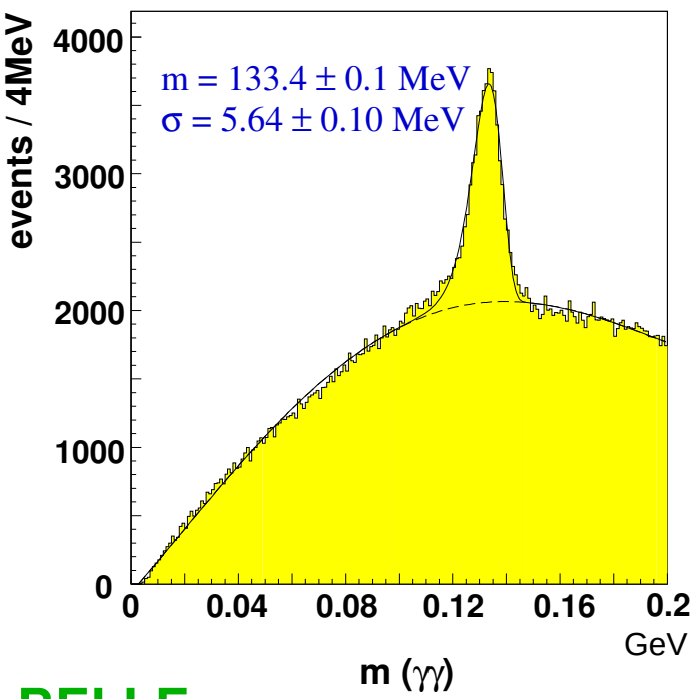
CDF: Decay length of J/Ψ

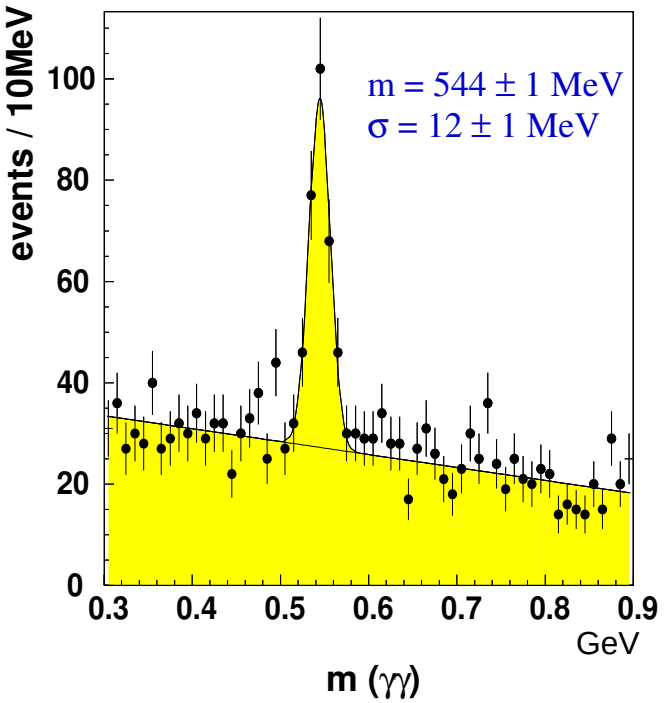


Features of B Physics

4. Good calorimeter to detect low energy neutrals

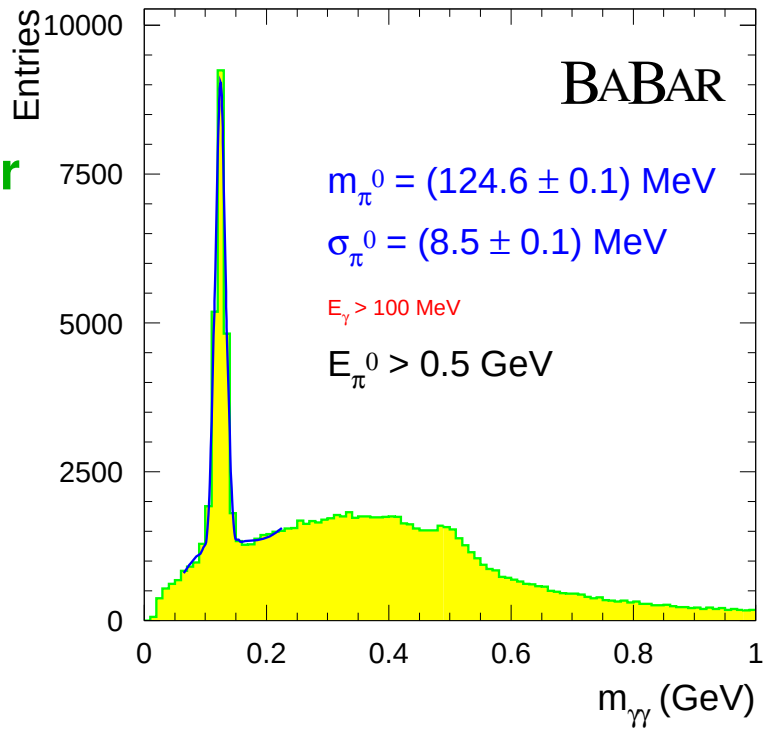
Crystal calorimeters (CsI, BGO, ...)





