Heavy Quarks at HERA-B and Tevatron

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- Introduction: why hadron machines?
- Collider experiments CDF, D0
- Fixed target experiment: HERA-B
- Collider forward experiment: BTeV
- Summary

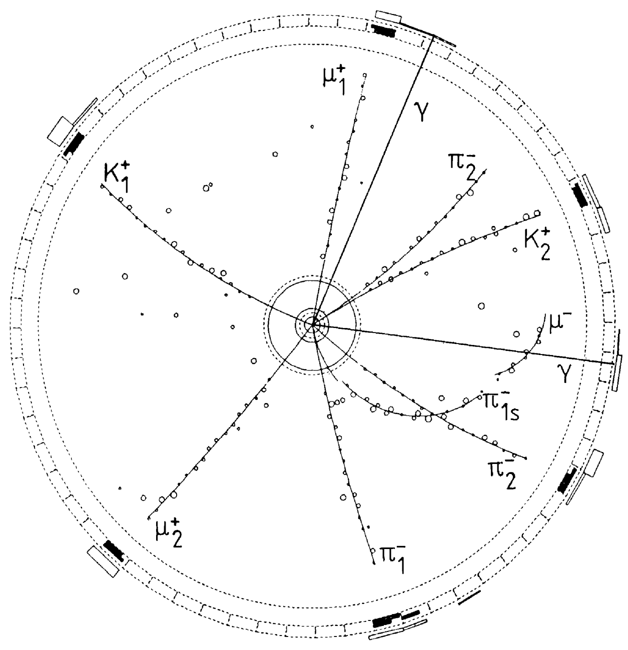
Why hadron machines?

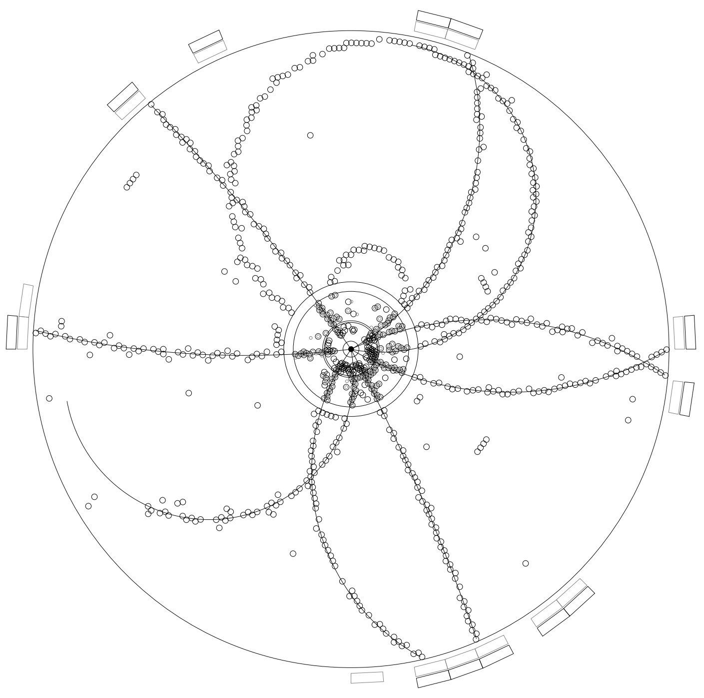
- large $b\bar{b}$ production rates
- large boosts: $< L >=< \beta\gamma > 480\ \mu$m
- in addition to $B^0/B^\pm$ also B_s, B_c, Λ_b,..

Production	$e^+e^- \to \Upsilon(4s) \to B\bar{B}$	$e^+e^- \to Z^0 \to b\bar{b}$	$pA \to b\bar{b}X$	$p\bar{p} \to b\bar{b}X$	$p\bar{p}(p) \to b\bar{b}X$ forward
Accelerator	CESR, DORIS PEPII, KEKB	LEP, SLD	HERA p	Tevatron	Tevatron, LHC
Spectrometer	CLEO, ARGUS BaBar, BELLE	ALEPH, DELPHI, L3, OPAL, SLD	HERA-B	CDF, D0	BTeV, LHCb
$\sigma(b\bar{b})$	≈ 1 nb	≈ 6 nb	≈ 12 nb	≈ 50 μb	≈ 100 μb (≈ 500 μb)
$\sigma(b\bar{b})$:$\sigma(had)$	0.26	0.22	10^{-6}	10^{-3}	$2 \cdot 10^{-3}$ ($6 \cdot 10^{-3}$)
B^0, B^+	yes	yes	yes	yes	yes
$B_s^0, B_c^+, \Lambda_b^0$	no	yes	yes	yes	yes
boost $< \beta\gamma >$	0.06 (0.5)	6	≈ 20	$\approx 2-4$	$\approx 4-20$
$b\bar{b}$ production	B's at rest (in c.m.s)	$b\bar{b}$ back-to-back	$b\bar{b}$ not back-to-back	$b\bar{b}$ not back-to-back	$b\bar{b}$ not back-to-back
multiple events	no	no	yes, 4	yes	yes, 2
trigger	inclusive	inclusive	lepton pairs (high p_t hadrons)	leptons only (high p_t hadrons)	displaced vertex

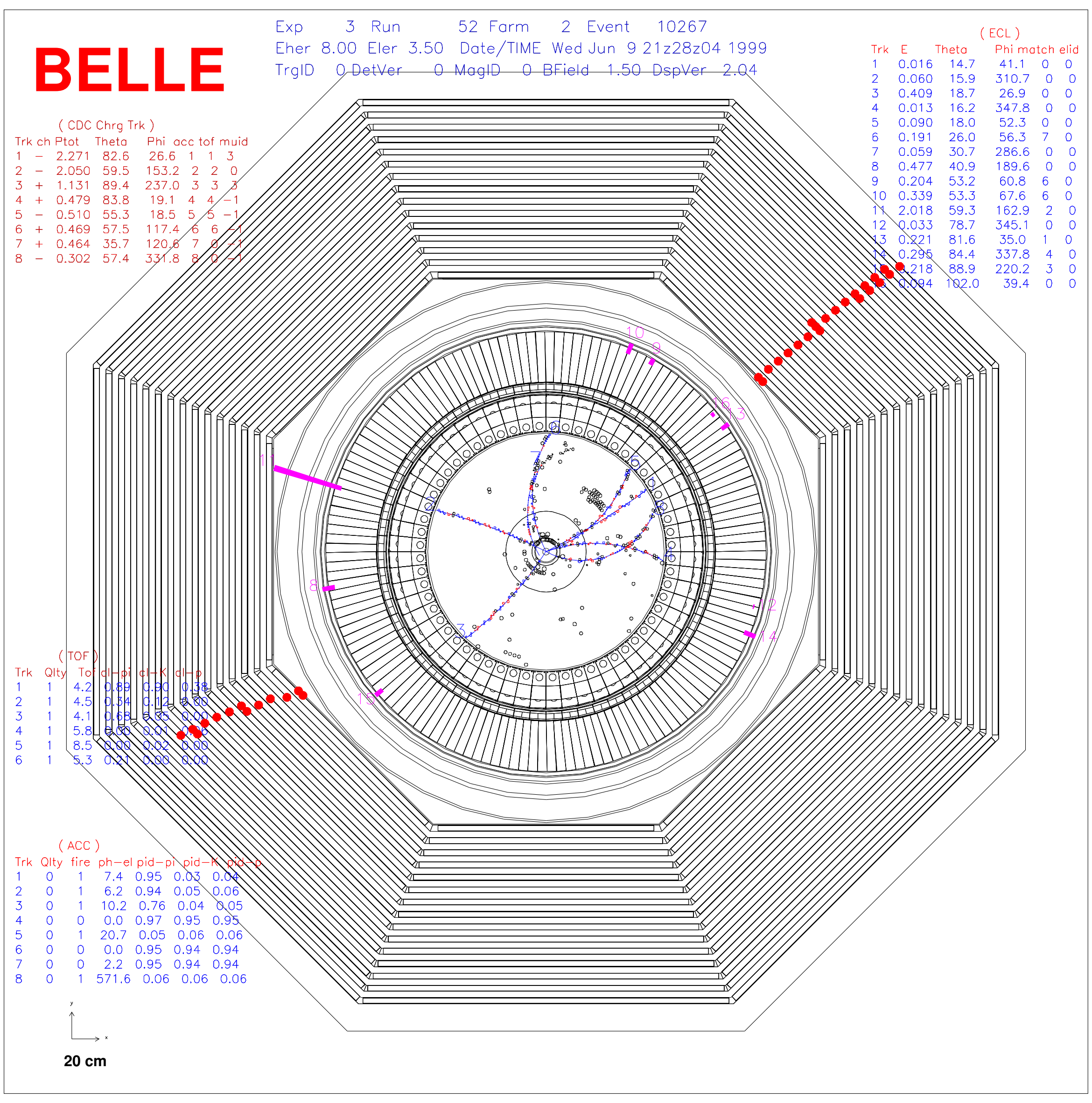
$b\bar{b}$ events at e^+e^- machines

ARGUS and CLEO

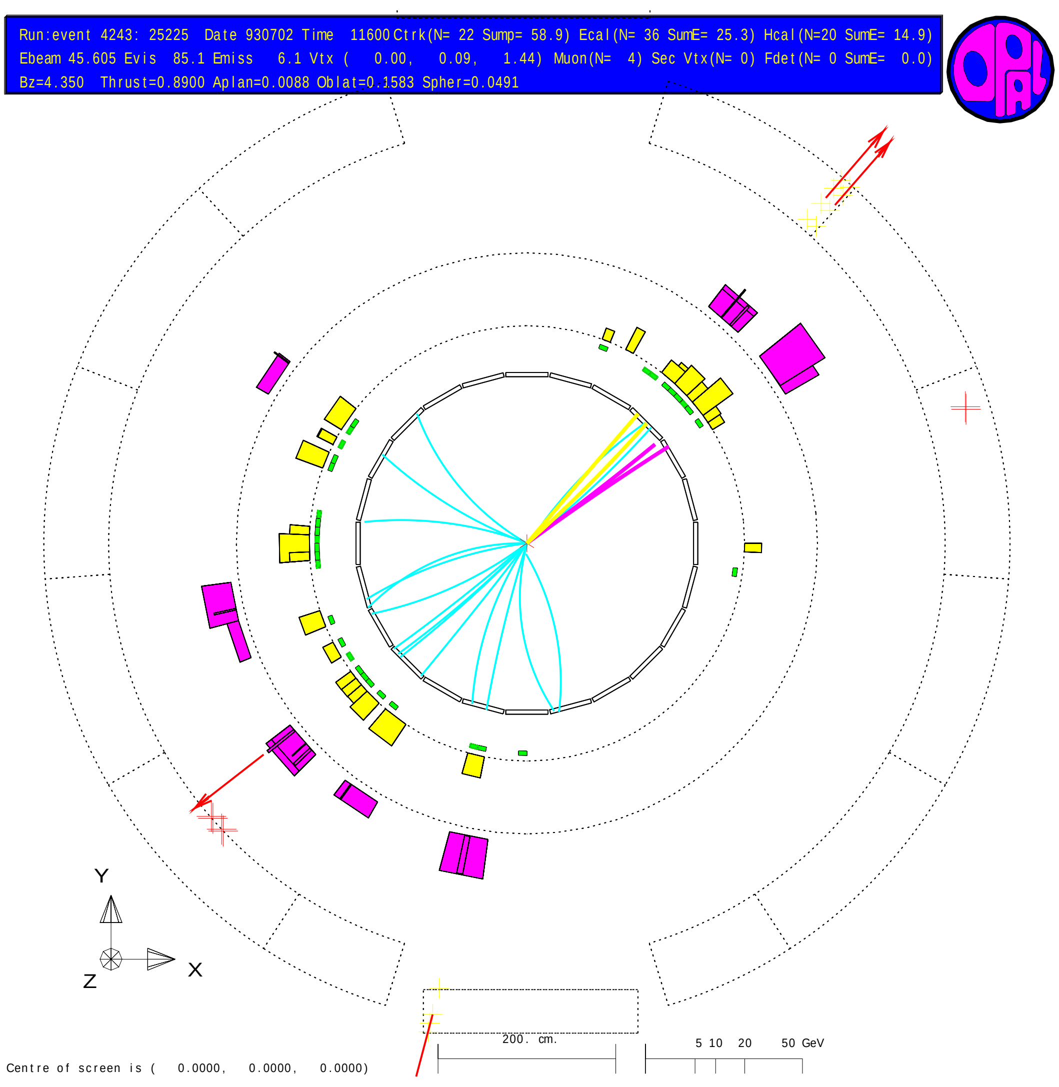




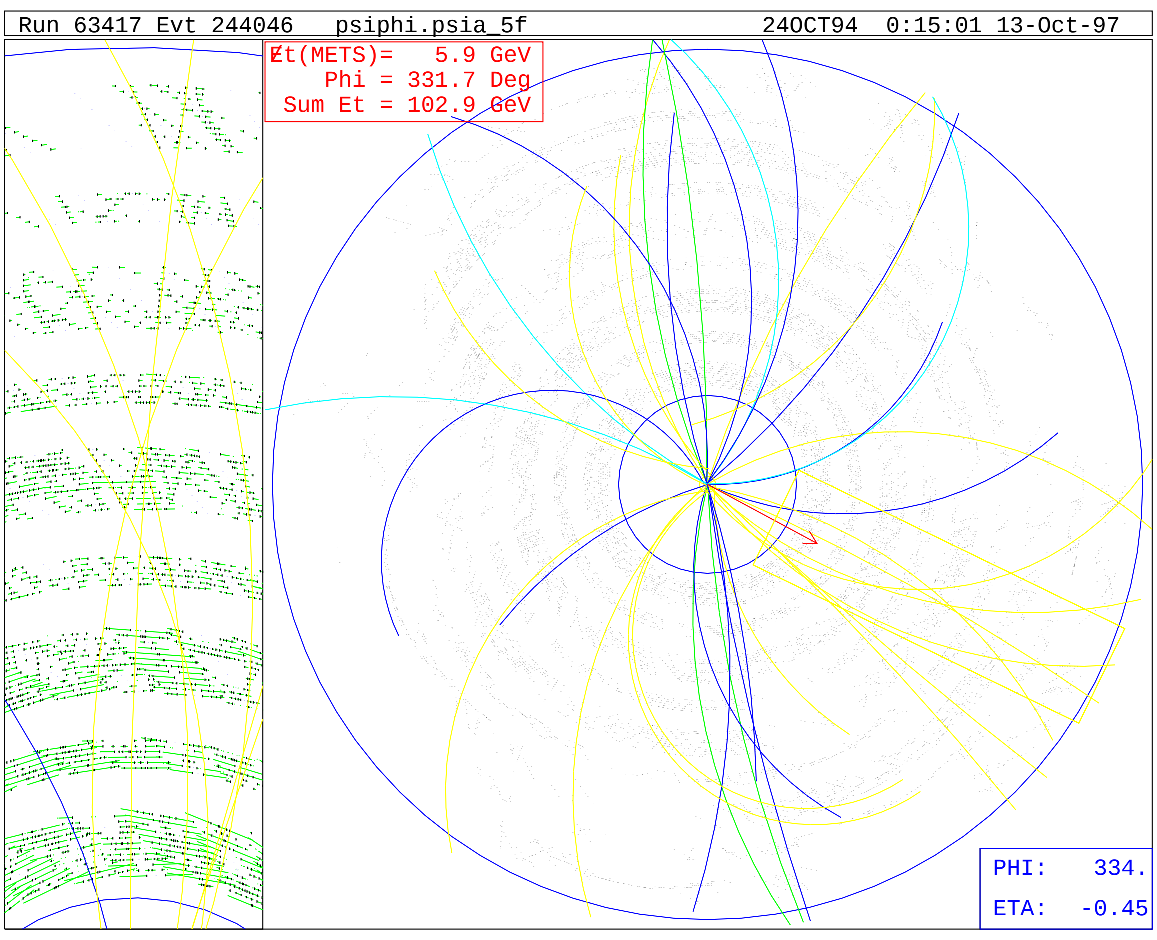
BELLE


BELLE
Exp 3 Run 52 Farm 2 Event 10267
Eher 8.00 Eler 3.50 Date/TIME Wed Jun 9 21z28z04 1999
TrgID 0 DetVer 0 MagID 0 BField 1.50 DspVer 2.04
(CDC Chrg Trk)
(ECL)
(TOF)
(ACC)
20 cm

OPAL

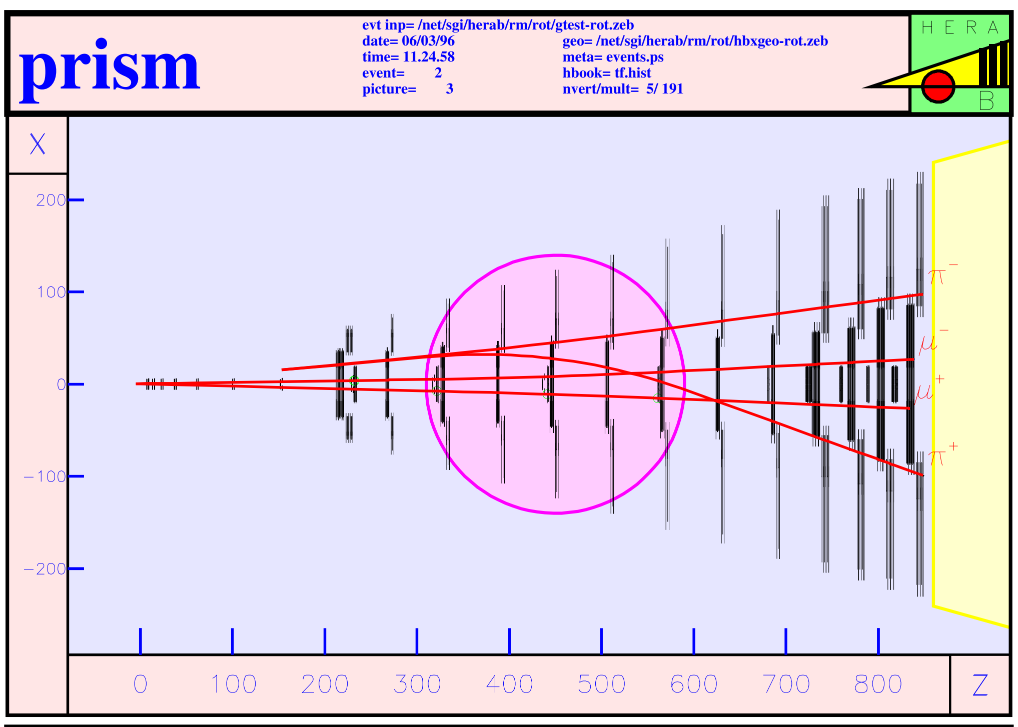

Run:event 4243: 25225 Date 930702 Time 11600 Ctrk(N= 22 Sump= 58.9) Ecal(N= 36 SumE= 25.3) Hcal(N=20 SumE= 14.9)
Ebeam 45.605 Evis 85.1 Emiss 6.1 Vtx (0.00, 0.09, 1.44) Muon(N= 4) Sec Vtx(N= 0) Fdet(N= 0 SumE= 0.0)
Bz=4.350 Thrust=0.8900 Aplan=0.0088 Oblat=0.1583 Spher=0.0491
Y
Z
X
200. cm.
5 10 20 50 GeV
Centre of screen is (0.0000, 0.0000, 0.0000)

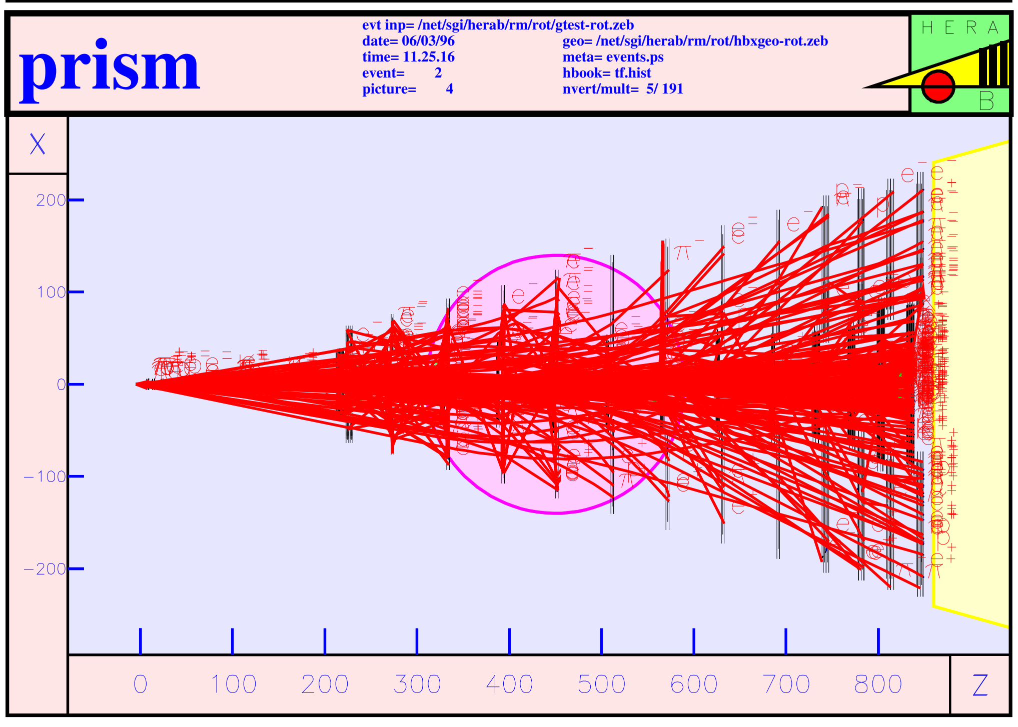
$b\bar{b}$ event at CDF



$b\bar{b}$ event at HERA-B

Needle in haystack





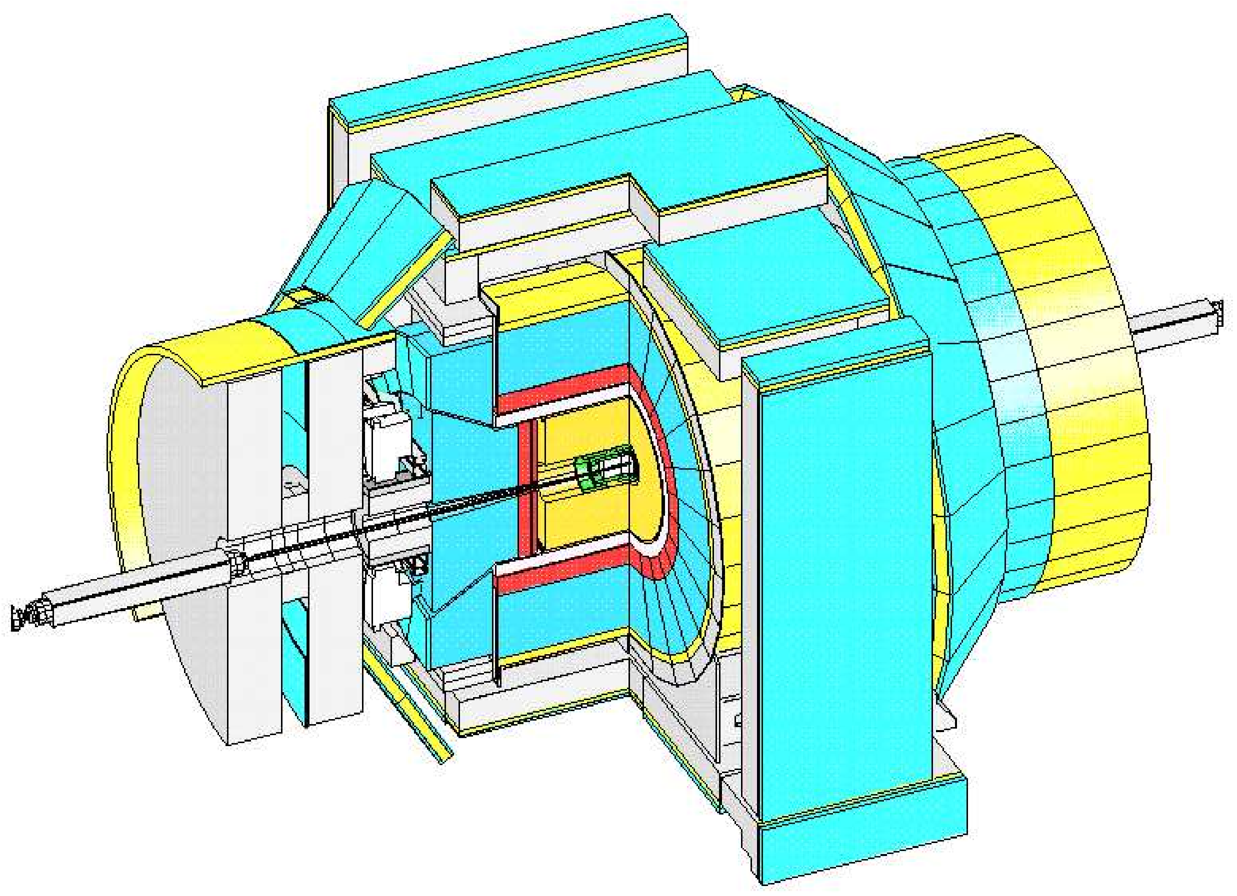
B detection in hadron collisions

What do we have to consider when designing a detector for B's at a hadron machine?

