First Results from the HERA-B experiment

A. Zoccoli
Università and INFN-Bologna

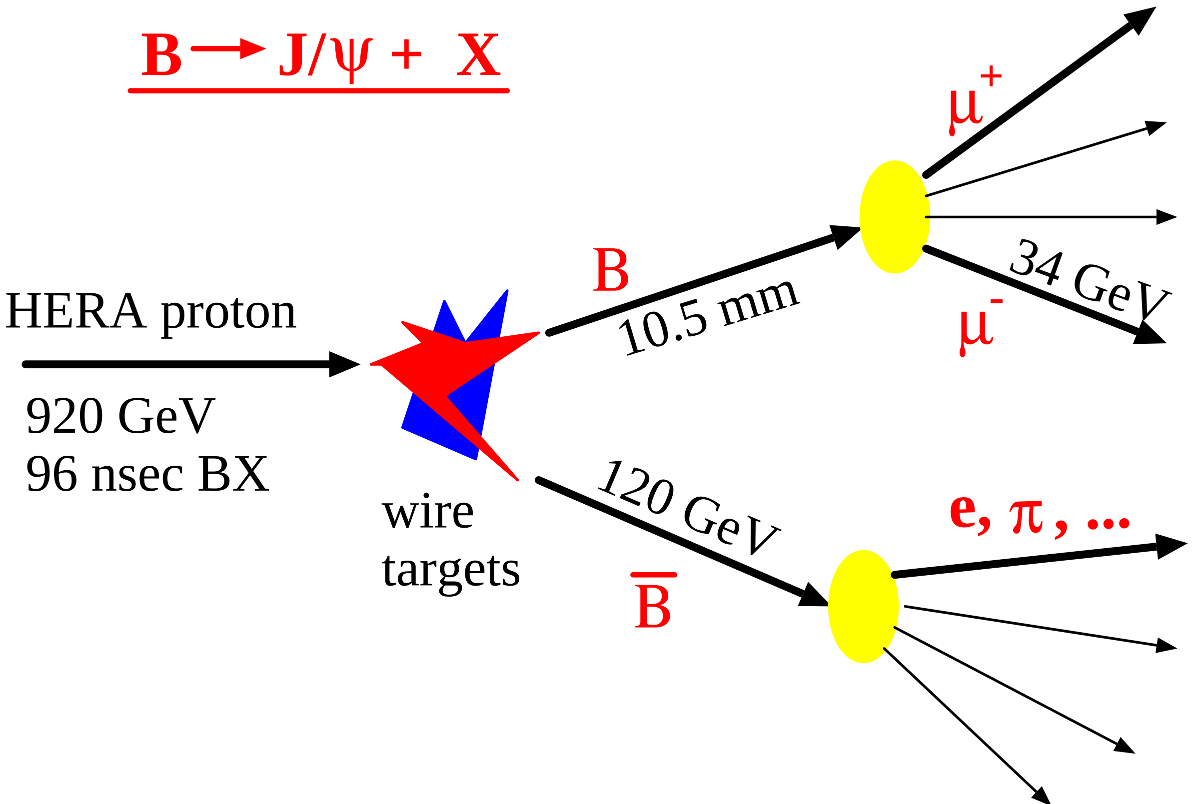
For the HERA-B Collaboration

- Introduction
- Detector status
- Trigger status
- J/ψ data
- Outlook and Conclusions

CPconf 2000
Ferrara, Italy
September 21th, 2000

The Hera-B experiment

$B \rightarrow J/\psi + X$



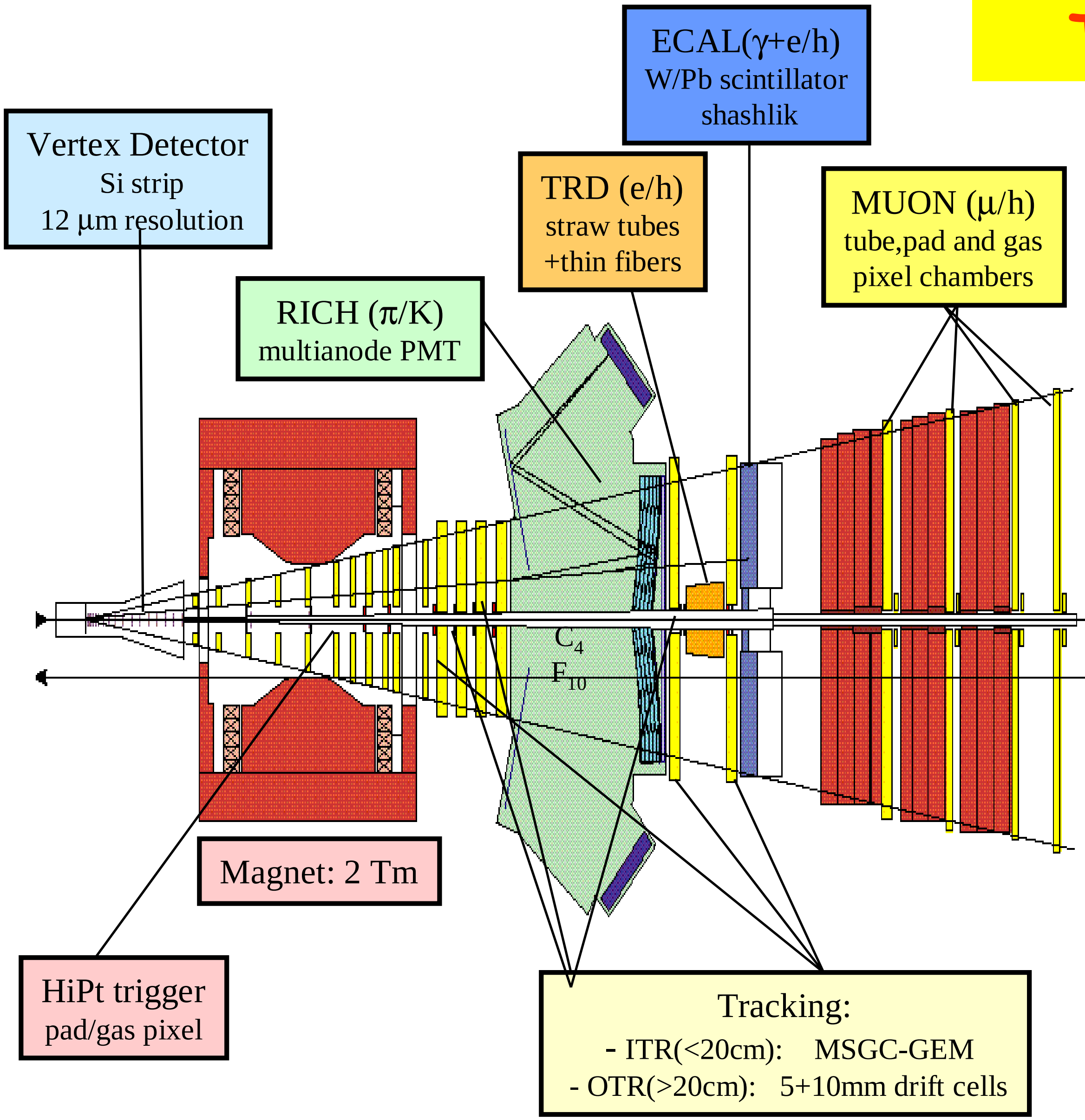
Fixed Target Hadronic B-Factory at HERA.

- ❍ Detect CP Violation in the Golden Channel $B \rightarrow J/\psi\ K_S$
- ❑ Measure other CP violating B decay channels
- ❑ B_S oscillations
- ❑ Rare B Decay
- ❑ b-barion production and features
- ❑ c-quark physics

Schedule:

- ➪ approved in 1995
- ➪ detector completed in spring 2000
- ➪ Commissioning until August 26th
- ➪ Hera shutdown until june 2001

The Hera-B detector



- 920 GeV HERA protons on wire targets:

$$p + N(target) \rightarrow b\bar{b} + X$$

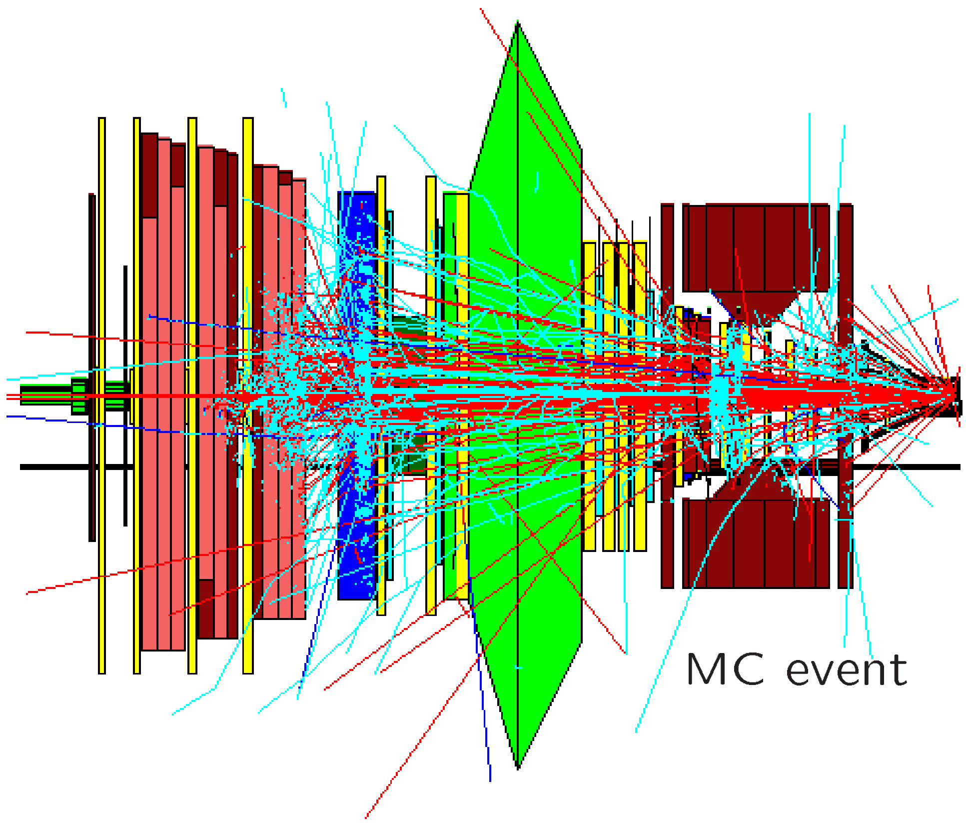
$$\sigma_{b\bar{b}} / \sigma_{INEL} \approx 10^{-6}$$

with $\sigma_{b\bar{b}} \approx 12nb$

- High selective trigger

- Design interaction rate up to 40 MHz
  - B rate up to 40 Hz
  - 10^6 produced $B \rightarrow J/\psi X$ per year