BELLE

BaBar

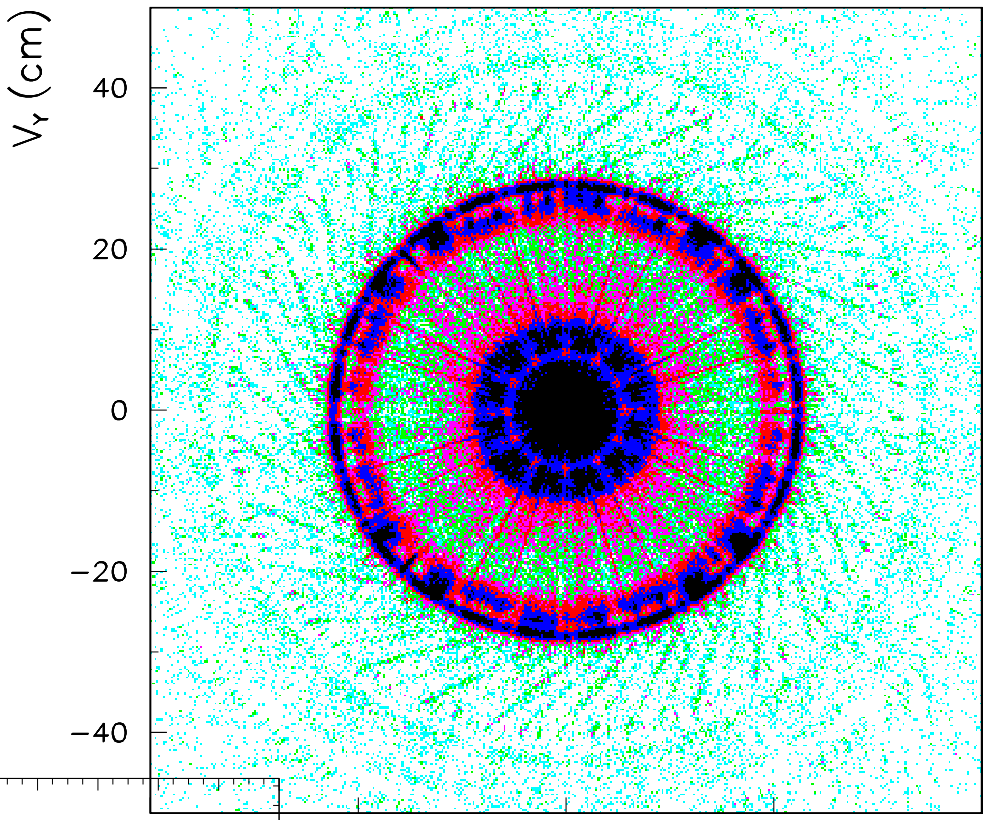


Excellent energy resolution translates into excellent diphoton inv. mass resolution

Features of B Physics

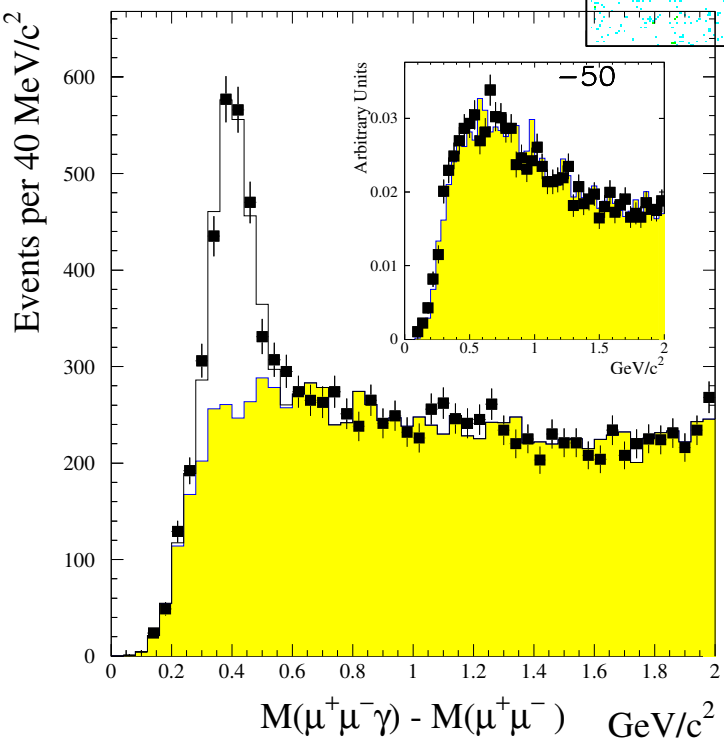
If calorimeter not well suited for low energetic photons
Use photon conversions $\gamma \longrightarrow e^+e^-$ (efficiency low)