- High particle fluxes $\rightarrow$ radiation hard detectors
- Early selection of interesting events $\rightarrow$ selective triggers
  - high p_t decay products: $B \rightarrow \mu\nu X$, $B \rightarrow J/\psi K_s \rightarrow \mu\mu\pi\pi$, $B \rightarrow \pi^+\pi^-$
  - displaced vertex: $< L > = < \beta\gamma > 480\ \mu$m

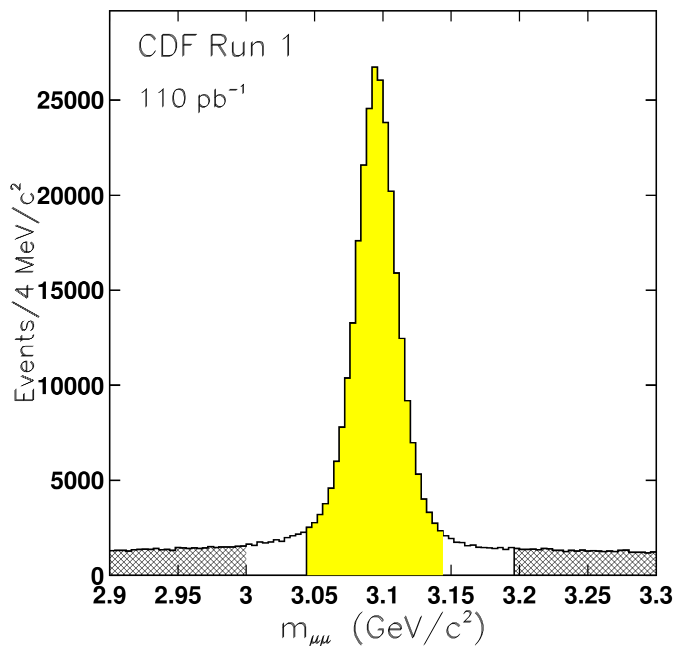
Proof of principle: CDF

CDF spectrometer

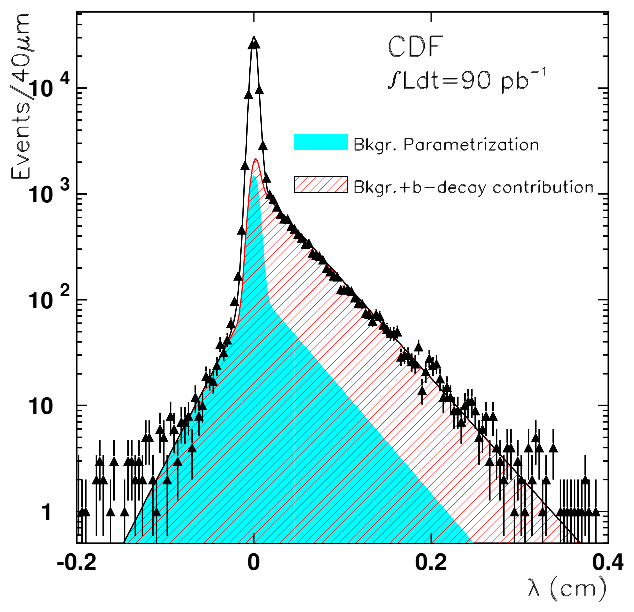


CDF performance

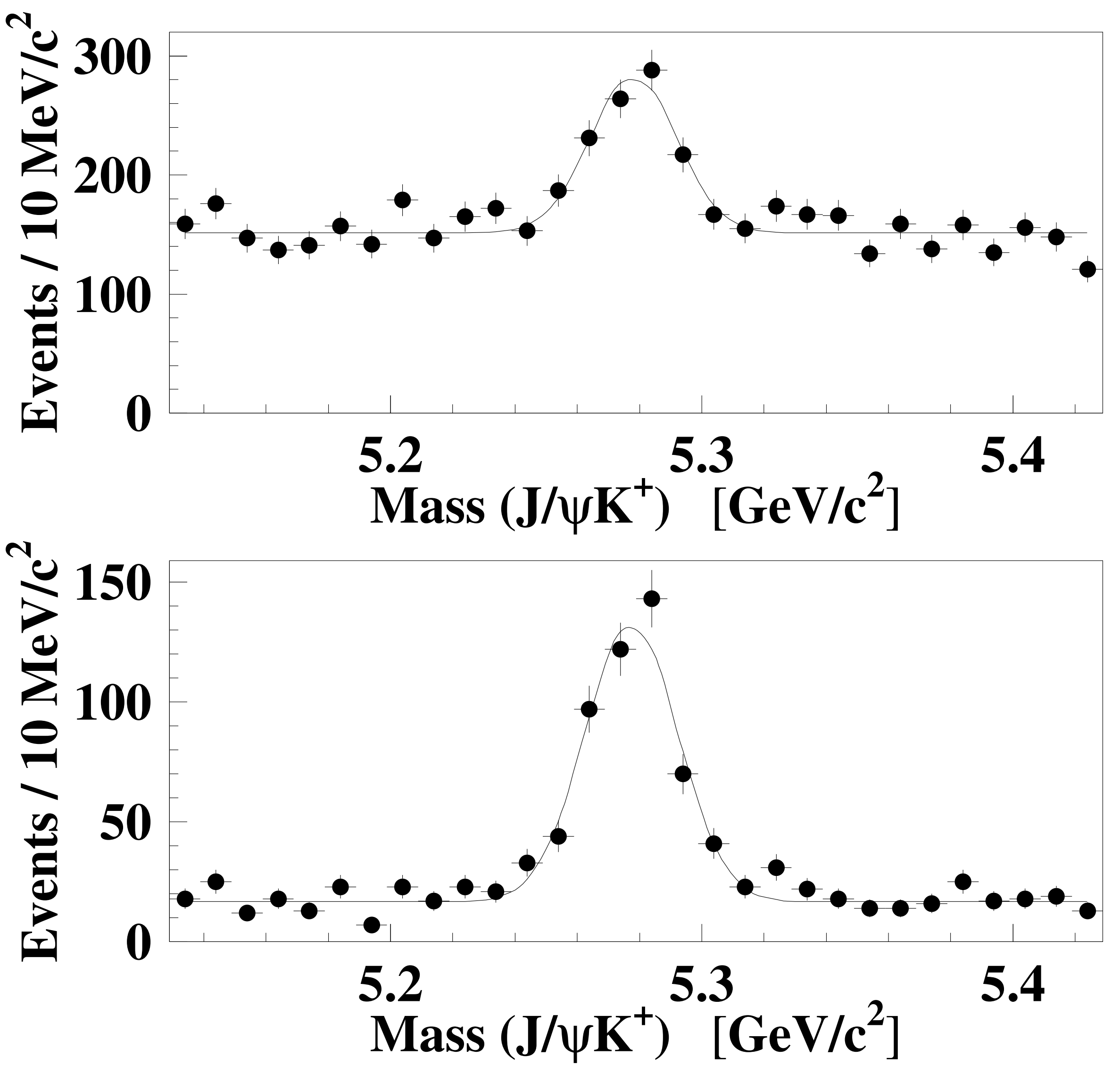
- Mass resolution on J/ψ: 16 MeV/c



- Decay length resolution: 40-50 μm



- Cleaning up the $J/\psi K^+$ signal:
  cut on decay length ($> 100\mu$m)



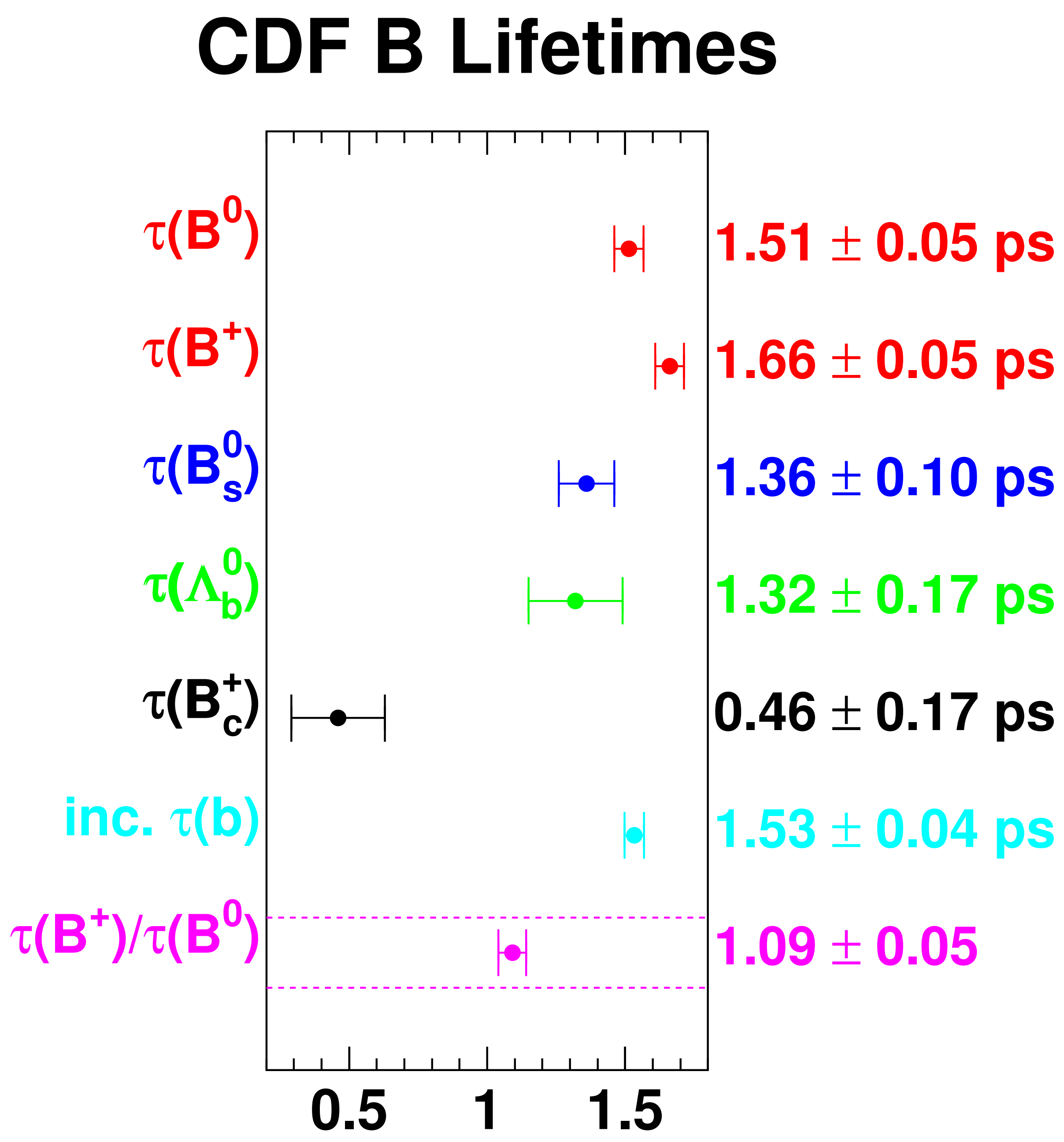
- Mass spectrum with decay length cut compared to no cut

CDF results

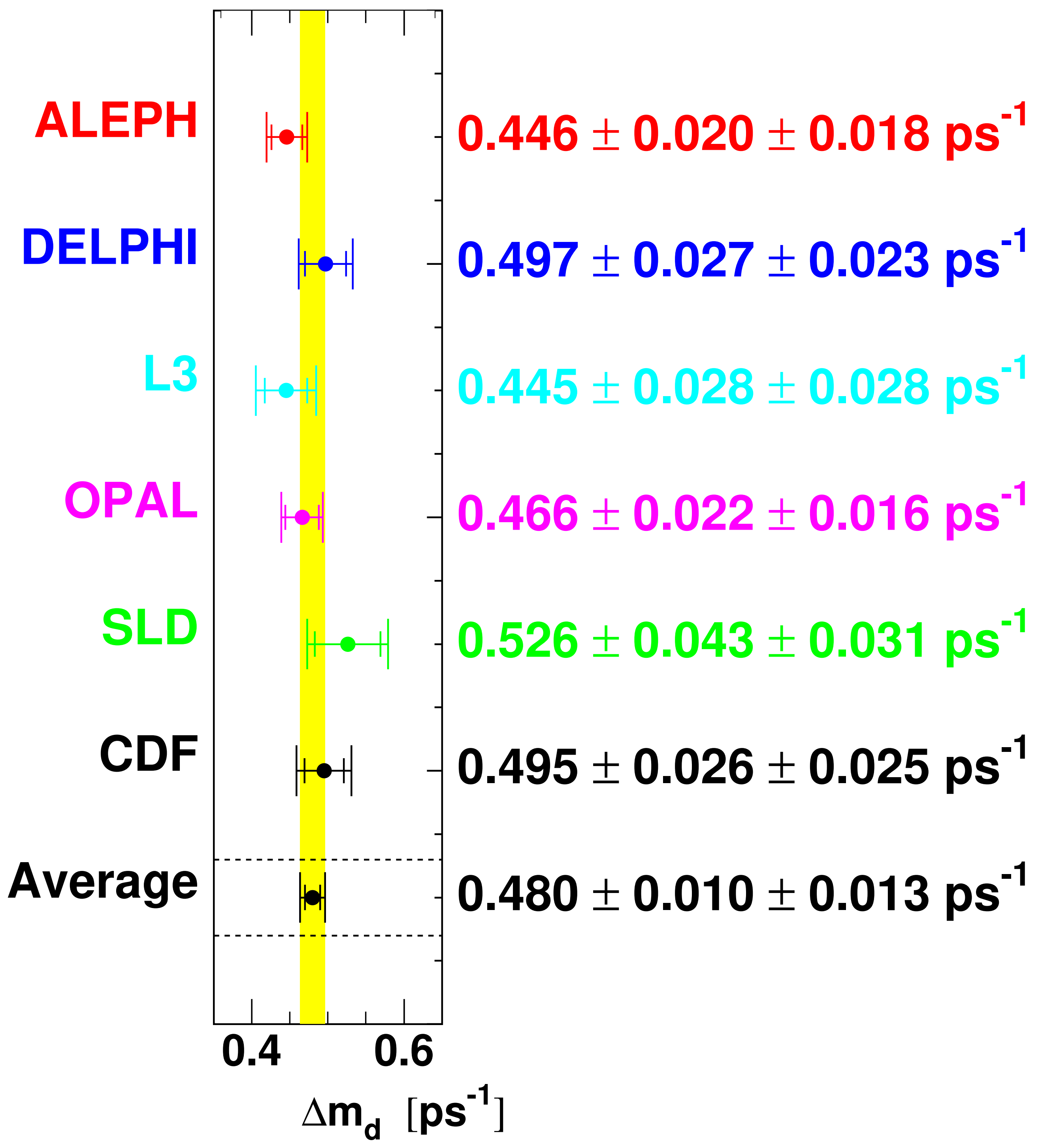
Highlights

- $\sigma(p\bar{p} \to bX)$ larger then theoretical predictions by about factor of 2
- masses of B_s, Λ_b, B_c
- lifetimes
- polarization in the $B_s \to J/\psi\phi$ decay (input for $\Delta\Gamma/\Gamma$ measurement)
- B_s mixing: lower limit $\Delta m_s > 5.8\text{ps}^{-1}$ (95%)
- first observation of B_c
- B_d mixing measurements
- measurement of $\sin(2\beta) = 0.79^{+0.41}_{-0.44}$
- rare decays

CDF results, 2



Δm_d Results



CDF, Tevatron upgrade

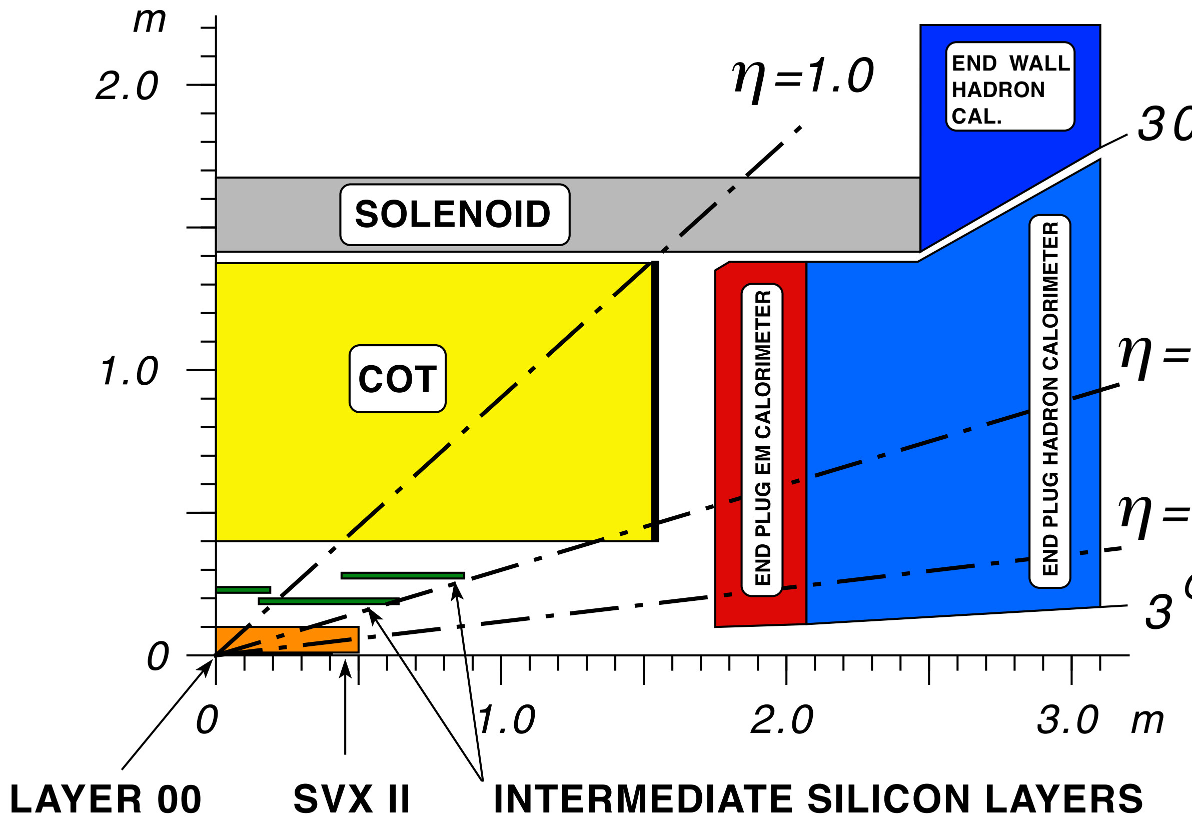
Tevatron upgrade:

For RUN II the injector and $\bar{p}$ source were upgraded. Expected: 2 fb^{-1} in 2001-02, 15 fb^{-1} until 2004 (compared to 0.1 fb^{-1} in Run I). The bunch spacing will change from 3.5 μs to 396 ns (132 ns).

Detector upgrade:

- increase muon system coverage
- increase silicon detector coverage
- improve vertex resolution with additional silicon layer L00 (for B_s mixing)
- add time-of-flight counter (for π/K separation up to 1.6 GeV/c)
- new central tracker, drift chamber with additional silicon layers
- trigger upgrade: fast tracker in L1, silicon vertex tracker in L2 $\rightarrow$ lower p_t threshold for μ, two track trigger

CDF run II



m
2.0
1.0
0
η=1.0
30°
η = 2.0
η = 3.0
3°
END WALL HADRON CAL.
SOLENOID
COT
END PLUG EM CALORIMETER
END PLUG HADRON CALORIMETER
0
1.0
2.0
3.0 m
LAYER 00
SVX II
INTERMEDIATE SILICON LAYERS

How to measure B_s mixing?

Measure: probability that a B_s (at $t = 0$) turns into $\bar{B}_s$ at time t.

Need:

- a well defined final state with precisely measured vertex position and momentum
- a tag to determine the initial B_s flavour (B_s or $\bar{B}_s$ at $t = 0$)

Final states:

- $\mu D_s \nu$, $D_s \to \phi\pi^+, K^+K_S, K^+K^*$
- $J/\psi K^* \to \mu\mu K\pi$
- $D_s^{(*)}\pi^+(\pi^+\pi^+\pi^-)$

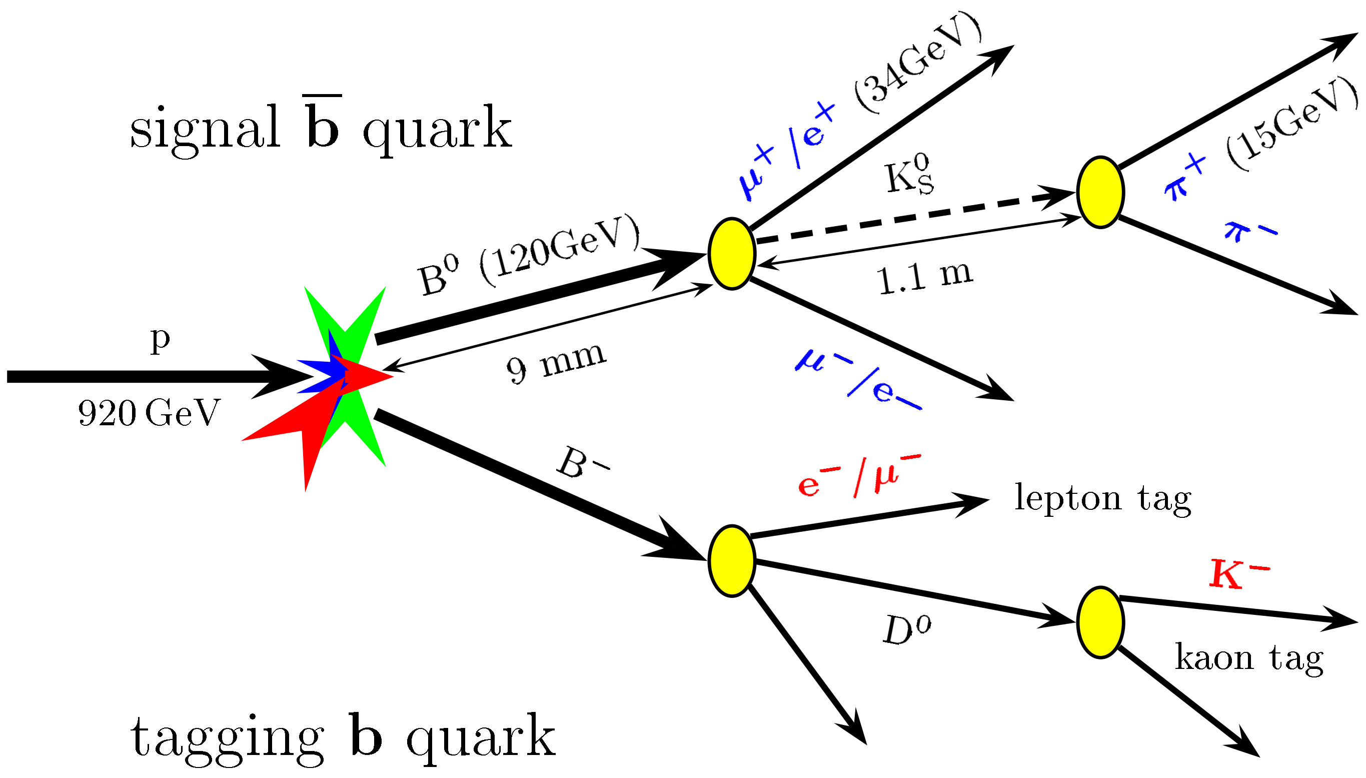
Tagging:

- charge of kaon from the associated B decay
- charge of lepton from the associated B decay

CDF physics plans, 2fb^{-1}

- measure $\sin 2\beta$ with 0.043 error
- B_s mixing up to $x_s = 60$ at 5σ
- $\Delta\Gamma/\Gamma$ (with 0.05 error) for B_s mesons through $B_s \to J/\psi\phi$
- A_{FB} in $B_d \to K^*\mu\mu$
- $b\bar{b}$ production section, $B_c \to J/\psi\ell\nu, J/\psi\pi$

HERA-B



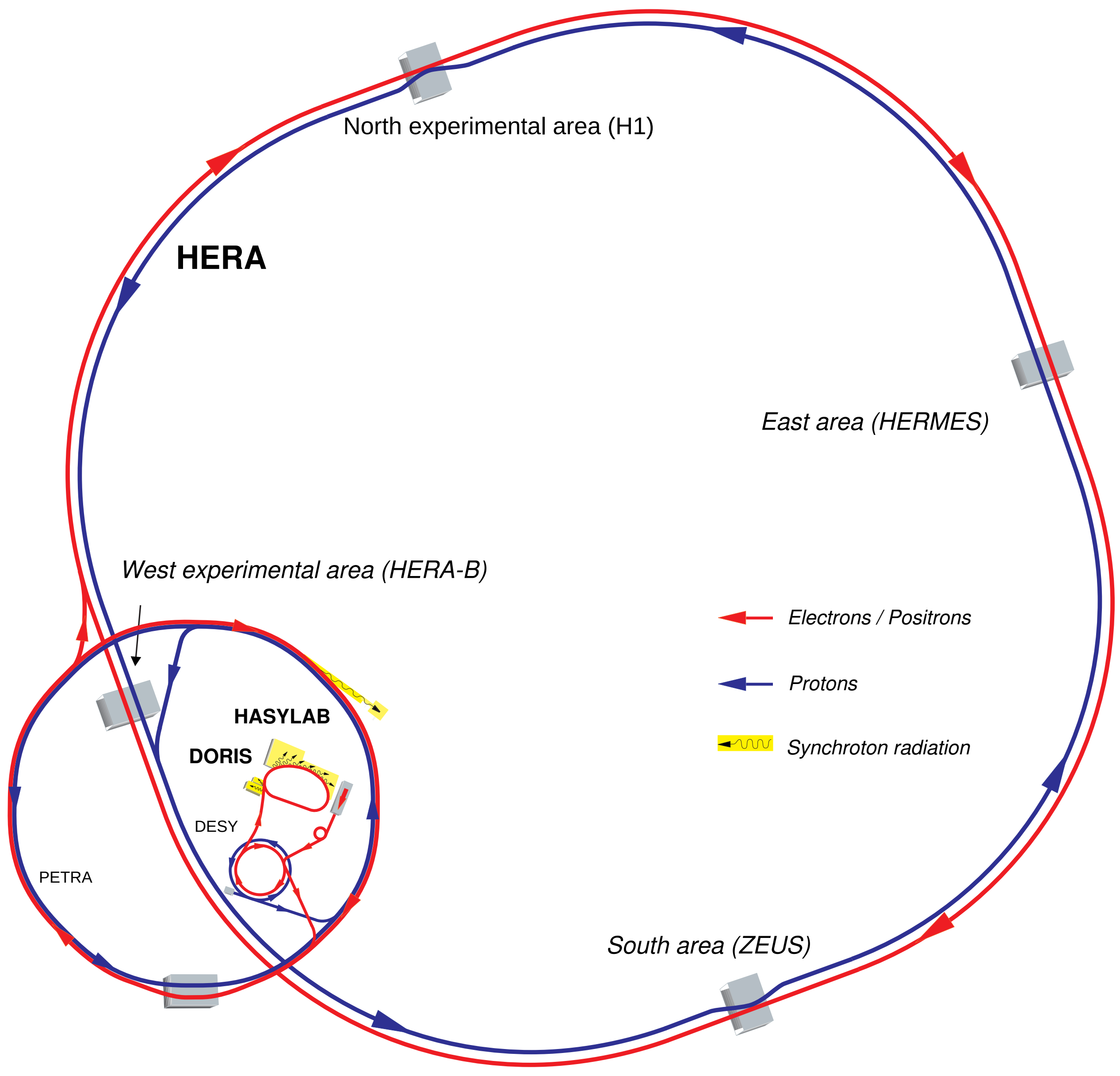
Fixed target B - Factory at HERA (DESY)
Originally designed for measurement of CP violation in $B \to J/\psi K^0_S$.

- proton energy is 920 GeV, $\sqrt{s} = 42$ GeV
- $\sigma_{b\bar{b}} \approx 12$ nb $\Rightarrow \frac{\sigma_{b\bar{b}}}{\sigma_{inel}} \approx 10^{-6}$
- Br for interesting decays of $\approx 10^{-5} - 10^{-4}$

- design pN interaction rate up to 40 MHz

Schedule:

- approved in 1995
- completed in spring 2000
- commissioning 2000–2002

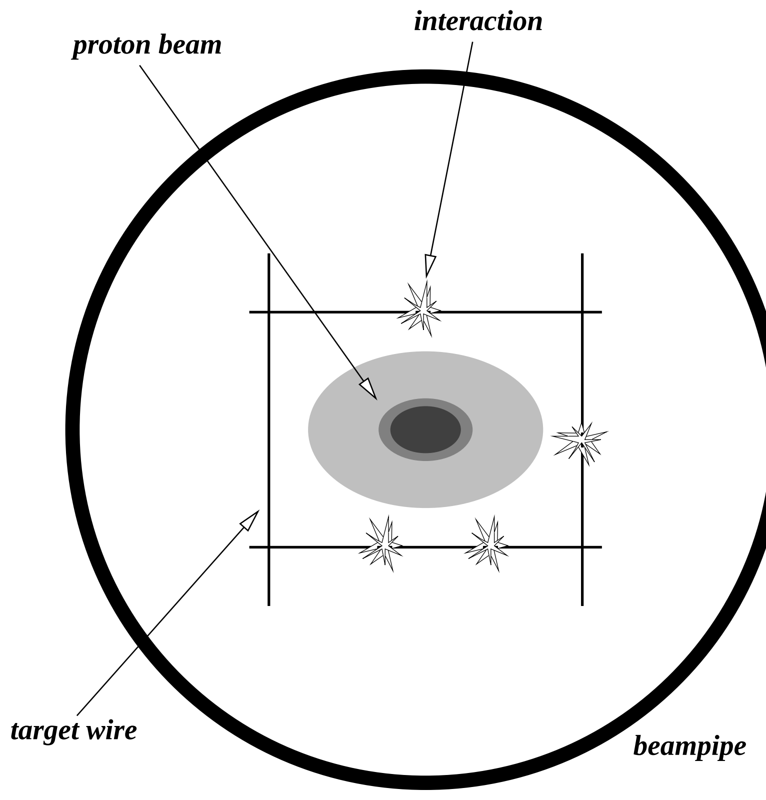


Parasitic running

- Interesting decays (e.g. $B \to J/\psi K_S^0$), triggered and reconstructed signal come 1 in about $4 \cdot 10^{11}$ inelastic ('minimum bias') interactions
- Need about 1000 signal events in 1 year $= 10^7$ s
- $\rightarrow$ run at $4 \cdot 10^7$ interactions per second $=$ 40 MHz
- Proton bunch spacing in HERA: 96ns, event frequency 10 MHZ
- $\rightarrow$ Need multiple events for 40 MHz interaction rate

- HERA proton beam looses about 10^8 protons per second
- $\rightarrow$ A parasitic target has to catch these protons very efficiently, about 1 out of 2.

Wire Target

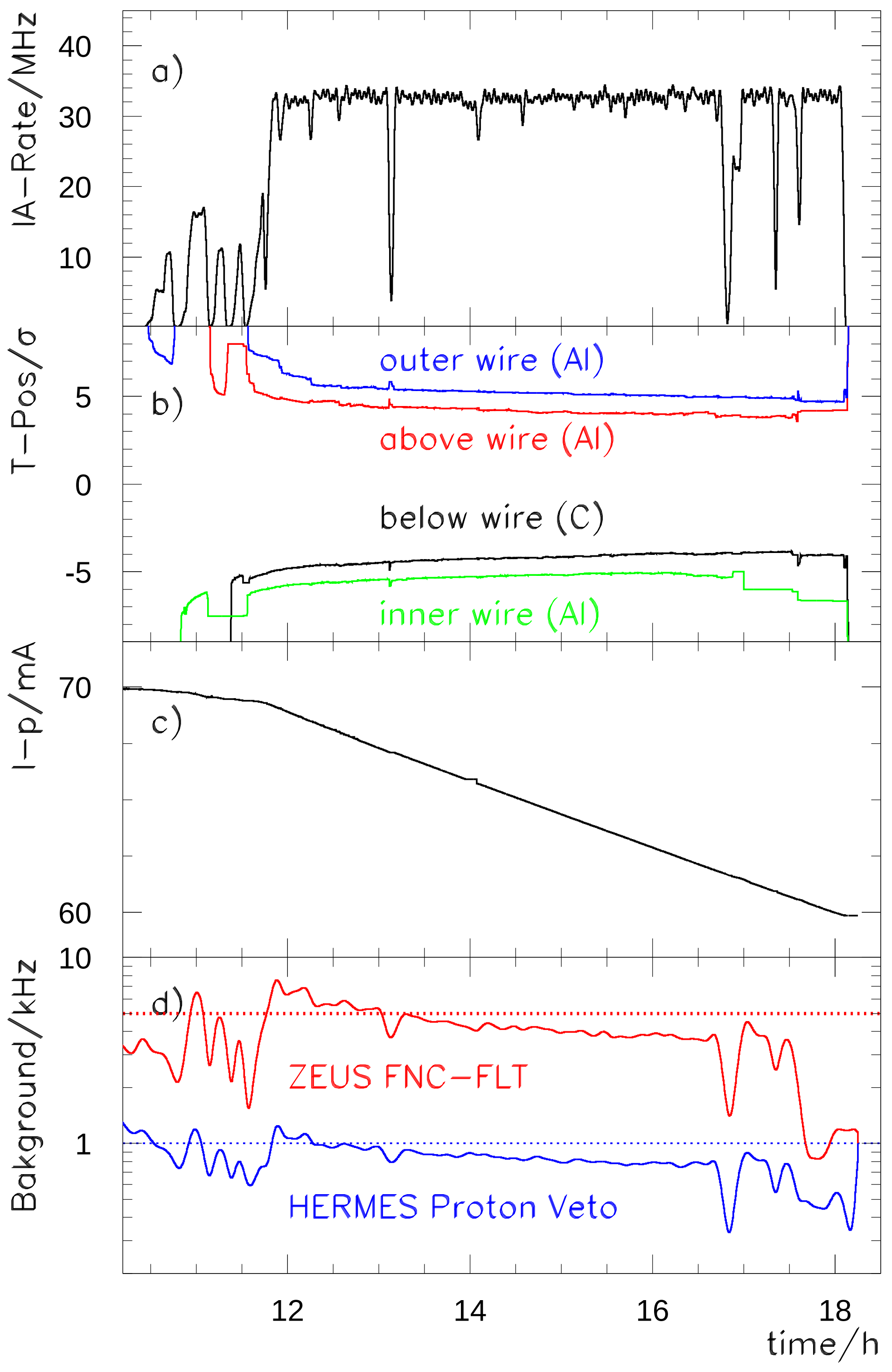


Needed: target in beam halo and efficient separation of primary vertices for high interaction rates.

- 2 stations with 4 thin wires (50 μm $\times 500 \mu$m) in proton beam halo
- target material: C, Ti, W, Al

Operation of the wire target has been reliable for years, little interference with HERA ep operation

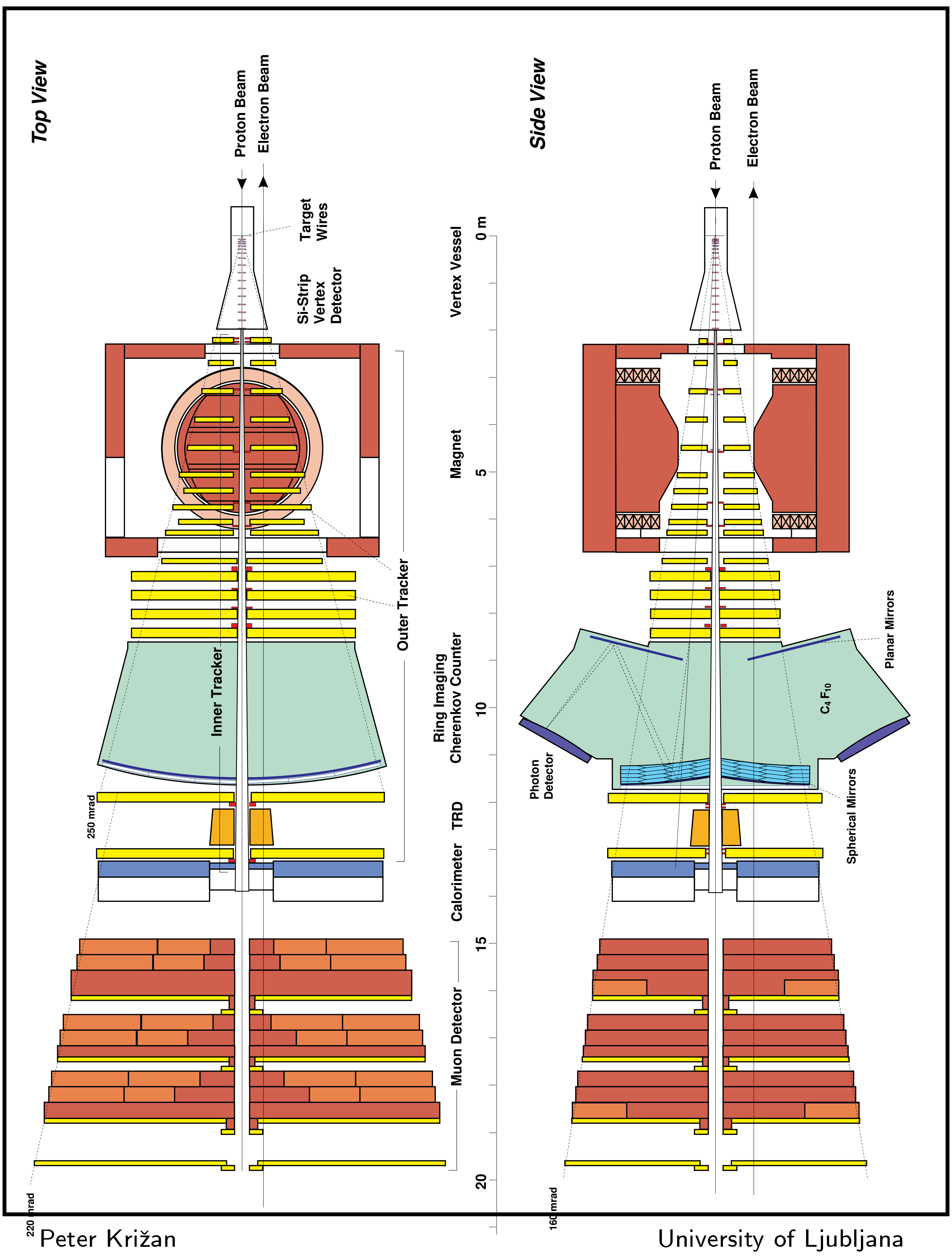
Target operation over one fill: rate, positions, backgrounds



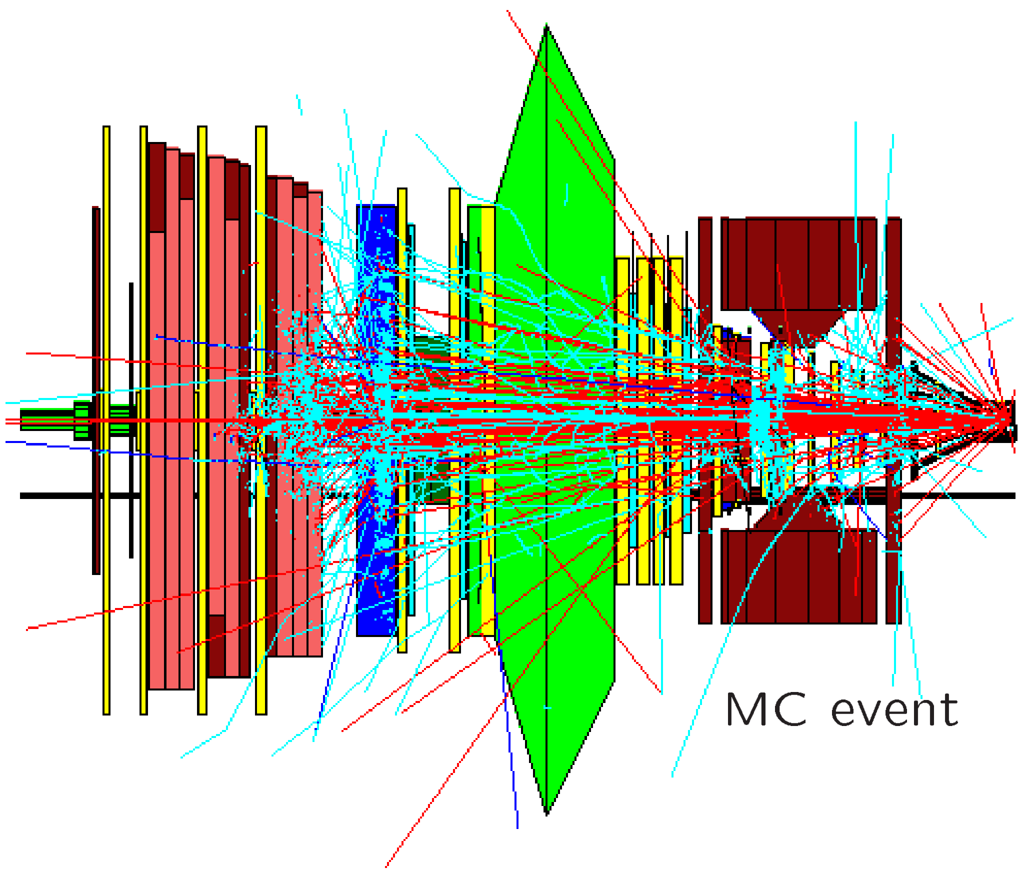
12 14 16 18

12 14 16 18

12 14 16 18


Top View
Proton Beam
Electron Beam
Target Wires
Si-Strip Vertex Detector
Vertex Vessel
Magnet
Outer Tracker
Inner Tracker
Ring Imaging Cherenkov Counter
TRD
Calorimeter
Muon Detector
250 mrad
220 mrad
Side View
Planar Mirrors
C_4F_{10}
Photon Detector
Spherical Mirrors
160 mrad
0 m
5
10
15
20

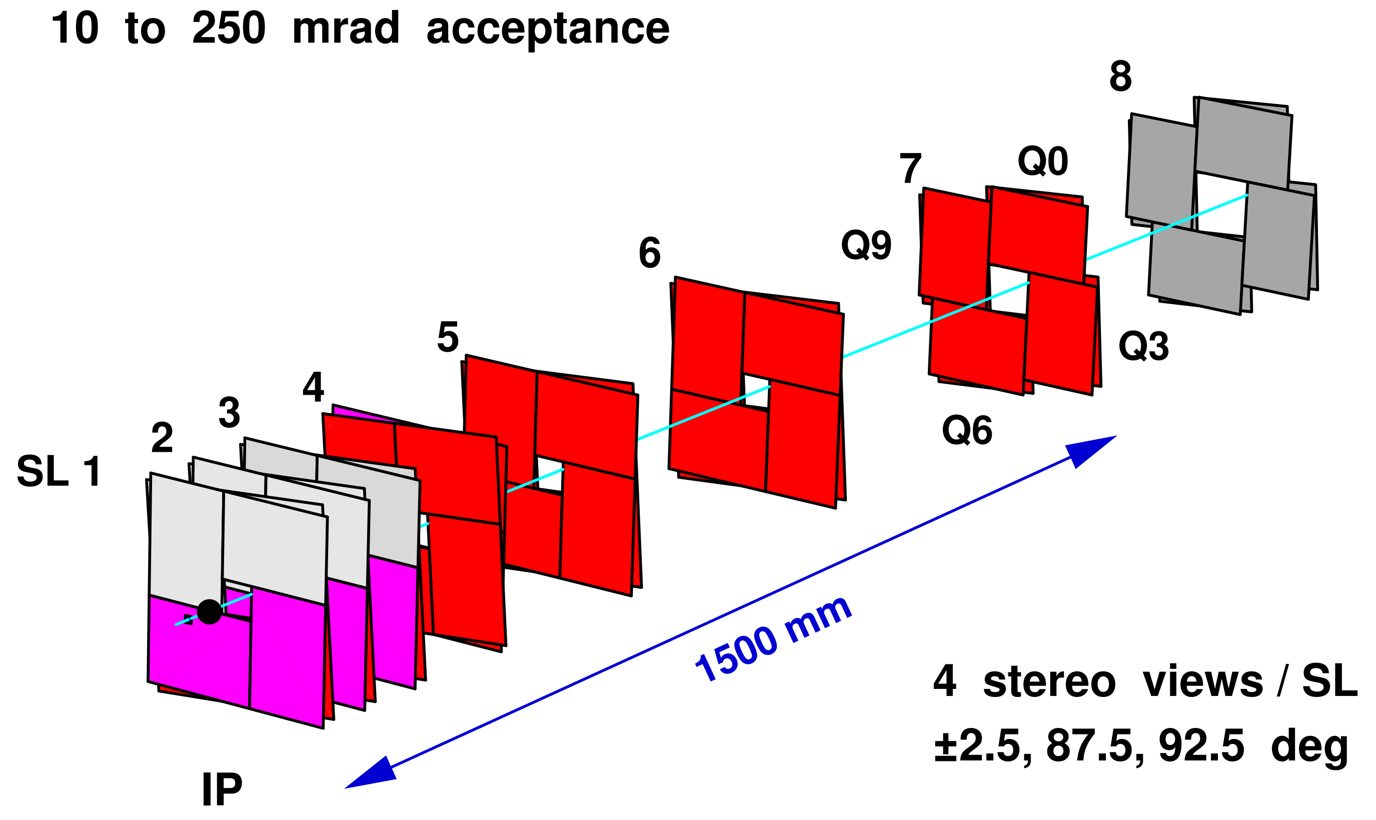
High-Rate Environment



HERA-B vertexing 1

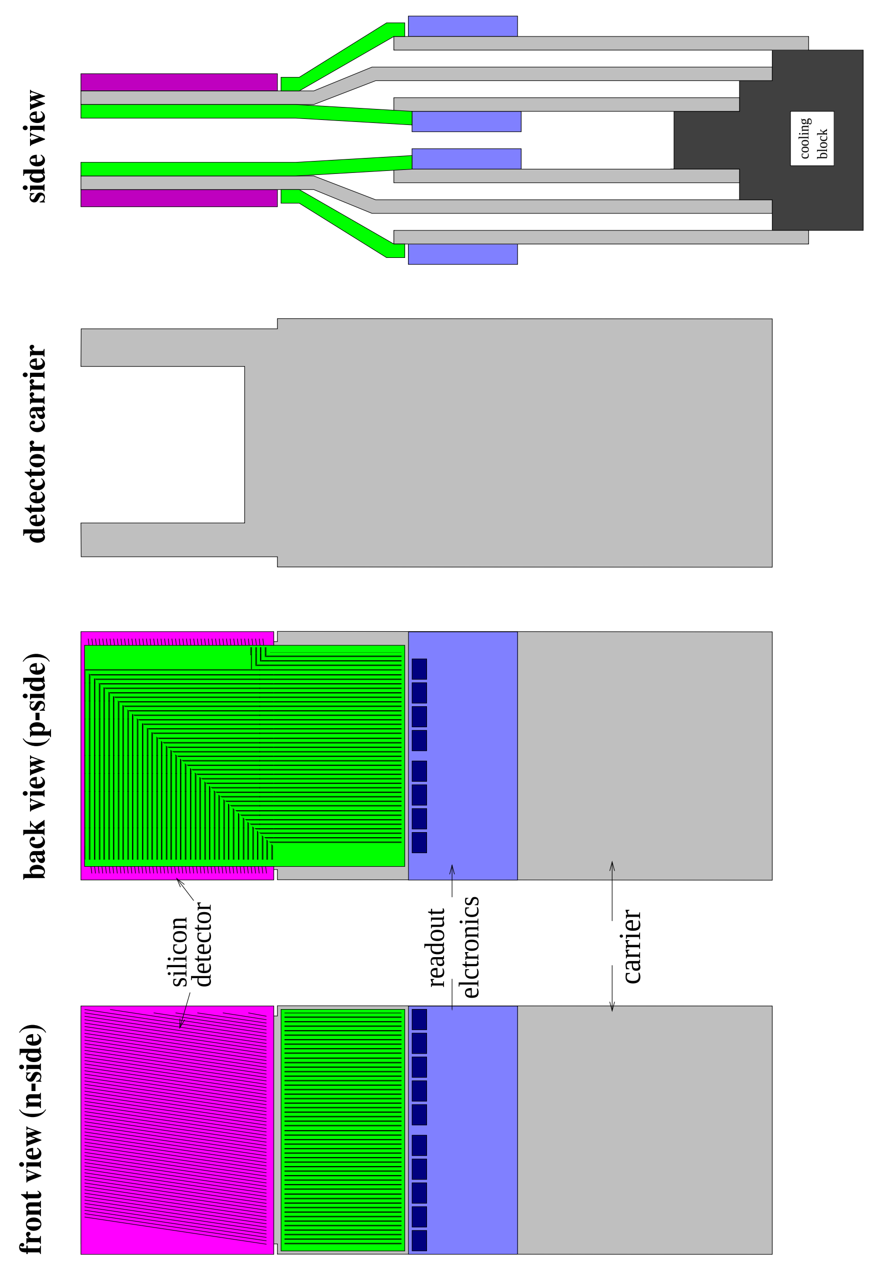
Provides track coordinates for reconstruction of primary and secondary vertices.

64 d.s. Si µstrip detectors in 8 superlayers
50 x 70 mm active area, 50 µm pitch
10 to 250 mrad acceptance



superlayers 1 to 7 : roman pot system

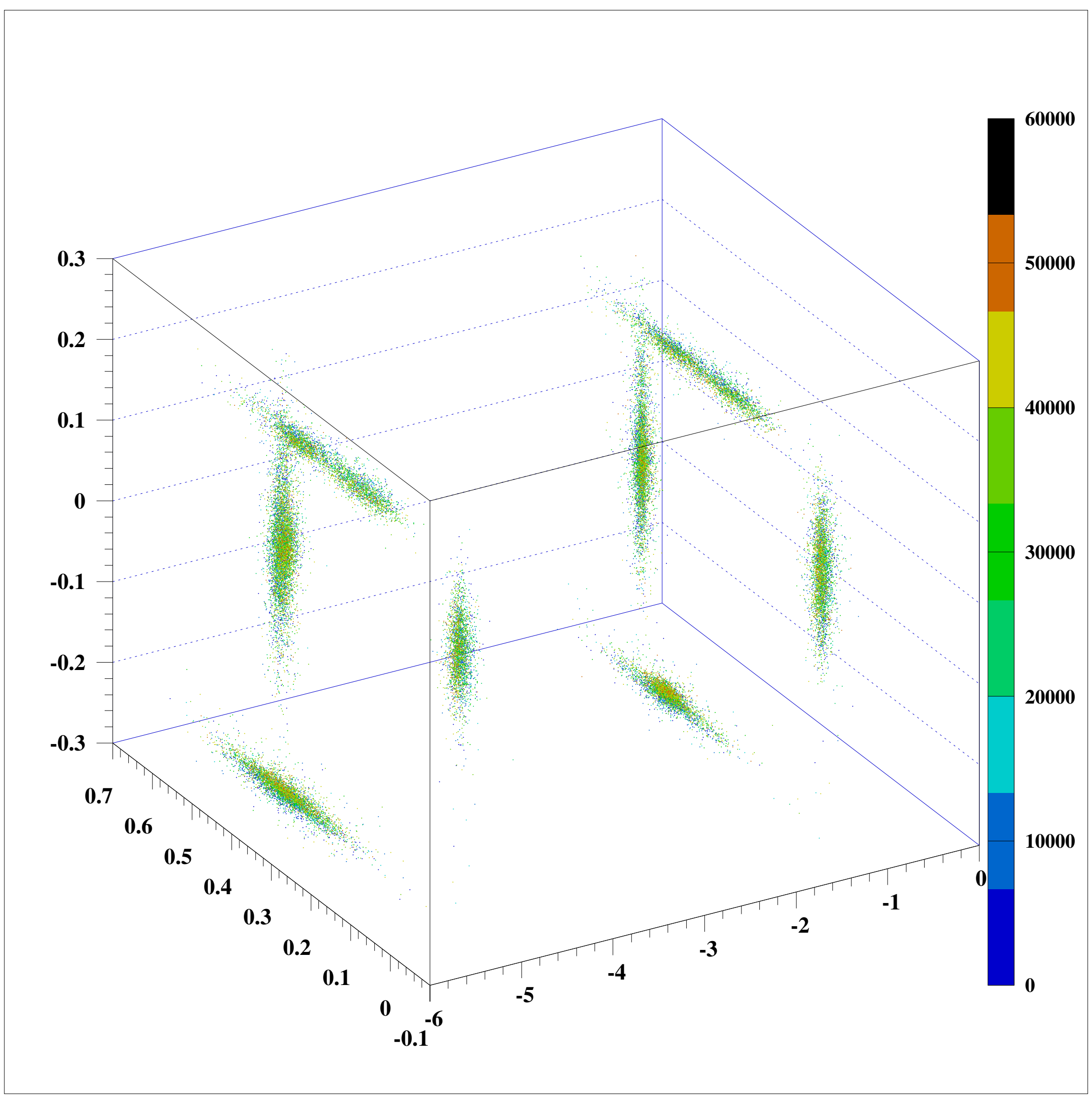
HERA-B vertexing 2



HERA-B vertexing 3

Performance close to design values

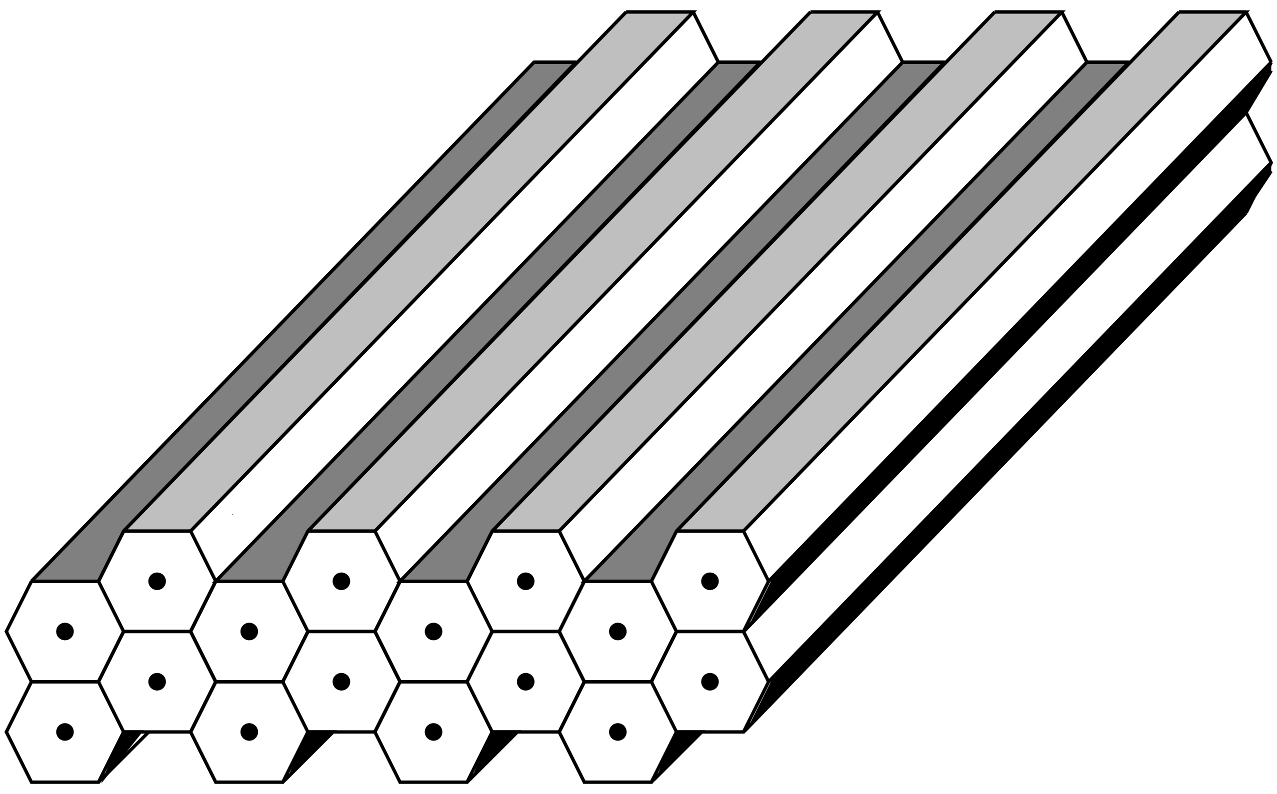
- hit resolution $\approx 10\mu$m
- primary vertex resolution: $\sigma_{x,y} = 50\,\mu$m, $\sigma_z = 500\,\mu$m



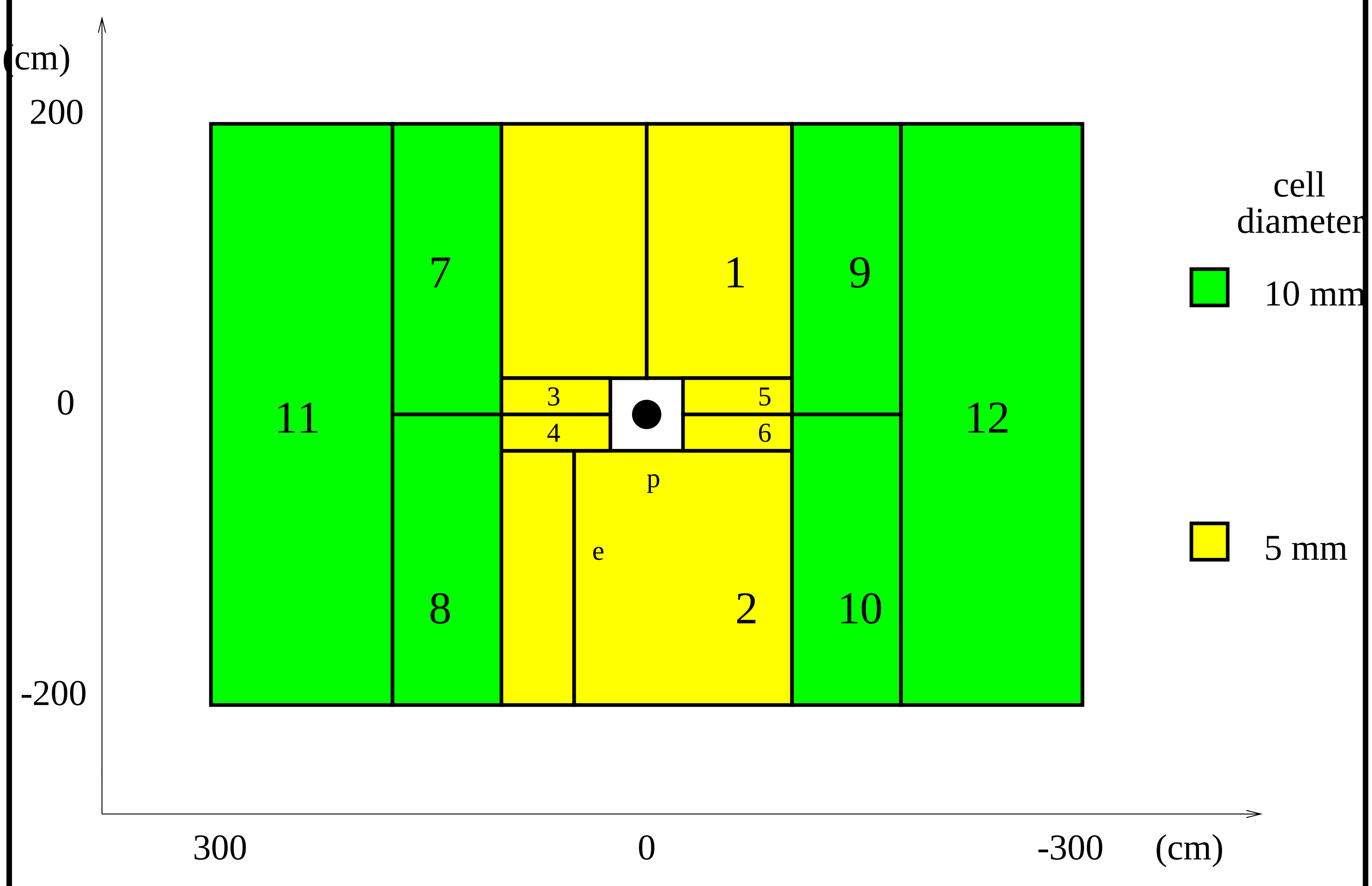
Reconstructed interaction vertices on 8 wires

HERA-B main tracking - Outer Tracker

Measures charged tracks in almost the whole geometrical acceptance.



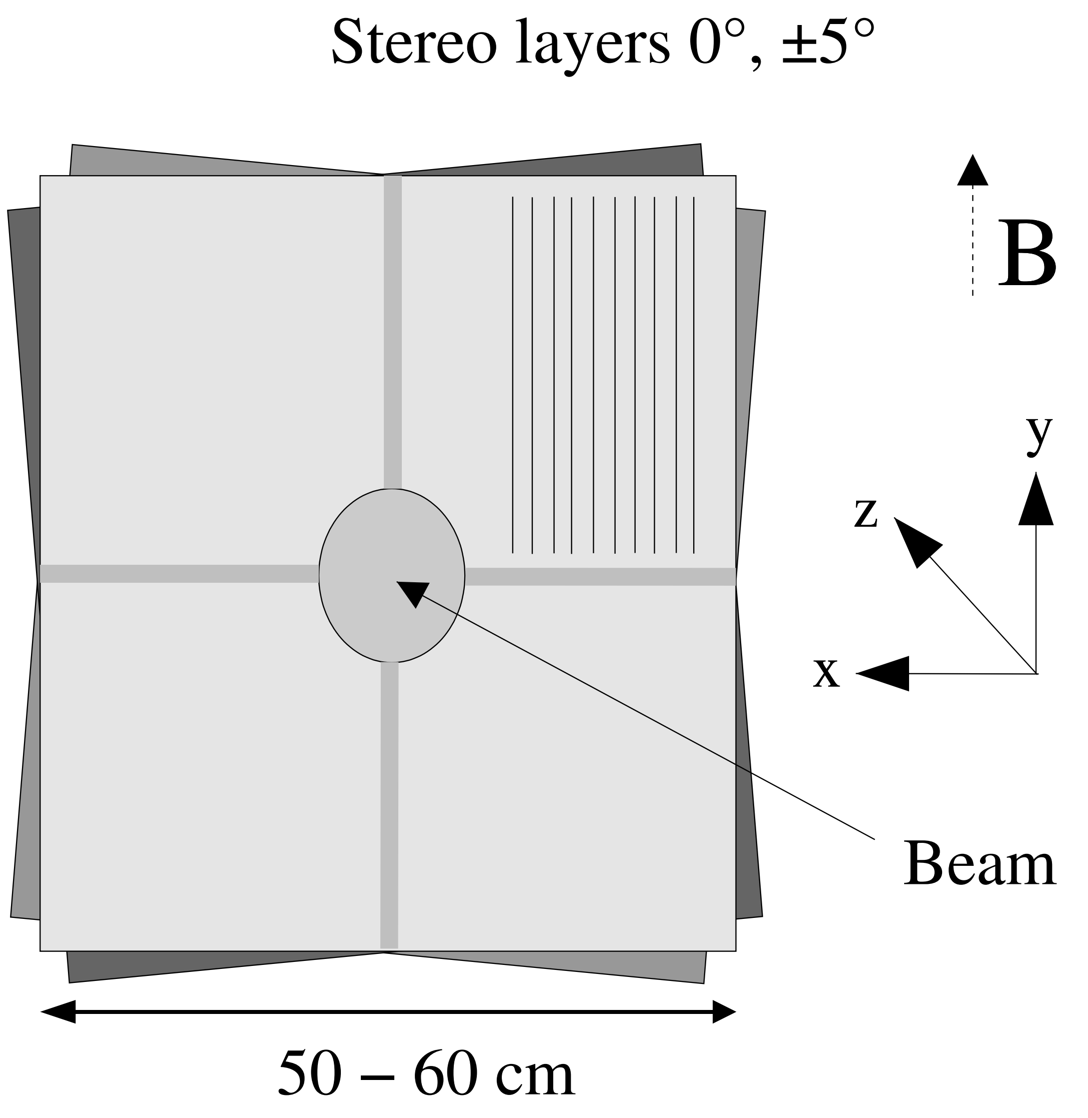
Based on honeycomb drift chamber of two sizes, 5 mm and 10 mm, and different wire lengths to cope with a strong angular dependence of particle flux density

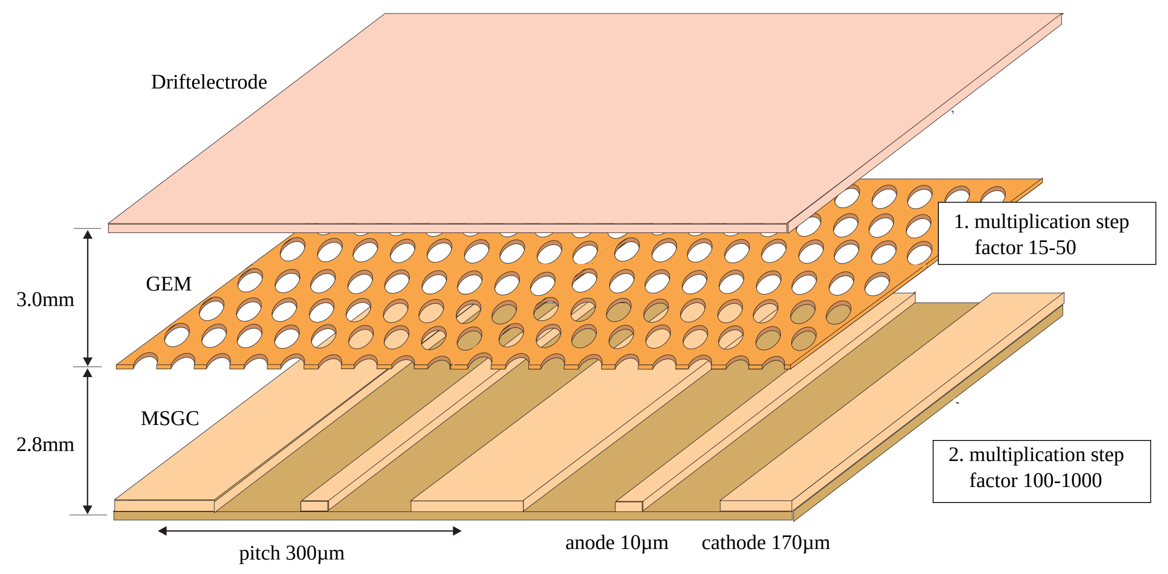


- 1000 m^2 of honeycomb drift chambers
- high radiation environment
- several fatal aging problems had to be solved
- first large area detector working in a LHC like environment

HERA-B main tracking - Inner

Inner tracker: tracking close to the beam pipe and input for the FLT.





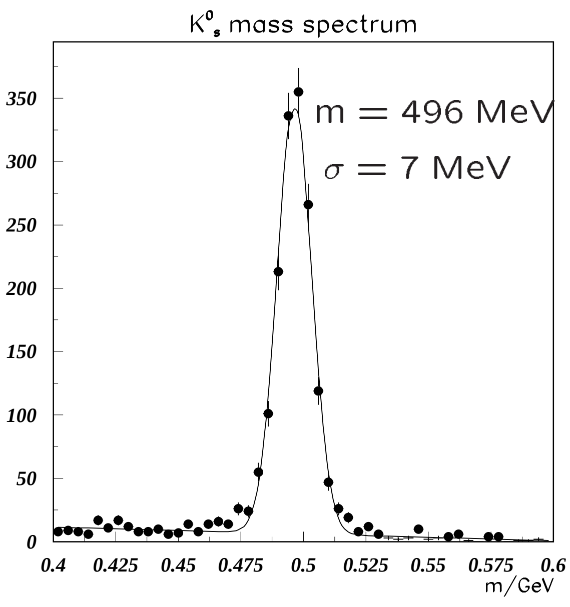
- MSGC-GEM detectors cover the region 6-25 cm around beam-pipe
- challenge: particle rates up to 2×10^6 cm^{-2} s^{-1}

Careful operation is required.

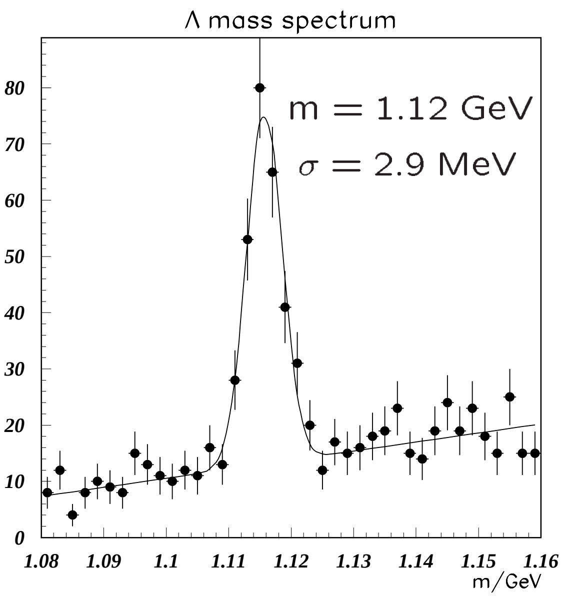
- single hit efficiency 90–96 % (design: 98%)
- hit resolution $\approx 100\mu$m (design: $\approx 80\mu$m)

Tracking: K_S^0 and Λ Signal

$K^0 \to \pi\pi$



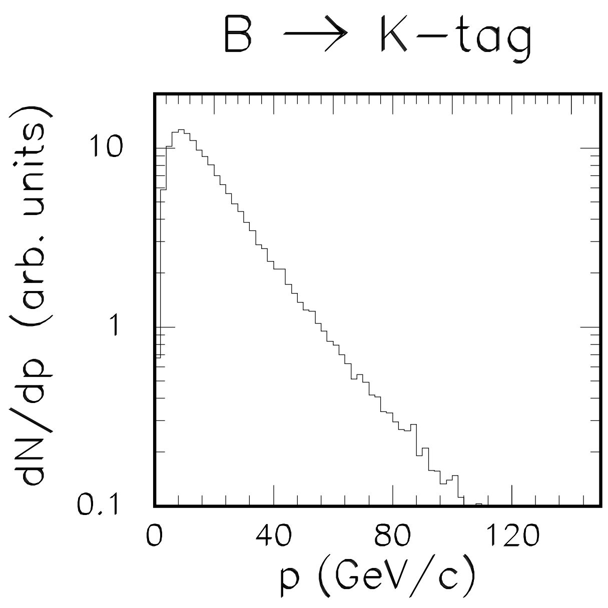
$\Lambda \to p\pi$



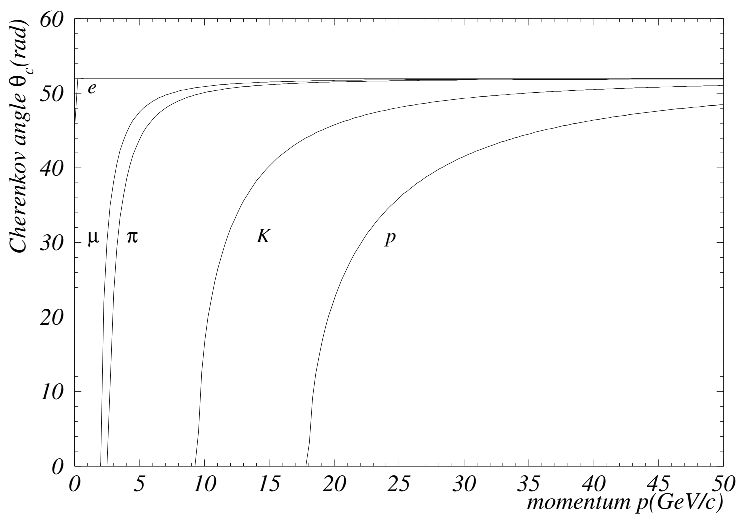
Selection involves vertex and tracking detectors.

HERA-B RICH

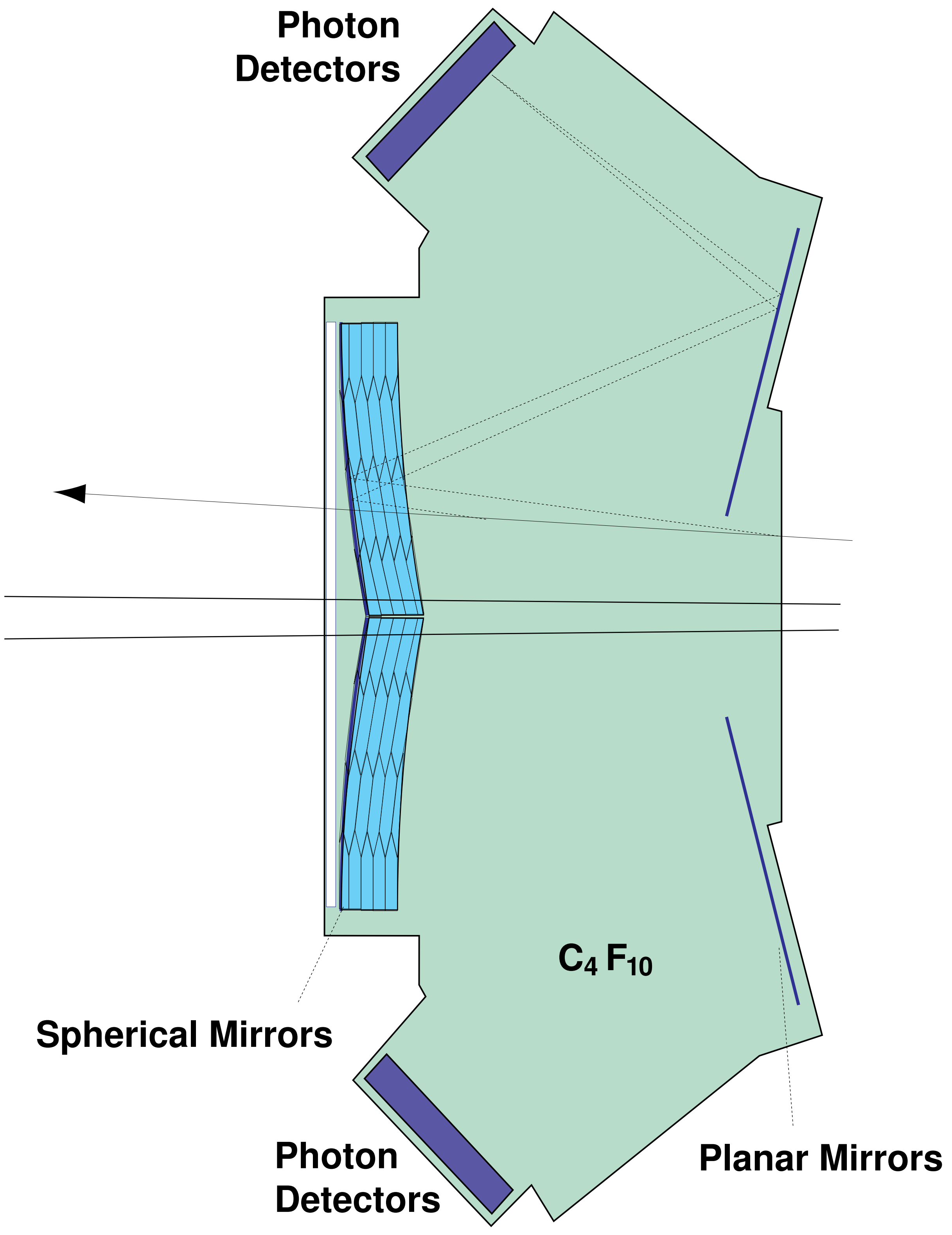
- Provide tagging K identification up to about 50 GeV/c



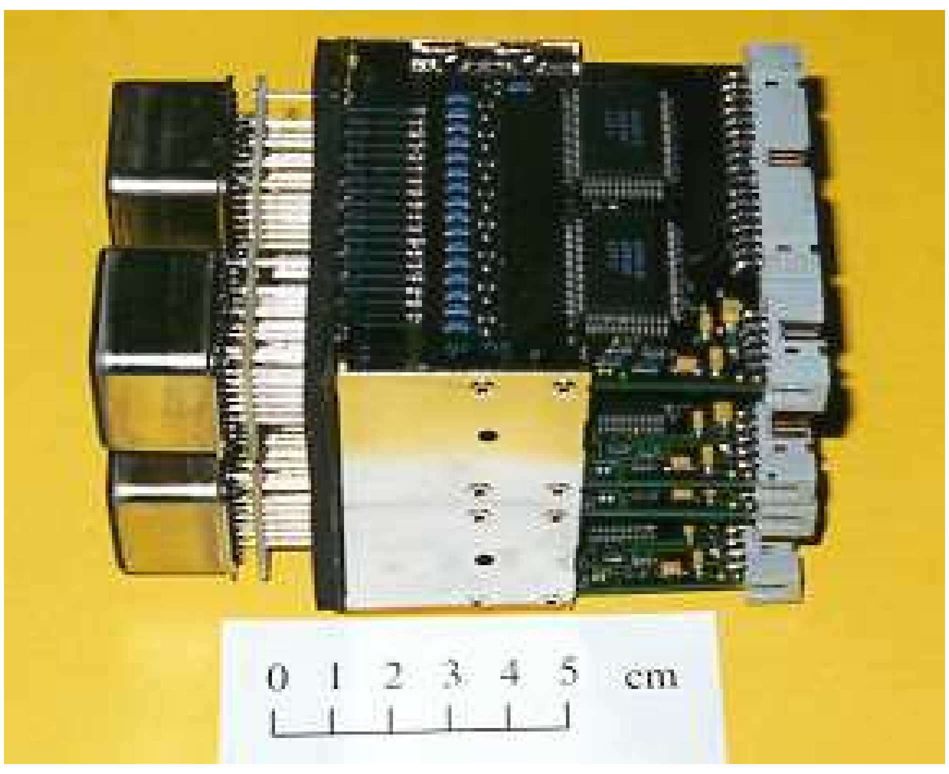
- Single radiator is enough: C_4F_{10}



HERA-B RICH

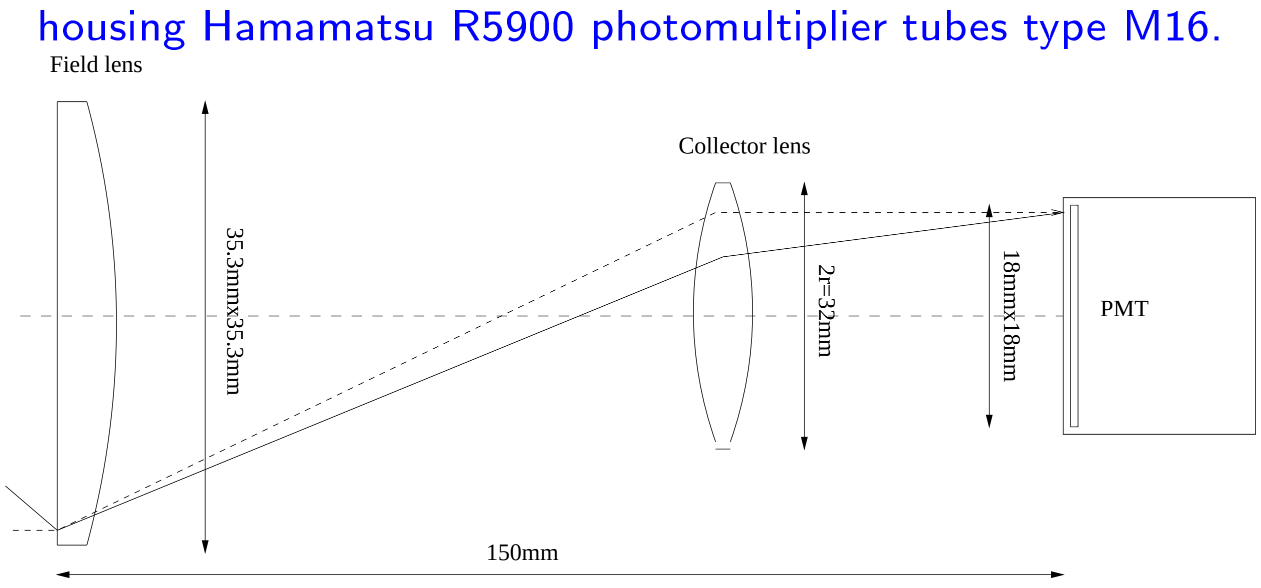

Photon
Detectors
Spherical Mirrors
$C_4 F_{10}$
Photon
Detectors
Planar Mirrors

HERA-B RICH, 1



Fully equipped photomultiplier basic module

housing Hamamatsu R5900 photomultiplier tubes type M16.

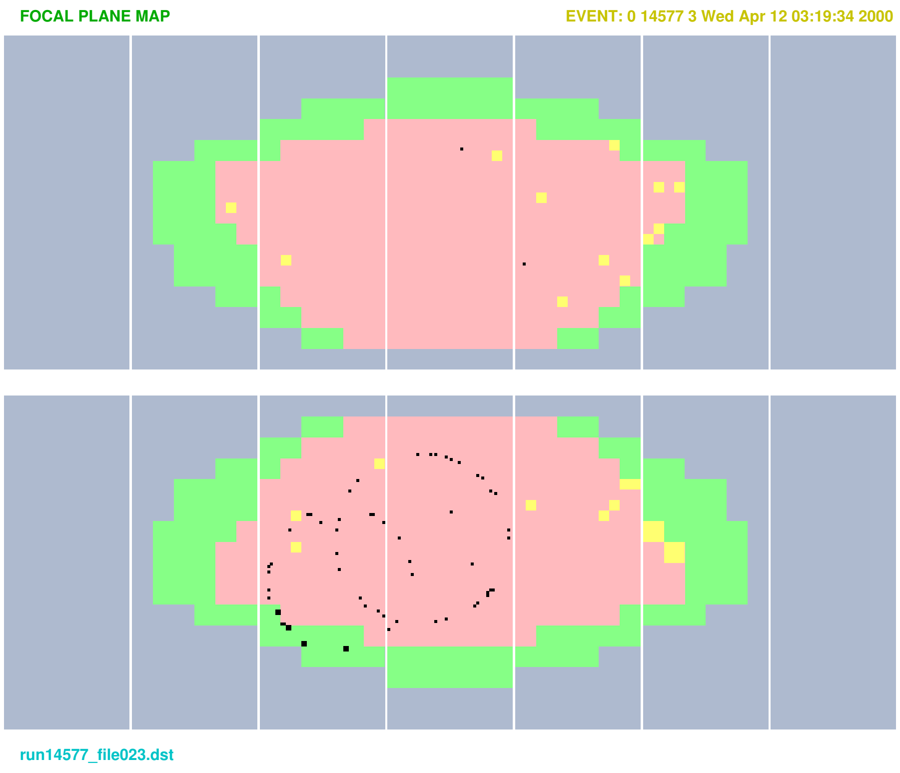


Light collection system for each PMT

Basic photon detector module →

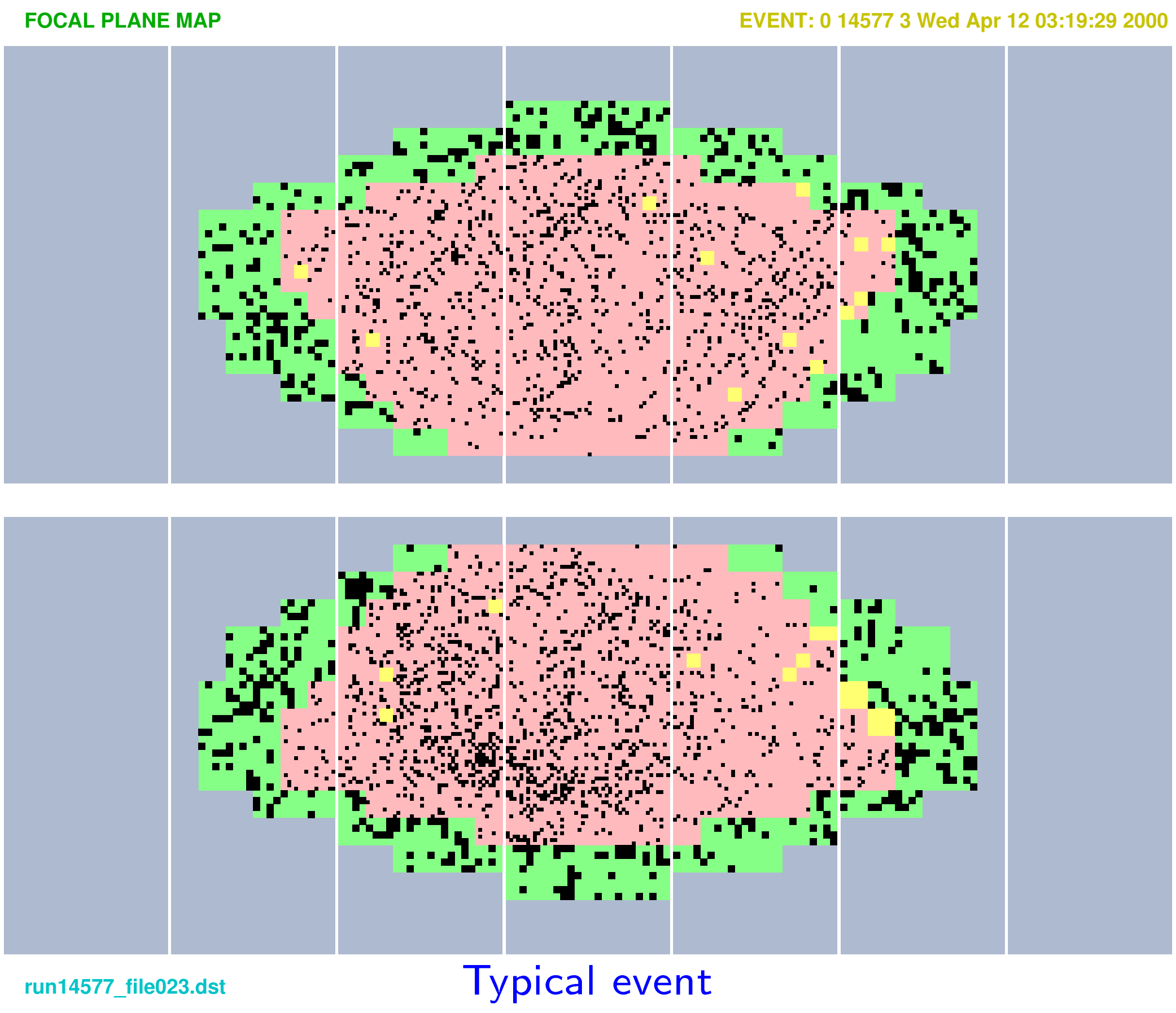
To match the variation in occupancy and reduce the cost two multianode PMT types are employed, 16 and 4 channel versions of R5900. →

- RICH performance: clear rings, no noise



HERA-B low occupancy background event

HERA-B RICH

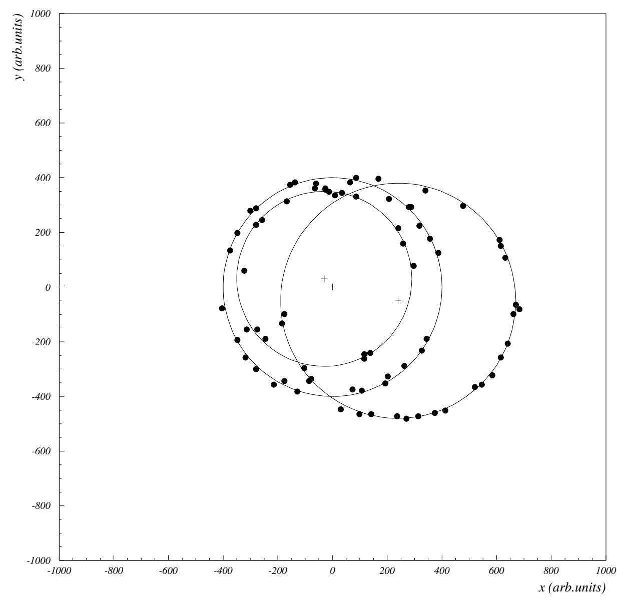


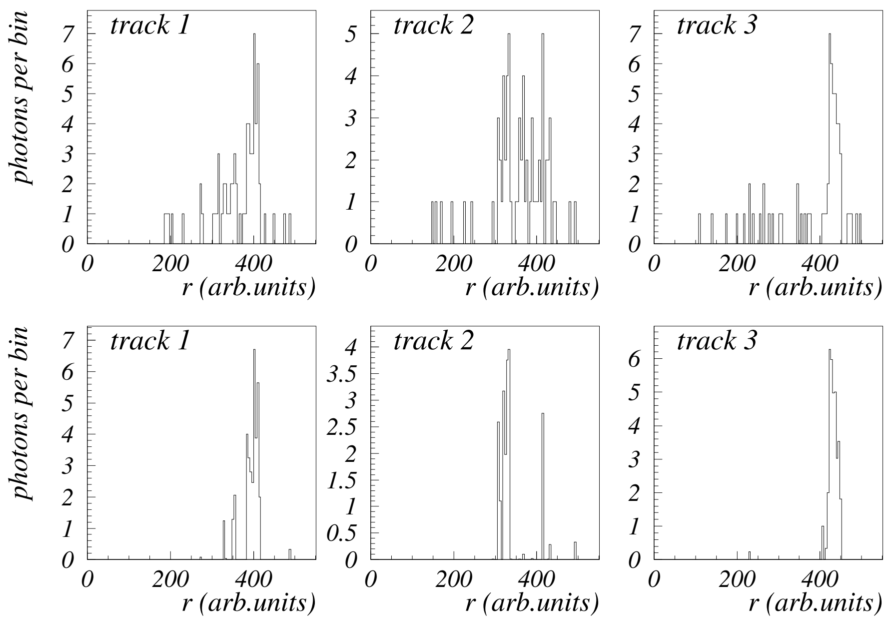
Typical event

- Typical rates: 1MHz in the hottest part
- In operation since summer 1998
- No degradation of performance has been observed

HERA-B RICH analysis

A new tool, an iterative pattern analysis was developed for such highly overlapping rings. Example:





HERA-B RICH Performance

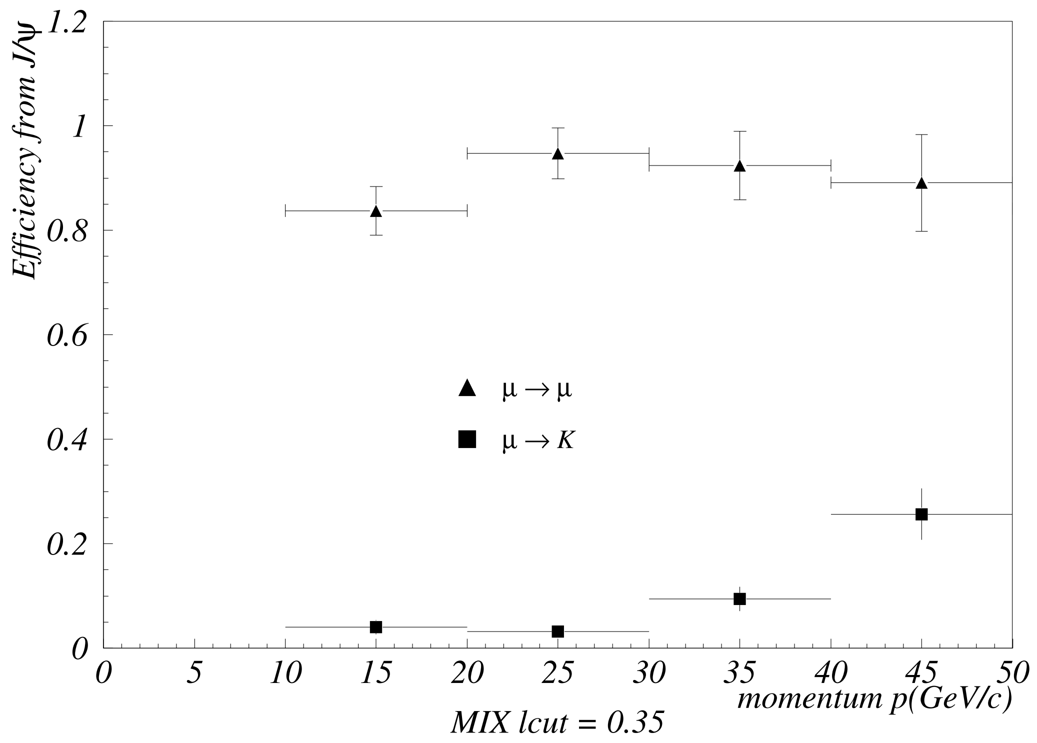
- RICH parameters:

  $N_0 = 43cm^{-1}$

  Number of photons $=$ 32 per saturated ring

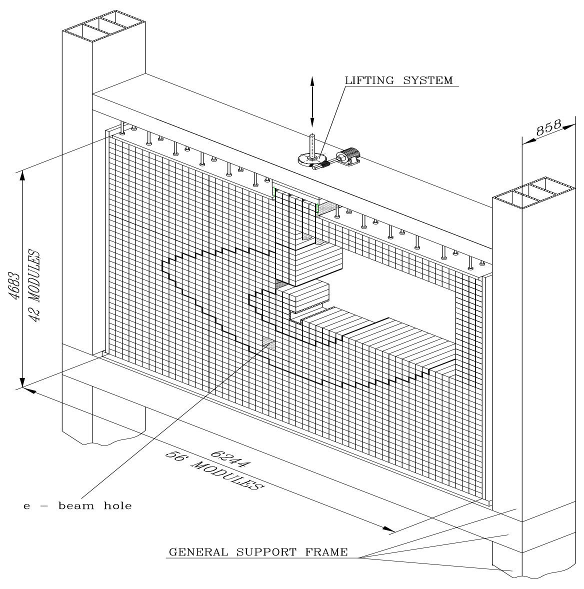
  Resolution $=$ 0.7 mrad (M16), 1.0 mrad (M4)

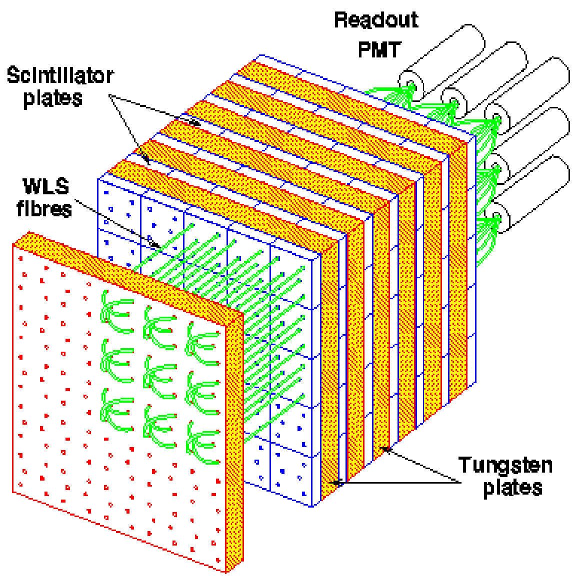
- $\rightarrow$ in very good agreement with expectations



- Particle identification efficiency as determined from $J/\psi \rightarrow \mu\mu$ decays

Electromagnetic Calorimeter



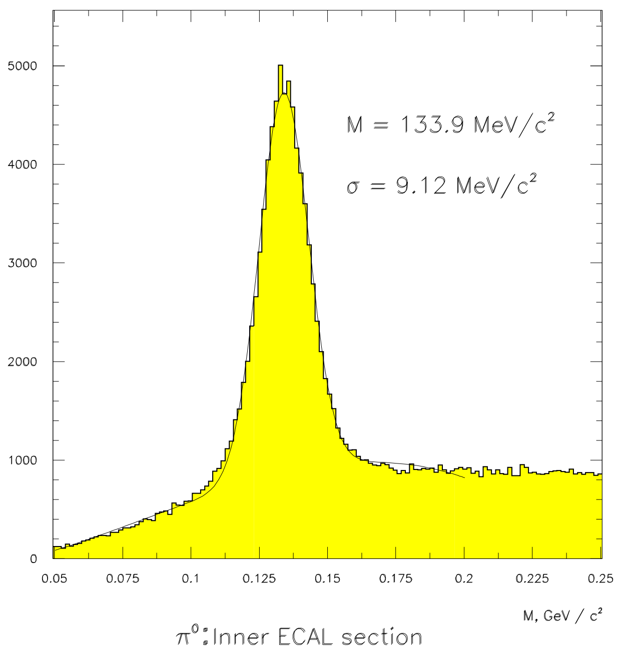


Measures photon energy, discriminates hadrons against electrons and gives electron pretrigger.

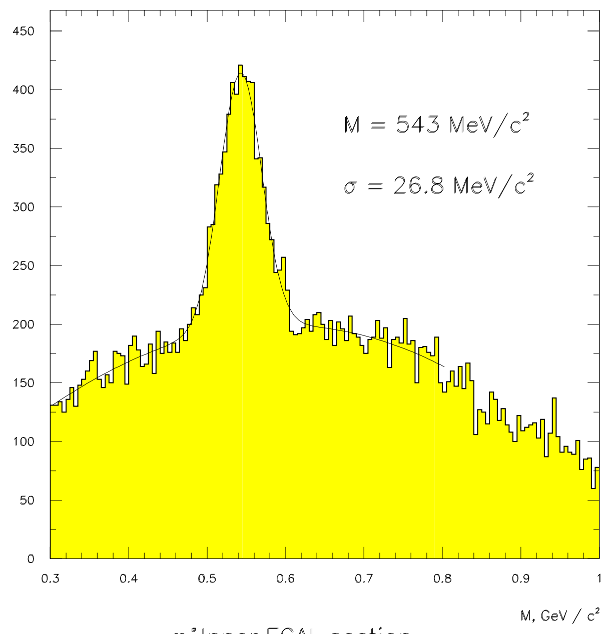
- shashlik sampling calorimeter
- 3 granularities to match occupancies

ECAL performance:

- $\frac{\sigma(E)}{E} = 1.7\% \oplus \frac{22.5\%}{\sqrt{E}}$ $(design : \frac{\sigma(E)}{E} = 1.5\% \oplus \frac{17\%}{\sqrt{E}})$
- stable operation



π^0: Inner ECAL section

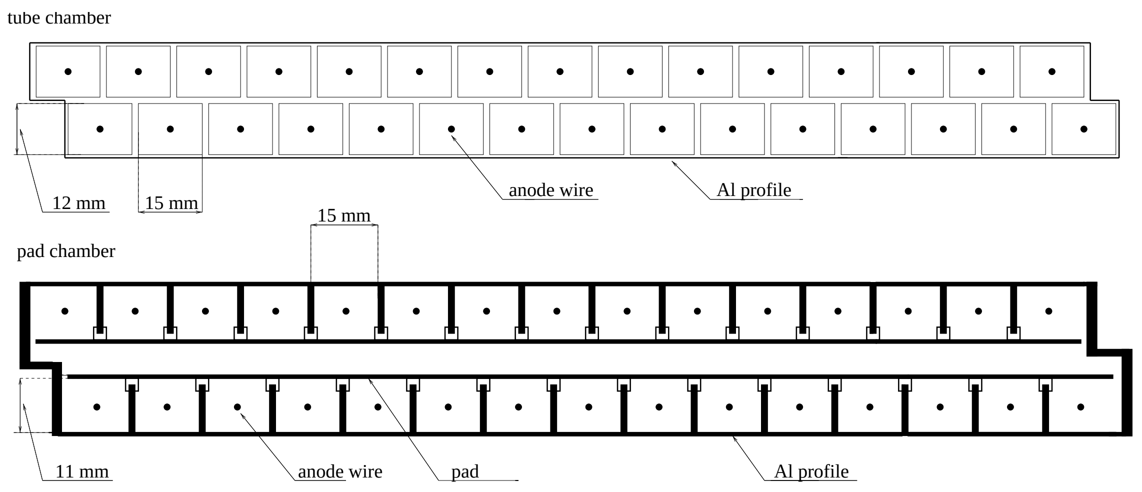


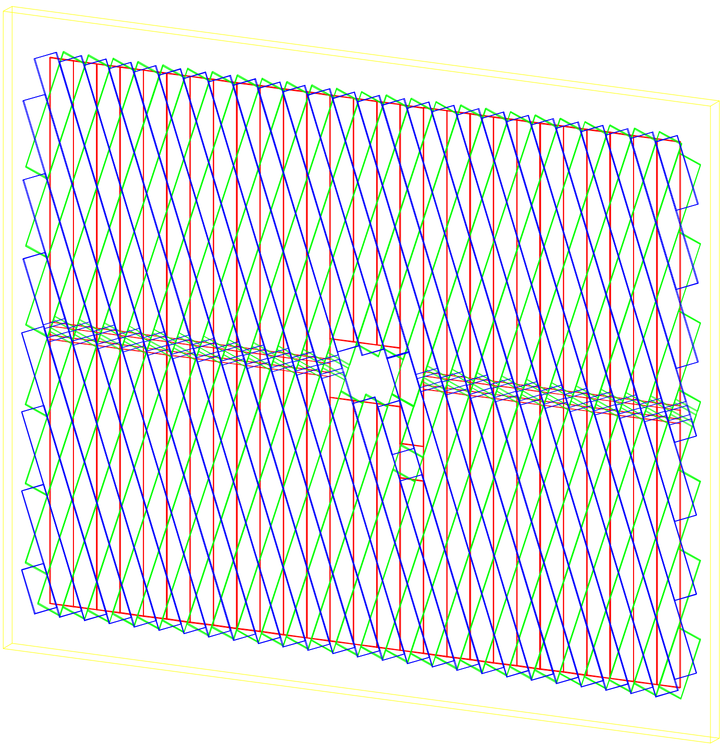
η: Inner ECAL section

Invariant mass of two photons.

Muon Detector

- Separates muons from hadrons and gives muon pretrigger.
- 4 layers of detector elements (tube, pad and pixel chambers) embedded in iron absorbers





Multi-level trigger scheme

Huge background of inelastic proton-nucleon scattering over the signal (10^{11}): need a highly selective and efficient trigger.

0 pretrigger, define regions of interest corresponding to high p_T particle
- calorimeter, muon system, tracking system
- latency: 5 μs
- rate reduction: -

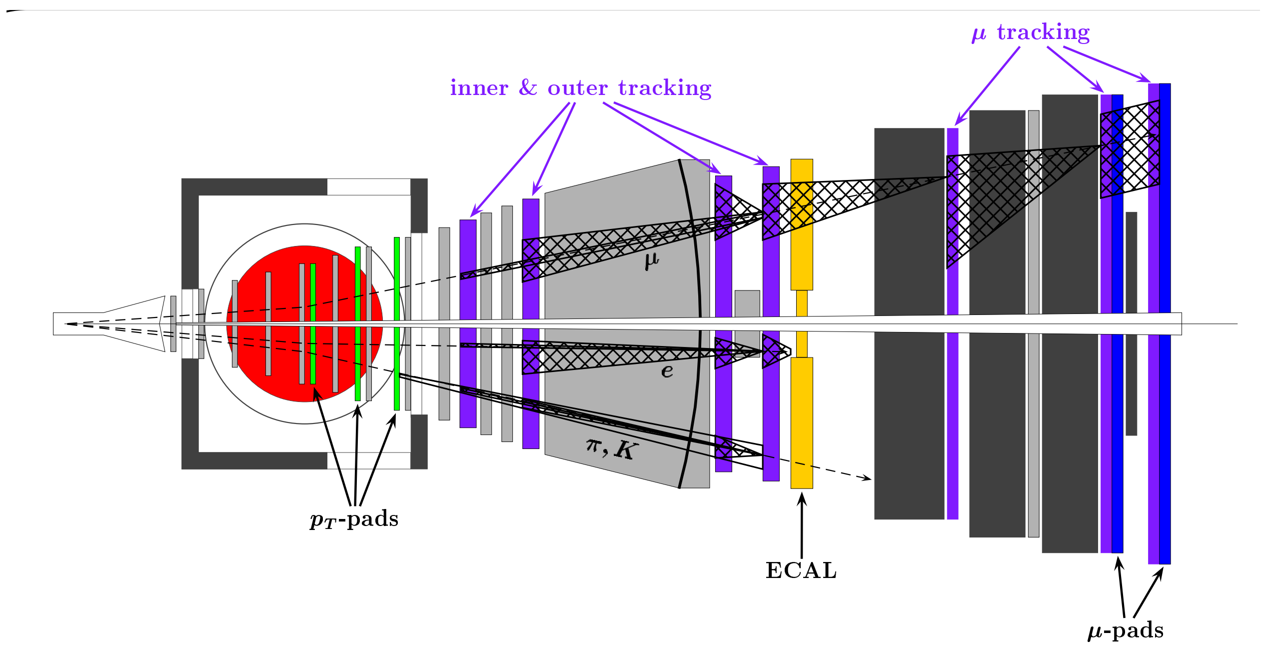
1 pattern recognition, track reconstruction, J/ψ mass
- calorimeter, muon system, tracking system
- latency: 12 μs
- rate reduction: 200

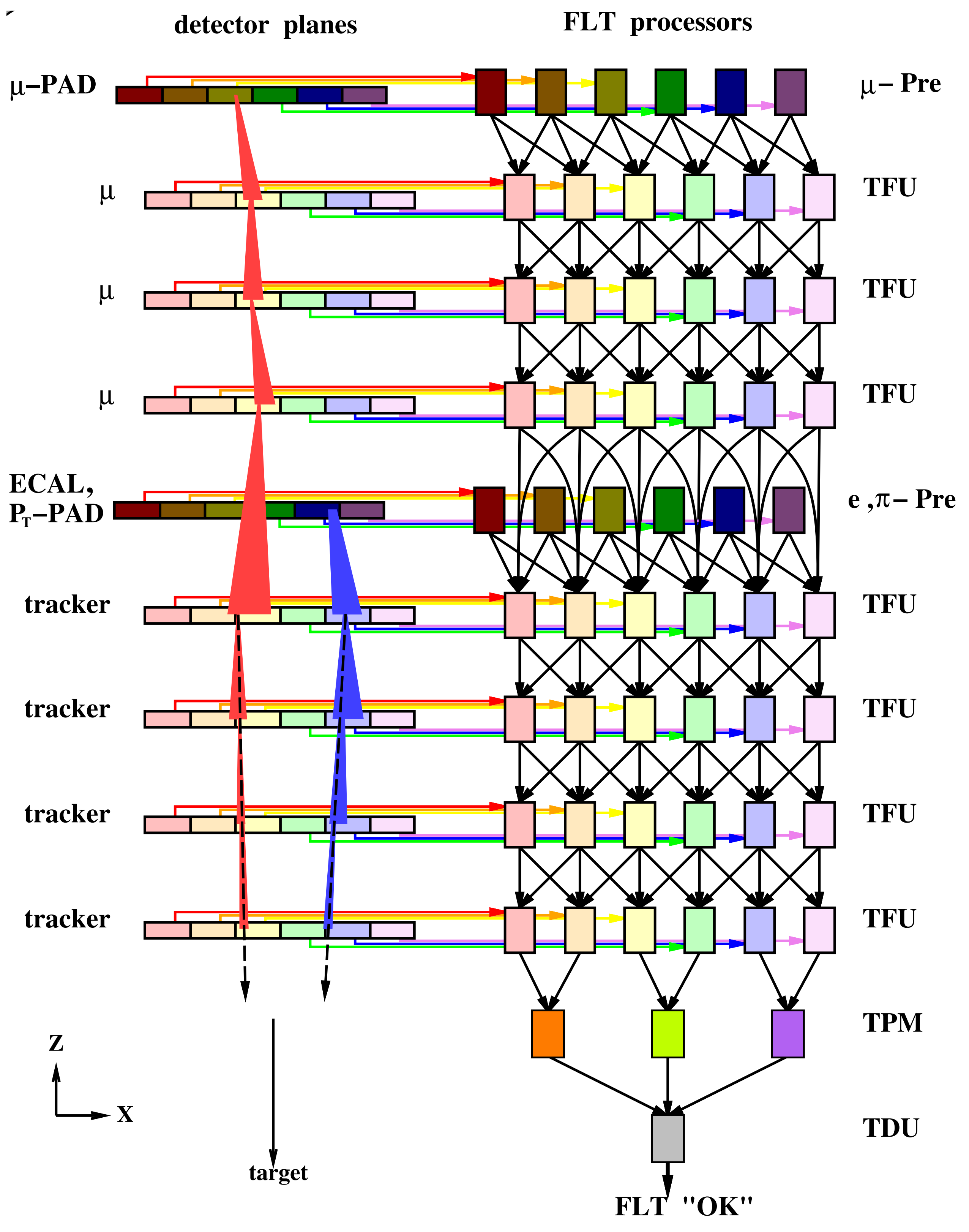
2 track fitting, common vertex/impact parameter
- tracking system, vertex detector
- latency: 5-50 ms
- rate reduction: 100

3 match information, global refit
- latency: 100 ms
- rate reduction: 10

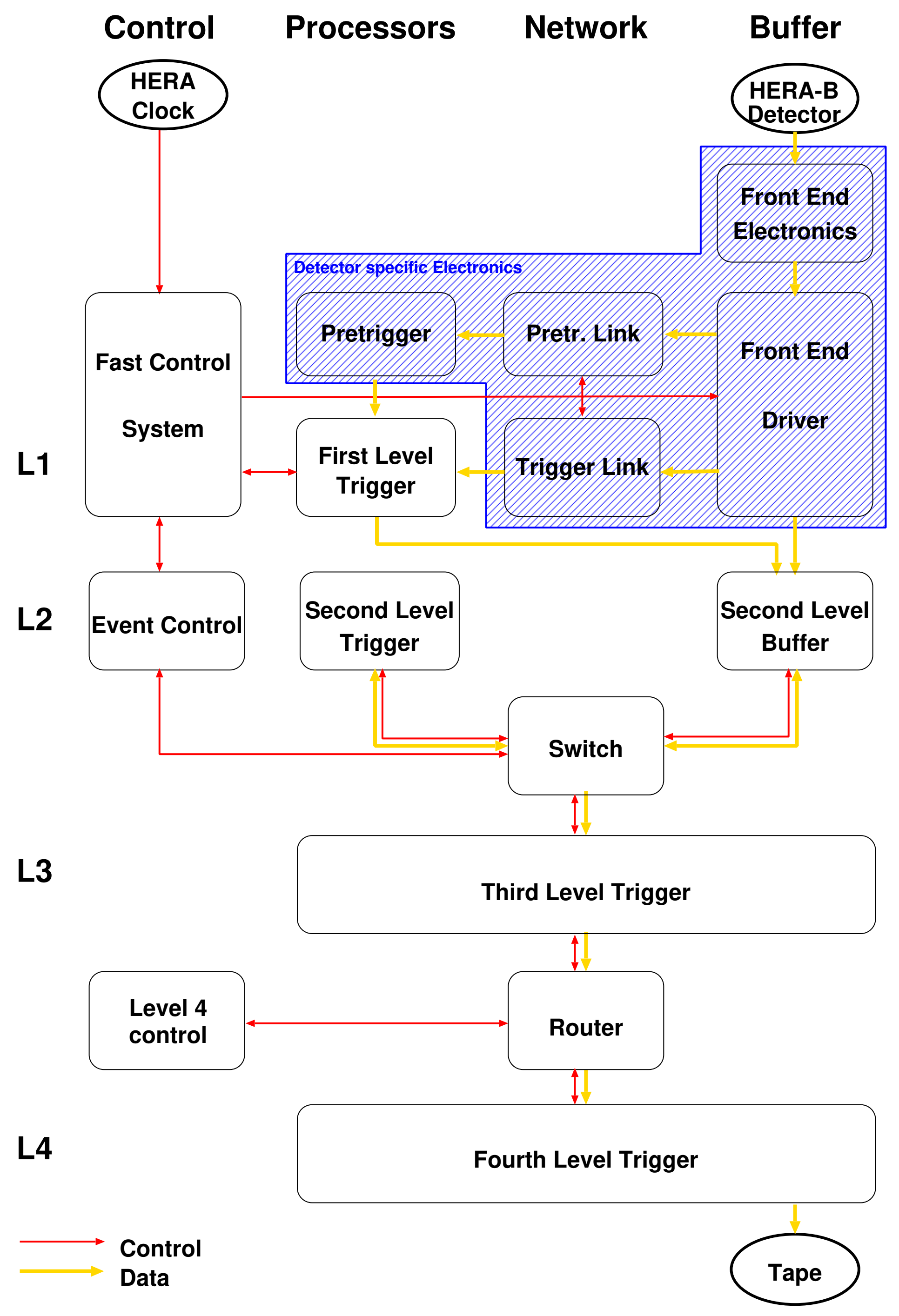
4 complete event reconstruction
- latency: 4 s
- rate reduction: -

HERA-B Trigger Level 1




detector planes
FLT processors
μ–PAD
μ– Pre
μ
TFU
μ
TFU
μ
TFU
ECAL,
P_T–PAD
e ,π– Pre
tracker
TFU
tracker
TFU
tracker
TFU
tracker
TFU
TPM
Z
X
TDU
target
FLT "OK"

HERA-B Trigger + DAQ



HERA-B Trigger Levels 2, 3, 4

Hardware:

- Levels 2, 3:

2500 digital signal processors (SHARC)
240 Pentium processors

- Level 4:

200 CPUs (Dual-Pentium)

Problems in 2000 running

- Outer tracker
  - hit resolution $\sigma \approx 500\mu$m (design 200 μm)
  - hit efficiency $\epsilon \approx 90\%$ (design 98%)
- Inner tracker
  - hit efficiency 90–96 $\%$ (design: 98%)
  - hit resolution $\approx 100\mu$m (design: $\approx 80\mu$m)
- Muon chambers
  - muon pretrigger provided a good J/ψ signal
  - however: hit efficiency of pad chambers (essential for pretrigger - fourfold coincidence) had large variations.
- First level trigger
  - $\rightarrow$ first level trigger efficiency much below the design value (e.g. 20% for single muons, 54% for single electrons, instead of 90%)
  - lepton pair trigger could only be run with the second lepton added in the second level trigger
- Unfortunately, at this stage of commissioning, the running had to be stopped because of the luminosity upgrade of the HERA machine.

HERA-B status, plans

The luminosity upgrade of the HERA collider (Sept. 2000 - July 2001) is finished, the commissioning of the machine has started.

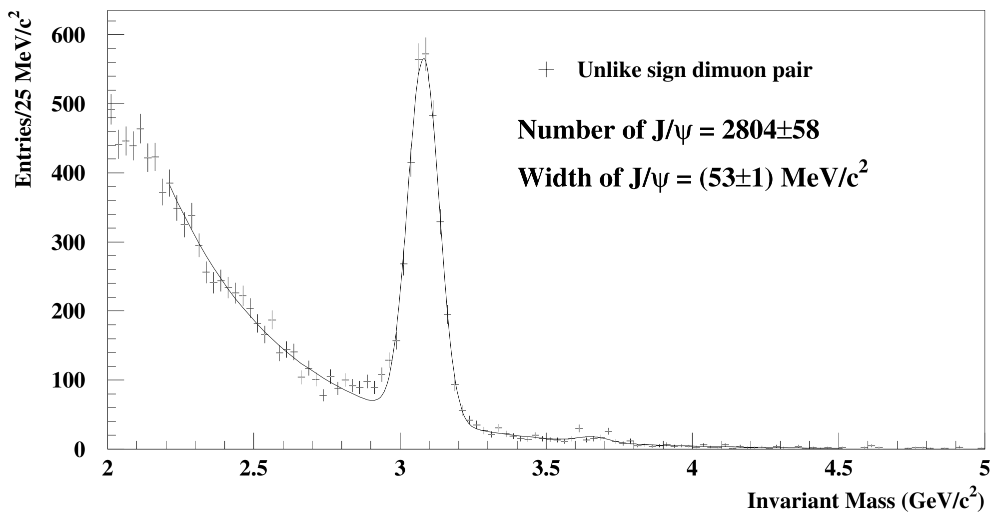
During this time HERA-B was not idle: most of the subdetectors were upgraded or repaired according to the experience of the 2000 running period.

Particular care:

- understanding the low efficiency of the first level trigger (FLT)
- relaxing requirements on the number of hits along the track, adding an additional trigger veto based on the multiplicity in RICH

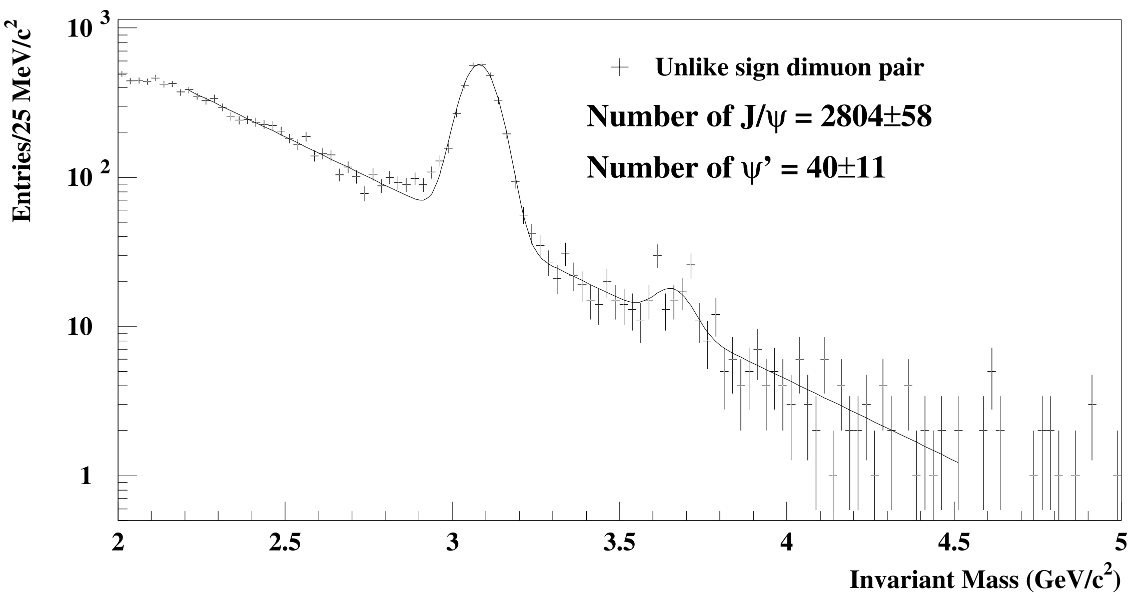
Physics program for 2001/02

- detector is optimized for events containing two high-p_T leptons
- due to late start of operation and a lower efficiency than expected, HERA–B is not competitive in measurement of CP violation
- in 2001/2002 concentrate on measurements of reactions which contain J/ψ
  - nuclear dependence of charmonium production
  - measurement of $b\bar{b}$ cross-section



The di–muon invariant mass spectrum.

J/ψ Yield



Continuum consists dominantly of combinatorial background from π and K decays in flight.

In 2001/2002 we expect a rate of recorded $J/\psi \to \mu\mu = 1500/\text{hour}$. Accordingly, we shall have $(0.5 \times 10^7) \times \frac{1500}{3600} = 2.1\,\text{M}\; J/\psi$ events

Nuclear Dependence of Charmonium Production

- Strong suppression of the yield per nucleon of heavy vector mesons in proton-nucleus, pion-nucleus, and heavy ion collisions is observed in heavy nuclei compared to light nuclei.

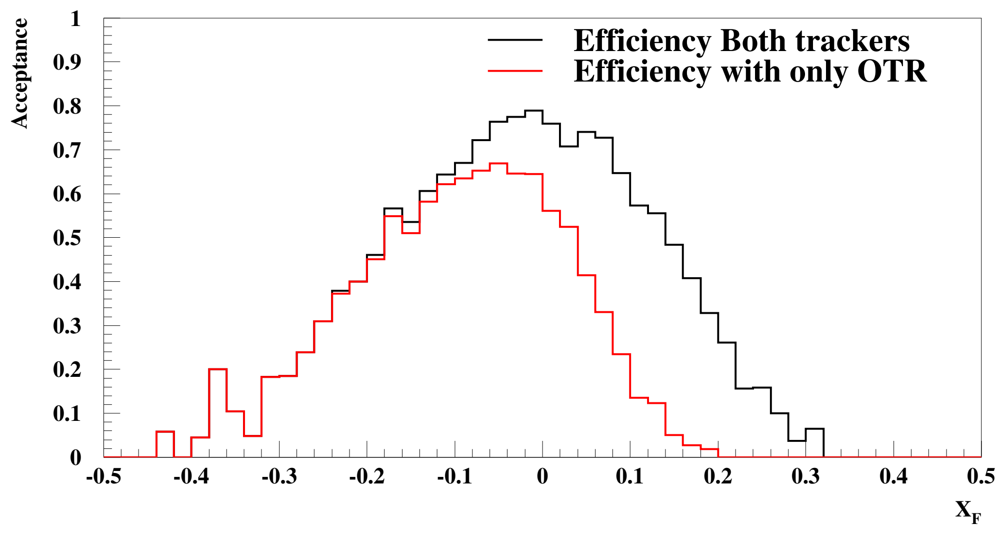
  $$\sigma = \sigma_n \times A^{\alpha} \quad \alpha < 1$$

  α can be determined comparing J/ψ yield for various nuclei. α strongly depends on x_F and p_T. ψ' is more suppressed than J/ψ. Various mechanisms can contribute to the suppression.

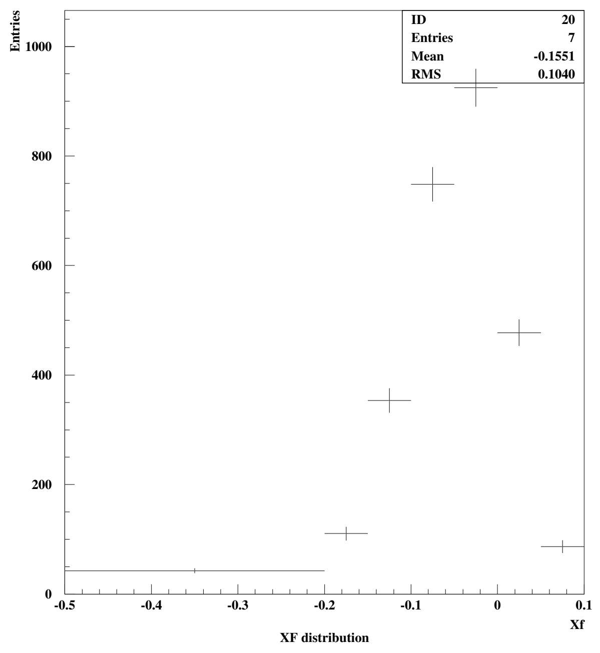
- Better understanding of J/ψ suppression in pN collisions can shed more light on observed anomalously strong suppression in Pb–Pb collisions.

- Existing data from other experiments are restricted to $-0.1 < x_F < 0.95$.

HERA–B can measure $J/\psi, \psi'$, $\chi_c \to J/\psi\gamma$ production in region $-0.4 < x_F < 0.3$



HERA–B acceptance for $J/\psi \to \mu\mu$ as determined from MC.



x_F distribution in the 2000 run data.

Measurement of $\sigma_{b\bar{b}}$

Two existing measurements (E771 and E789) of $\sigma(pA \to b\bar{b}X)$ in the kinematic region around 800 GeV proton beam energy differ by a factor of 7.

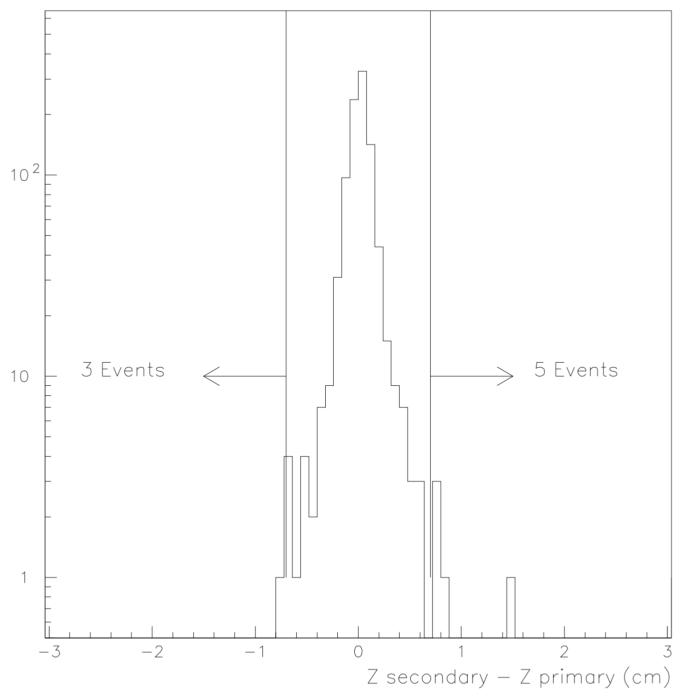
HERA–B measurement will be based on a comparison of inclusive $b \to J/\psi X$ with direct J/ψ production.

The resulting $\sigma_{b\bar{b}}$ will have statistical accuracy of about $5 - 10\%$.

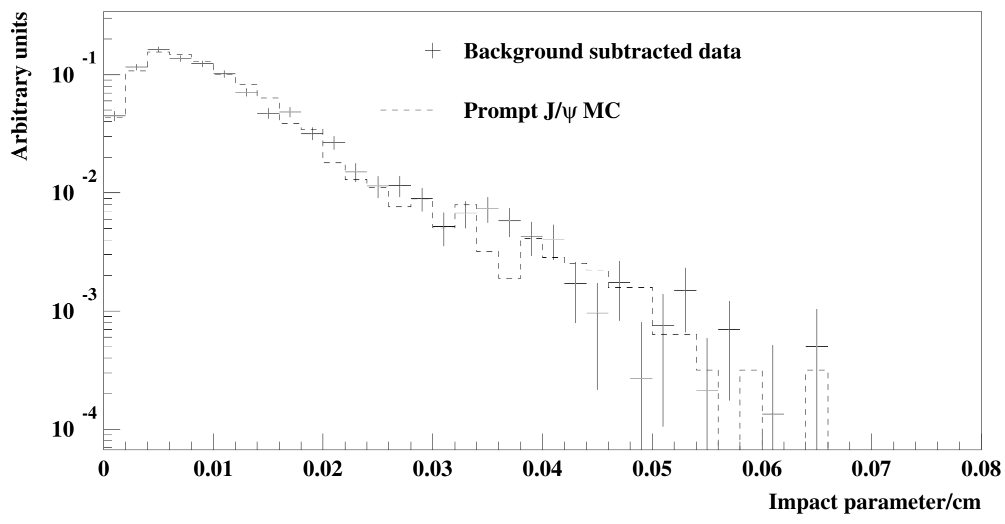
Systematical error:

- b momentum estimate $< 8\%$
- experimental error on $\sigma_{J/\psi}$

2000 data:



The decay length distributions in J/ψ mass region.



Impact parameter distribution for muons from J/ψ: agreement of 2000 data and MC for prompt J/ψ.

HERA-B summary

HERA–B is a large experiment working in a LHC like environment.

The operation of most of the subsystems is stable and reliable, but in some critical cases the efficiencies are below the design values.

The main goals for 2001/2002 are:

- upgrade and repair during the 2001 shut–down (inner tracker, outer tracker, muon system) $\rightarrow$ done
- final commissioning of the detector, in particular the trigger
- measurement of:
  - nuclear dependence of charmonium production
  - B cross section
- Find a competitive physics program for 2002$\rightarrow$

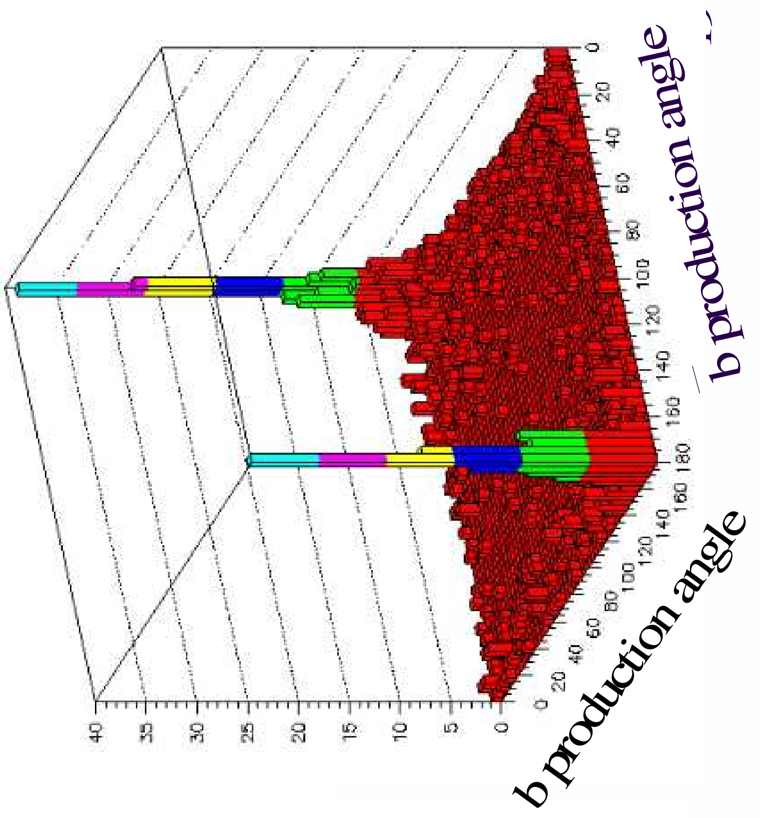
BTeV - a second generation

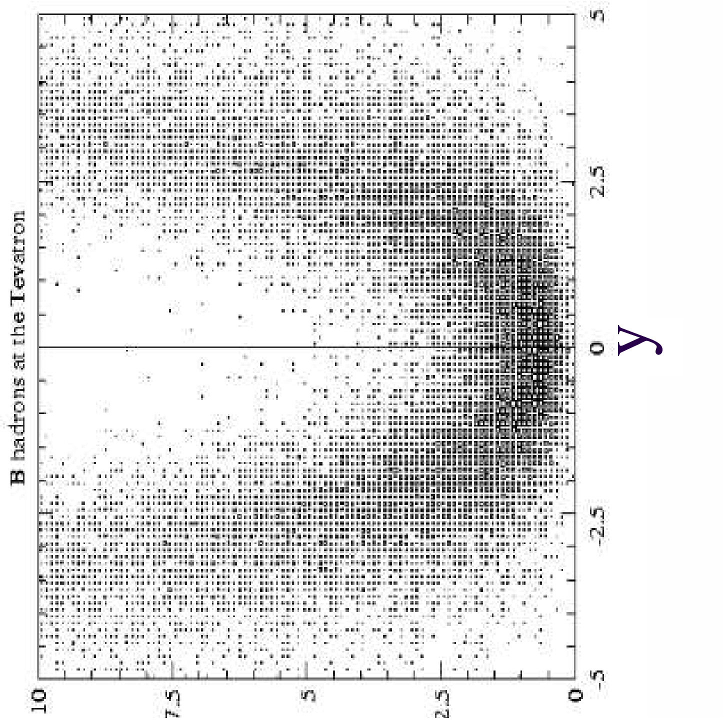
B factory

Motivation

- B factories will establish evidence for CP violation in B decays
- Several questions will remain open due to lack of statistics, and restricted final states
- Goals: high precision measurements of CP parameters γ, α, χ, in decays of B^0, $B^{\pm}$, B_s mesons, as well as search for new physics in rare and FCNC decays

BTeV - $b\bar{b}$ production

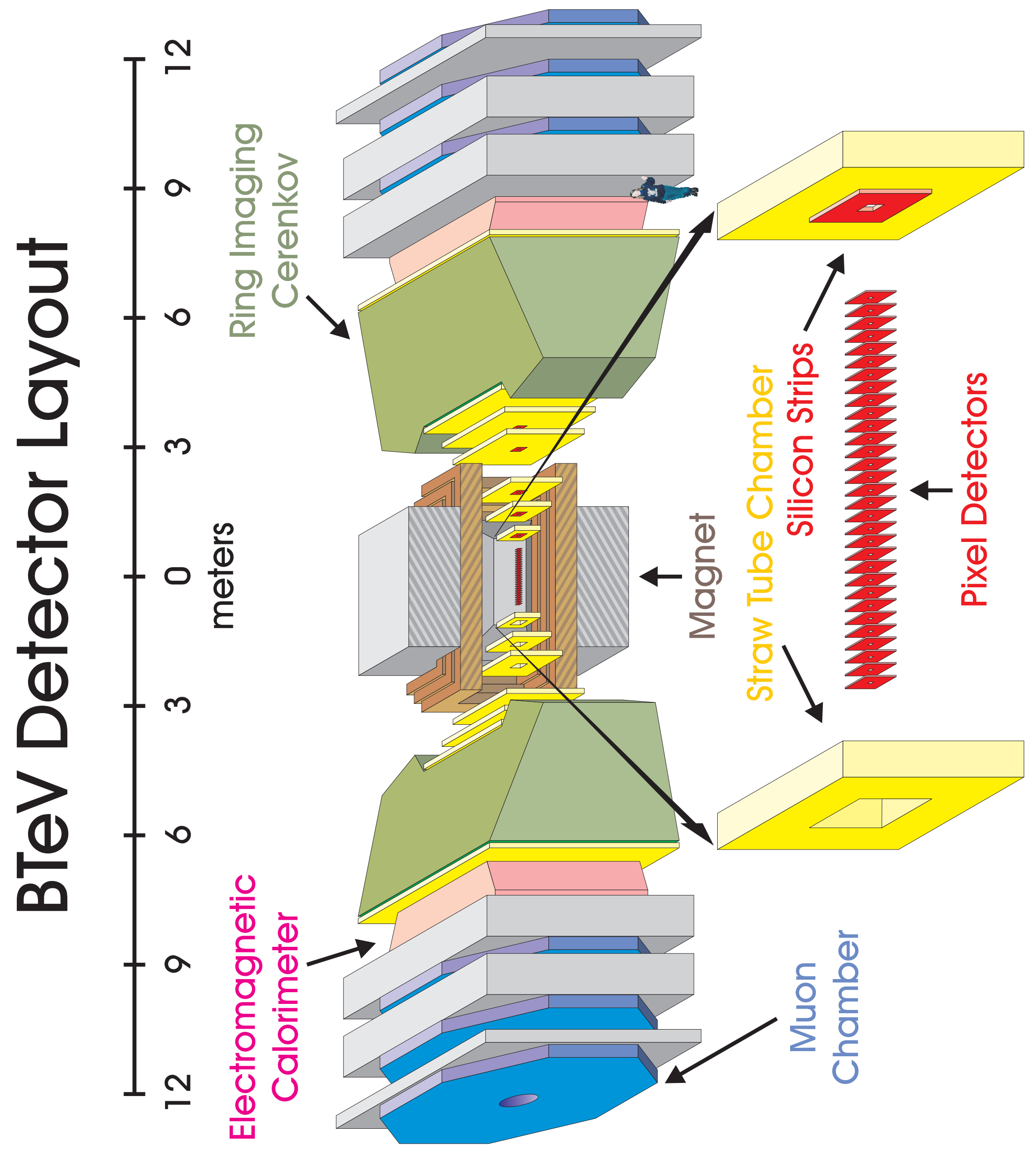




BTeV - requirements

- Efficient trigger for hadronic B decays
- High resolution vertex detector (B_s oscillations)
- Excellent PID system and high resolution electromagnetic calorimeter (π^0 reconstruction)
- Survive high interaction rates
- Allow for a high capacity DAQ system

BTeV layout


BTeV Detector Layout
12
9
6
3
0
3
6
9
12
meters
Ring Imaging Cerenkov
Magnet
Straw Tube Chamber
Silicon Strips
Pixel Detectors
Electromagnetic Calorimeter
Muon Chamber

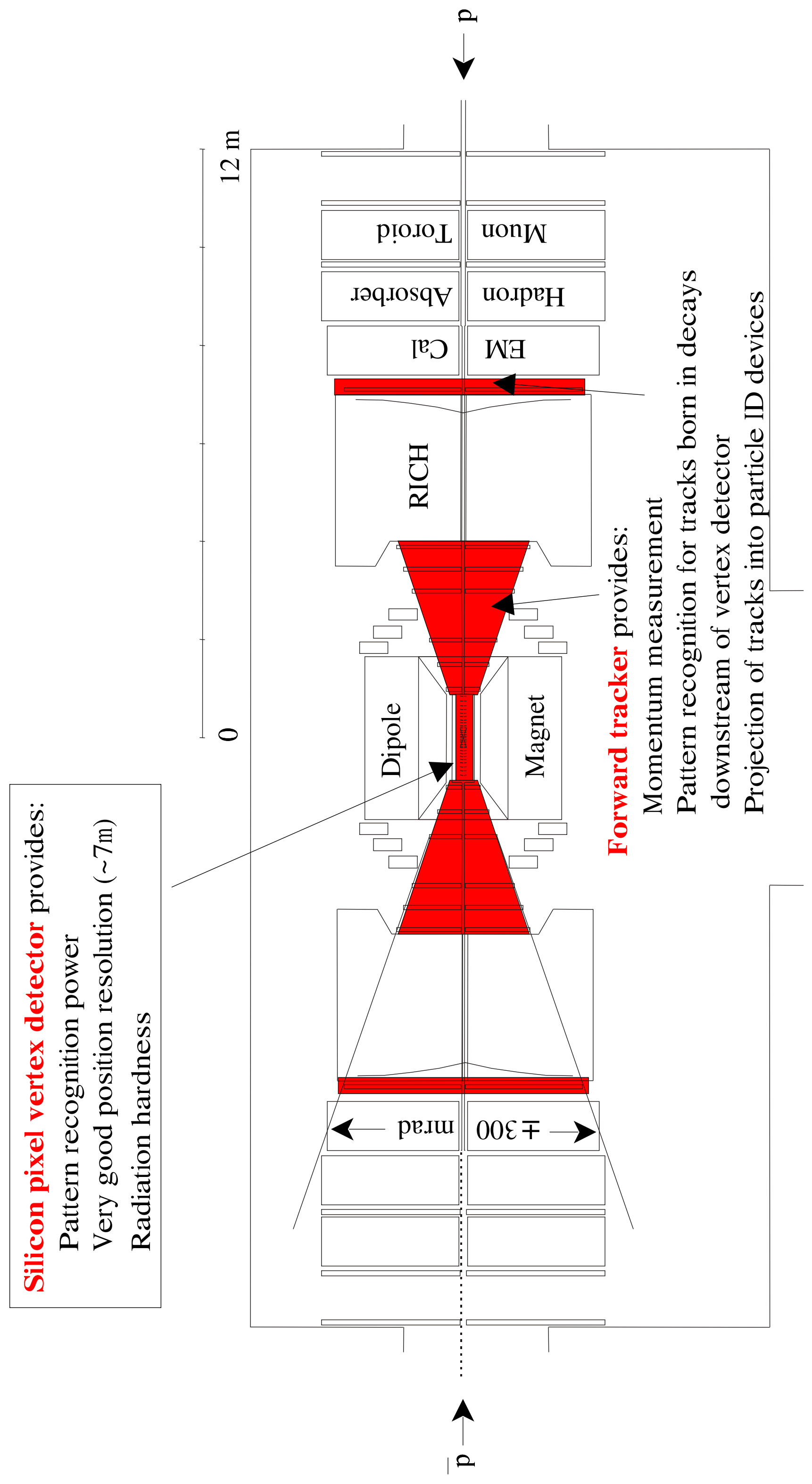
BTeV tracking

- Vertex: pixel detectors
- Tracking: straw-tube chambers
- Tracking close to beam pipe: silicon strip detectors

Pixel detectors

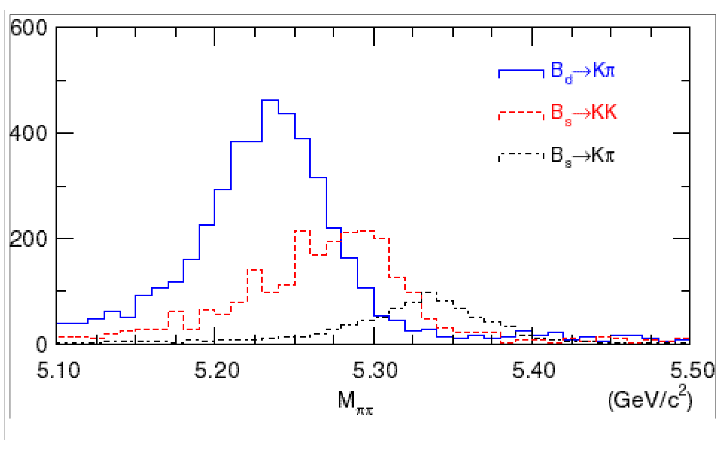
- Essential to eliminate ambiguity in the high track density region
- Provides the detached vertex trigger
- Low noise
- Read-out electronics: radiation hard due to the deep submicron process used

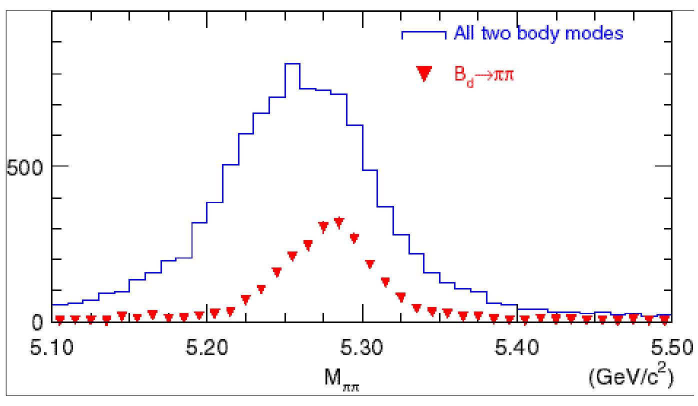
BTeV tracking



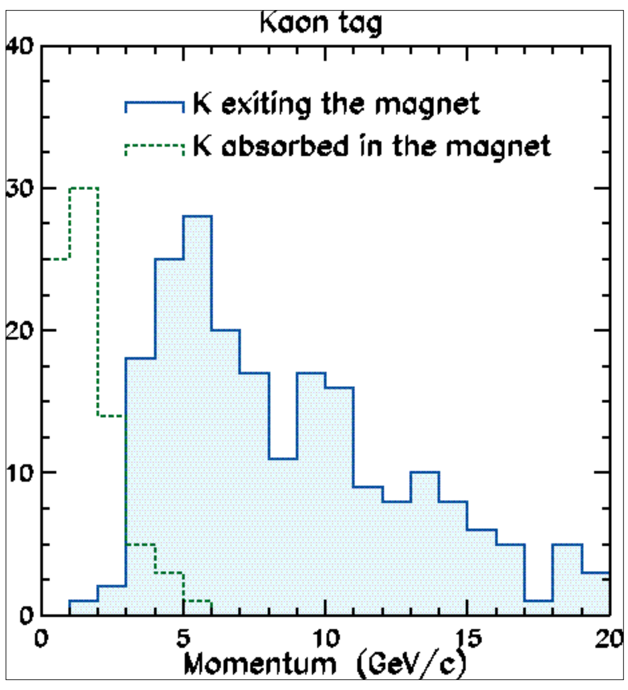
BTeV hadron PID

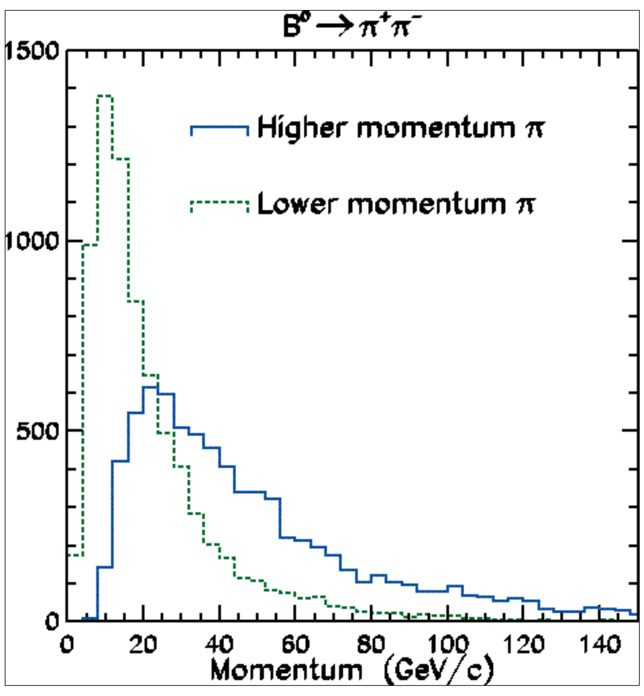
- Needed: for kaon tagging, and for $B \to \pi^+\pi^-$





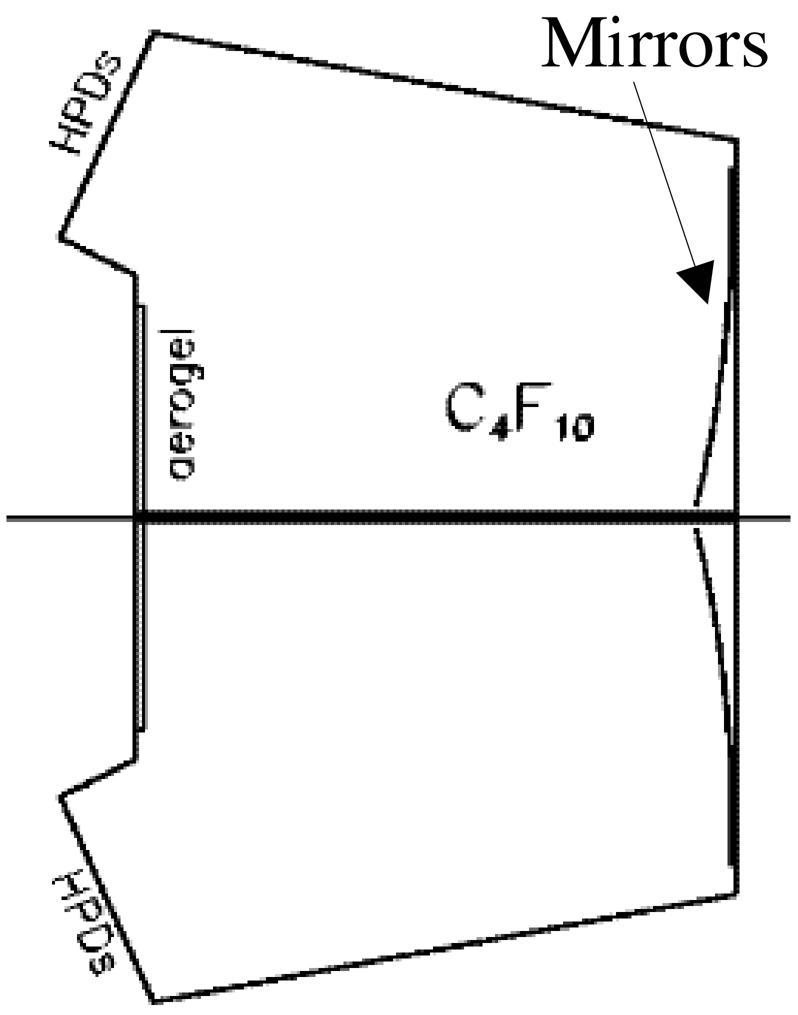
- Momentum spectra of tagging K's and pions from $B \to \pi^+\pi^-$





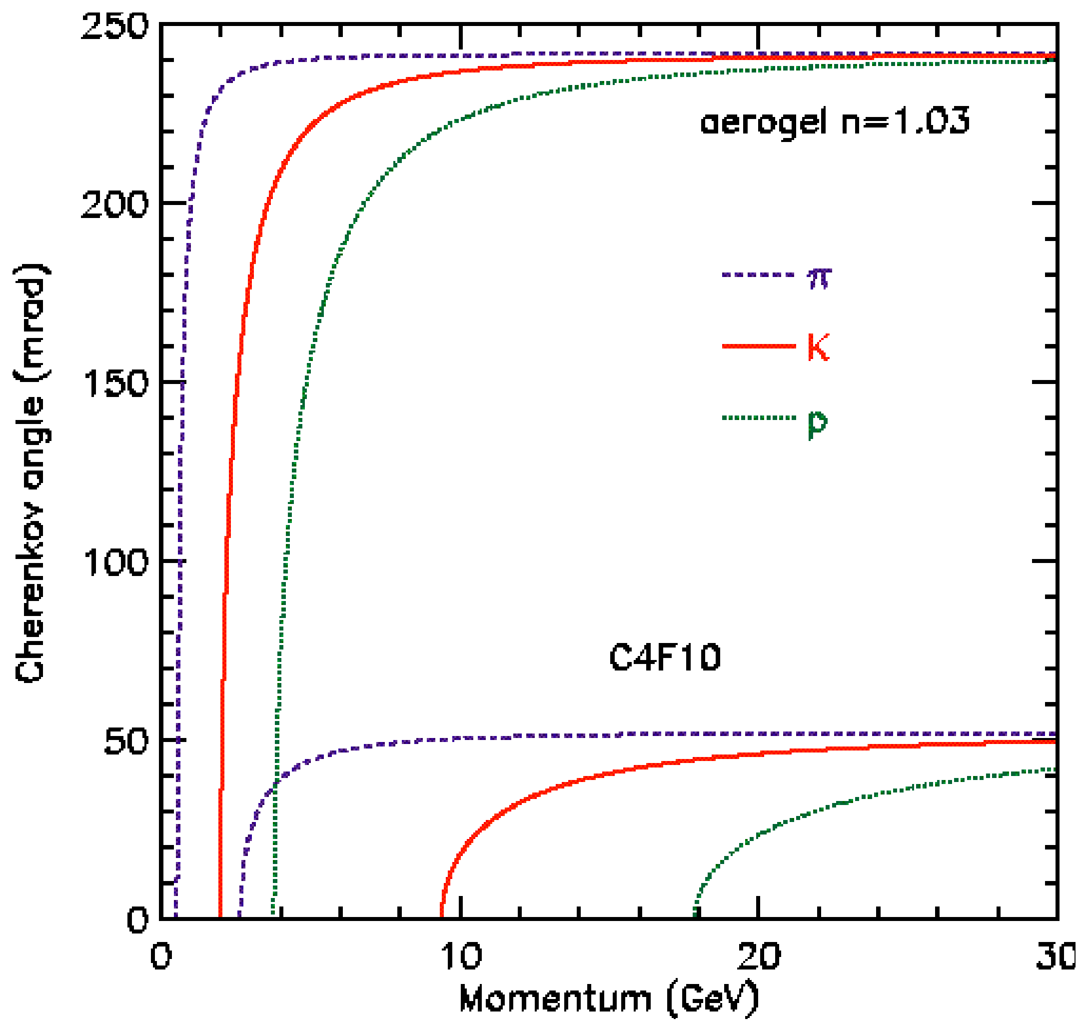
BTeV hadron PID

- Cover π/K separation, $3 < p < 70$ GeV/c: **RICH**
- Radiator: C_4F_{10} with pion threshold at 2.7 GeV/c



- Possible option: lowering threshold to 0.4 GeV/c with aerogel

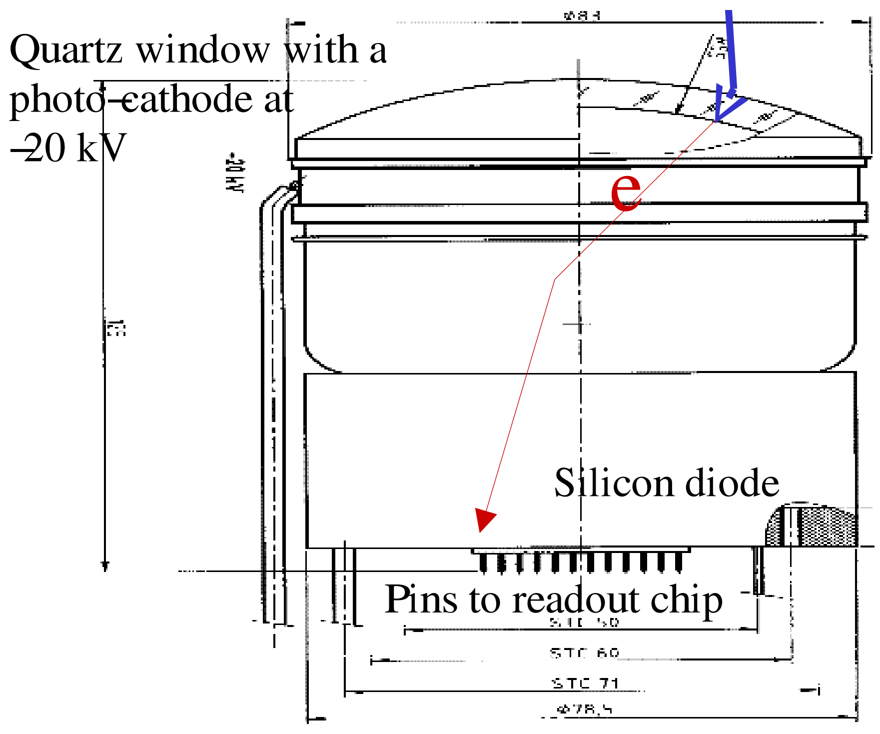
BTeV RICH radiators

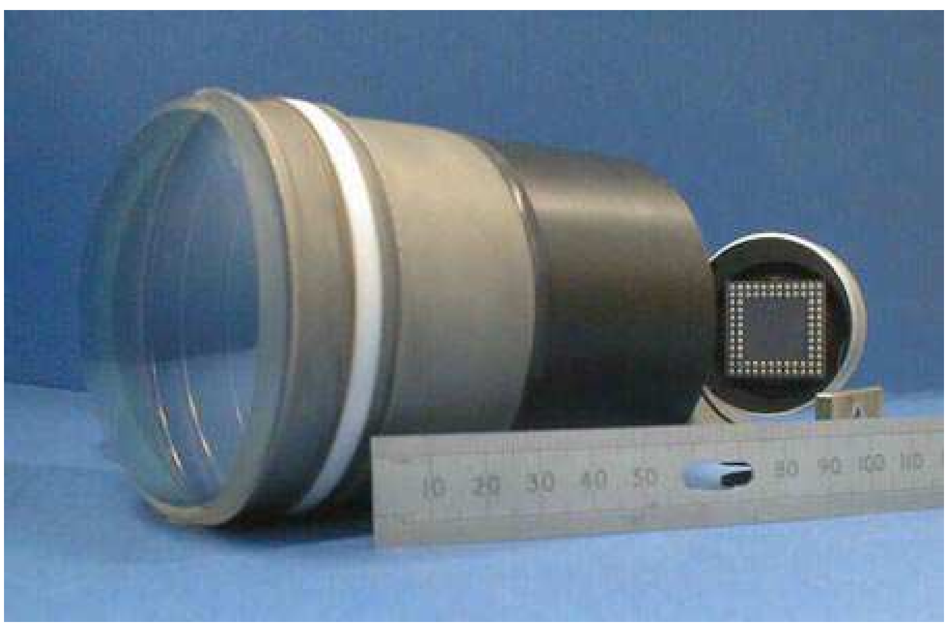


- With two radiators the separation of K and p improves substantially.

BTeV RICH

- Photon detector: HPD





$PbWO_4$ Calorimeter

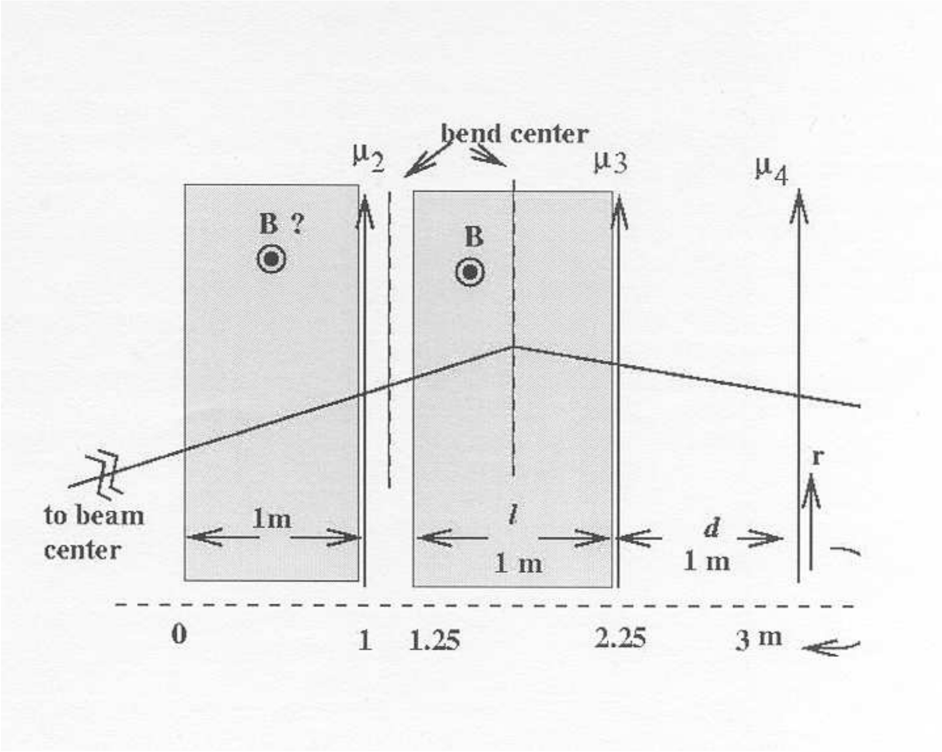
- Same crystal technology as CMS, use 2x11,000 pieces, 27x27x2220 mm^3
- Crystals are rad hard, fast scintillators (99% of light in less than 100 ns)
- Read-out with PMTs (no B field)

Calorimeter performance: expect (full GEANT simulation)

- Energy resolution $\sigma_E = \sqrt{\frac{(1.6\%)^2}{E/GeV} + (0.55\%)^2}$
- Position resolution $\sigma_x = \sqrt{\frac{(3500\mu\mathrm{m})^2}{E/GeV} + (200\mu\mathrm{m})^2}$
- Example: $B \to K^*\gamma$ $\to$

BTeV Muon Detector

- Identify muons
- Provide a di-muon trigger at Level 1:checks of detached vertex trigger, commissioning
- Two torroids with three detector sets

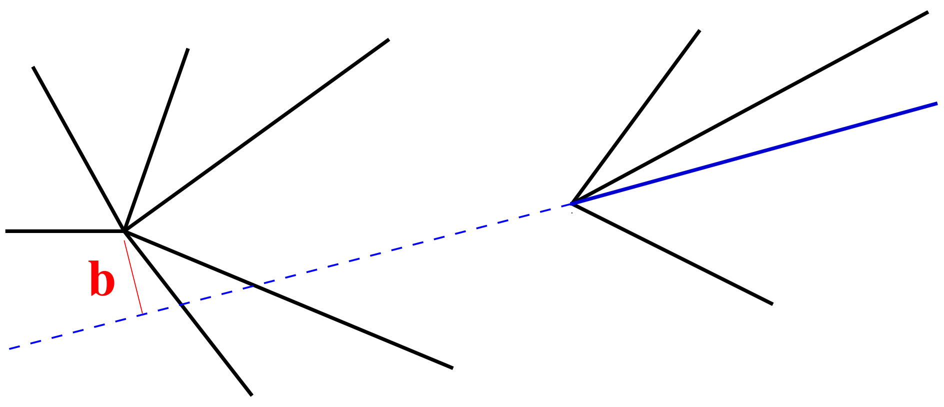


BTeV Trigger Level 1

- Find segments in the entrance and exit of the pixel detector

$\rightarrow$

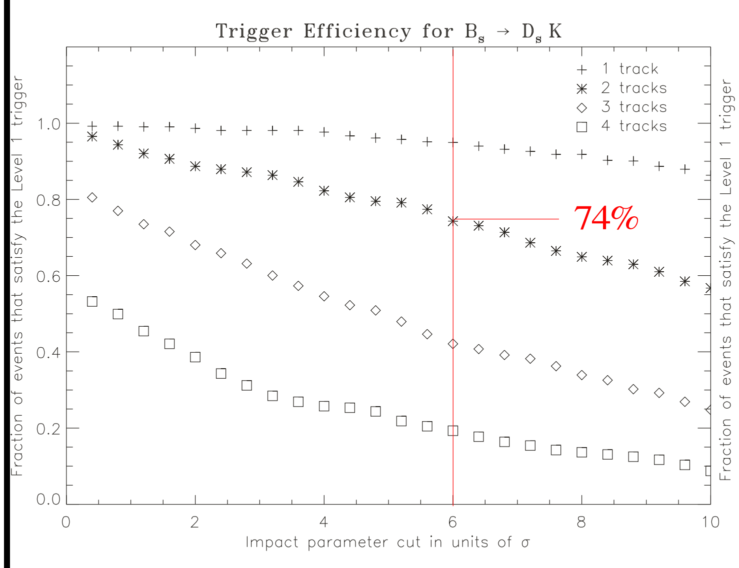
- Find primary vertex, find tracks which miss it, and calculate the significance of detachment, $b/\sigma(b)$, for each track

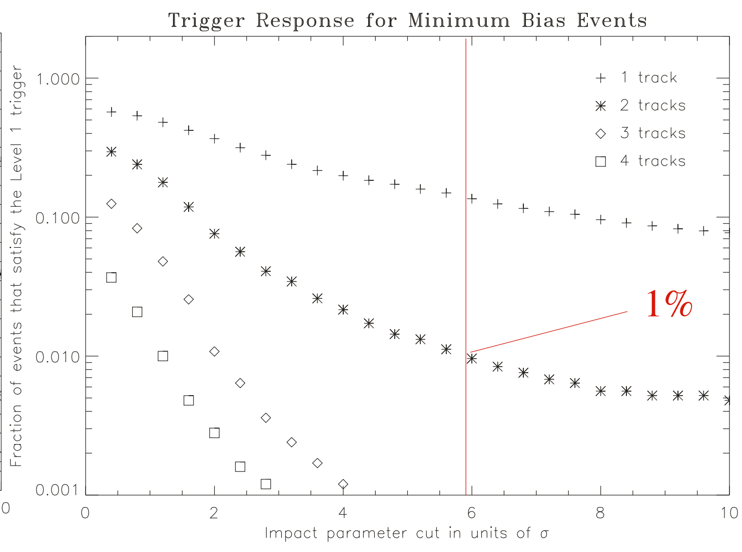


- Goal: factor 100 or more rejection of crossings with no b events, and efficiency of $> 50\%$ for good events with b's.
- Example: two tracks with $b/\sigma(b) > 6$ leaves 1% of beam crossings, and has 63% efficiency for $B^0 \rightarrow \pi^+\pi^-$, 70% for $B^- \rightarrow D^0 K^-$, 50% for $B^0 \rightarrow J/\psi K^0_S$

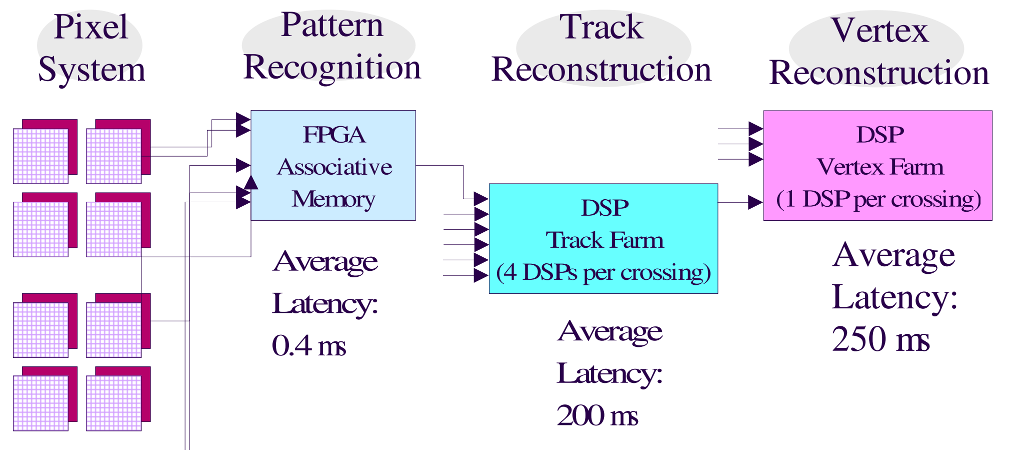
BTeV Level 1

- Signal example: Effiency for $B_s \to D_s K$
- Rejection power: efficiency for minimum bias events





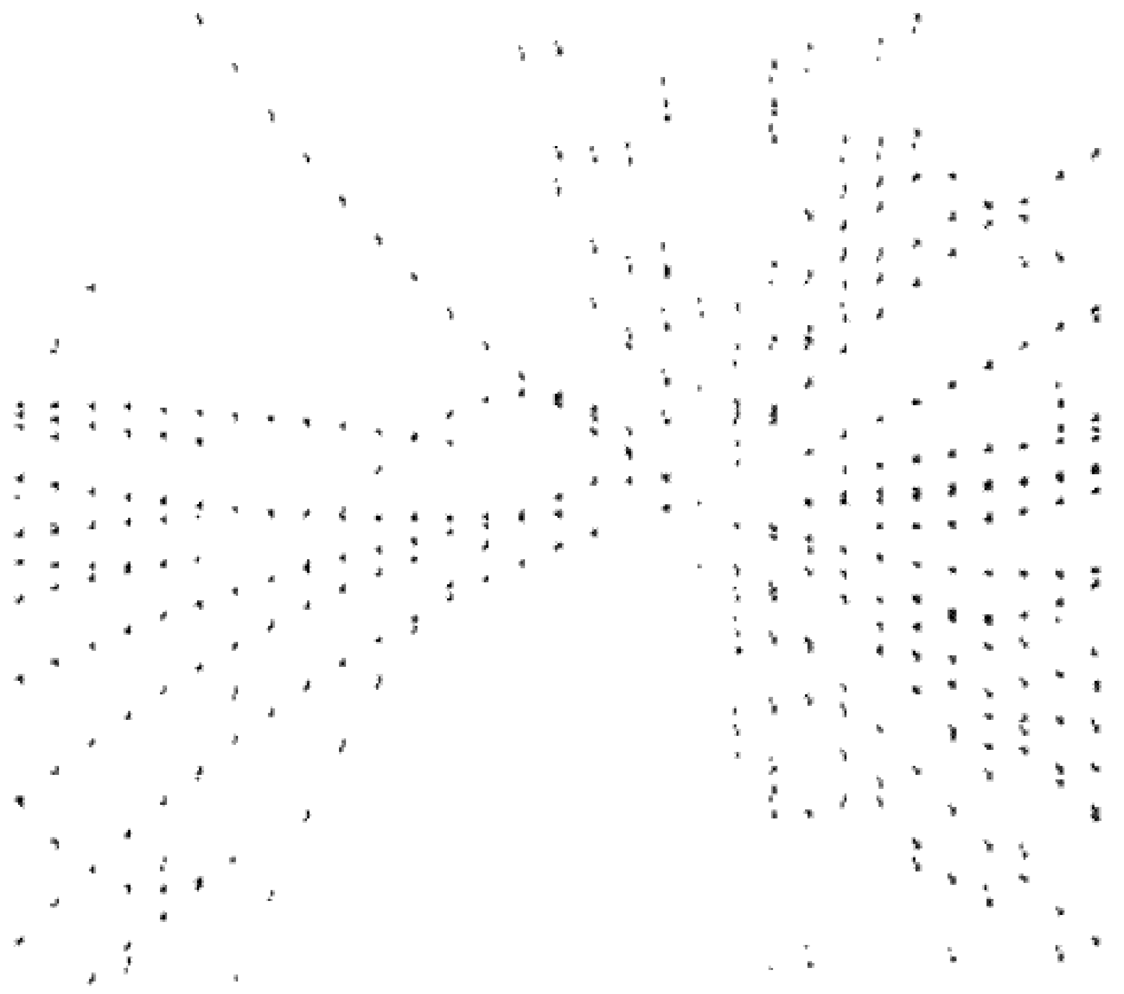
- Level 1 hardware



Average latency for the Level 1 trigger: 0.5 ms
Number of DSPs (e.g. TMS320C6701):
2000 + 500 = 2500

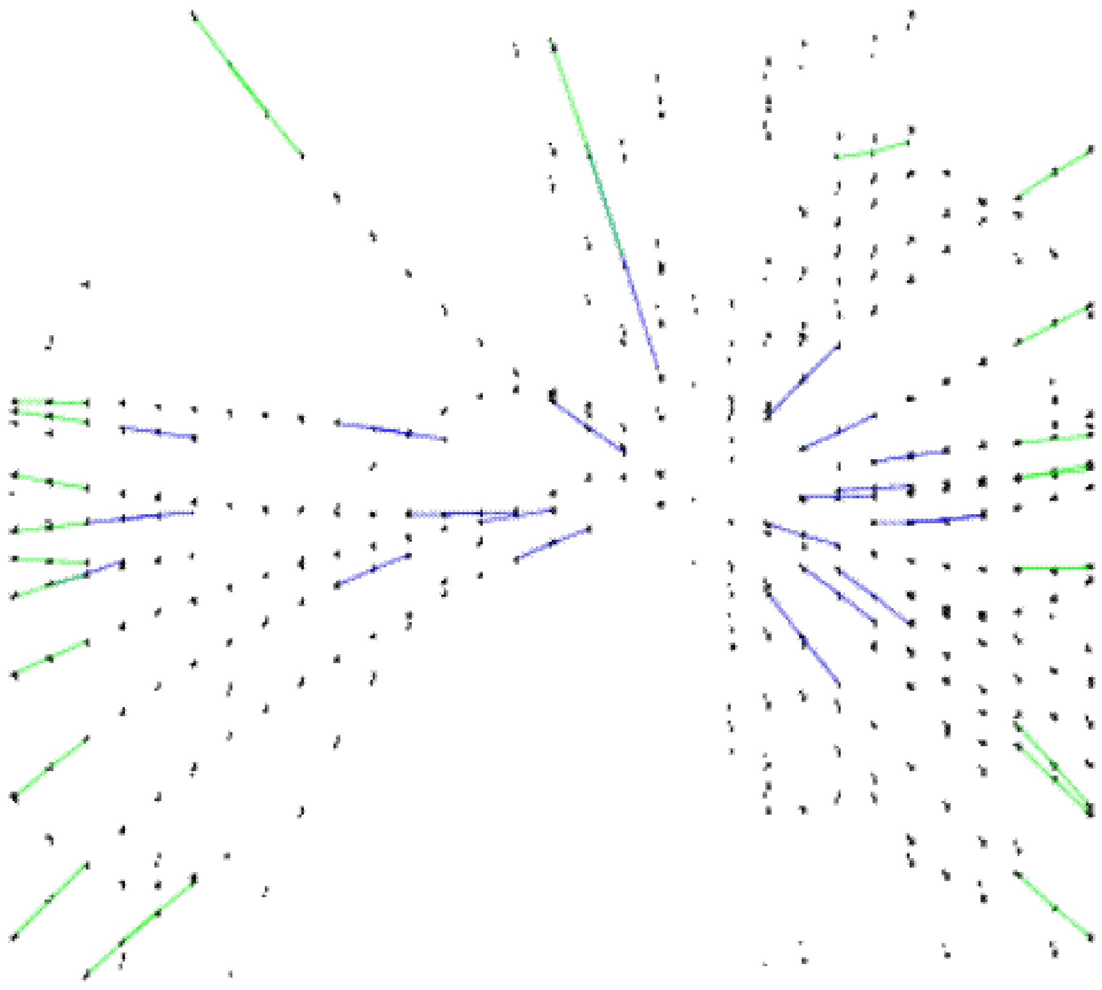
BTeV: event in the pixel detector

Event in the pixel detector (horizontal coord. compressed by factor 10)



BTeV pixel segments

Segments found in the entrance and exit of the pixel detector



Match segments, get crude momentum estimate, reject low momentum tracks from vertex determination (multiple scattering).

BTeV trigger Levels 2 and 3

- Level 2: Refit the pixel segments, include more hits, link tracks to downstream tracker (straws and strips) for accurate momentum measurement, redo the fit for a better $b/\sigma(b) \rightarrow$ goal: rejection of factor of 10 or more at 90% efficiency
- Level 3: More processing, goal event output rate 4 kHz (each 40 kbyte)

BTeV physics reach 1

Reaction	# of Events	S/B	Parameter	Error or (Value)
B^{o}®$p^{+}p^{-}$	24,000	3	Asymmetry	0.024
B_{s}® D_{s} K^{-}	13,100	7	g	7^{o}
B^{o}® J/y K_{S}, J/y ®$m^{+}m^{-}$	80,500	10	sin(2b)	0.025
B_{s}® D_{s} p^{-}	103,000	3	x_{s}	(75)
B^{-}® D^{o} ($K^{+}p^{-}$) K^{-}	300	1		
B^{-}® D^{o} ($K^{+}K^{-}$)	1,800	>10	g	10^{o}
K^{-}® K_{S} p^{-}	8,000	1		
B^{o}® $K^{+}p^{-}$	108,000	20	g	<5^{o}
B^{o}®$r^{+}p^{-}$	9,400	4.1		
B^{o}®$r^{o}p^{o}$	1,350	0.3	a	~10^{o}
B_{s}® J/y h,	1,920	15		
B_{s}® J/y h' J/y ®$m^{+}m^{-}$	7,280	30	sin(2c)	0.033

BTeV physics reach 2

Reaction	B (10^{-6})	Signal	S/B	Physics
B^o® $K^{*o}m^+m^-$	1.5	2200	11	polarization & rate
B^-® $K^-m^+m^-$	0.4	1280	3.2	rate
b® sm^+m^-	5.7	3600	0.13	rate: Wilson coefficents

Mode	BTeV (10^7s)		B−fact ($400fb^{-1}$)	
	Yield	Tagged	Yield	Tagged
B^-®f K^-	11000	11000	560	560
B^o®f K_s	2000	200	160	50
B_s® J/yh(◊)	15000	1500	–	–
B^o®K*m^+m^-	2200	2200	~40	~40
b® sm^+m^- ( )	360	360	~50	~25
D^{*+}®p^+D^o, D^o ® K^-p^+	~10^8	~10^8	$6x10^5$	$6x10^5$

( ) backgrounds significant

Summary

- Hadron production of B and D mesons has a large cross section
- However: background levels are high.
- High rate operation is required over extended run periods.
- CDF results prove that B physics can be done at hadron machines.
- HERA-B spectrometer components ready, trigger being commissioned - valuable experience for the next generation.
- A new generation of experiments, the second generation of B factories, BTeV and LHCb is under construction

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