High-Rate Environment

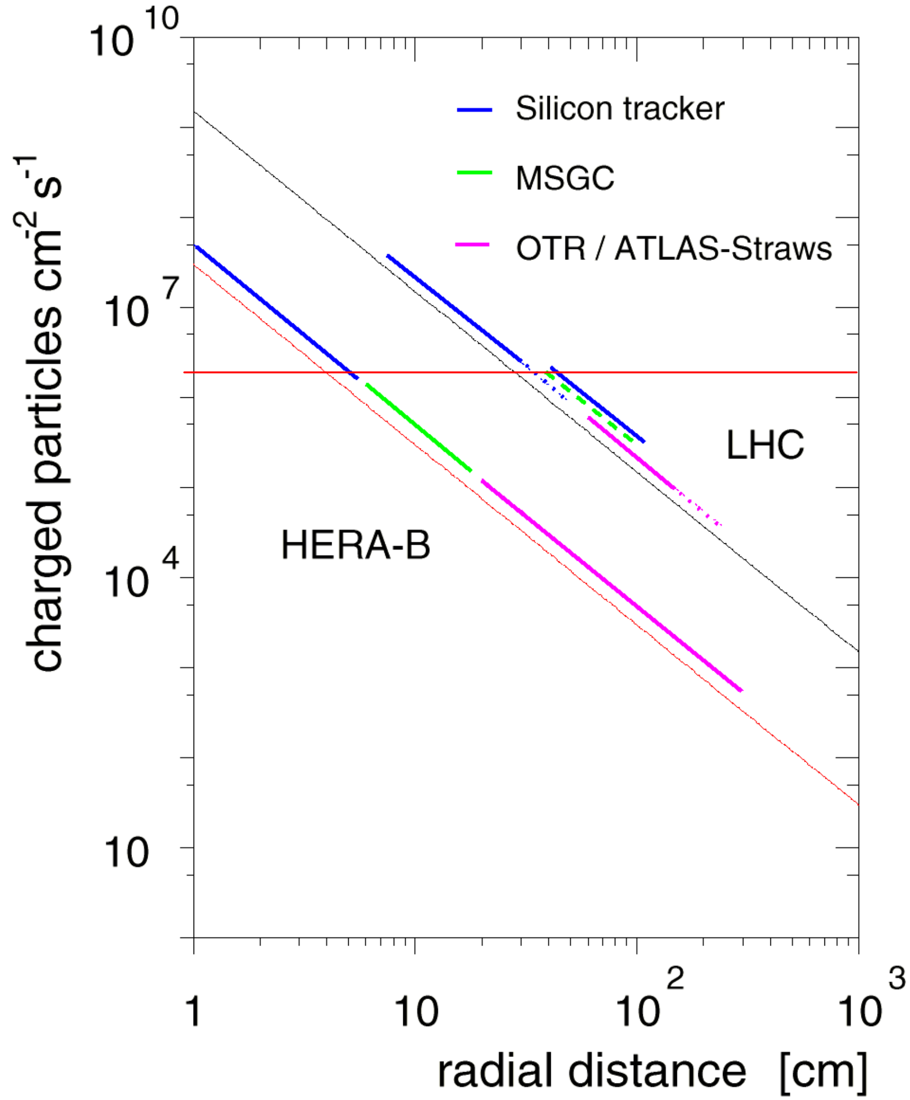


at IA rate of 40 MHz:

- 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 $\approx 10^{-9}$

Radiation levels



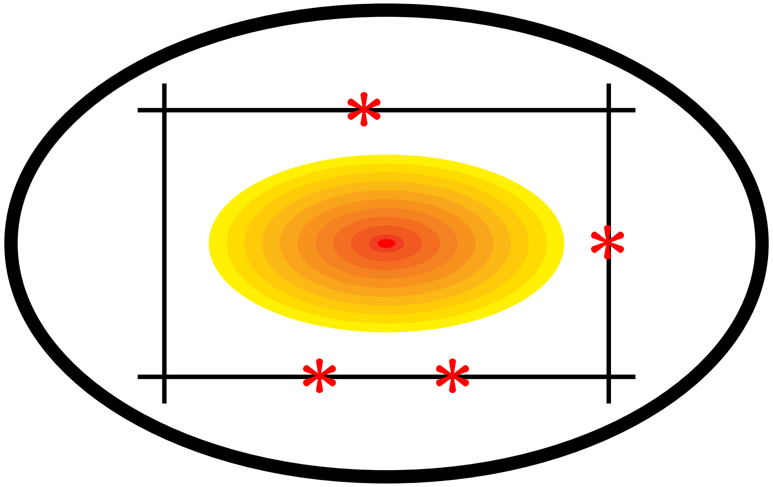
HERA-B detectors have to face particle fluxes similar to what future LHC experiments will encounter.

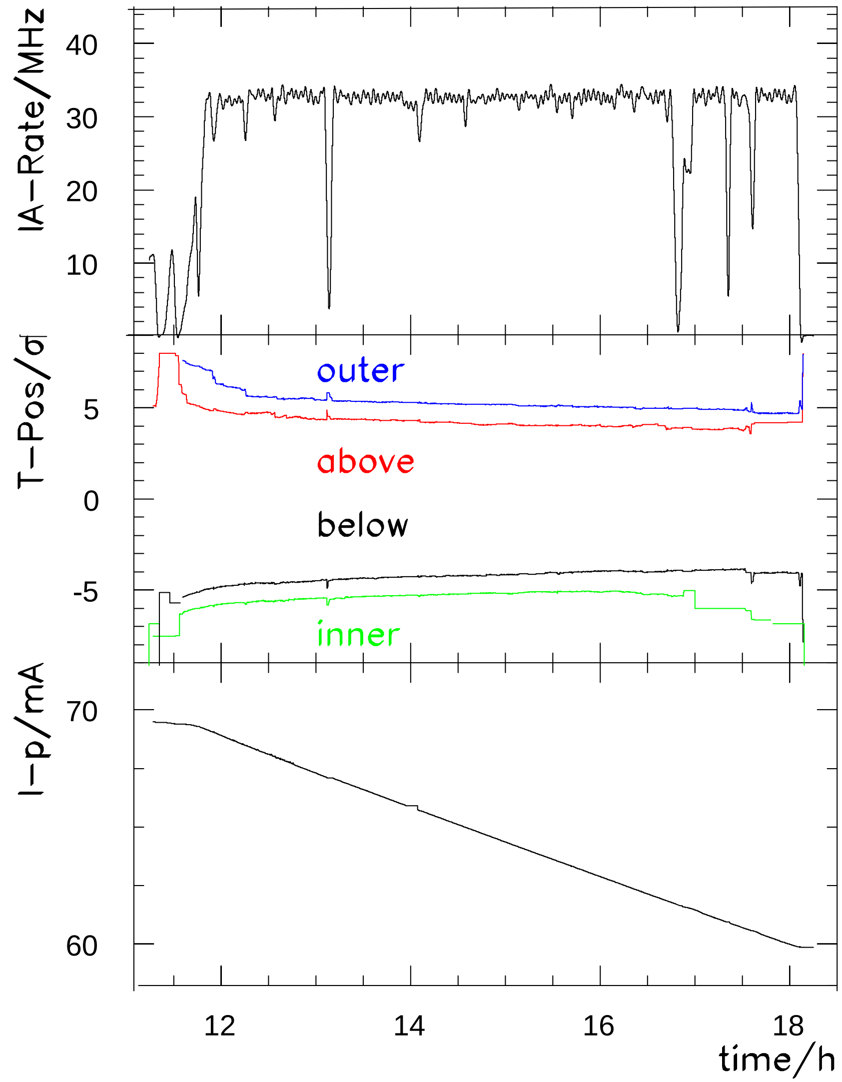
Particle flux/year:
$2 \cdot 10^{14} / R^2$ [cm^2]
➪ 10^5 gray/year in the SI-detector
➪ 0.6 C/cm/year in Drift chamber

➪ Radiation damage

➪ Substantial R&D for tracking detectors

Target



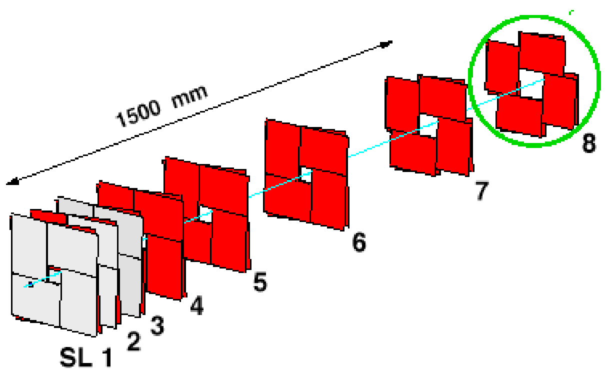


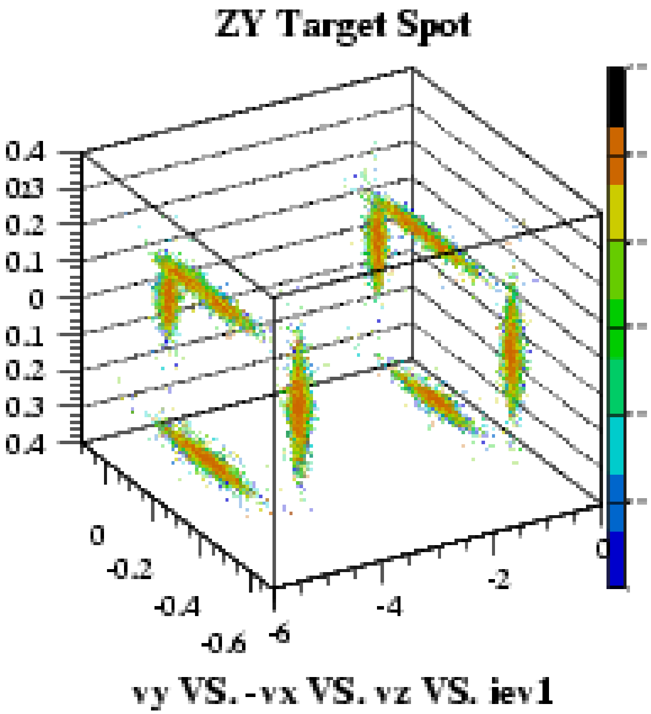
Insert thin wires into beam halo
→ Absorb protons leaving the beam core
→ Little interference with Hera operations

Two stations with 4 wires each
→ target materials: Ti, C, AL, W

→ Reliable operations
Small interference with other experiments

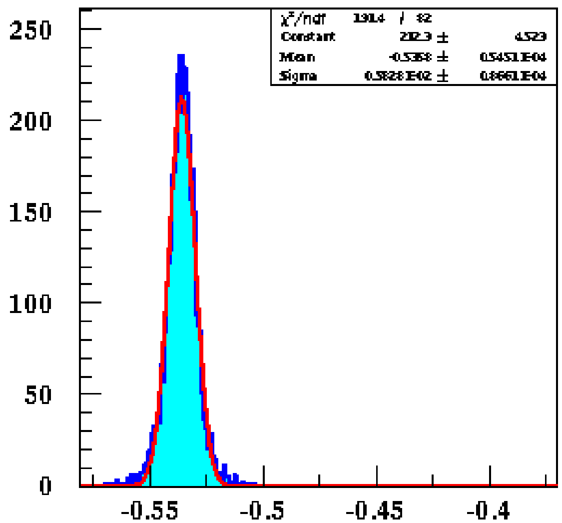
Vertex Detector System



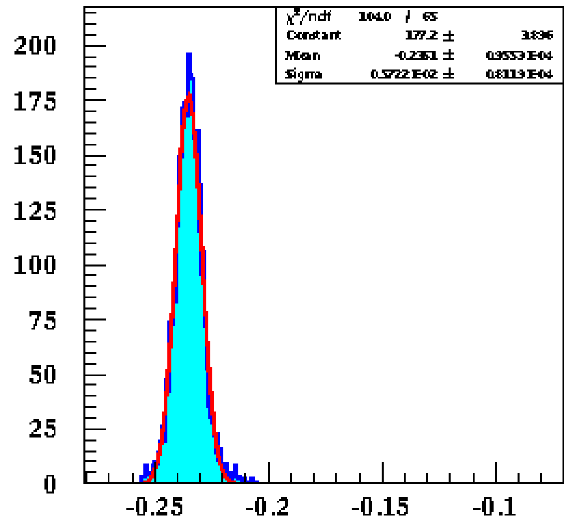


- 8 layers, 64 Si detectors (double+single side) 150000 channels
- layer 1-7 in roman-pots
- Runs stable, high data quality
- Hit resolution ~10 μm
- Up to 10 Mrad/year