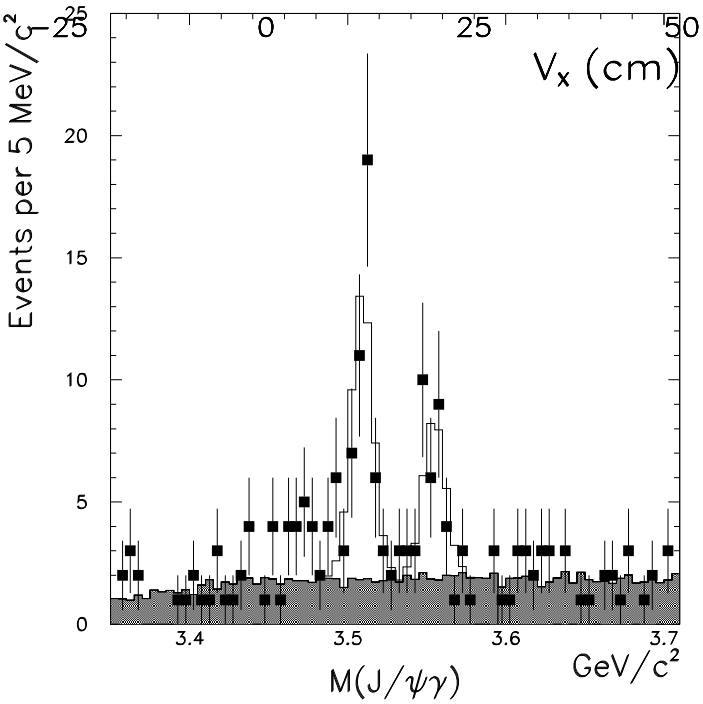
CDF: Xray of inner detector



Example:

