BEAUTY 2000
Sea of Galilee

Status and Commissioning Results

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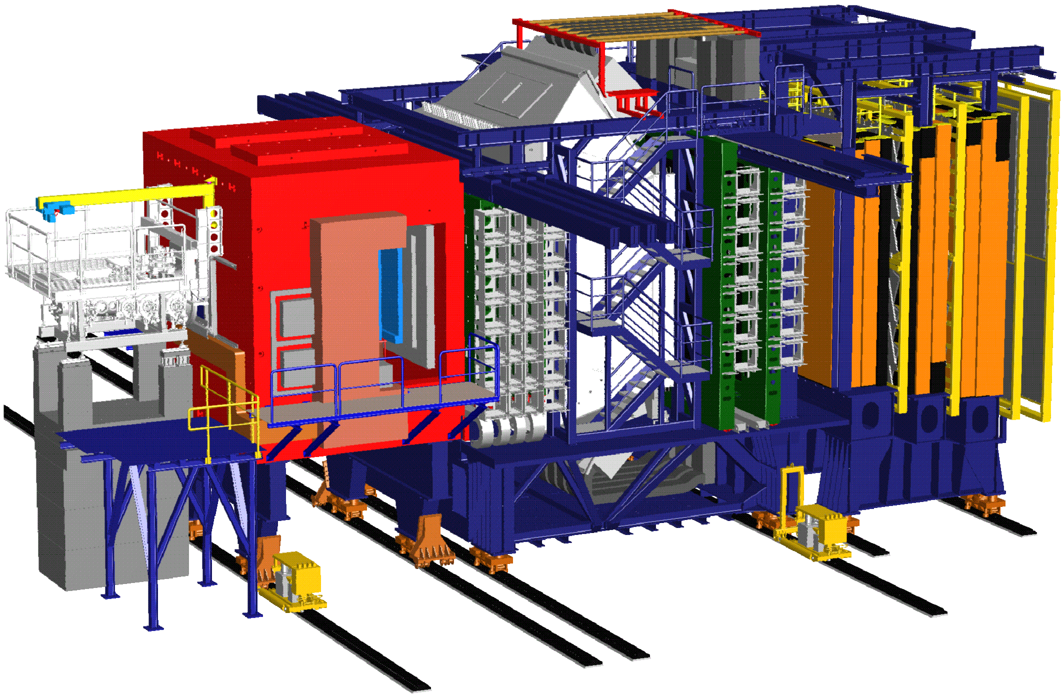
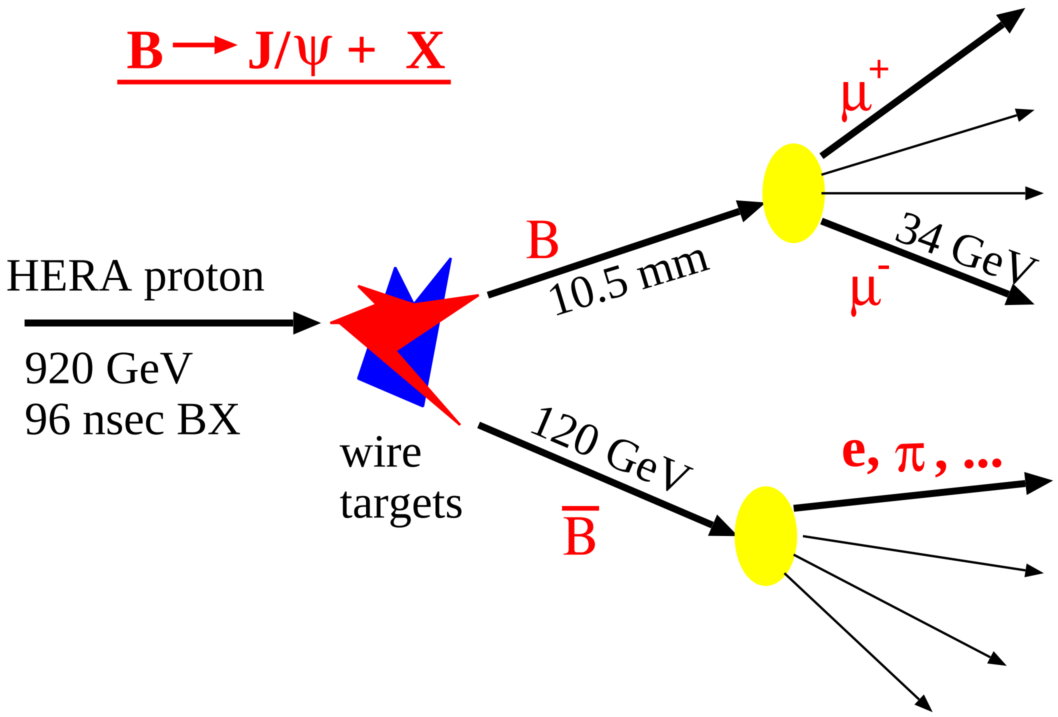
for the HERA-B Collaboration



Outline

- Introduction
- Wire Target
- High Rates
- Sub-detector Status
- Trigger Status
- J/ψ Data
- Outlook & Conclusion

HERA-B Experiment



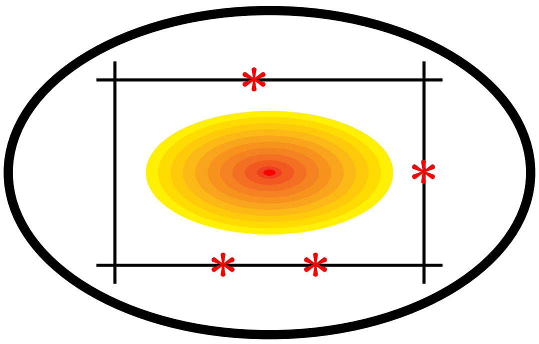
Fixed Target Hadronic B-Factory at HERA

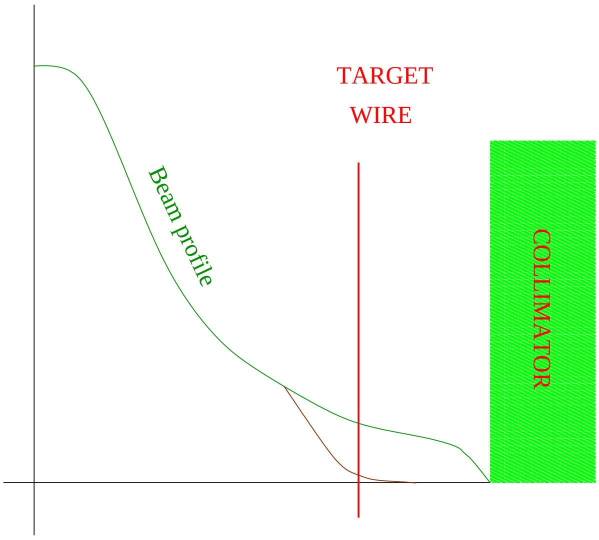
- 920 GeV HERA protons on wire targets:
  p + N(target) $\to b\bar{b}$ + X
  $\sigma_{b\bar{b}}/\sigma_{\mathrm{inel}} \approx 10^{-6}$ with $\sigma_{b\bar{b}} \approx 12$ nb
- design interaction (IA) rate up to 40 MHz
  $\Leftrightarrow$ B rate up to 40 Hz
  $\Leftrightarrow$ 10^6 produced $B \to J/\psi X \to \ell^+\ell^- X$ per year

Schedule:

➢ approved in 1995
➢ detector completed in spring 2000
➢ commissioning until August 26
➢ HERA shutdown until June 2001

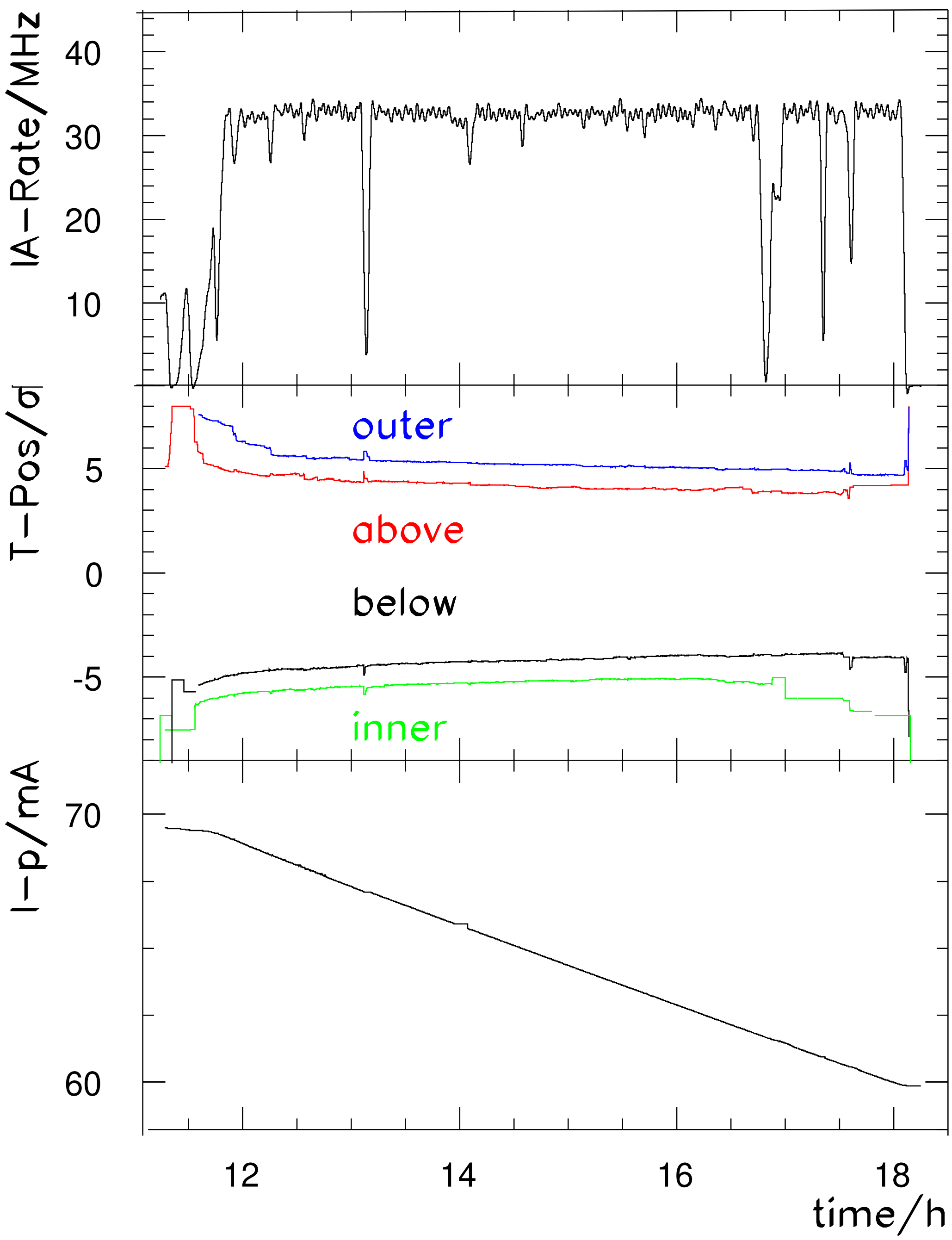
Wire Target





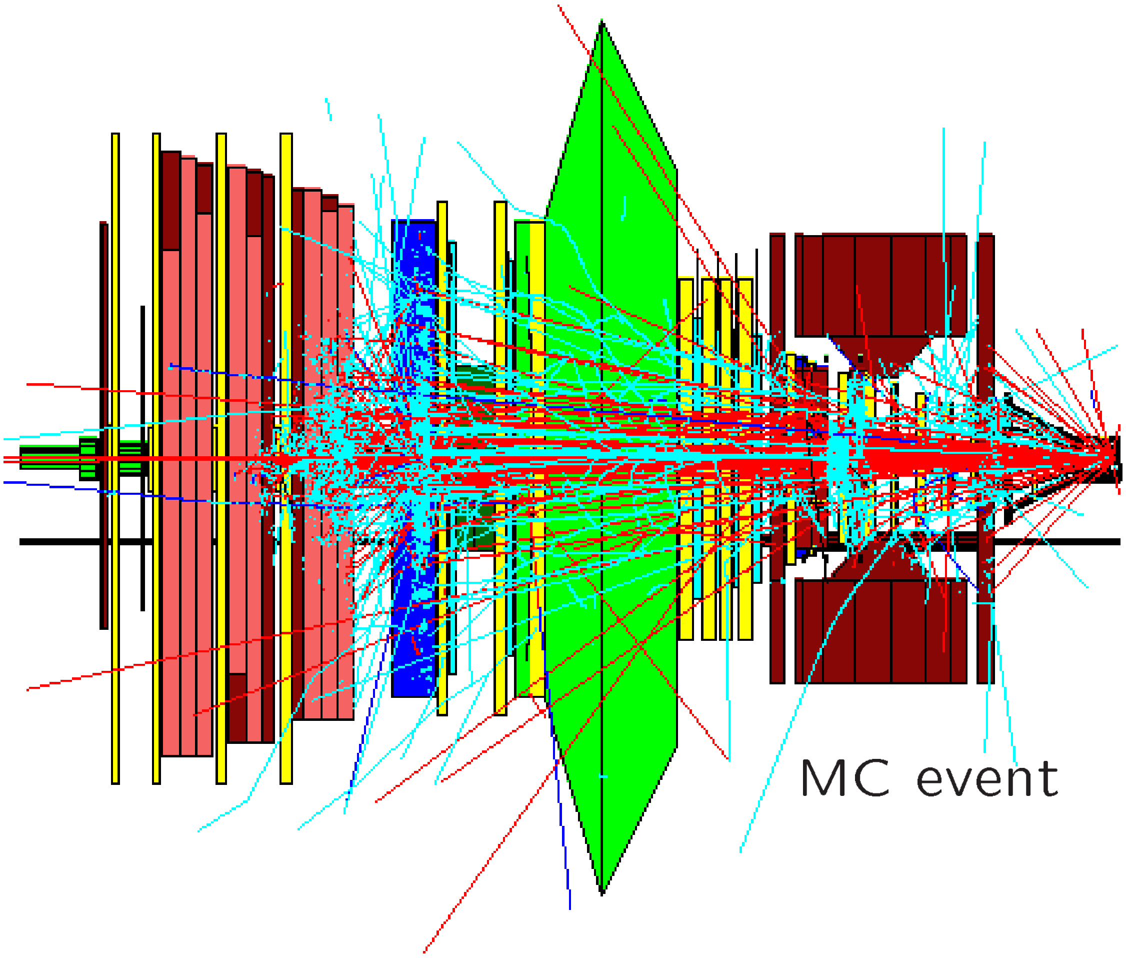
- insert thin wires (50μm$\times$500μm) into beam halo
  - → absorb protons, leaving beam core
  - → little interference with HERA ep operation
- 2 stations with 4 targets each
  - → separation of vertices for high IA rate
- target material in use: Ti, C, Al, W

Target Operation



- reliable and secure multi-wire steering
- small influence on HERA e-p luminosity
- small interference with other experiments

High-Rate Environment

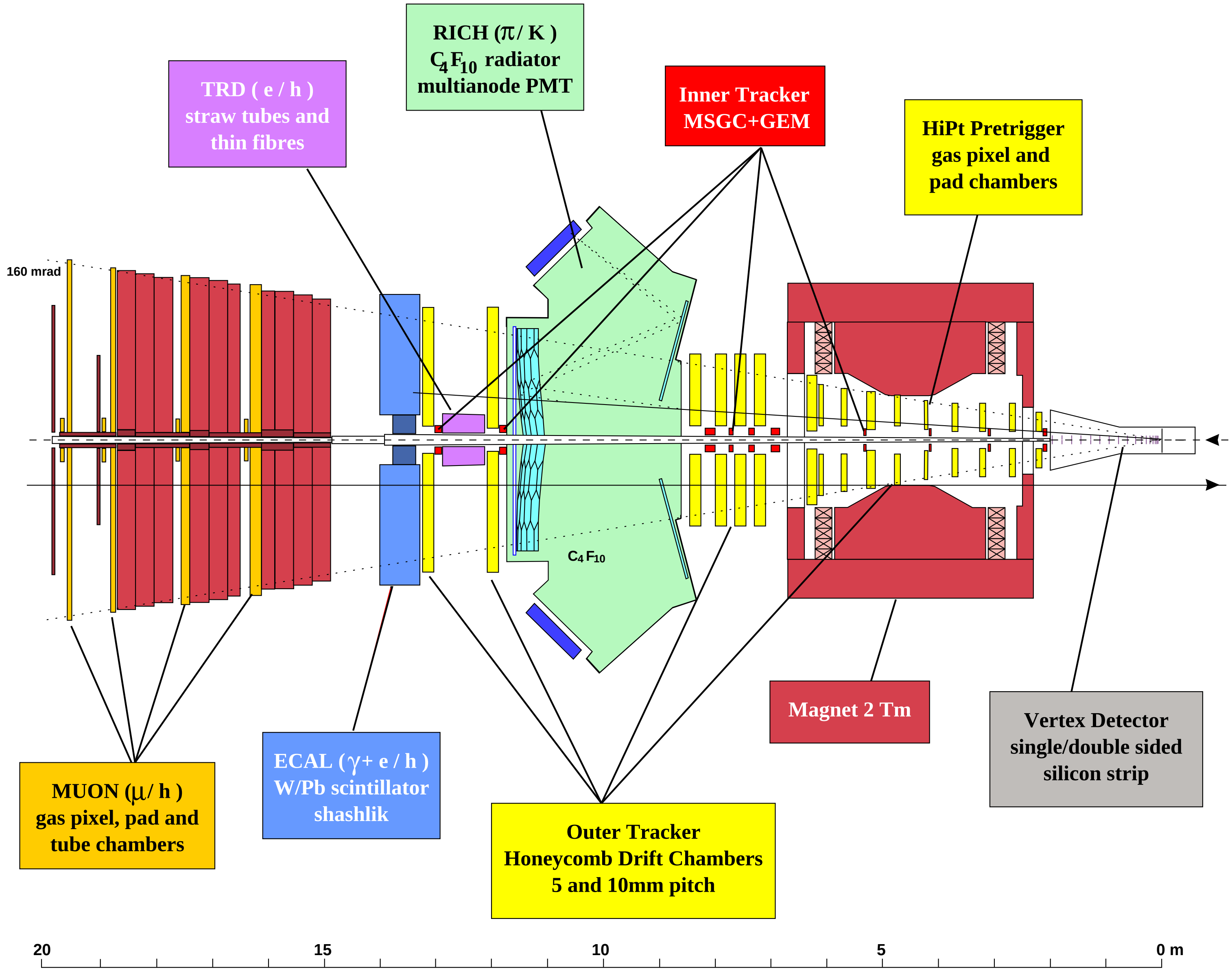


<u>at IA rate of 40 MHz:</u>

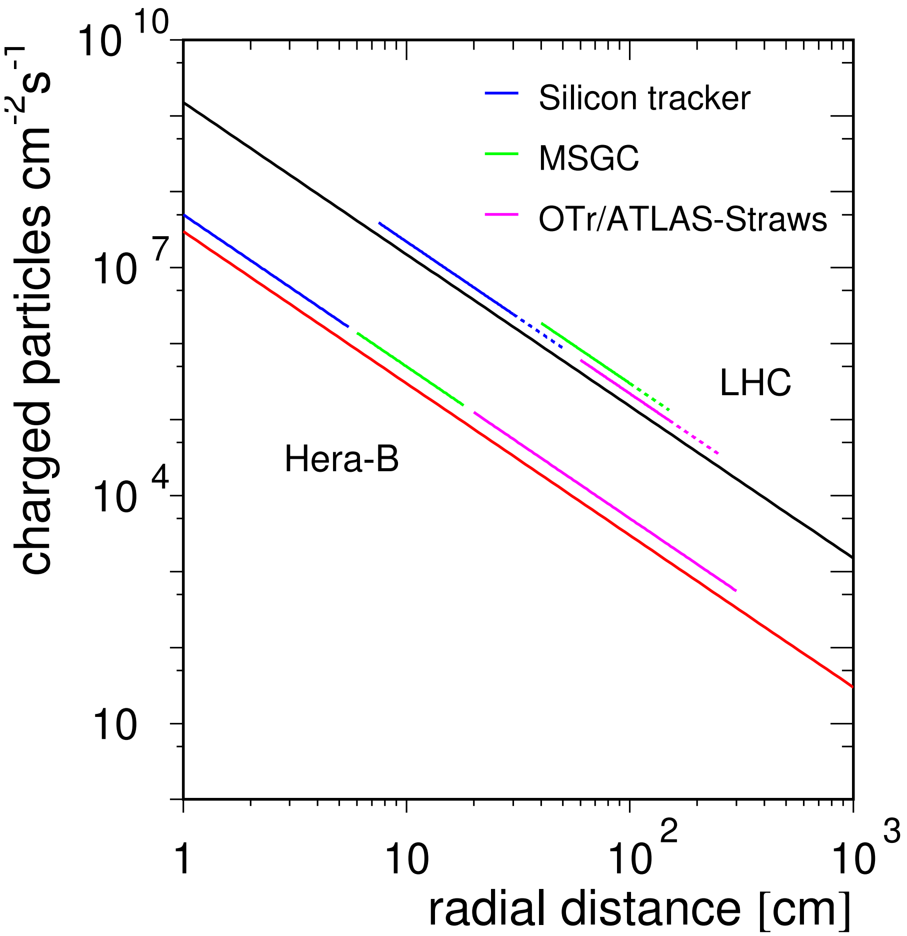
- 4 – 5 pN interactions / BX (96ns)
- $\mathcal{O}(150)$ charged tracks per event
- occupancies up to 20%

→ highly selective trigger for B decays
designed for B $\Rightarrow J/\psi X \rightarrow \ell^+\ell^- X$
signal/background $\approx 10^{-9}$

HERA-B Detector



Radiation Level



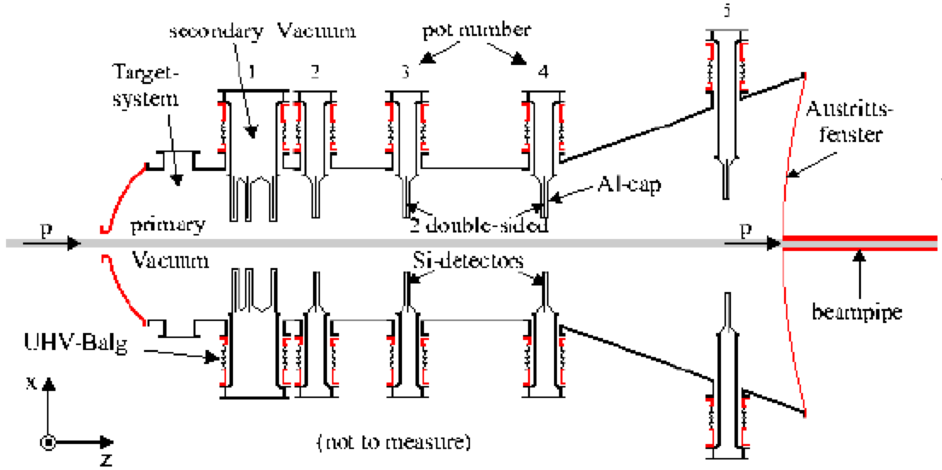
LHC-like particle densities:

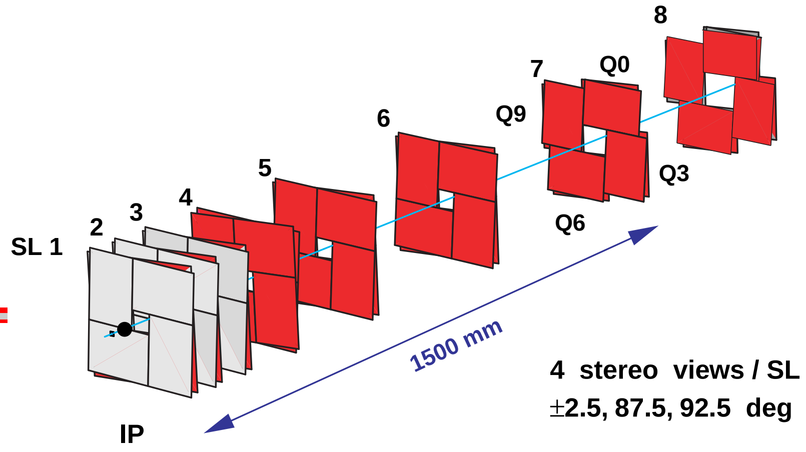
- Flux/year/area $= 2 \times 10^{14}/R^2[cm^2]$
- 10^5 gray/year in Si detectors
- up to 0.5 C/cm/year in drift chambers

Exploring a new regime of radiation load:

Substantial R&D for tracking detectors

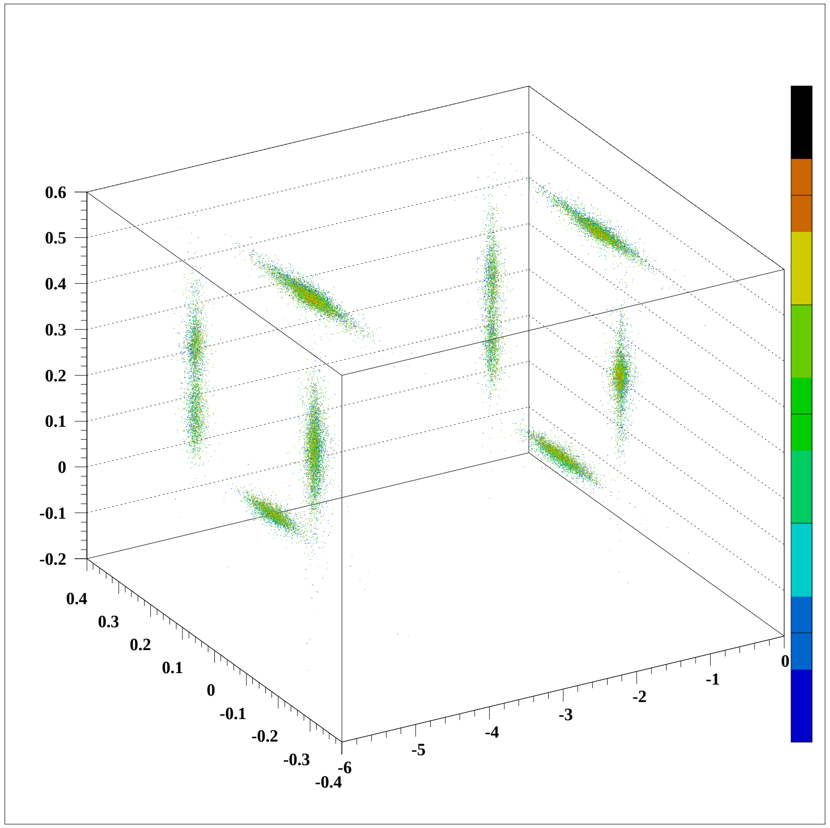
Silicon Vertex Detector

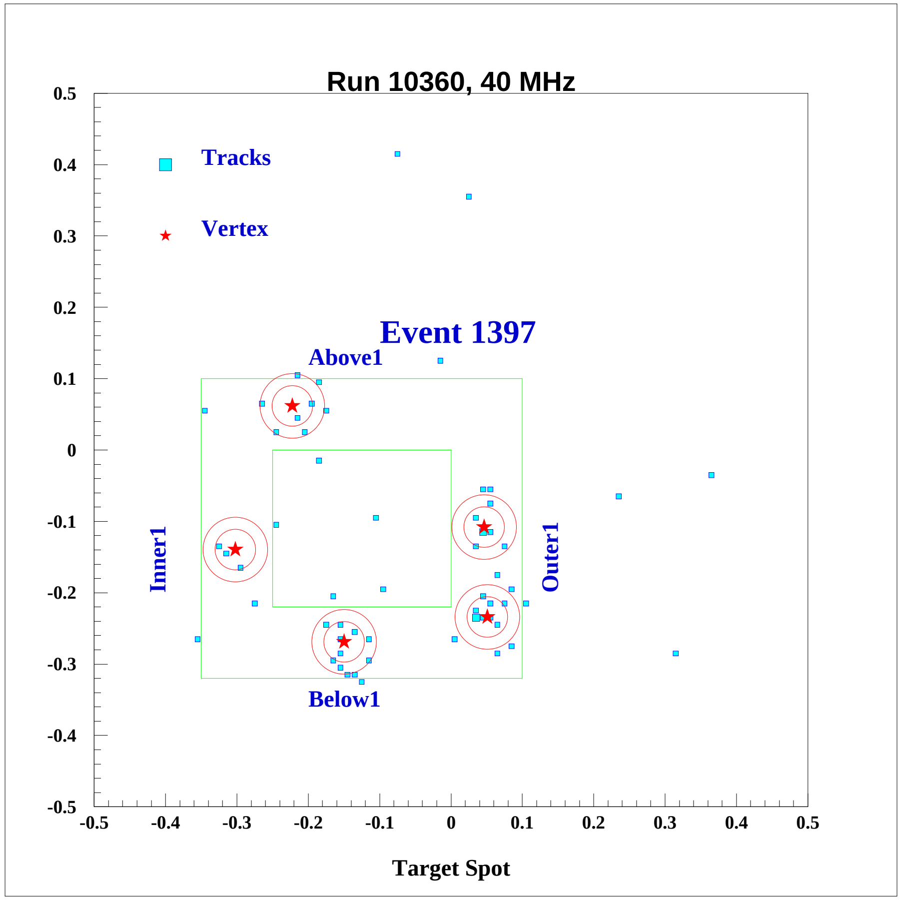




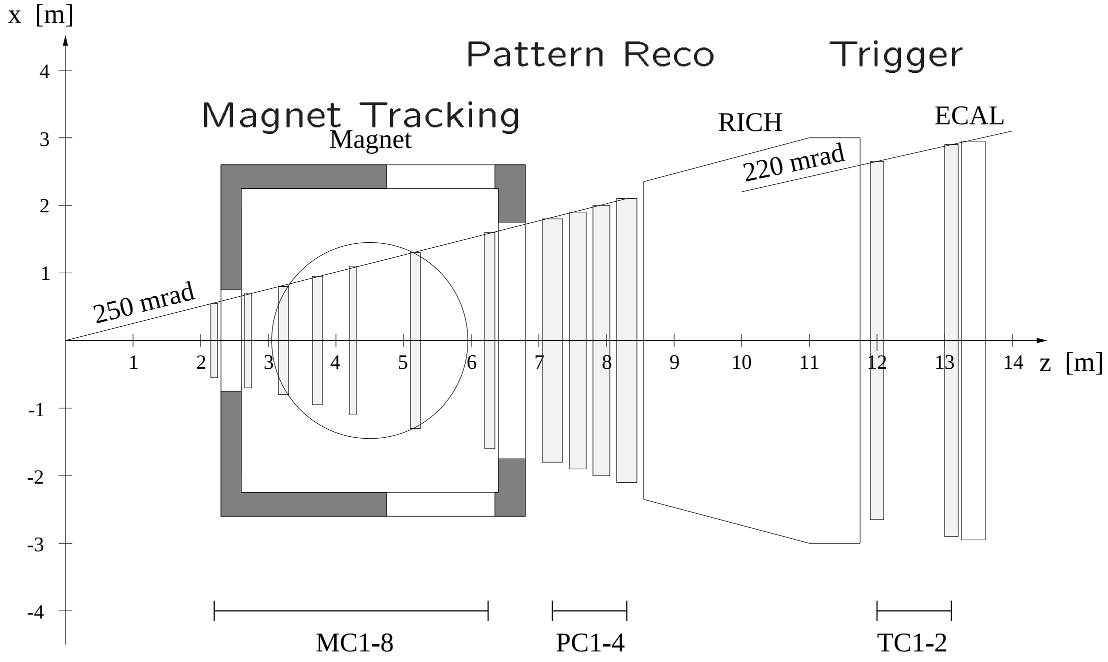
- 8 layers, 64 silicon detectors (double+single sided), 150000 channels
- layer 1–7 mounted in roman-pots inside vacuum vessel
- system runs stable, high quality data
- hit resolution $\approx 10\ \mu$m
- vertex resolution: σ_x, σ_y $\approx 60\mu$m, $\sigma_z \approx 500\mu$m

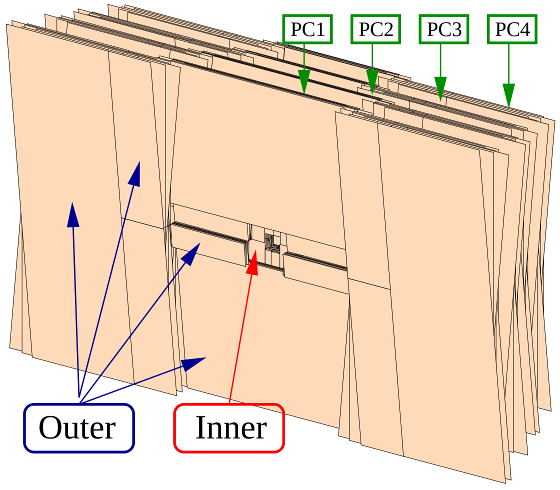
Reconstructed Primary Vertices





Main Tracker





Segmentation of pattern layers

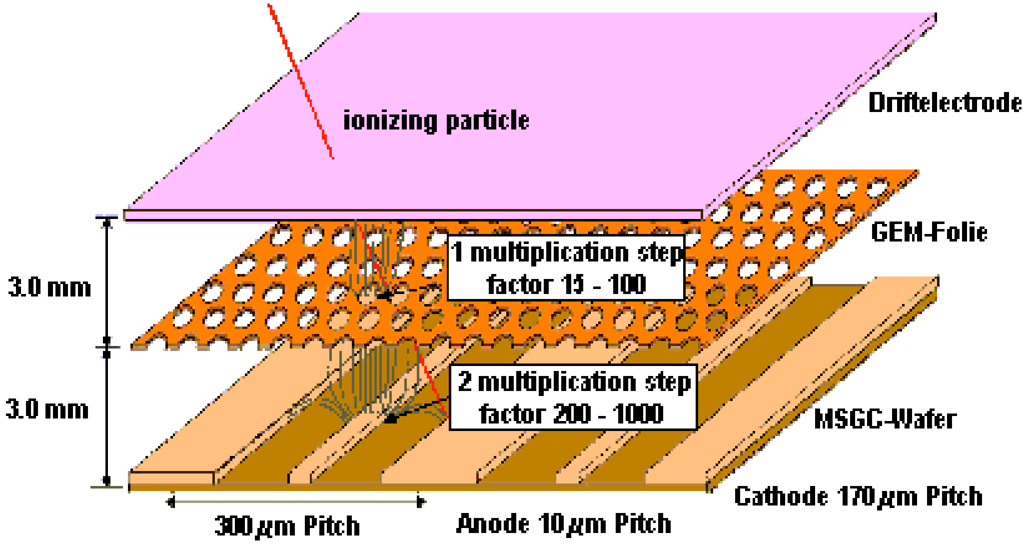
Inner tracker: MSGC-GEM detectors

- $R_{min} \sim 6$ cm $\Rightarrow 10^6$ particles cm^{-2}s^{-1}
- 300 μm pitch
- 184 chambers: max. 25×25 cm^2
- 140,000 channels

Outer tracker: honeycomb drift chambers

- $R_{min} \sim 20$ cm $\Rightarrow 10^5$ particles cm^{-2}s^{-1}
- 1000 single modules, 5/10mm cell size
- max. size: 4.6 m $\times$ 6.5 m
- 1000 m^2 $\rightarrow$ 115,000 channels

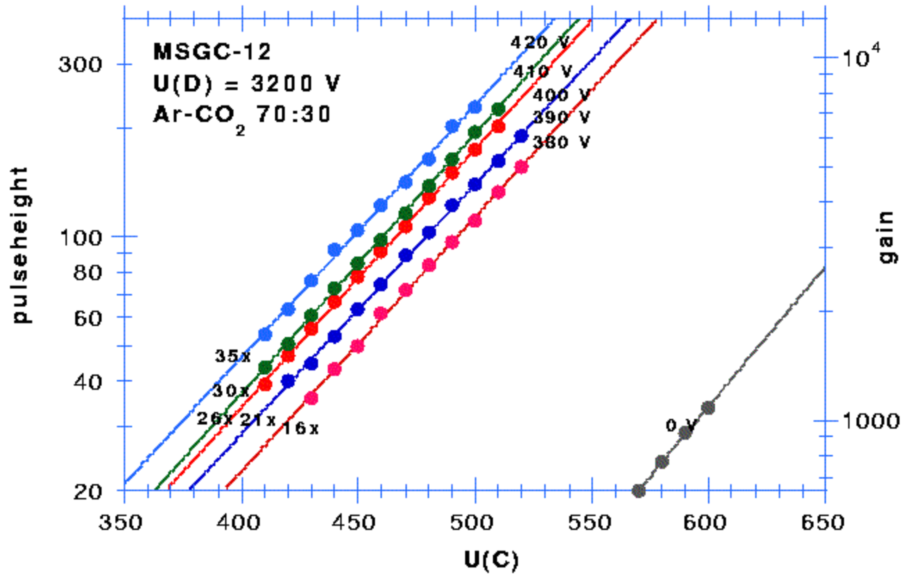
Inner Tracker



Mostly completed after 6 years of struggle and intense R&D:

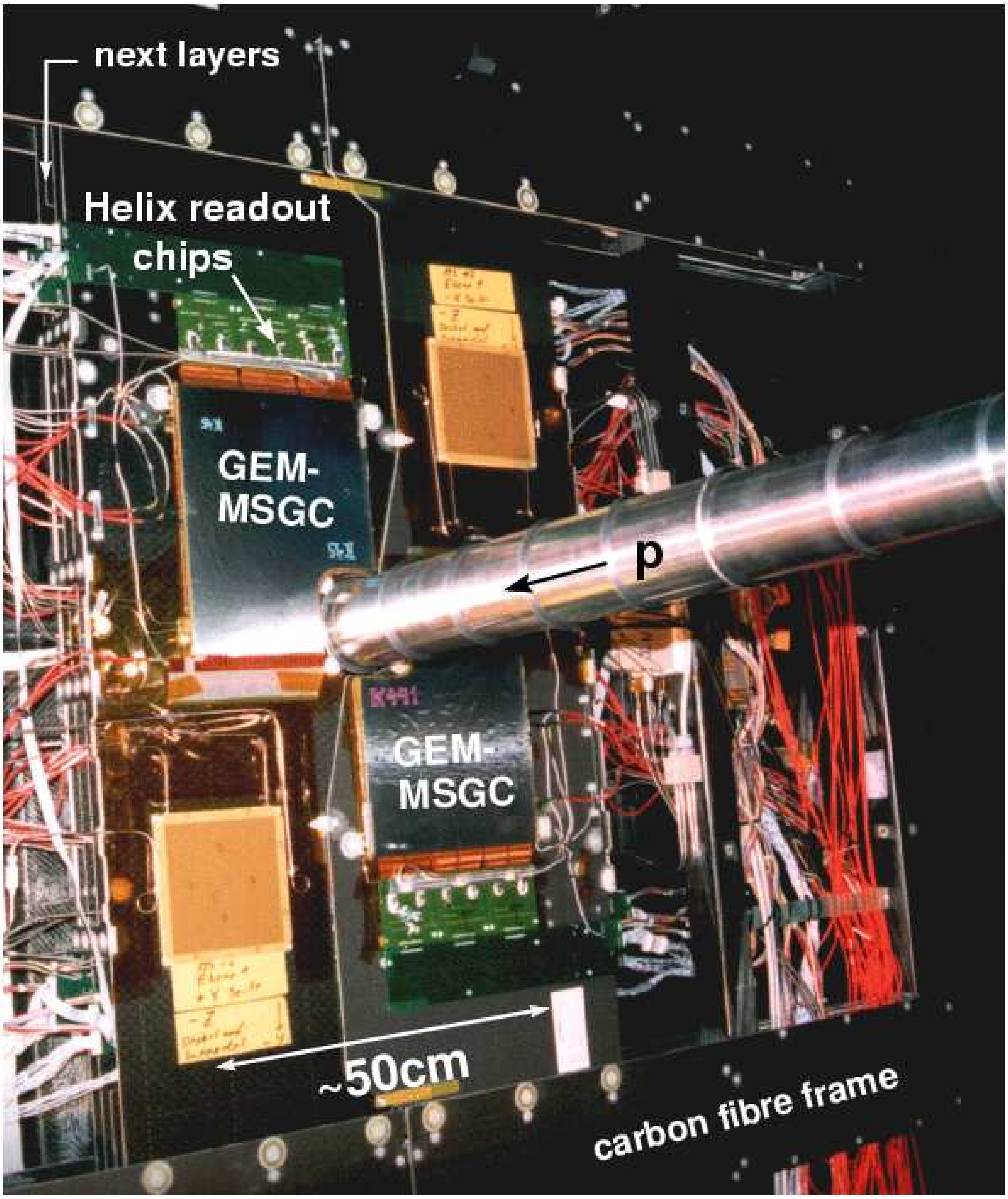
➢ Gas Electron Multiplier   F.Sauli et al.
→ $G_{tot} = G_{GEM} \times G_{cathode}$

➢ Ar:CO_2 to prevent anode aging



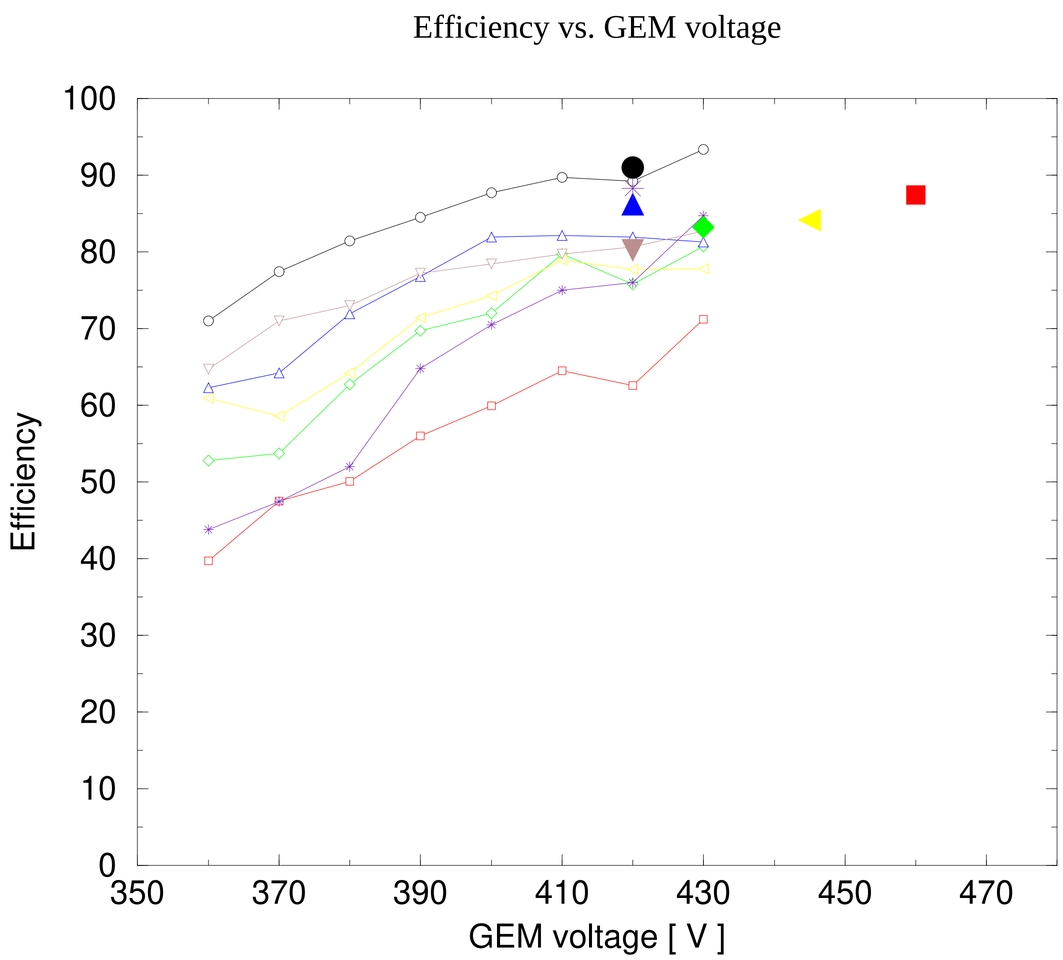
- Radiation problems seem to be solved
- Detectors running reliable in last months

Inner Tracker Station



World's largest Micro Pattern Detector

MSGC Performance



- hit efficiency (from tracks) after individual adjustment of GEM voltage between 80 and 90 %

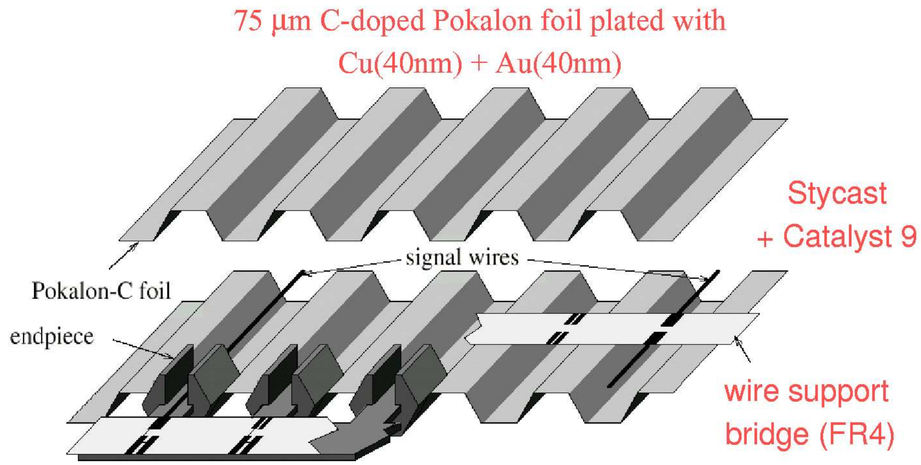
- no contribution to trigger during this year:
  - large noise generated by trigger drivers
    replacement successfully tested
  - last 2 trigger stations (48 chambers) not installed

Outer Honeycomb Tracker

Several fatal aging problems solved:

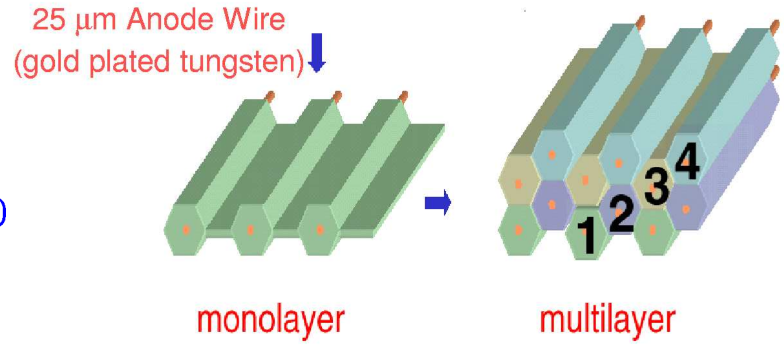
- ➢ Malter effect
- ➢ anode aging with $Ar/CF_4/CH_4$
- ➢ dark currents with CF_4 based gas

test chambers operated up to 2 C/cm



Logistical effort:

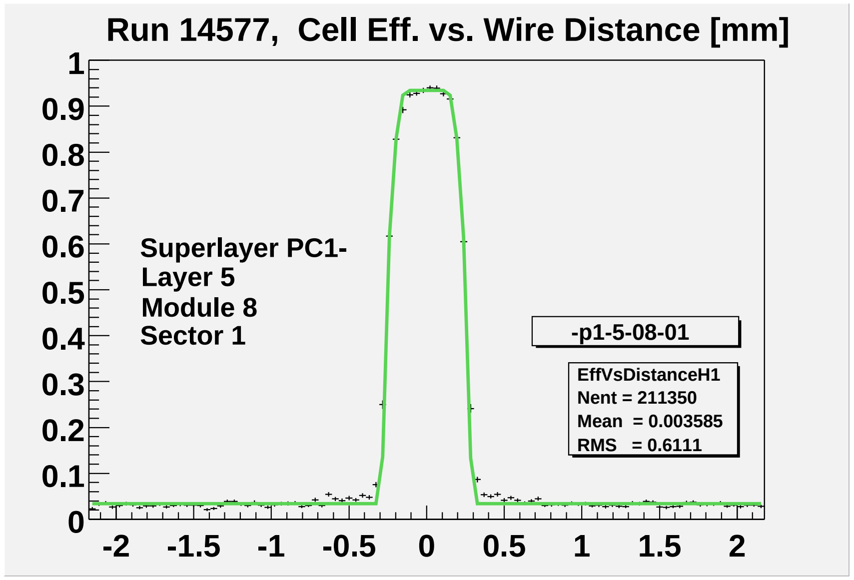
Production, assembly and installation within 1 year. Completed in January 2000



Chamber Installation

Outer Tracker Operation

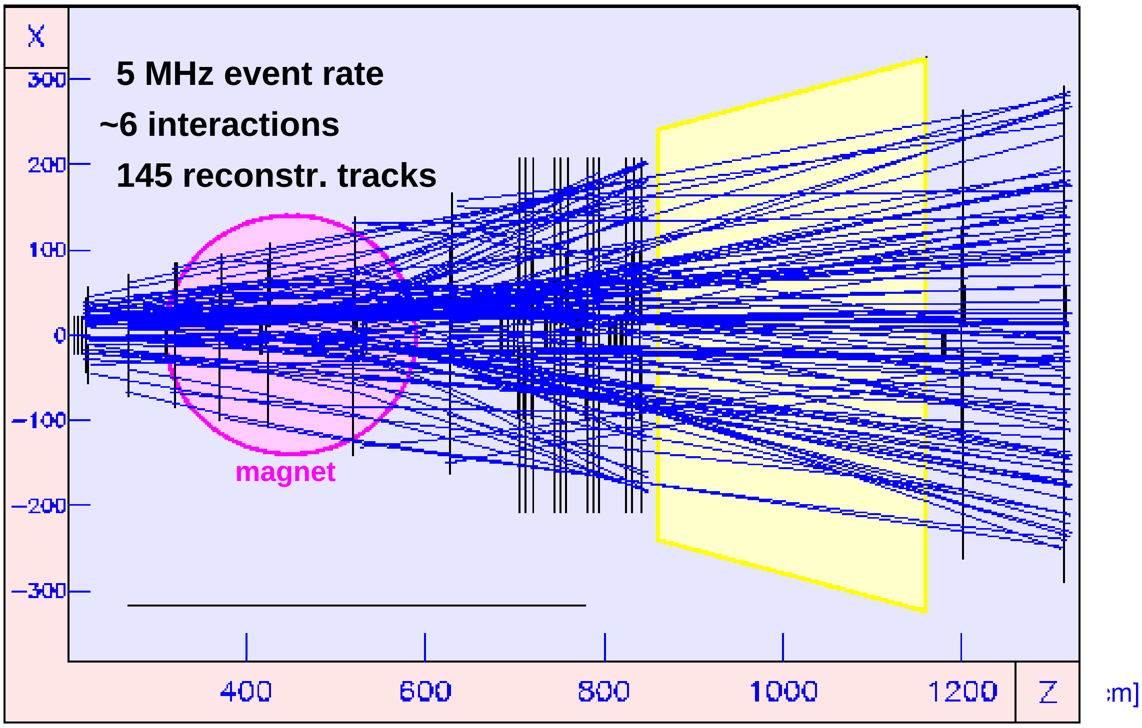
- detector routinely operated
- HV shorts for 0.5% of drift cells
  → HV grouping: 8% of dead channels:
  - reduce HV to stabilize the effect
  - repair broken groups in shutdown
- increase of threshold (2.5fC→4fC):
  noise from trigger outputs of TDC

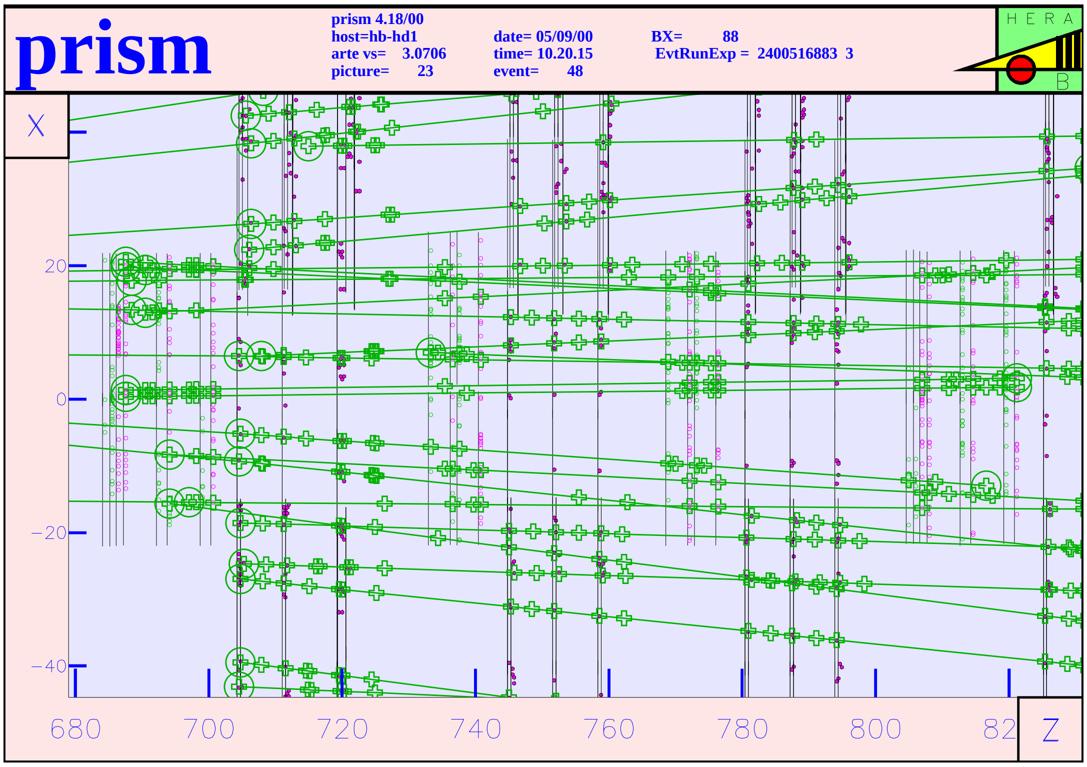


Inefficiency affects trigger

cell effic.:	$\sim$ 90%	(design: 98%)
hit resol.:	$\sim 350\mu$m	(design: 200μm)

Track Reconstruction



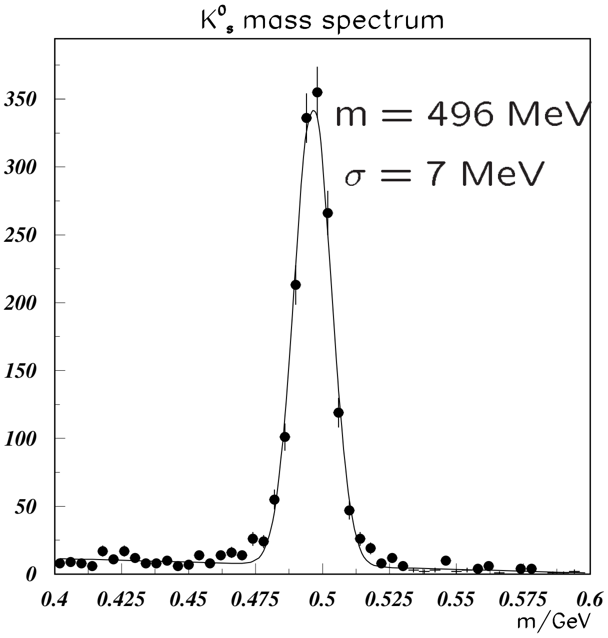


Reconstruction affected by chamber performance: dead channels, hit efficiency, resolution, mis-alignment

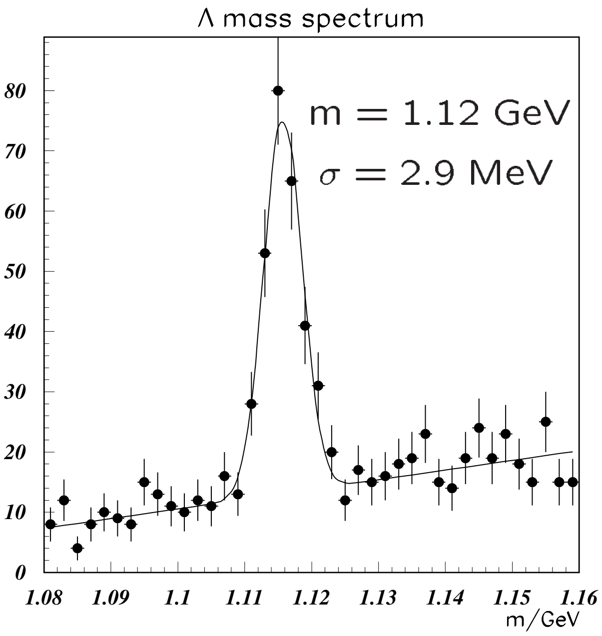
Current track reconstruction efficiency: ∼90%

Tracking: K_0 and Λ Signal

$K^0 \to \pi\pi$

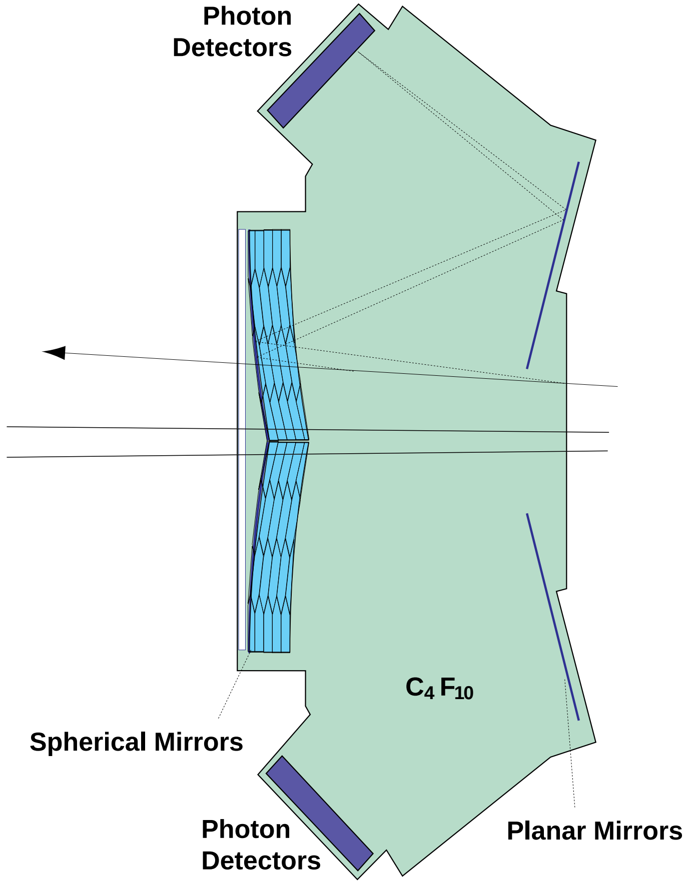


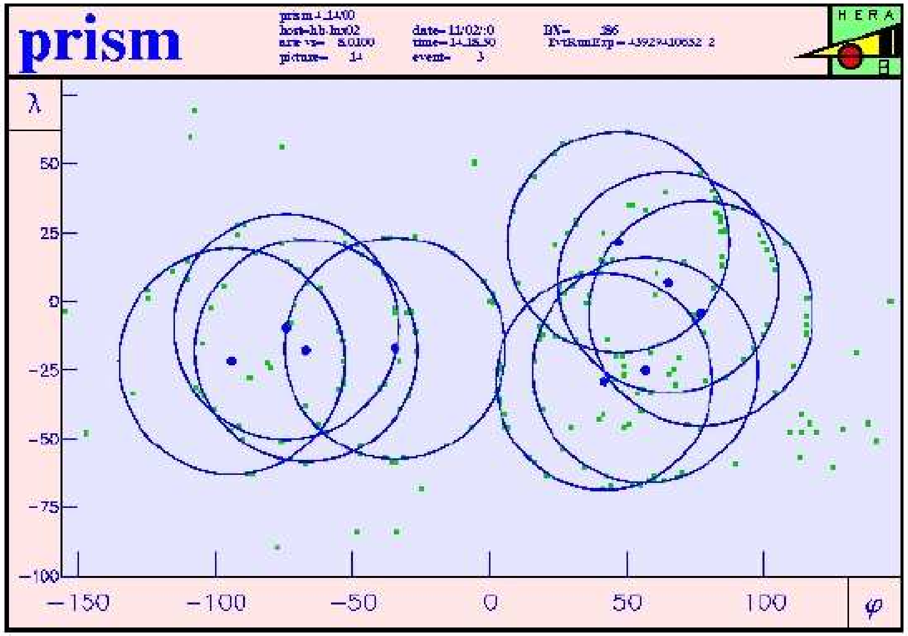
$\Lambda \to p\pi$



<u>Selection:</u> involves vertex and tracking detectors
→ cut on secondary vertex
of pairs of unlike charge tracks

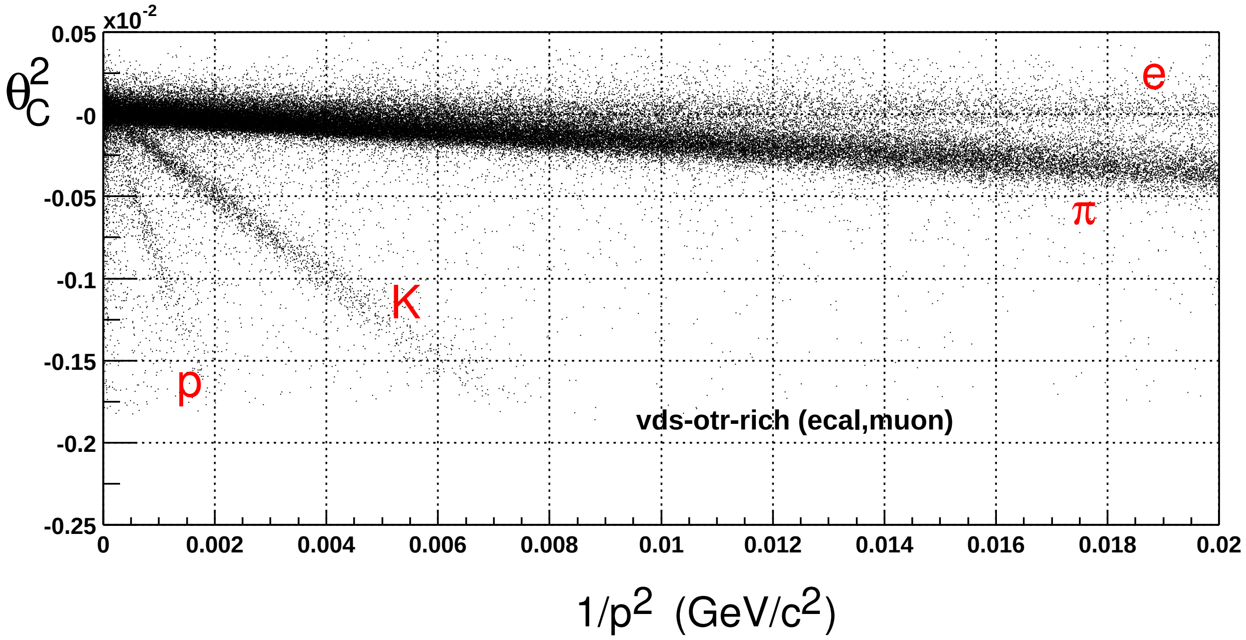
Ring Čerenkov Counter





parameter	design	measuerd
light yield ($\beta = 1$)	35 γ / ring	35 γ / ring
angle error [mrad]	0.65	0.7 – 1.0

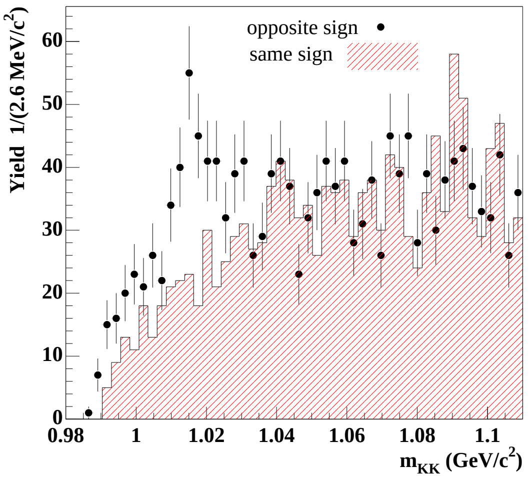
RICH Particle Identification



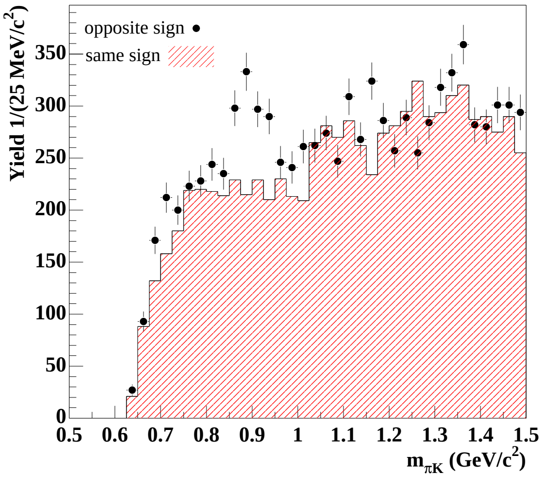
Čerenkov relation $\cos\theta_c = \dfrac{1}{n\beta}$: $\theta_c^2 = \theta_0^2 - \dfrac{m^2}{p^2}$

4σ separation	reached
$e-\pi$	3.4–15 GeV/c
$\pi-K$	12–54 GeV/c
$K-p$	23–85 GeV/c

$\phi \rightarrow K^+K^-$

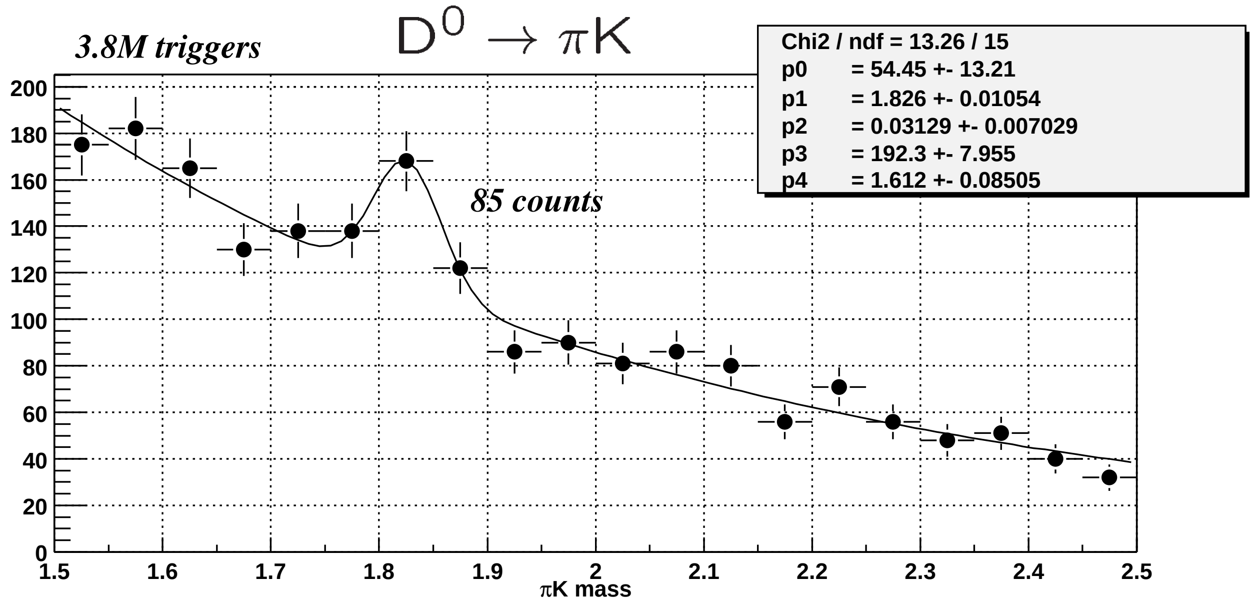


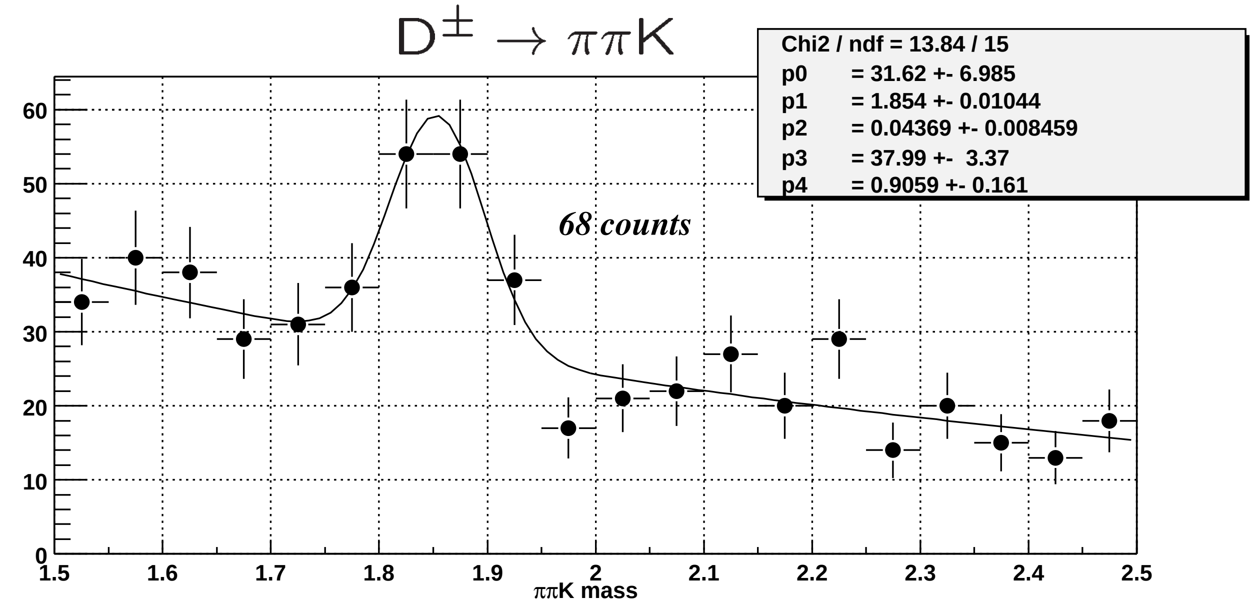
$K^{0*} \rightarrow \pi^\pm K^\mp$



(vertex and RICH information)

Open Charm Signal

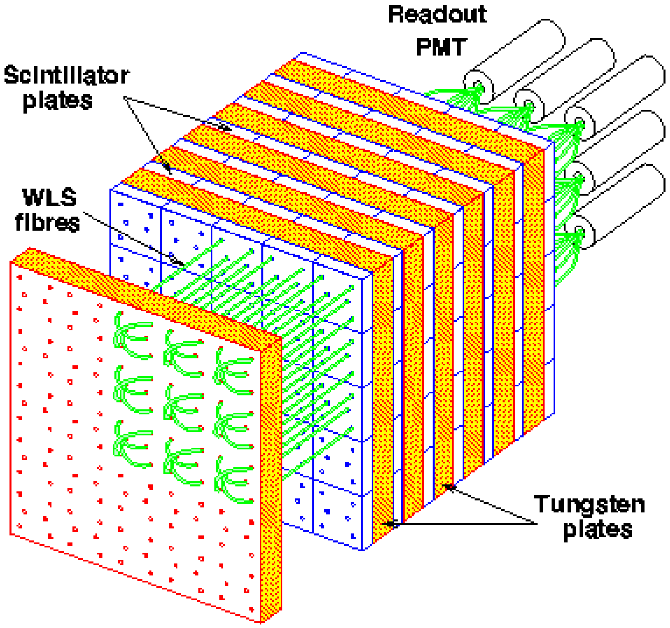


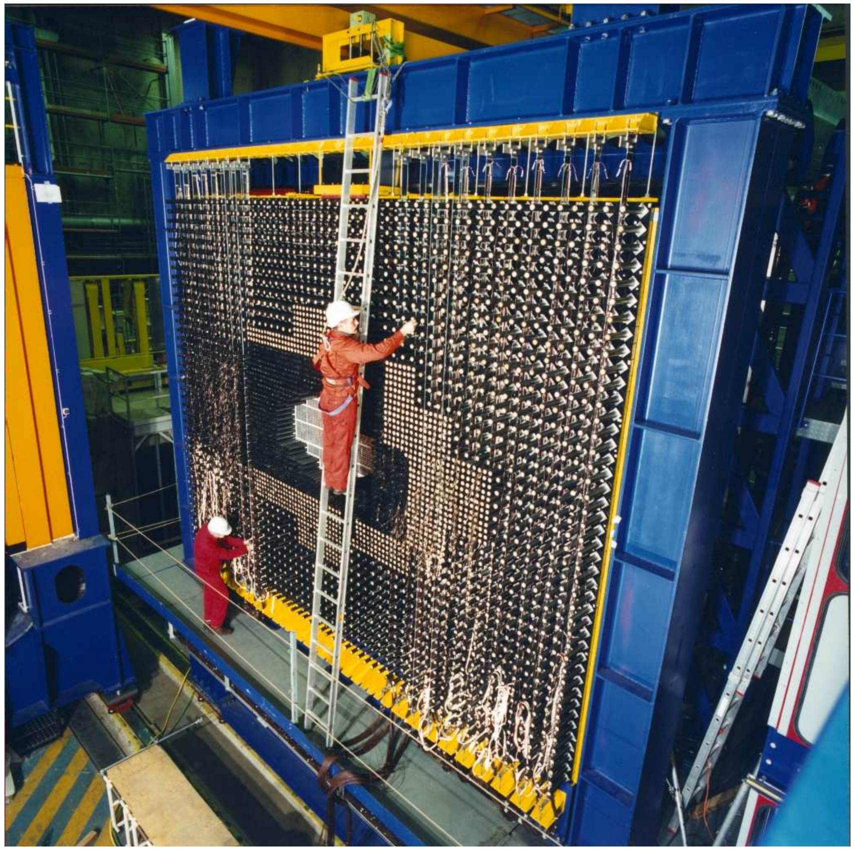


$m\ /\ \mathrm{GeV}/c^2$

<u>Selection:</u> involves vertex detector, tracking detectors and RICH particle ID

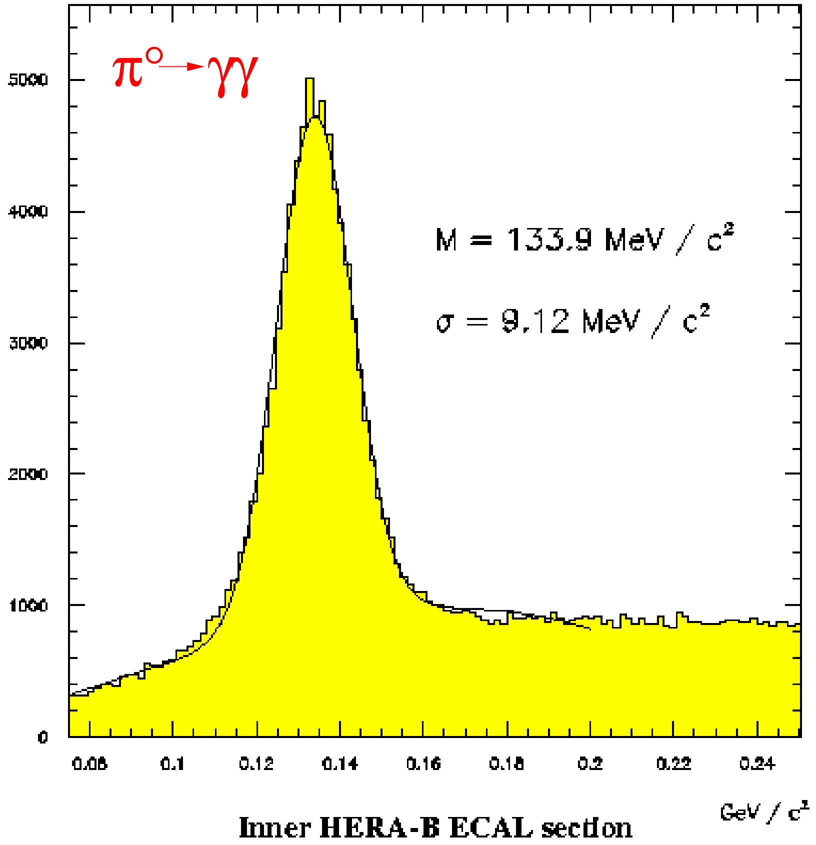
Electromagnetic Calorimeter

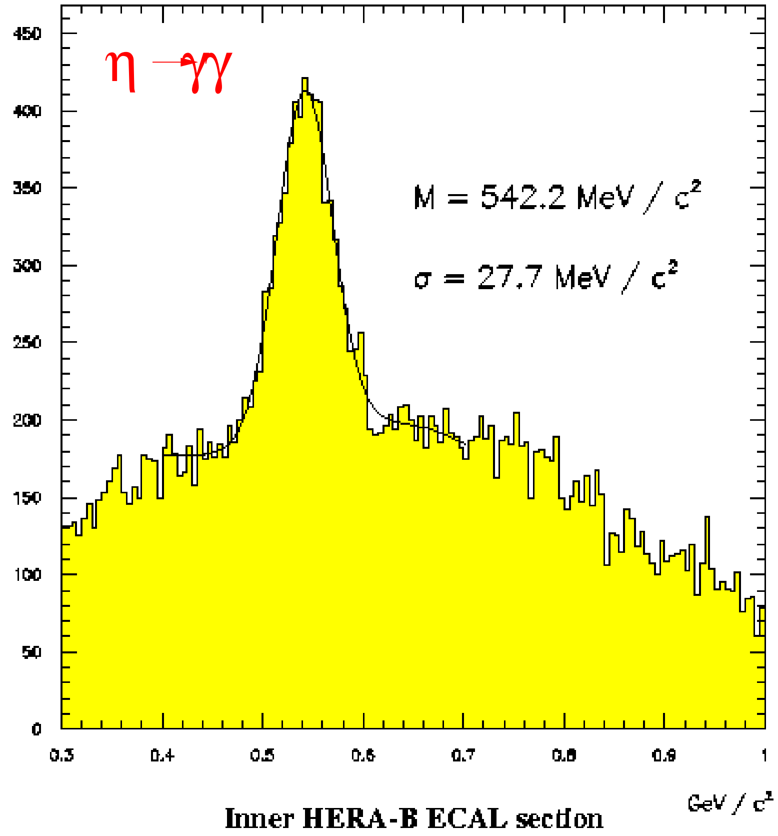




- Shashlik sampling calorimeter
- 3 lateral sections to match occupancies

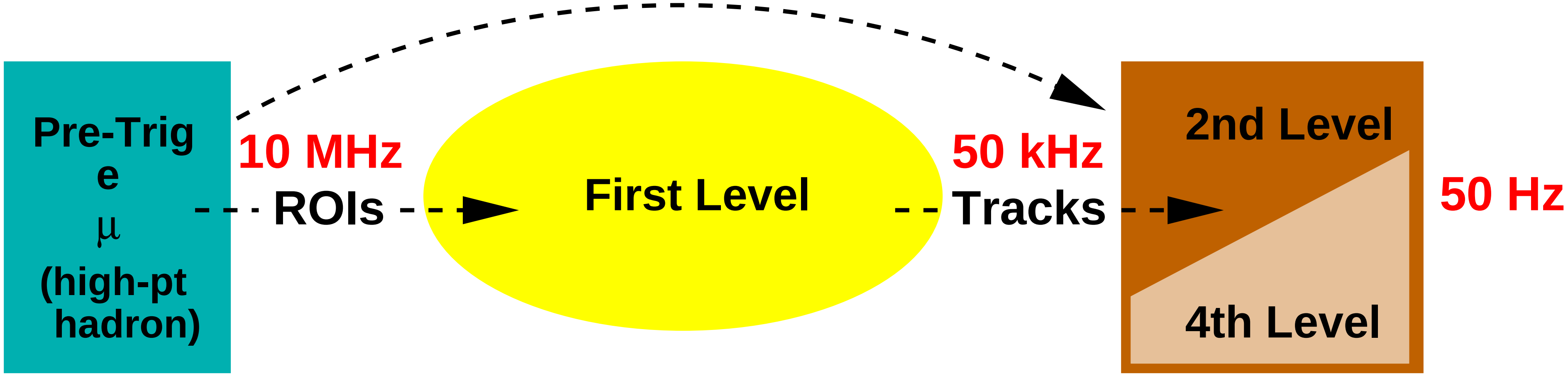
Electromagnetic Calorimeter





- stable operation, minor problems with hot channels
  → only source of pretriggers until June 2000
- stand-alone calibration using $\pi^0 \to \gamma\gamma$ signal: $\sigma_m/m = 6.7\%$

Multi-Level Trigger

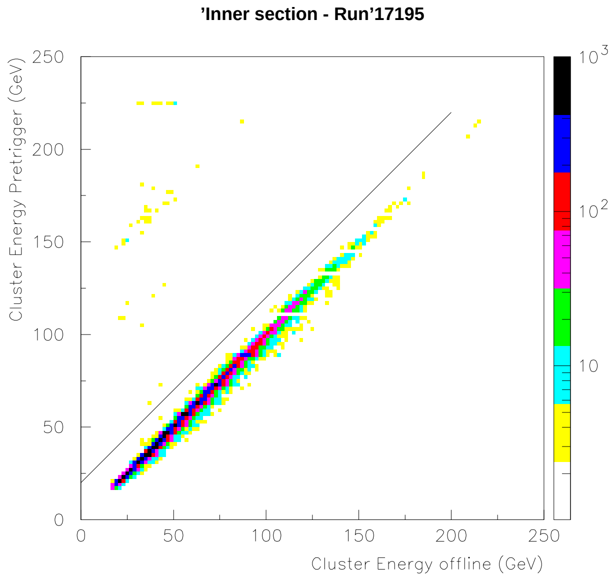


Pretrigger:	define Regions-of-interest (ROI) for high p_t particles
1st Level Trigger (FLT):	ROIs $\rightarrow$ tracks behind magnet
2nd Level Trigger (SLT):	refines tracks, match to vertex detect. $\rightarrow$ vertex
3rd Level Trigger (TLT):	for non-lepton triggers (not used in run 2000)
4th Level Trigger (4LT):	event reconstruction, classification and logging

Pretriggers

e-Pretrigger

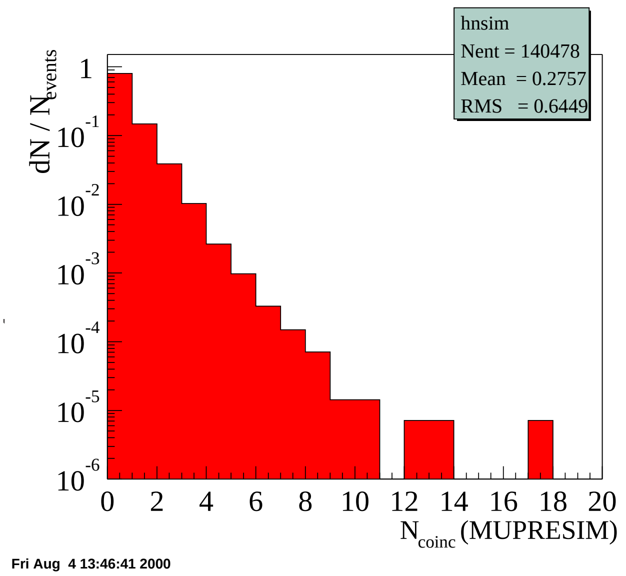
working, efficiency ∼96%



μ-Pretrigger

routine operation since June
using cathode pads of μ cham.

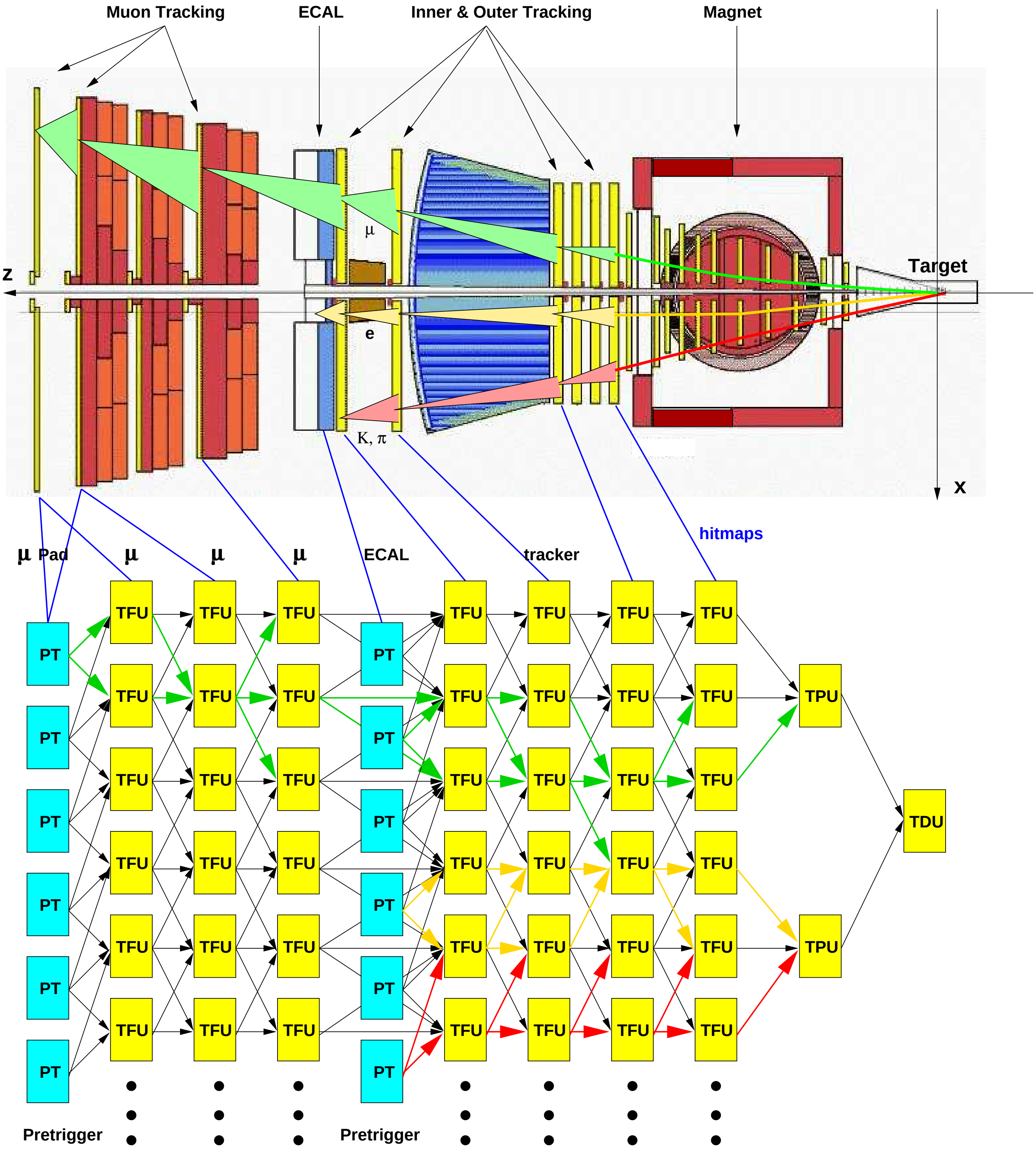
cathode pad effic.: $70 - 90\%$



High-p_t Pretrigger

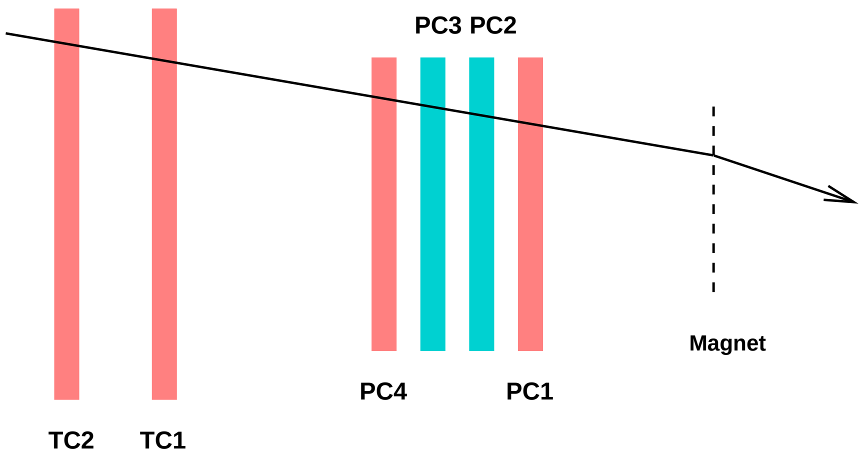
- ➢ inner (gas pixel) chambers installed and commissioned: chamber efficiency $> 90\%$
- ➢ outer (straw) chambers commissioning ongoing
- ➢ transmission problems of pretrigger electronics

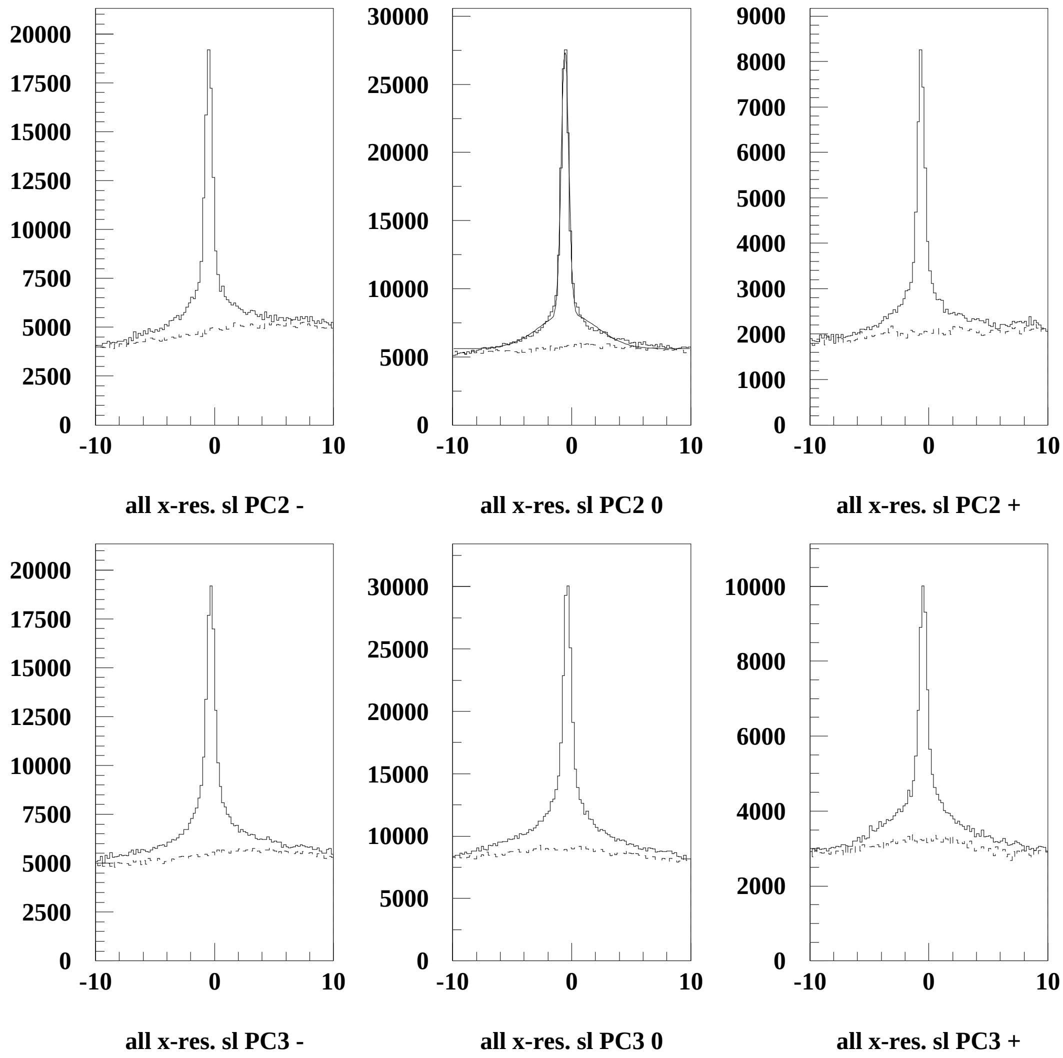
First Level Trigger



Custom made trigger processors:
Track-Finding Unit (TFU)
Track-Parameter Unit (TPU)
Trigger-Decision Unit (TDU)

1st Level Tracks





→ FLT tracks confirmed by unused chambers

track residuals: 3 mm (design 1.4 mm)

1st Level Status

Commissioning has reached the following level:

- efficiency for single electrons of 60 – 70% (Outer Tracker effic., data transmission problems)
- efficiency for single muons of 20% (alignment, muon chamber efficiency)
- no results for the pair trigger

→ efficiency of the tracking detectors has to increase
→ no principle obstacles has been encountered so far

FLT Online Tracking requires understanding of channel mapping, efficiencies, geometry and alignment of all involved components → gained only during running

Second Level Trigger

2nd Level algorithm on PC farm with 240 nodes:

- tracking code
- magnet traversal
- vertexing code

Performance of trigger algorithm close to design.

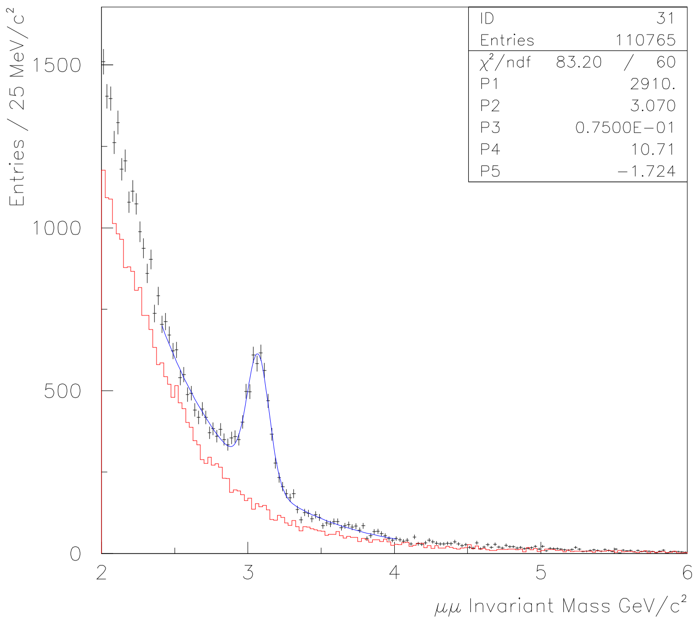
J/ψ production runs in 2000: $\rightarrow$ by-pass FLT

e pretrigger+SLT(di-lepton):	13×10^6 events
e/μ pretrigger+SLT(di-lepton):	3.7×10^6 events

(data taken at IA rate of 5 MHz)

Di-Lepton Triggers

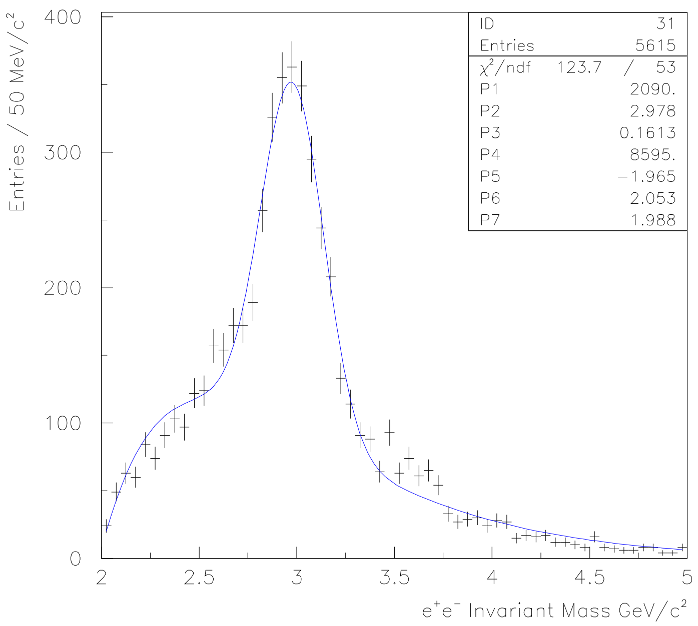
$J/\psi \to \mu^+\mu^-$



— unlike sign
— like sign

~3000 events (all data)

$J/\psi \to e^+e^-$



bremsstrahlung

for electron id

~2000 events (half data)

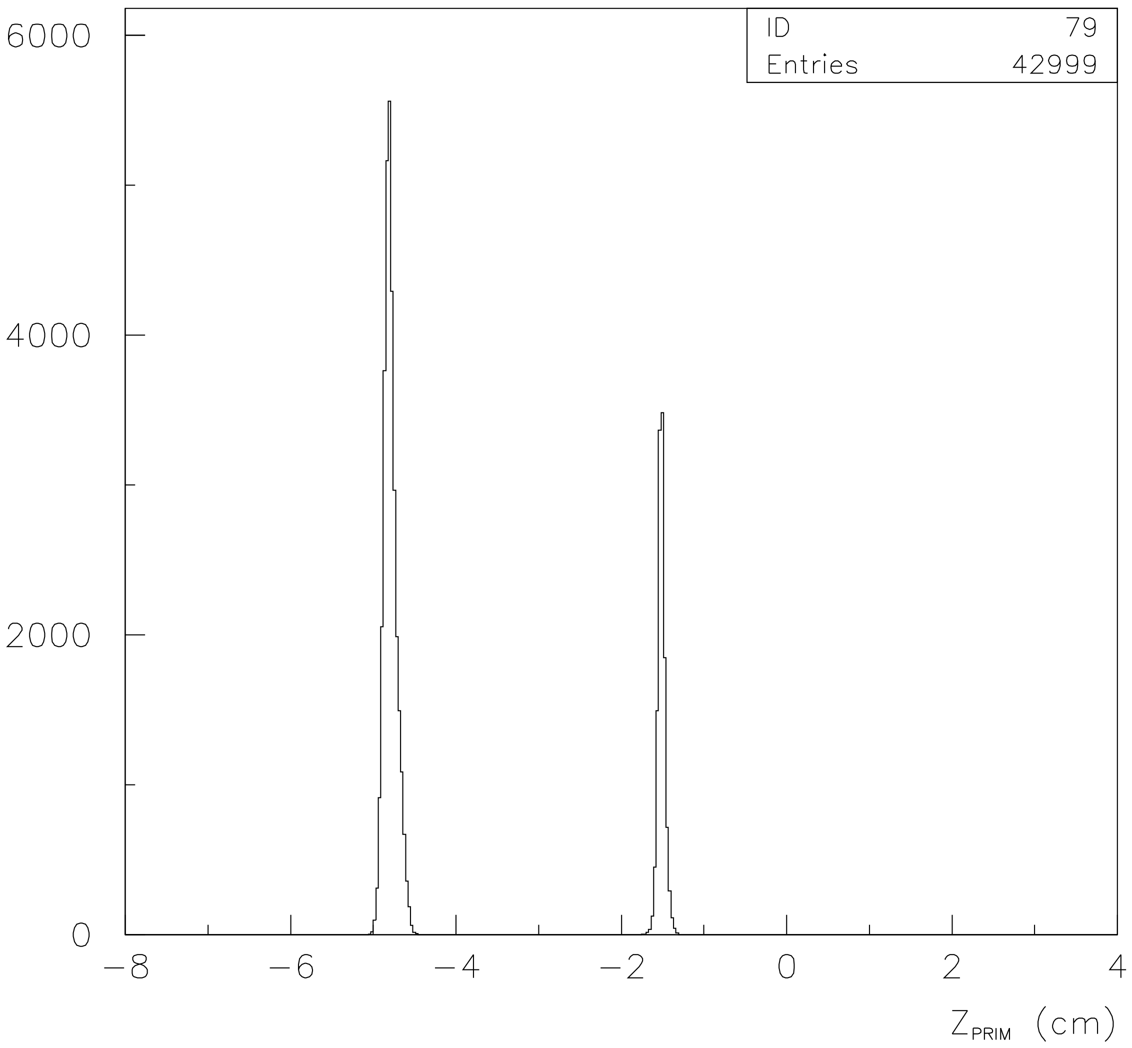
⇔ 40000 J/ψ events

w/o Bremstr cut (all data)

Primary Vertices of $J/\psi \to \mu^+\mu^-$

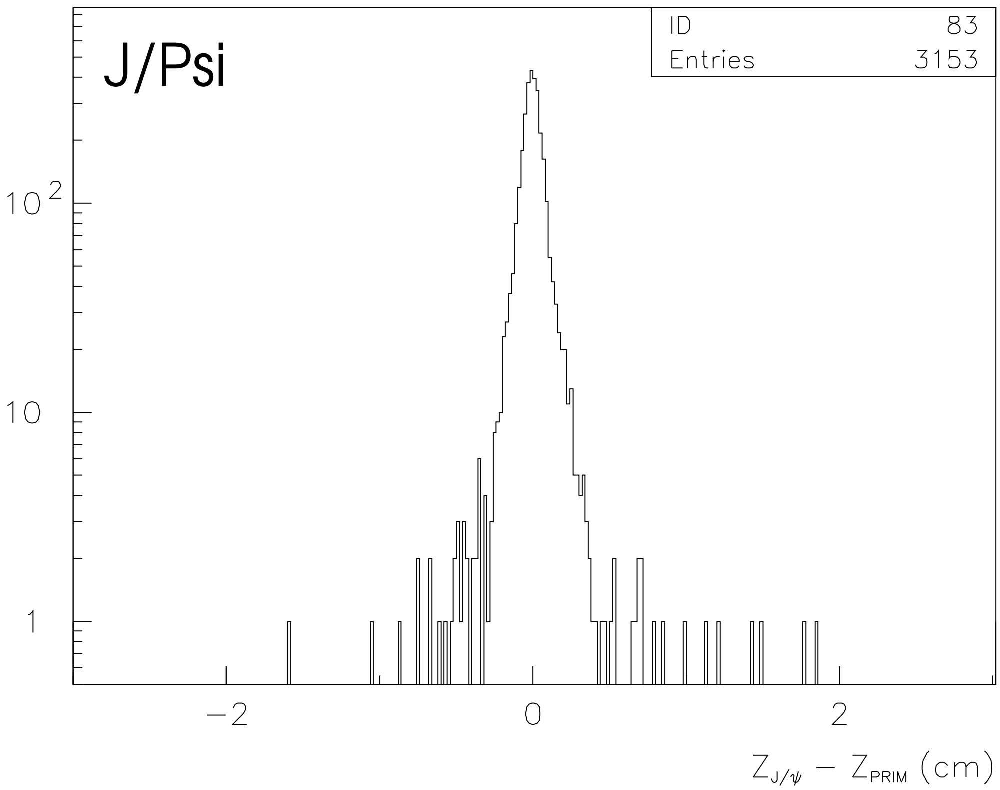
Selection of $J/\psi \to \mu^+\mu^-$ events:

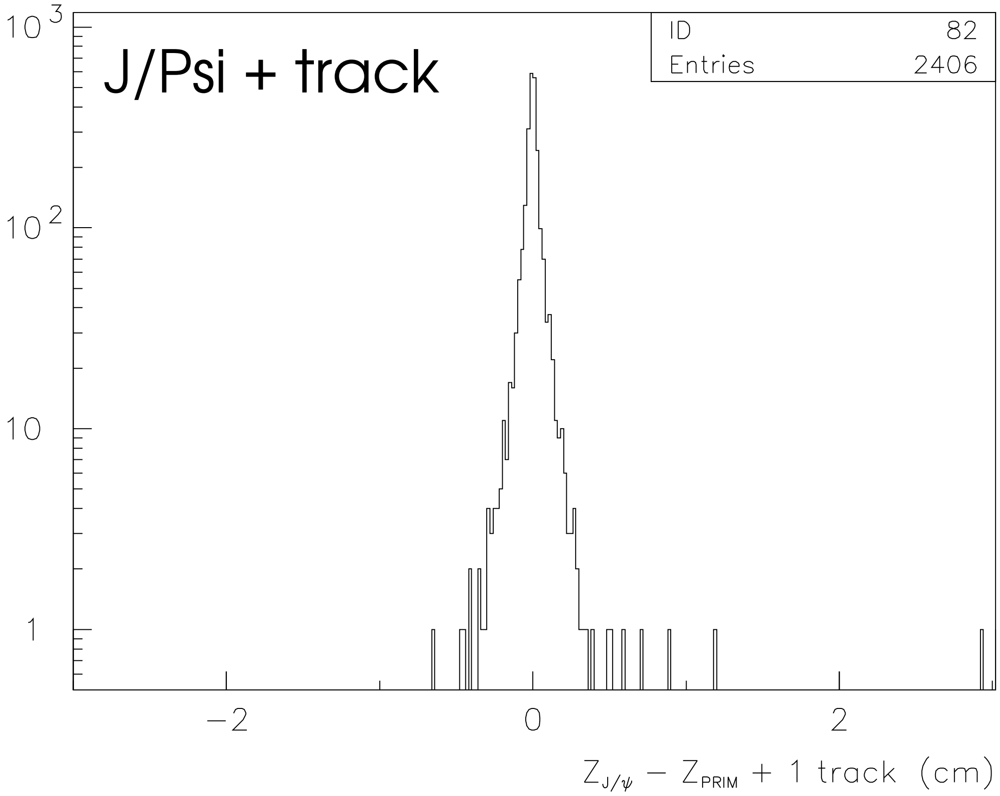
- refit vertex and momenta of both μ constraining $m_{\mu\mu}$ to J/ψ mass
- test J/ψ hypothesis: $\mathcal{P}(\chi^2) > 5\%$



Detached Vertices ?

Δz between primary and J/ψ vertex:





→ small background, detached vertices !

Summary of Subsystem Status

Well Running Systems	
Target	routinely operated
Vertex Detector	design performance
RICH Counter	close to design performance
ECAL	close to design performance
Pre-Triggers	e,μ pre-triggers working
2nd Level	close to design performance
DAQ	design performance

Systems with Problems	
Inner Tracker	routinely operated hit efficiency only between 80 and 90% no trigger signals in 2000
Outer Tracker	routinely operated loss of cells $\rightarrow$ repaired in shutdown hit efficiency $\sim$90% (lower HV)
Muon Chambers	routinely operated low efficiency of pads
1st Level	commissioning has started too late track efficiency low no basic problem encountered yet

Outlook

Schedule: – HERA shutdown until June 2001
→ work on known problems
– first luminosity in Sept 2001
→ continue FLT commissioning

Prospects: 1 year (10^7s) data-taking

$\epsilon_{trig} \times \frac{IA}{40MHz}$

1/4

trigger & reconstruct:
22000 $B \to J/\psi X \to \mu^+\mu^- X$
650 $B \to J/\psi K^{0*} \to \mu^+\mu^- K\pi$
?$\to$ 16 $B \to \mu^+\mu^- K^{0*} \to \mu^+\mu^- K\pi$ – FCNC

1/2

with working high-p_t hadron trigger:
120(140) $B_s \to D_s\pi(3\pi)$
reach to mesure B_s oscillation
$x_s < 42$ at 3σ

1

720 $B \to J/\psi K^0_s \to \ell^+\ell^-\pi^+\pi^-$
→ $\Delta \sin 2\beta = 0.16$

Conclusion

- The HERA-B detector is essentially completed
- HERA-B has made valuable contribution to the field of high-rate tracking detectors: A large area honeycomb tracker and the largest MSGC-GEM detector system are operated in an LHC-like environment.
- Commissioning of sub-detectors is well advanced.
- Commissioning of the full trigger chain – in particular of the First Level Trigger – has not yet finished.
  No trivial task!
- Efforts are under way to bring all detector components close to their design values.
- If design values are reached HERA-B can make contributions to B physics.