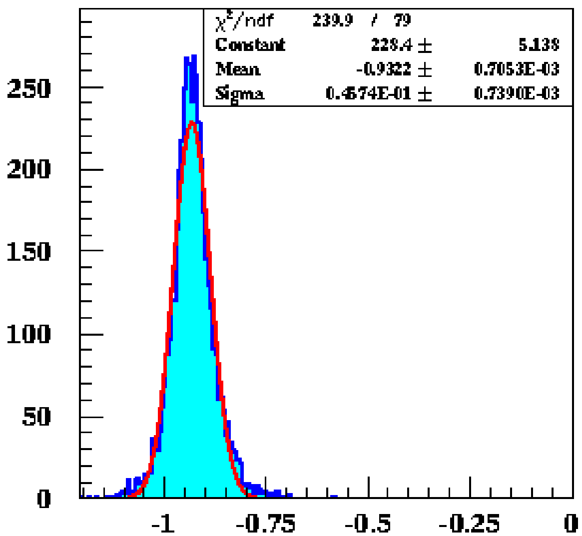
Vertex distribution



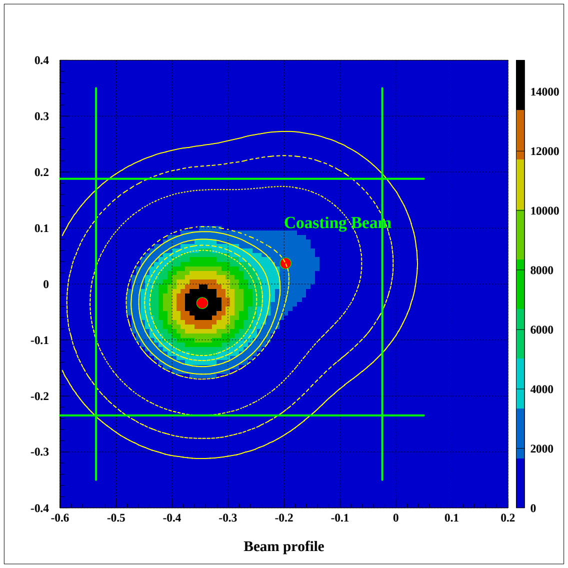
X proj. Inner1



Y proj. Below1



Z proj. Inner1



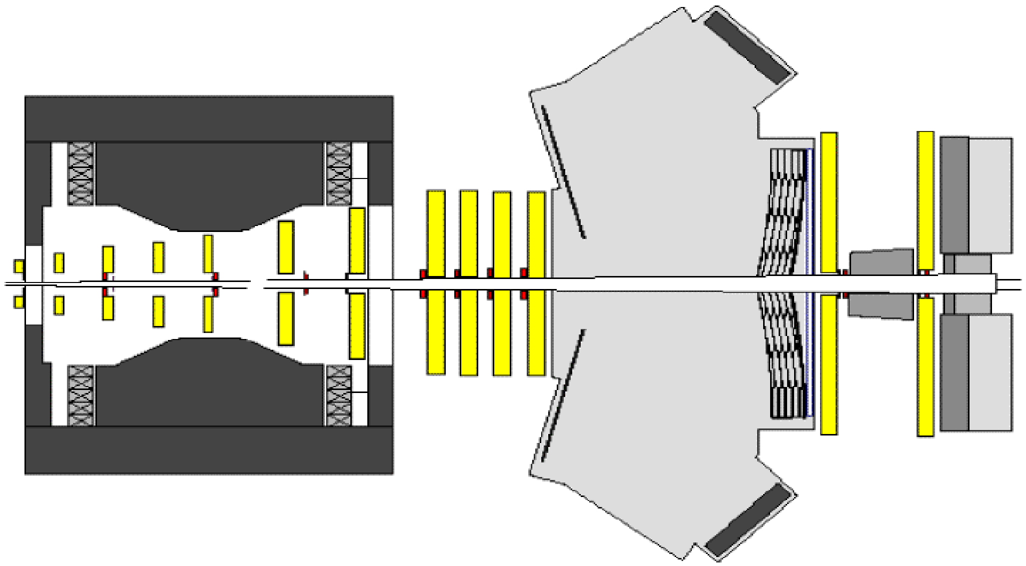
Close to the nominal resolution of the detector:

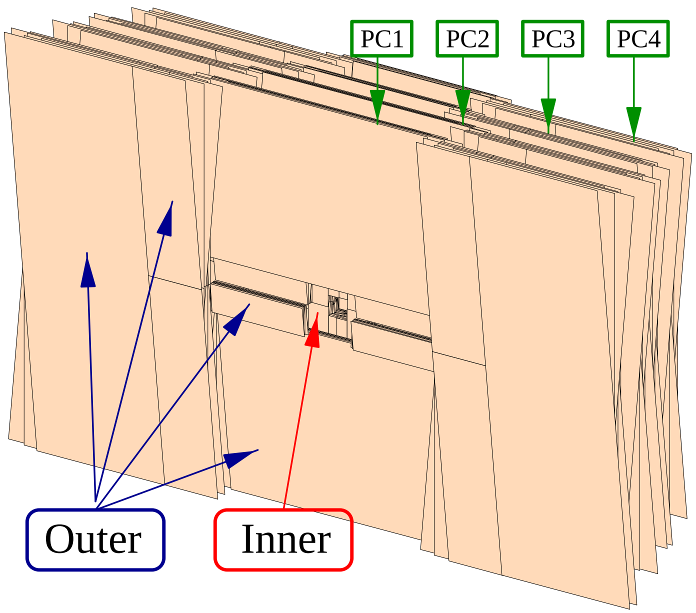
$$\sigma_{xy} \cong 60\mu m$$

$$\sigma_z \cong 500\mu m$$

Beam profile and Coasting beam

Main tracker





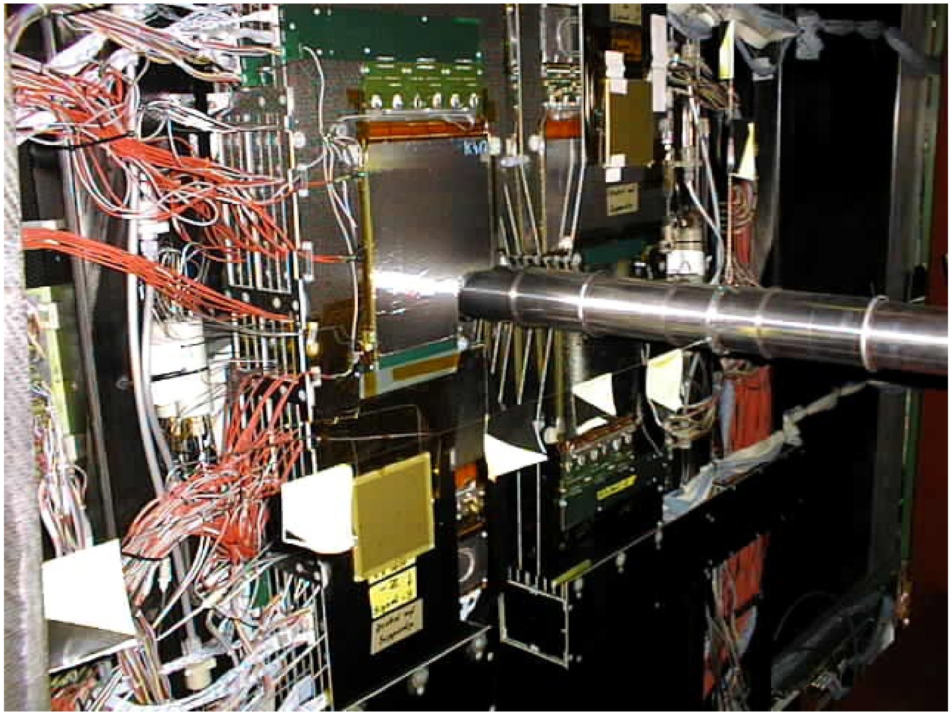
Inner tracker:

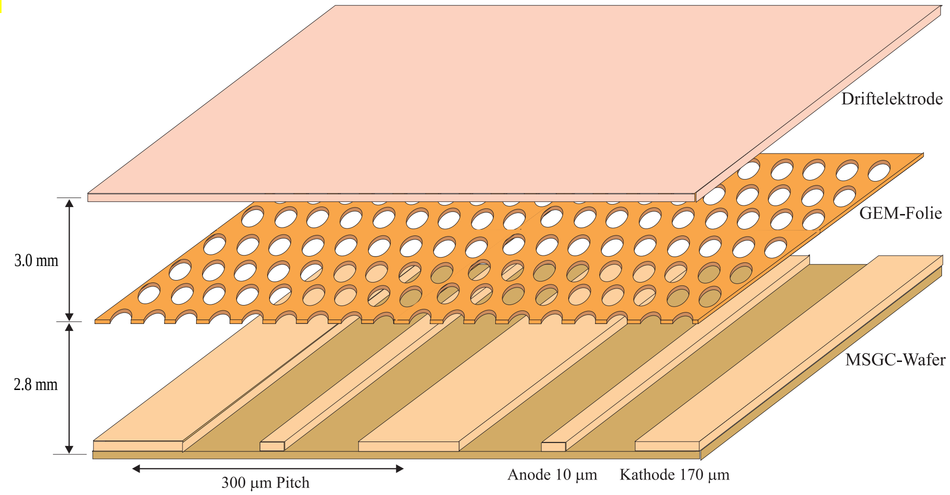
MSGC - GEM detectors
pitch: 300 μm,
size: 25 cm x 25 cm
184 chambers,
140,000 channels
Up to 1 Mrad/year

Outer tracker:

Honeycomb Drift Chamber
pitch: 5 and 10 mm,
size up to: 4.6 m x 6.5 m
1000 modules, 1000 m^2,
115,000 channels

Inner tracker



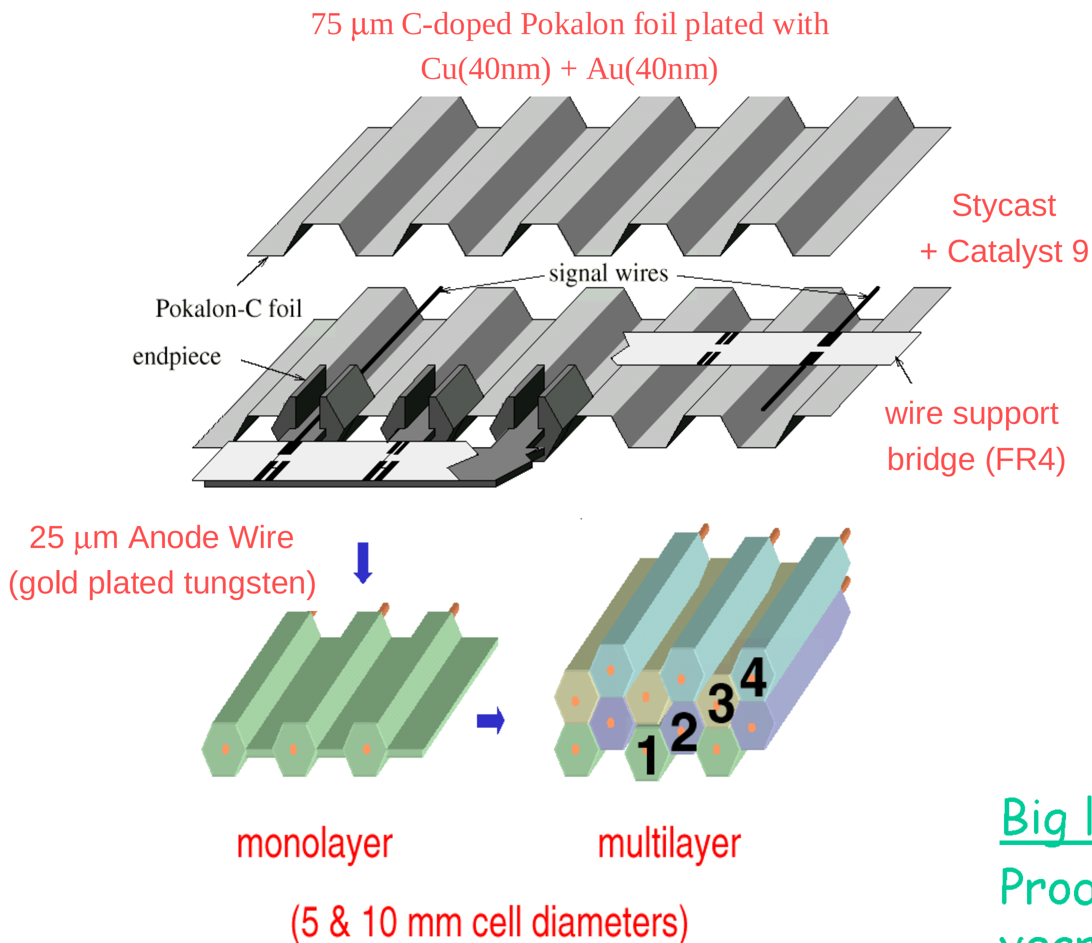


- Charge up of insulating surface
  diamond coating of MSGC surface
- Sparks destroy MSGC structure:
  add preamplification in gas (GEM)
- Anode aging:
  use Ar:CO_2 (70:30) gas mixture

- Detectors are in stable operation.
- Hit efficiencies up to ~90% reached (design: 98%)
- New: Individual adjustment of GEM-voltages
- Hit resolution: ~80 µm (design reached)

⇒ NO contribution to FLT in year 2000, due to electronic noise

Outer tracker



- Malter Effect with pure Pokalon-C cathode:
  Au/Cu coated Pokalon-C surface
- Anode aging with $Ar:CF_4:CH_4$:
  use $Ar:CF_4:CO_2$ (65:30:5) gas mixture
- Dark current with CF_4 based gas:
  water concentration < 500 ppm

Big logistical effort:

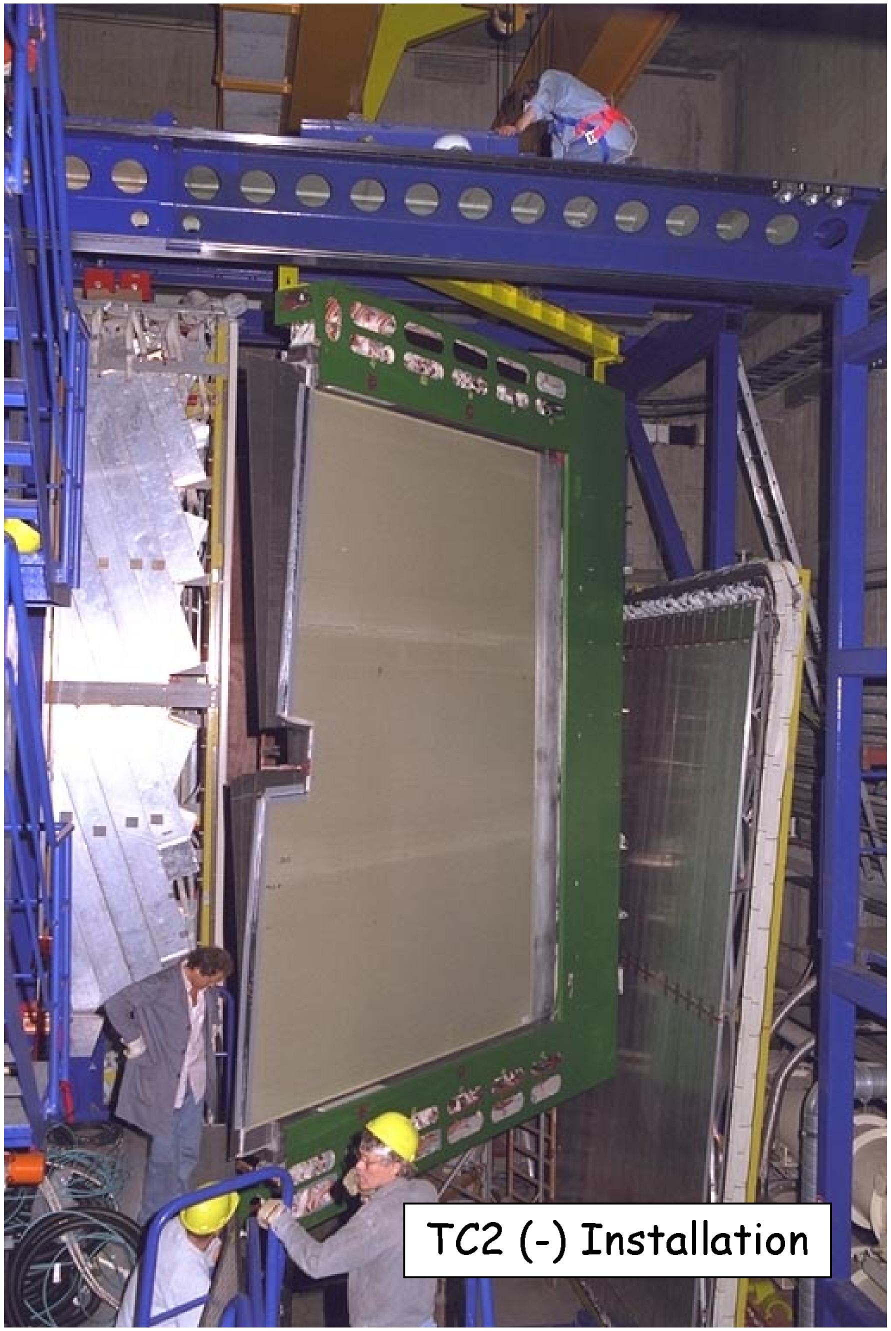
Production, assembly and installation within 1 year. Completed beginning 2000.

Chamber Operation

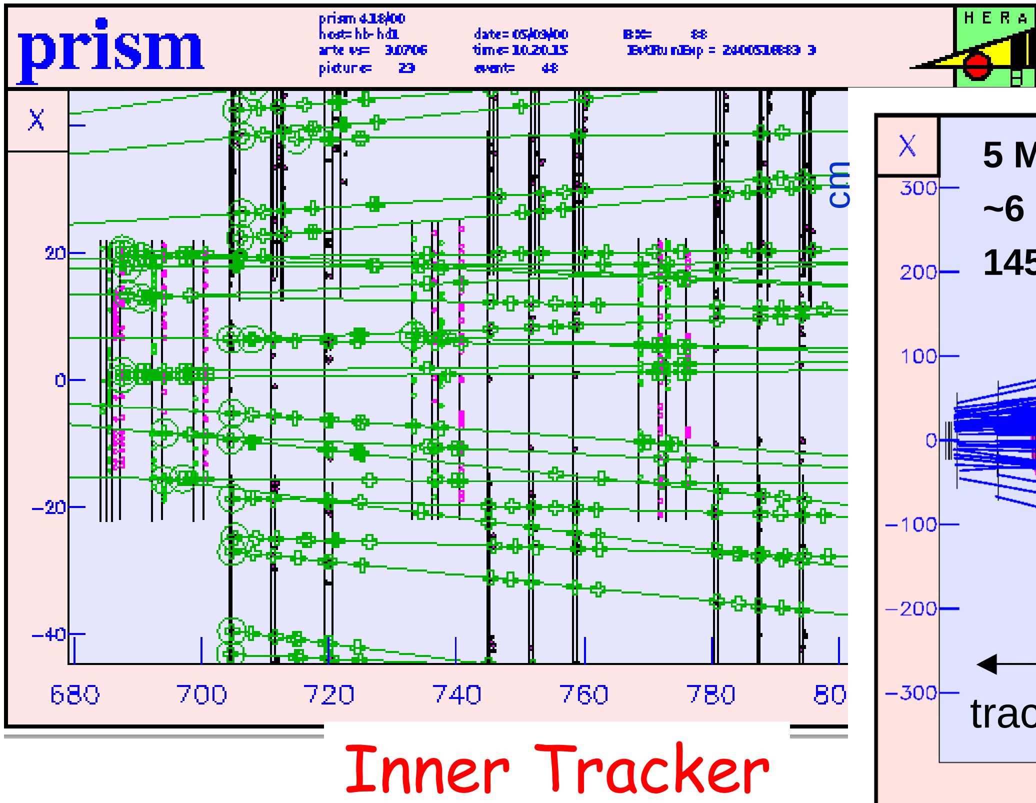
- Detector routinely operated
- HV shorts for 0.5% of drift cells
  → HV grouping: 8% of dead channels

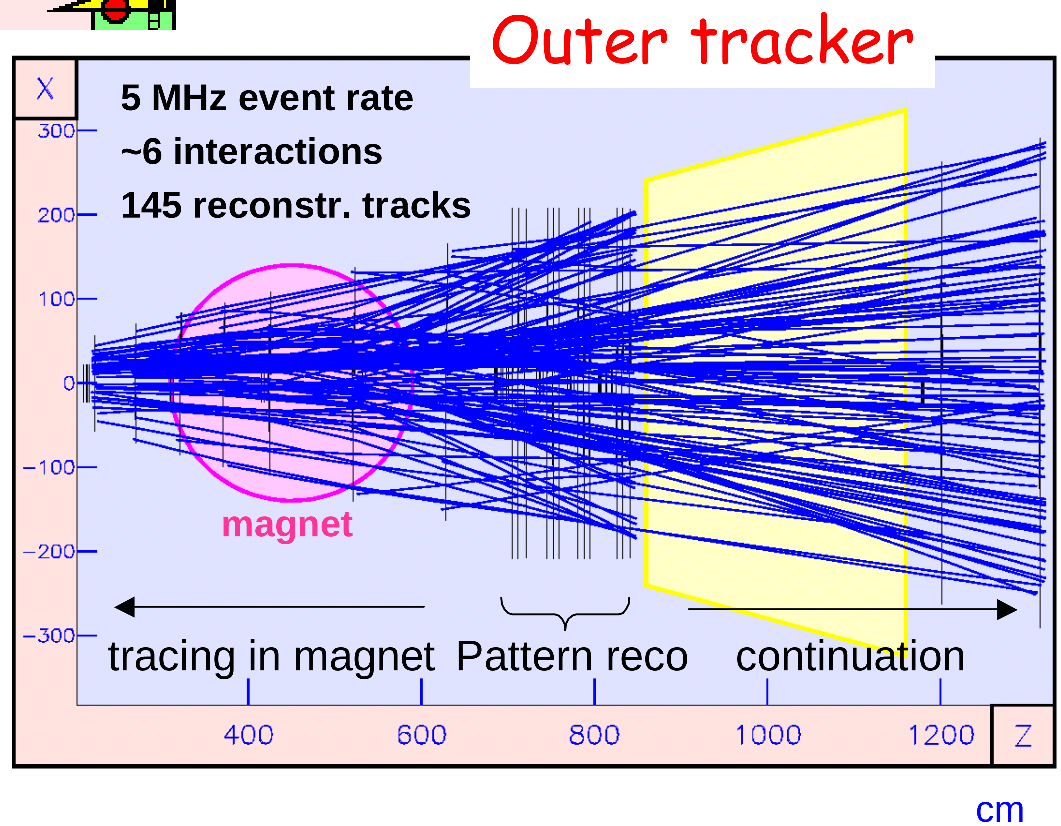
  - reduce HV to stabilize the effect
  - repair broken groups
- increase thresholds to reduce noise from trigger output
- Inefficiency affects Trigger

Cell efficiency: ~90% (design 98%)
Hit. Resolution: ~350 μm (design: 200 μm)



Track reconstruction

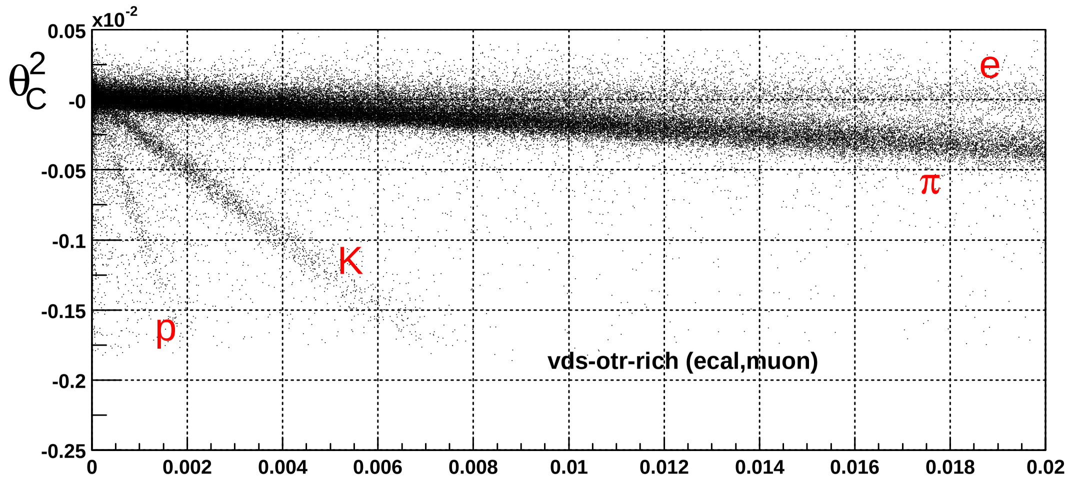




Reconstruction suffers from current chamber performance:

- improvements of the algorithms to reduce impact of dead channels , lower hit resolutions and hit efficiencies.
- 90% for tracks with at least 18 hits

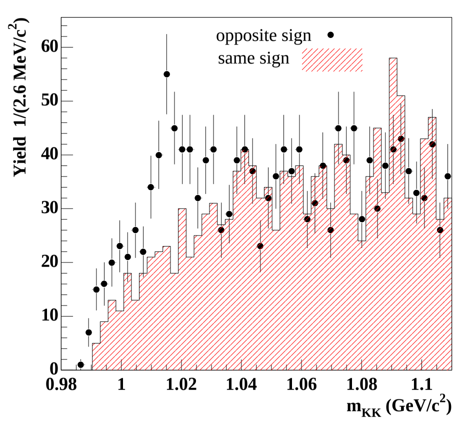
RICH Particle Identification



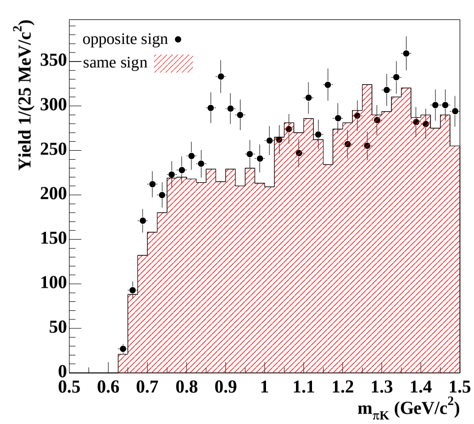
Čerenkov relation $\cos\theta_c = \frac{1}{n\beta}$: $\theta_c^2 = \theta_0^2 - \frac{m^2}{p^2}$

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

$\phi \to K^+K^-$

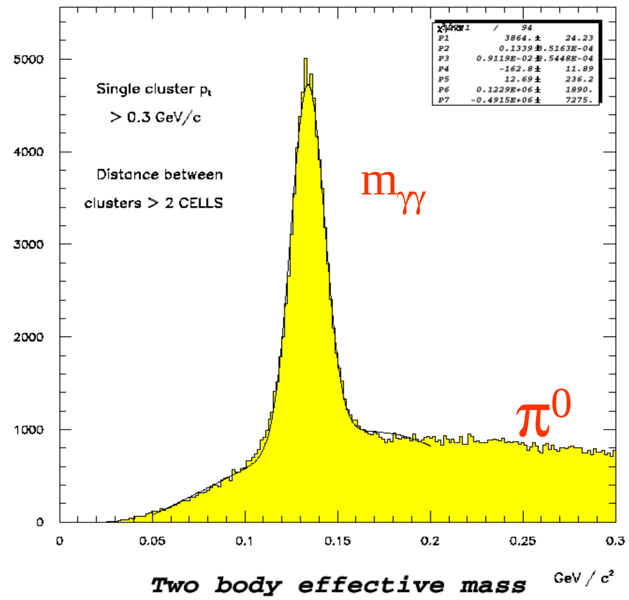


$K^{0*} \to \pi^\pm K^\mp$

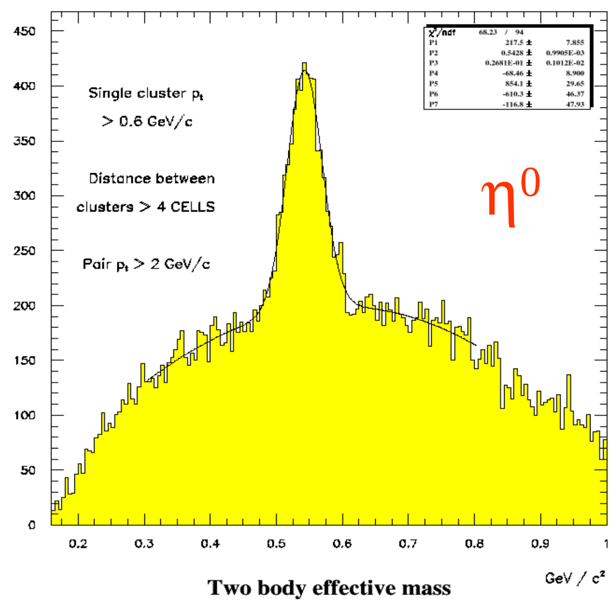


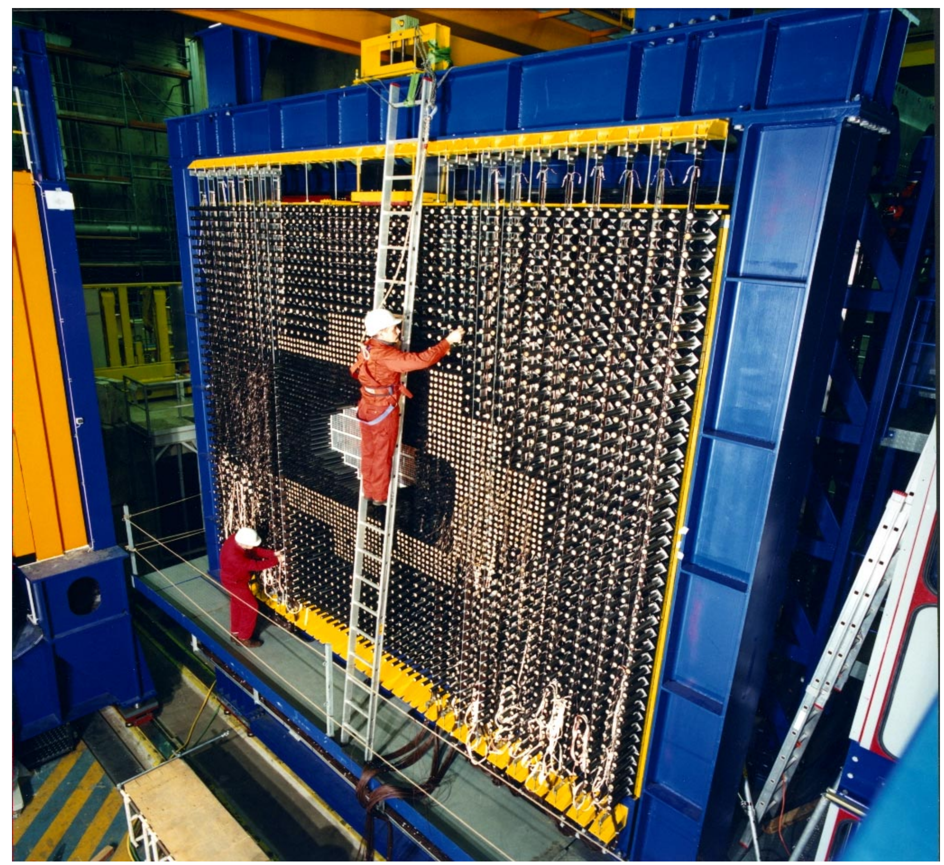
(vertex and RICH information)

Elettromagnetic Calorimeter

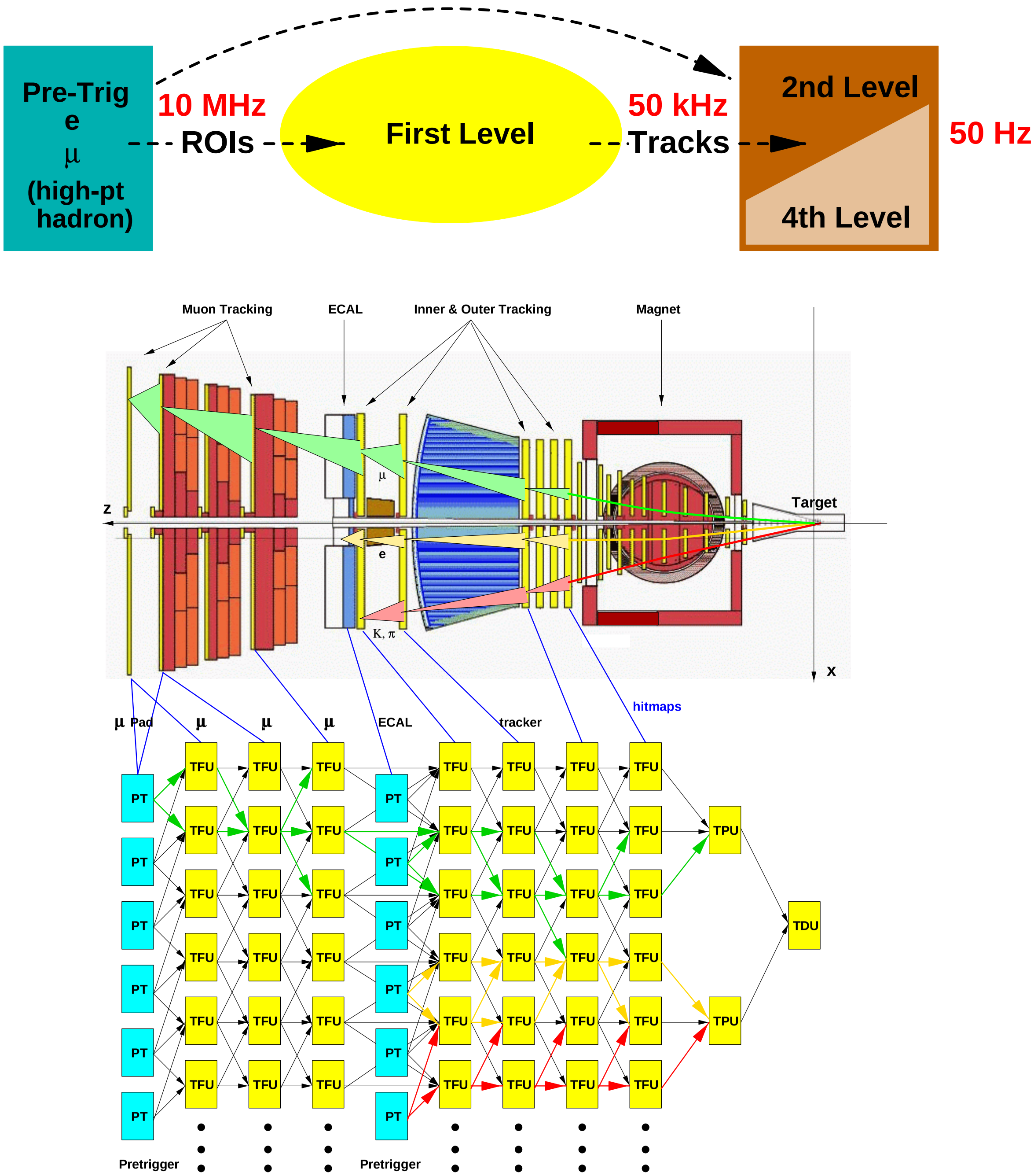


Shashlik sampling calorimeter.
3 lateral sections to match occupncies
Stable operation
→ Only source of pretriggers until June 2000





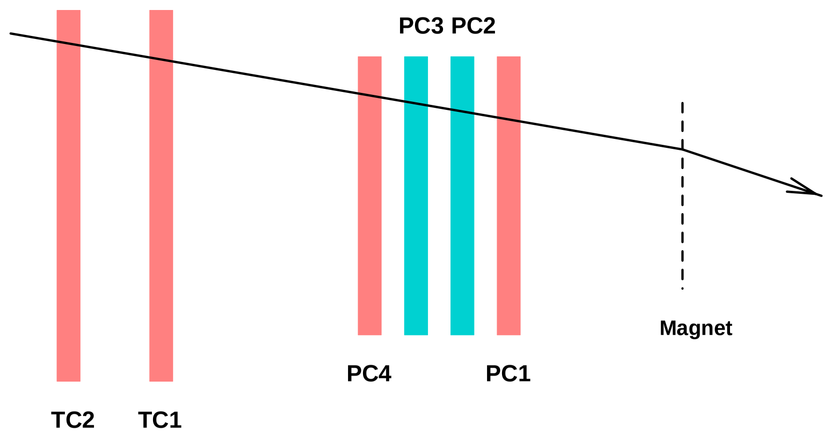
The Multi-Level trigger

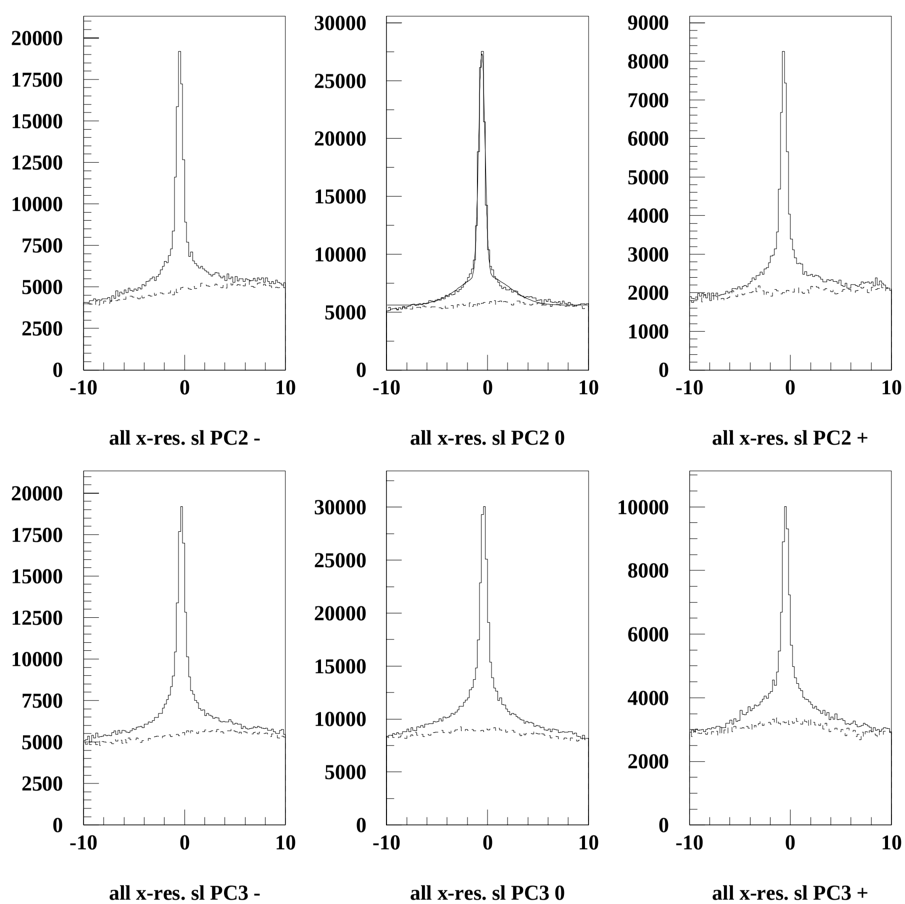


Kalman Filter based trigger

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

FLT Tracks





FLT tracks confirmed by unused chamber

track residuals: ~ 3mm (design 1.4mm)

FLT status

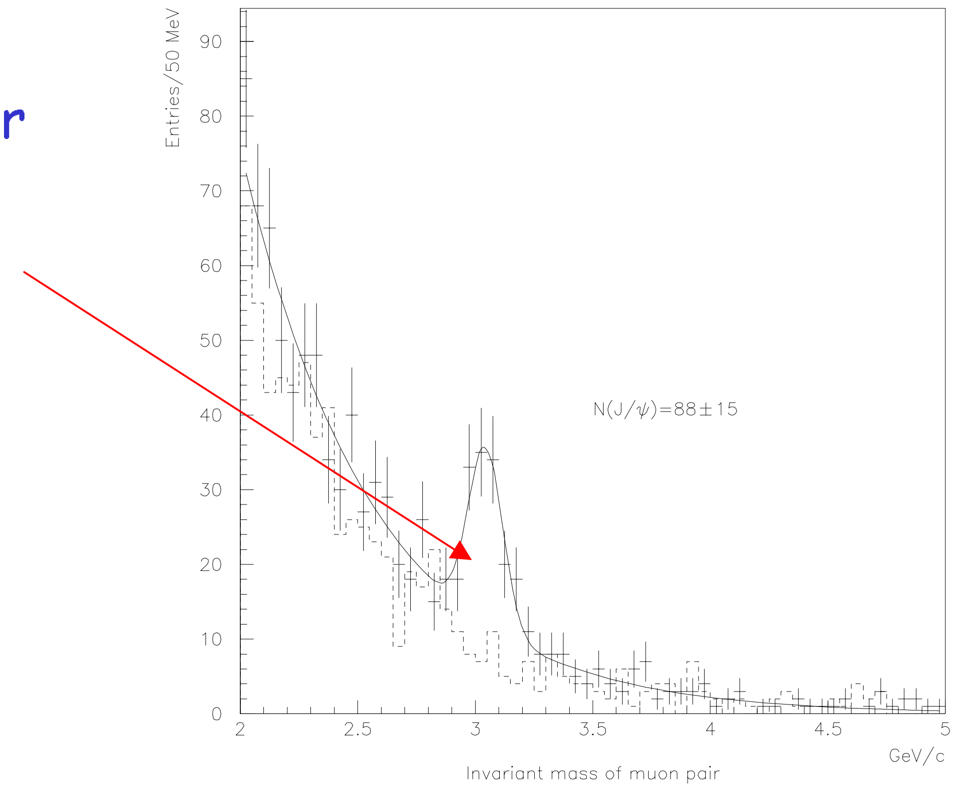
- FLT = Online tracking ⇨ depends on the trackers stauts and understanding (mapping, efficiencies, geometry, alignment ….)

Present status:
data taken with Single-Lepton trigger and Di-Leton trigger

❍ Single muon track efficiency very low (20%) ⇨ J/ψ seen with the full trigger chain

❍ Better situation for electrons

❍ No J/ψ in Di-Lepton FLT trigger seen



Efficiency of the detector has to increase
➔ No principle obstacles has been encountered so far

Second Level Trogger

Second Level Trigger Farm

The second level algorithm works on PC farm of 240 nodes.

- -Tracking with refit
- -Propagation in the Magnet
- -Di-lepton vertexing

Performances close to design

Extensively used in data taking and J/ψ Production. (IA mainly at 5MHz)

FLT by- pass:

-Di-lepton e-pretrigger	$13 \cdot 10^6$ ev
-Di-lepton e/μ -pretrigger	$3.7 \cdot 10^6$ ev

<u>With FLT, Full trigger Chain:</u>

Single lepton	$4.5 \cdot 10^6$ ev

Summary of Subsystem Status

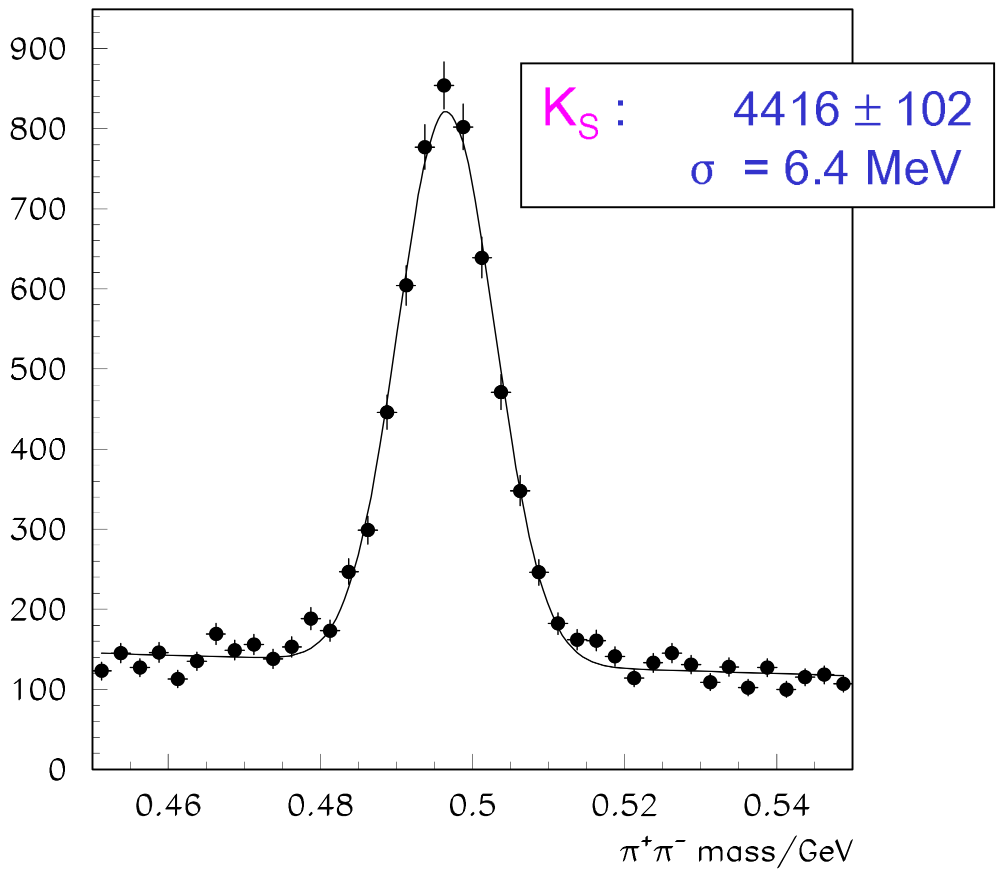
Well Running systems

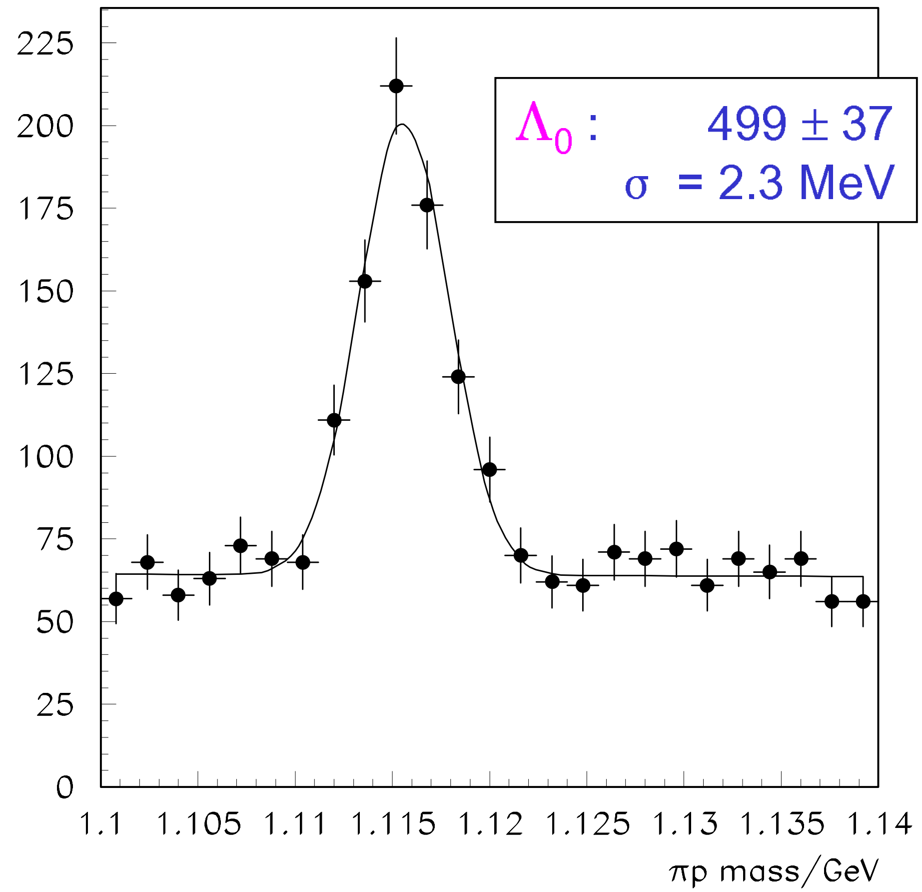
Target	Routinely operated
Vertex Detector	Design performances
RICH	Close to Design performances
ECAL	Close to Design performances
Pre-Triggers	e/μ pretriggers working
SLT	Close to Design performances
DAQ	Design performances

Systems with problems

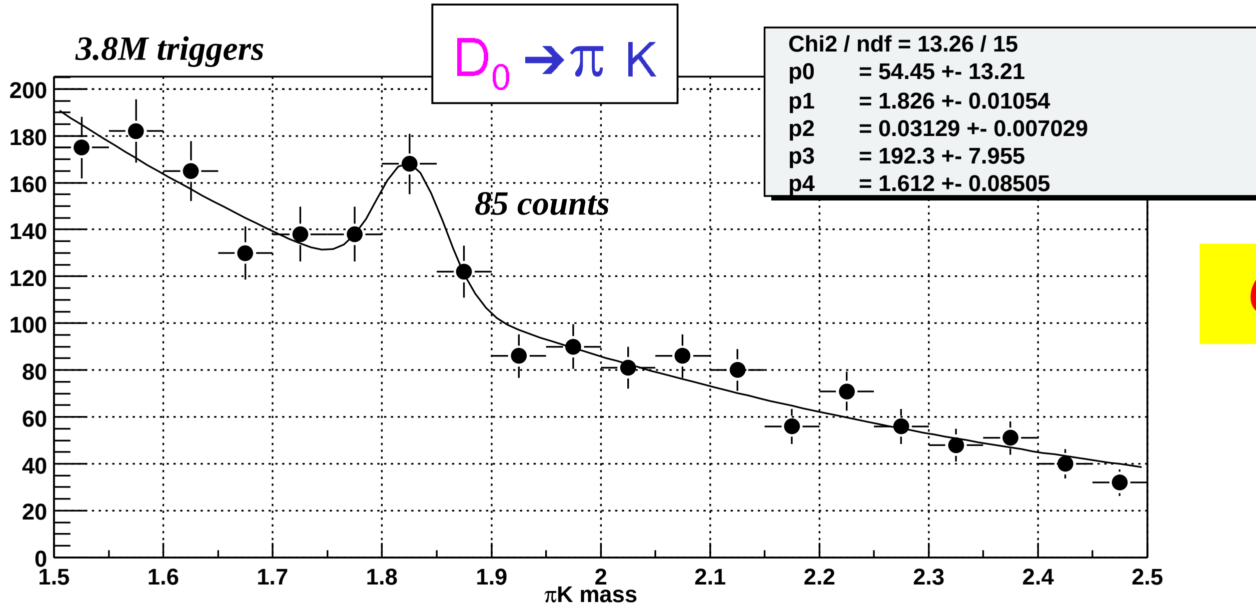
Inner Tracker	Routinely operated, hit efficiency between 80-90%, NO FLT signals in run 2000
Outer Tracker	Routinely operated, hit efficiency at 90% Loss of cells $\rightarrow$ repaired in shutdown
Muon Chamber	Routinely operated, Low pads efficiency
FLT	Comissioning started too late Very low track efficiency

Single lepton trigger



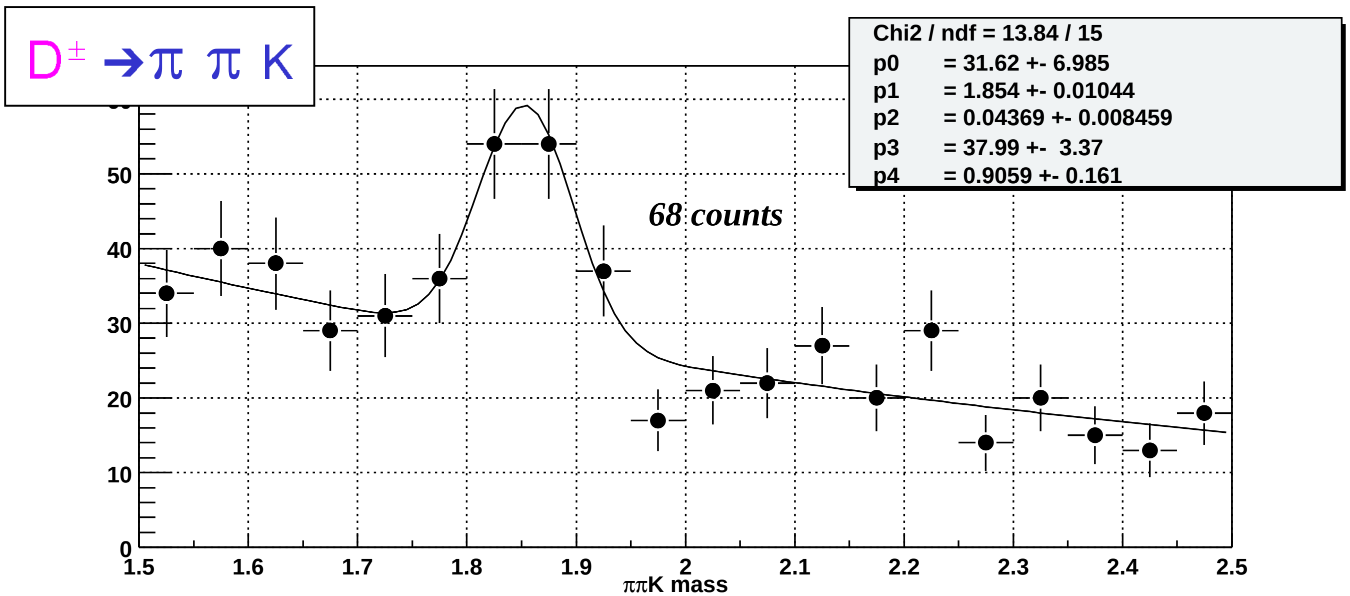


Selection: involves vertex and tracking detectors
-> cut on secondary vertex on pairs of unlike charge tracks



Open Charm Signal

Selection: involves vertex and tracking detectors

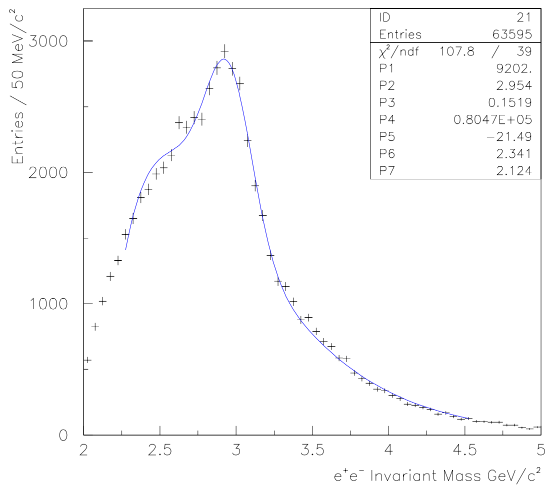


Two tracks pointing to the primary, but not belonging to it.

Di-Lepton Triggers

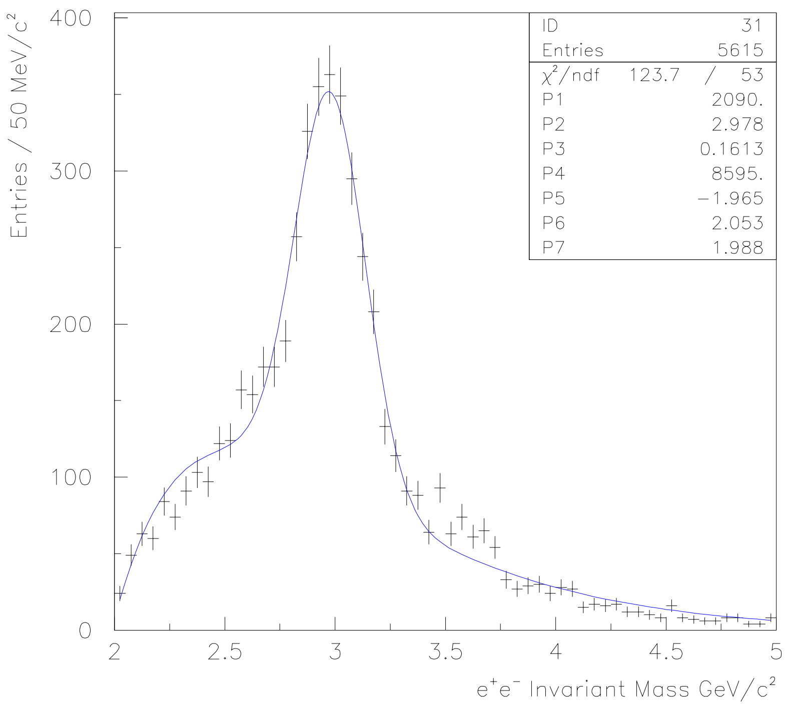
Data taken in different trigger conditions, mainly:

- pretrigger+SLT
- pretrigger +SLT with FLTE+SLICER+REFIT+L2Sili (wth OTR!)



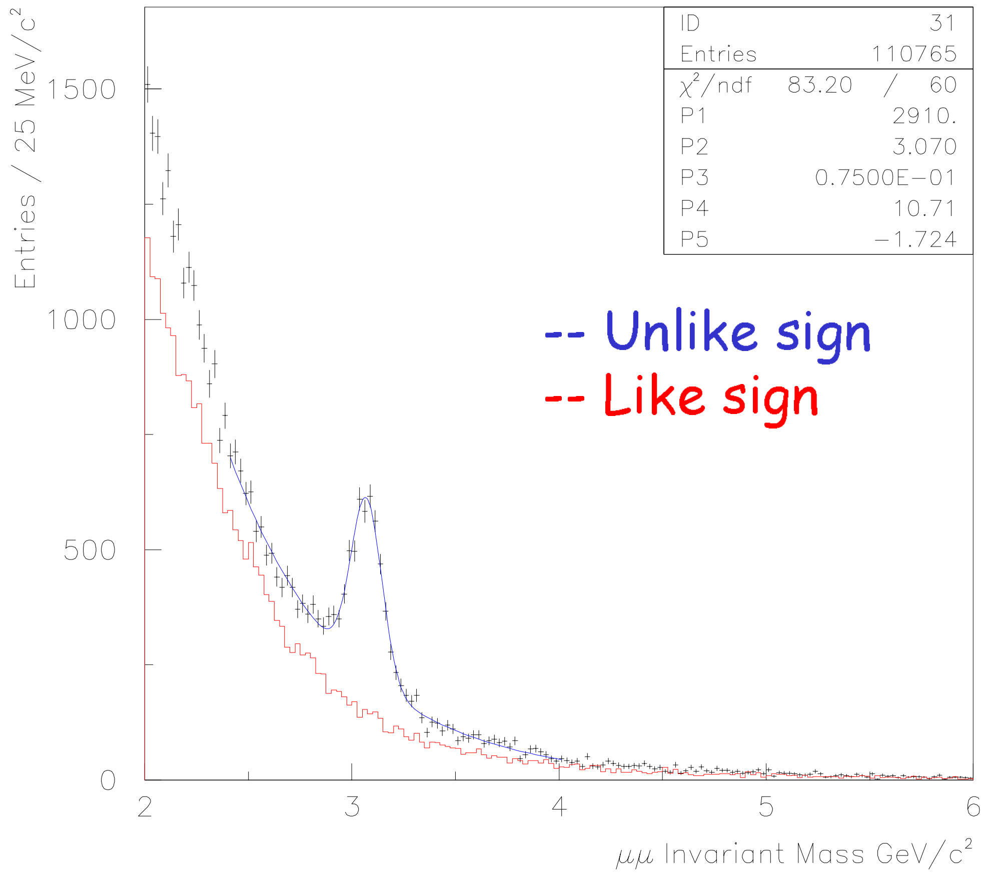
At least 1 BR requested

2 BR requested

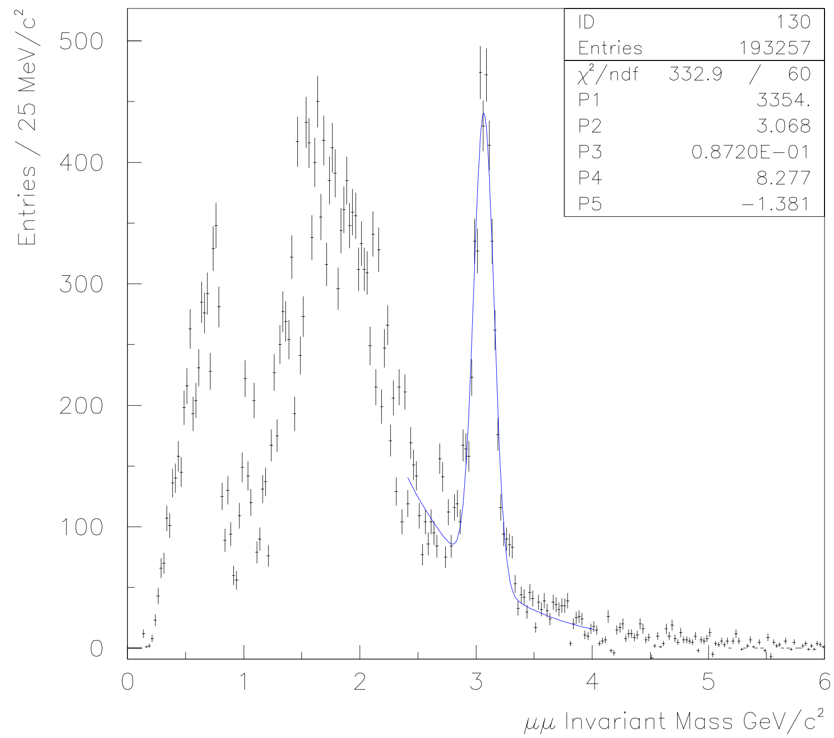


40000 J/ψ expected in the full sample without Bremsstrahlung request

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

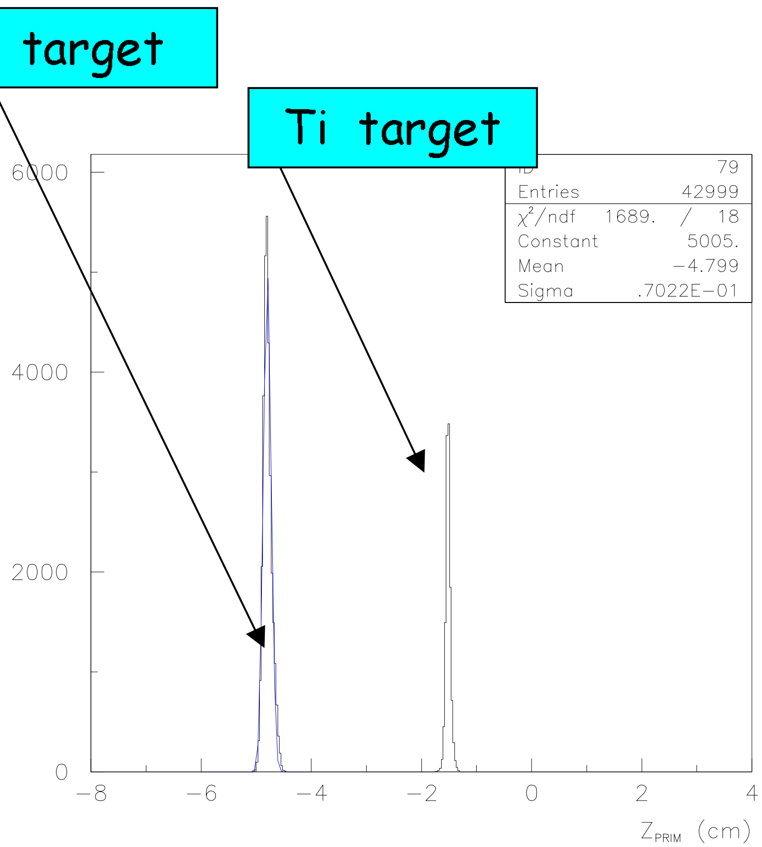


Subtraction of the two distributions:



~ 3000 events from 80% of the full statistics

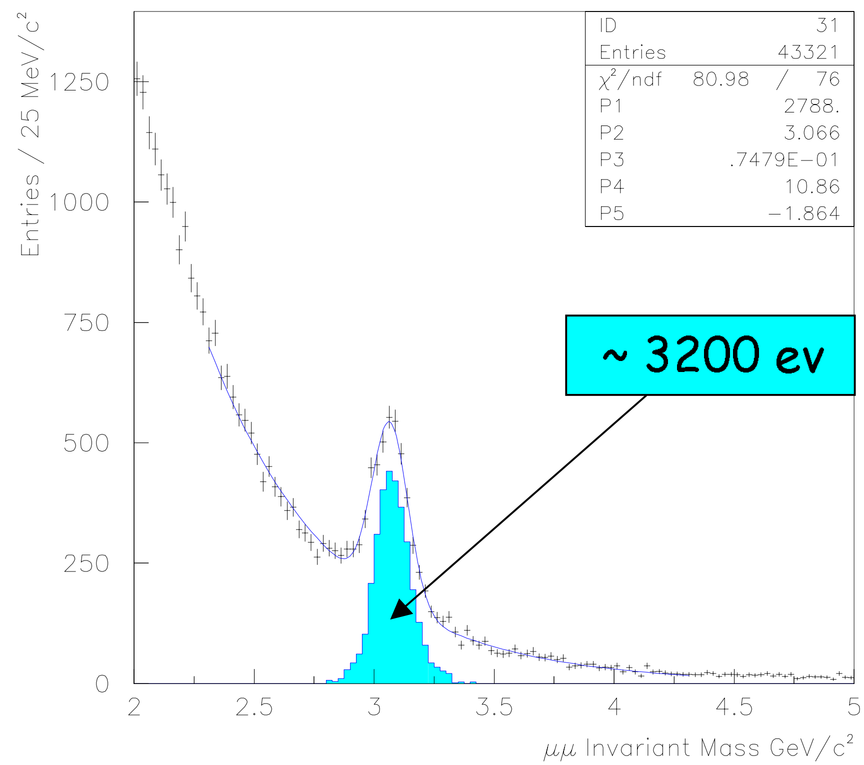
$J/\psi \rightarrow \mu^+ \mu^-$: search for secondary vertices



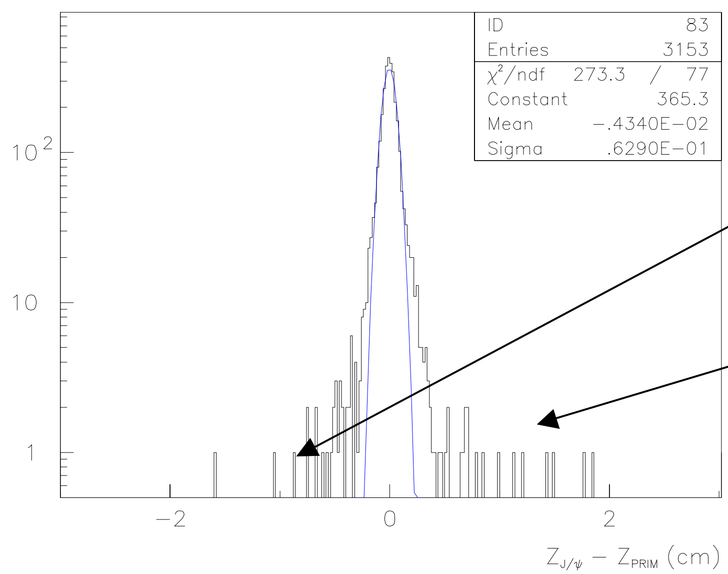
Z distribution of primary vertices
Mainly from VDS reconstruction

Selection of events asking for secondary VTX + mass constraint fit:

$P(\chi^2) > 5\%$



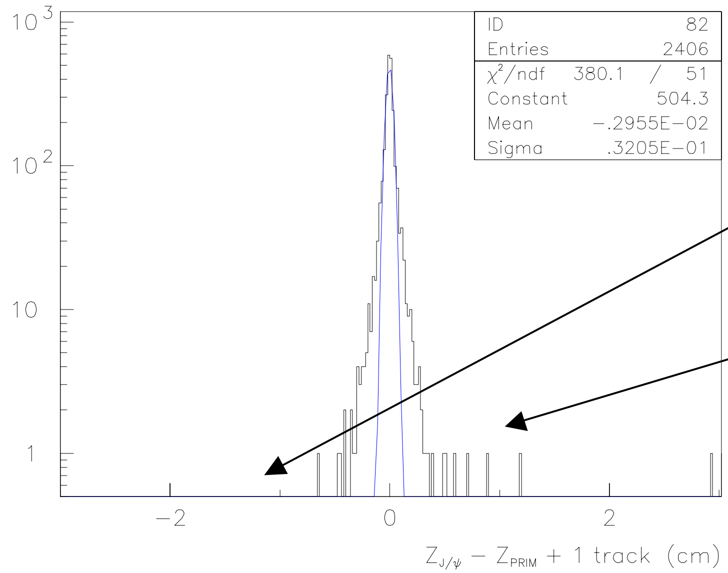
Z(J/ψ) – Z(primary) Distribution



Upstream [-2.0 ÷ -0.5 cm] : 15 ev

Downstream [0.5 ÷ 2 cm] : 18 ev

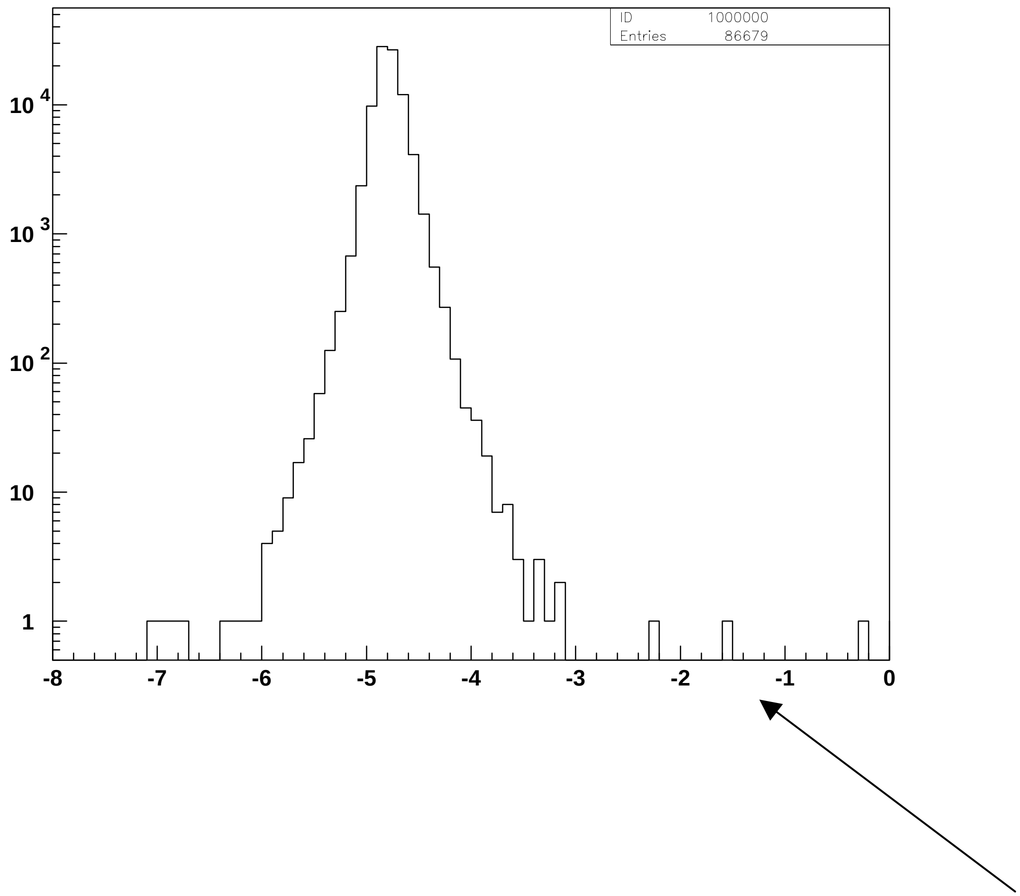
Requiring at least 1 extra track in the J/ψ secondary vertex:



Upstream [-2.0 ÷ -0.5 cm] : 1 ev

Downstream [0.5 ÷ 2 cm] : 5 ev

Search for secondaries in B-semileptonic decays



The signature:

$$B\overline{B} \to \mu^+\mu^- DX$$
$$D \to 3\,prong$$

⇒Look for 3 track detached vertices.

Expectation from MC: 1-2 ev/3000 J/ψ
For 20 nb bb cross section

Geometrical reconstruction of the 3-prong vertices.

Result of the first iteration on half of the muon statistics.

2 candidates with distance from $\mu^+ \mu^-$ greater then 300μm.

Outlook

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

B Potential for 1st year (10^7 s)

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

1/4

trigger & reconstruct:

22000 $B \to J/\psi X \to \mu^+\mu^- X$

650 $B \to J/\psi K^{0*} \to \mu^+\mu^- K\pi$

+16 $B \to \mu^+\mu^- K^{0*} \to \mu^+\mu^- K\pi$ (FCNC)

1/2

with working high-p_t hadron trigger:

reach to mesure B_s oscillation

$x_s < 42$ at 3σ

1

720 $B \to J/\psi K^0_s \to \ell^+\ell^-\pi^+\pi^-$

→ $\Delta \sin 2\beta = 0.16$

Conclusions

- The HERA-B detector is essentially completed
- HERA-B did a big R&D work in the tracker area. One of the largest honeycomb tracker and MSGC-GEM detector system are operating in a rad-hard environment (LHC-like).
- The commisioning of the sub-detectors is well advanced, as well as the SLT and DAQ.
- The commisioning of the FLT has not yet finished. At the moment very low track efficiency. No major problems encountered. No trivial task.
- Efforts are underway to bring the detector close to the design performances
- With performacens close to the design values HERA-B can still make valuable contributions to B physics.