$\chi_c \longrightarrow J/\Psi\ \gamma$

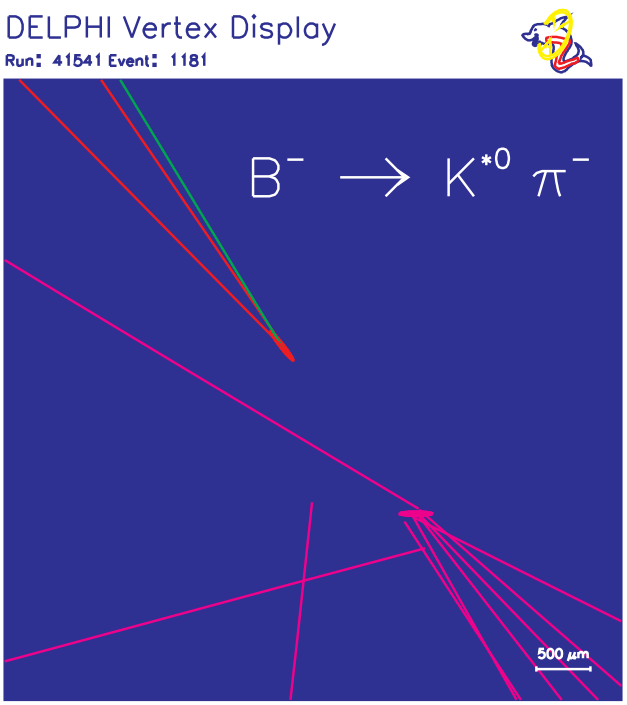




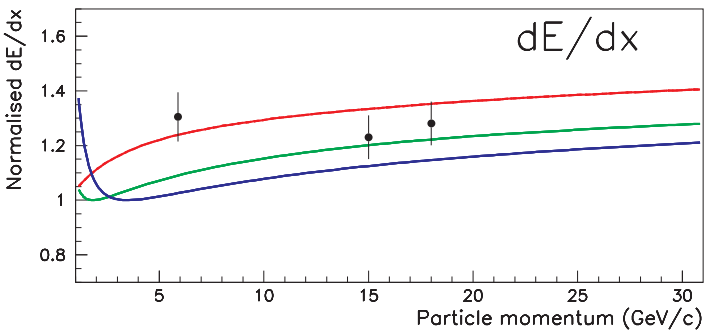
Features of B Physics

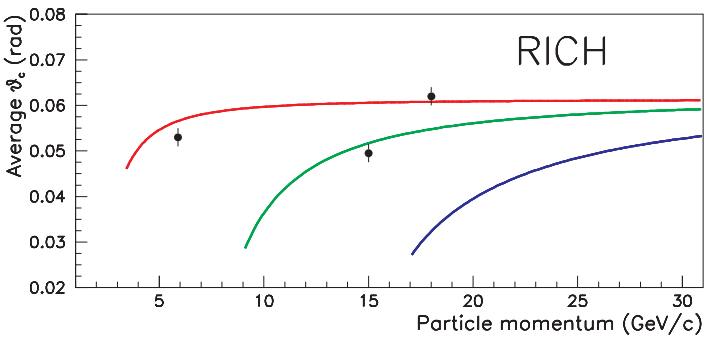
5. Good particle identification (pion/kaon separation)

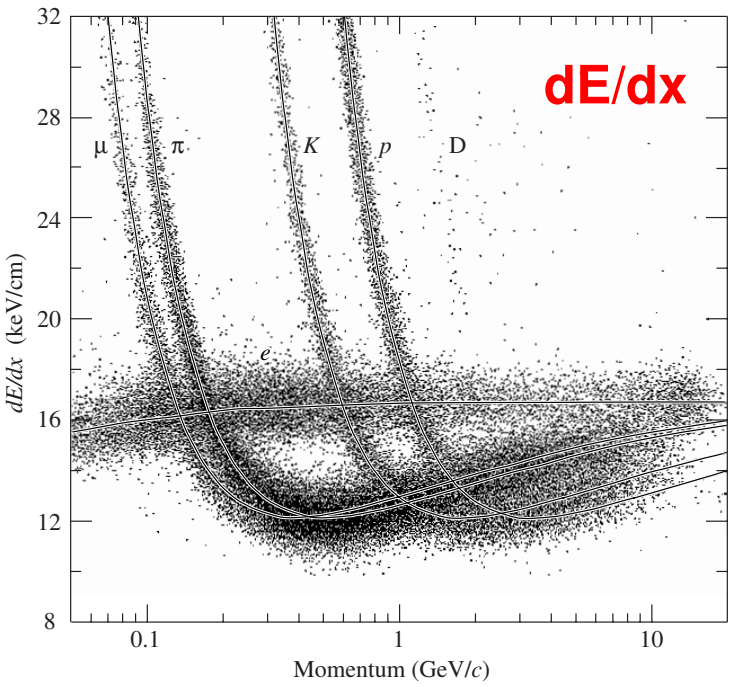
dE/dx, ToF, Ring imaging Cerenkov counter

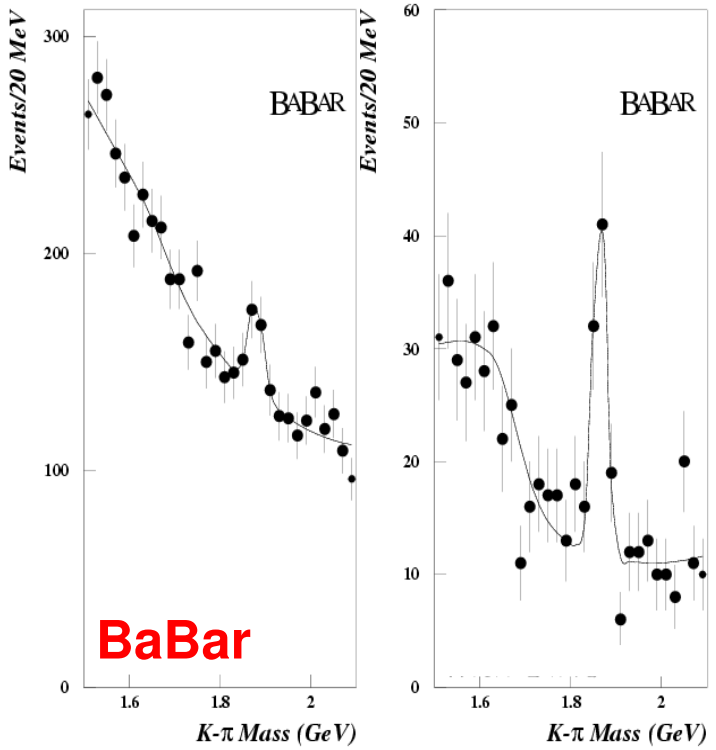


DELPHI



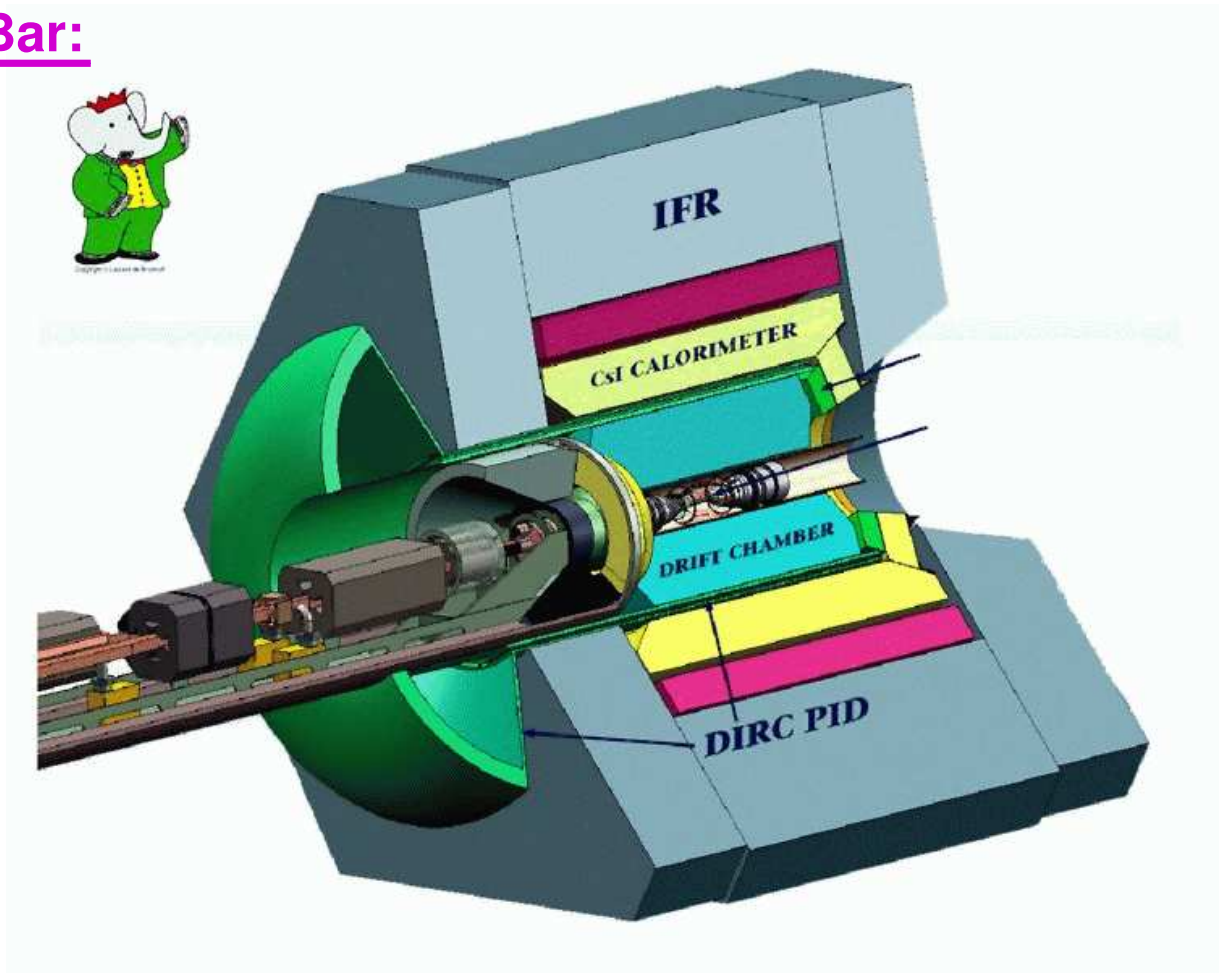






Features of B Physics

⋆ Summary of elements for successful B physics:

- High rate B production
- Excellent tracking in central tracker & silicon
- Superb vertexing with silicon vertex detector
- Good calorimeter to detect low energy neutrals
- Particle identification (π/K separation)
- Efficient identification of electrons and muons

BaBar: