Summary for Parallel session D4
Muon detector and particle I.D.

Muon Detectors Session D4
25-26 October 2000

Wednesday 25 October 2000		Parallel Session D4: Muon Detectors
9:00	David Koltick	Welcome & Announcements
9:05	Laszlo Gutay	CMS Wire Chambers as Forward or Low Angle NLC Muon Detectors
9:30	Adam Para	Scintillator Strip Muon Detectors
9:50		Coffee
10:15	Leo Piilonen	Resistive Plate Chambers
10:40	Marcello Piccolo	TESLA Muon System
11:10	David Koltick	P-detector costing
11:20	David Koltick	Muon Group at Snowmass 2001
11:30	All	Discussion - Detector Options for Study
12:00		Lunch
Thursday 26 October 2000		Parallel Session D4: Particle ID
9:00	Marcello Piccolo	Welcome & Announcements
9:15	Michael Hauschild	Particle ID using a TPC
9:45	Robert Wilson	General Issues of Particle ID
10:15		Coffee
10:45	Luca Lista	The BaBar Muon System
11:15	Marcello Piccolo	Discussion
12:00		Lunch

Agenda V1.1
Last update : October 25, 2000
Link to Muon Group Web Pages

Marcello Piccolo
FermiLAB. Oct. 2000

Topics, issues

- Sessions divided almost 50-50.
- Muon detectors part with different reports on designs and description of operational systems.
- Particle Identification in a sense a bit less advanced and I'll try to discuss why later.
  - We had five presentations concerning design of muon systems .
  - Two presentations concerned descriptions of operational systems for muons detectors
  - Two presentations on particle (hadron) I.D.

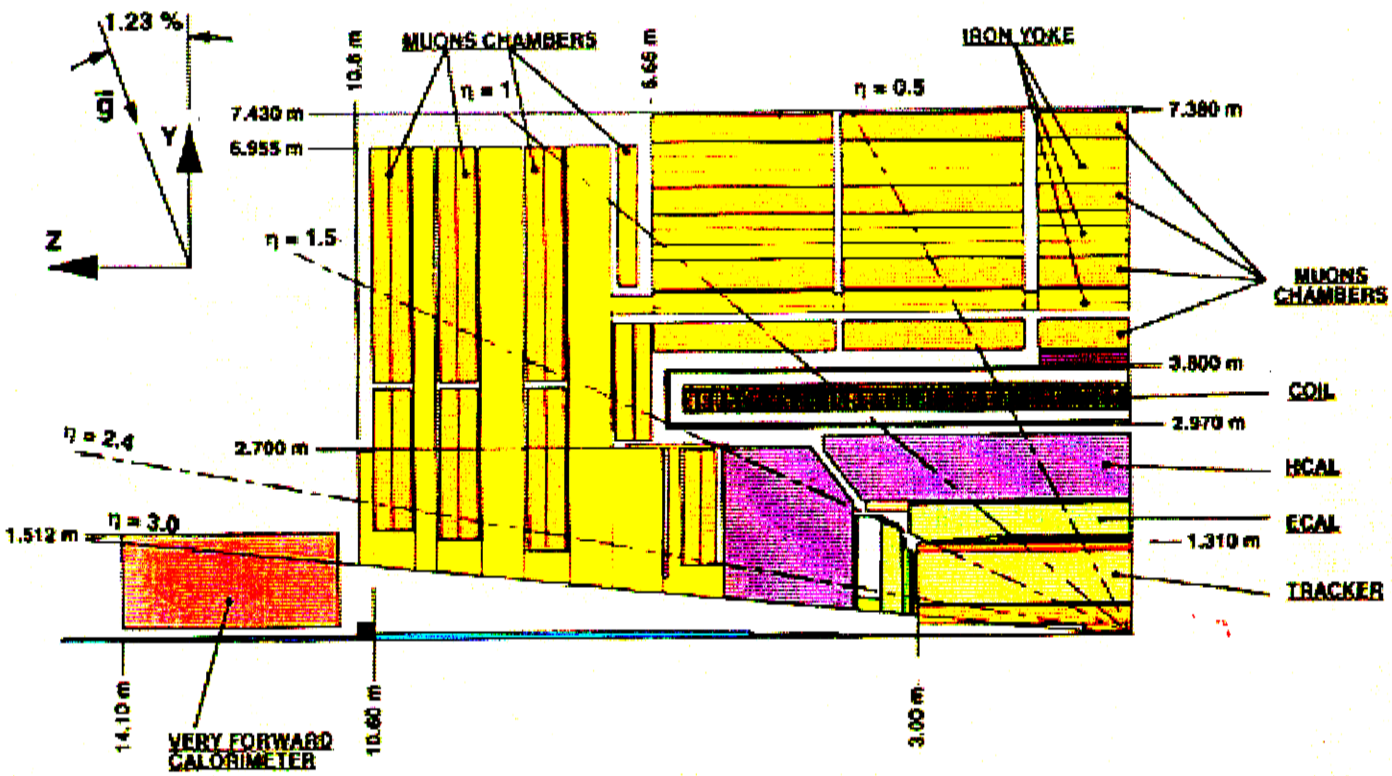


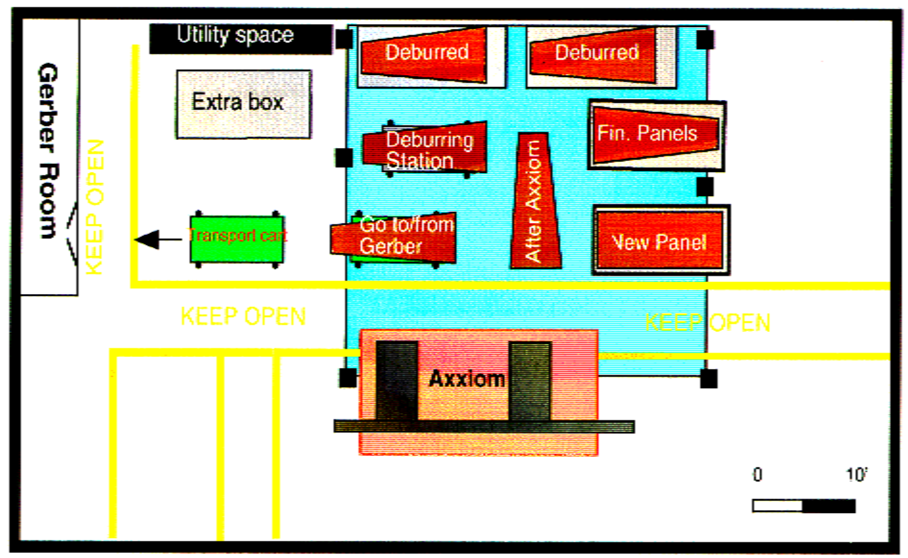
Fig. 5.3.2: Longitudinal view of the CMS detector.

Tooling Setup @ Lab 8

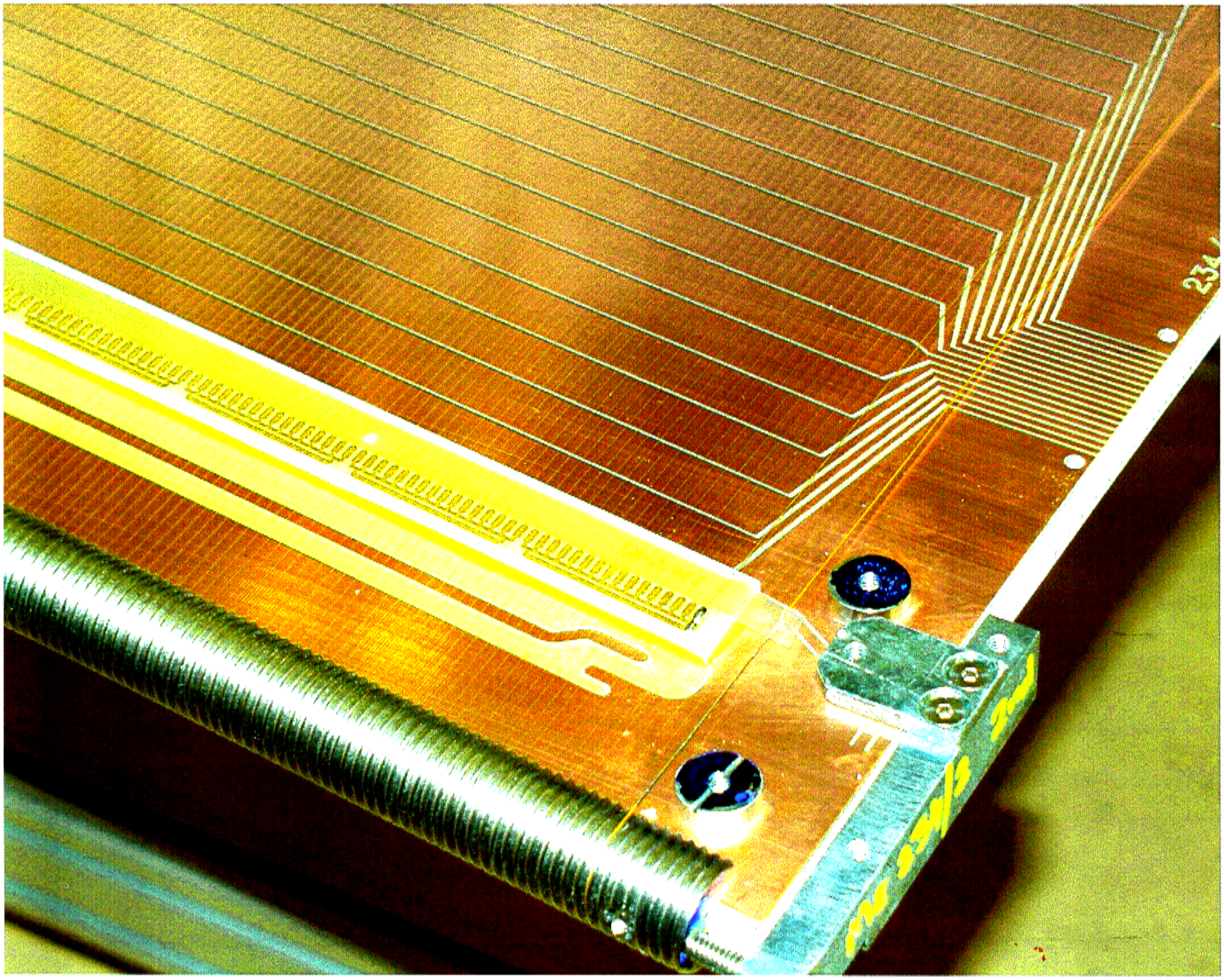
Main Tools

- **Axxiom Machine**
  - panel cutting
  - setup being completed
- **Gerber Machine**
  - cathode strip grooving
  - operational
- **Panel Lifting Crane procured**

Production Flow of ME234/2 Panels



Goal:
Start Panel Production in April 1999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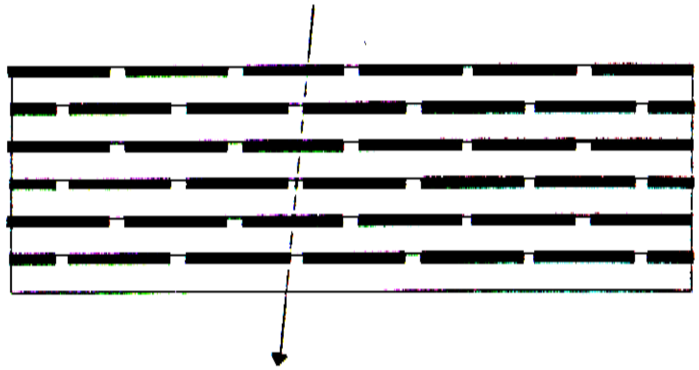
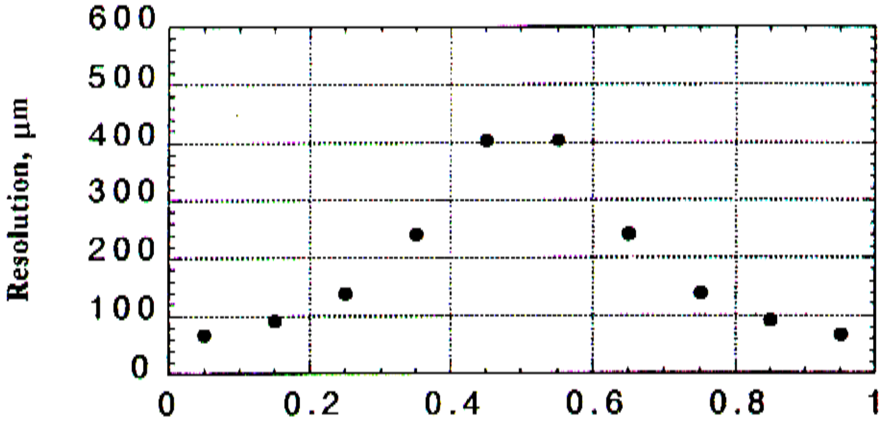
staggered strips and chamber resolution

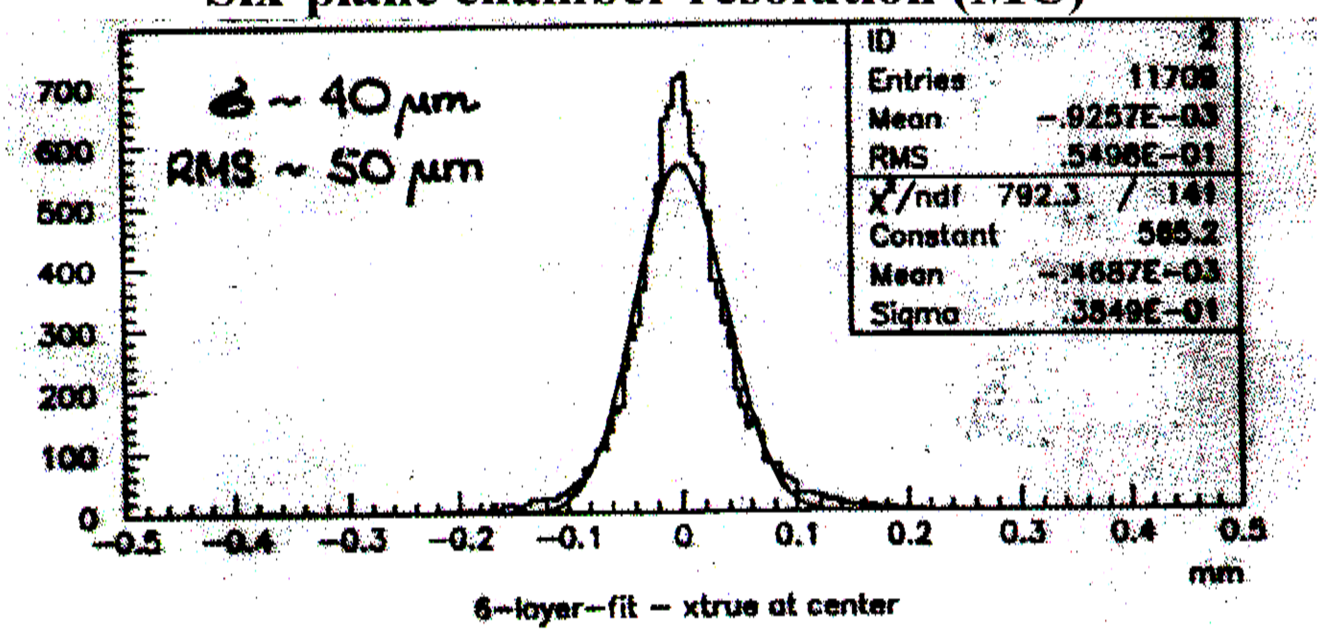


Spatial Resolution per plane across a 16 mm wide strip (data)



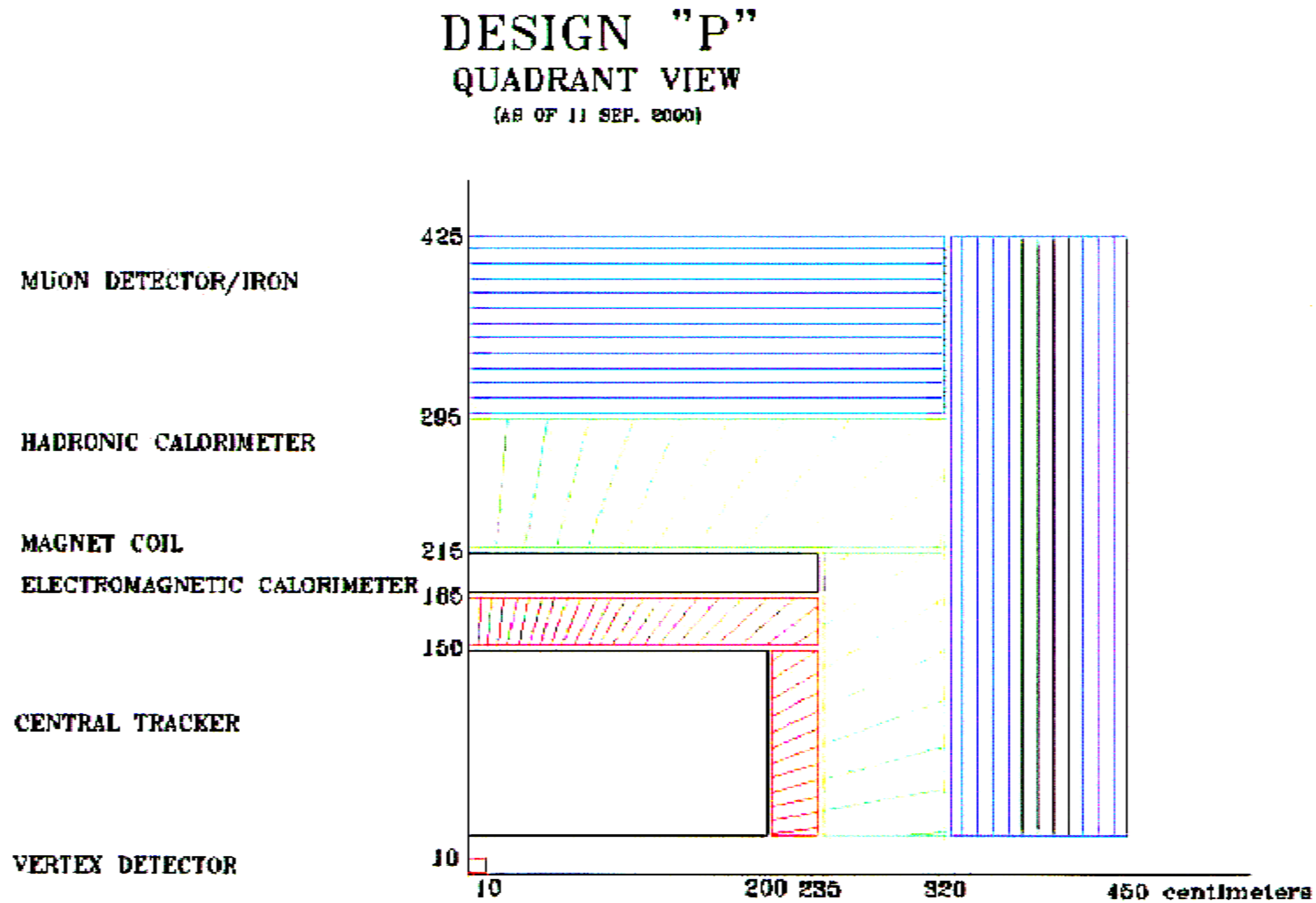
Track position across a strip (strip width units)

Six-plane chamber resolution (MC)



Why a P-Detector ?

- High Energy Region can not run Below 250 GeV
- Low Energy Region 90 GeV to 250 GeV
- Low Energy Program:
  - Precision run at Z-pole 10^9 polarized Z's.
  - Run at the Higgs Thresh-hold if Light (H-factory?)
    - $E_{cm} \sim M_H + M_z + 10$ GeV
  - W-W Thresh-hold, $\sin^2(\Theta)$ measurement.
  - Study SUSY at Thresh-hold if Light.
  - $\gamma\gamma \longrightarrow H^o$
    - $E_{e+e-} \sim 1.25\ (1/2\ M_H)$ since $E_\gamma \sim 0.8\ E_e$



Design P - Quadrant View

For a postscript version, please click here.

Home

Muon Detector

- 10 Iron plates, 10 cm thick each.
- 2 cm gap between Iron plates with gas chambers.
- Muon system will serve as calorimeter tail catcher.
- Strip read out with 1 cm resolution for muon tracking.
- All layers to have strips parallel to beam direction
  2 layers to have transverse strips to measure Z

P-Detector
Muon System Cost Estimate

David Koltick
Purdue University

- Cost Based on Resistive Plate Chambers (RPC)
- Cost Based on Experience at BELLE/ BaBar
- BELLE (Mechanical only) $660/m^2$.

ITEM	Outcome	Manpower	Materials	Activity
Preliminary R&D	Chamber type to be developed	3 engineers 1 year	$150k	Detailed Studies of Detector match to NLC needs: RPCs Scintillating Paddles Wire Chambers
Design and Prototype	Tests of NLC prototype muon chamber End Cap Barrel	2 engineers 2 techs 1 year	$200k	Build and Test End Cap and Barrel Muon prototypes
Final Prototypes	Build Final Version of NLC End Cap and Barrel muon chambers Mass production techniques developed.	3 engineers 2 techs	$300k	Pre-production prototypes with development of mass production techniques.

P-Detector Muon System Costs

- EDIA $1.6M
- Barrel $2.9M
- Endcap $2.8M
- Other $1.5M

Total Muon System Costs $8.8M

Adam Para

Thoughts on a possible muon system

Functions of the muon system:

- identification of isolated muons
- identification of soft muons within hadronic jets
- measurement of the tails of jet energy (improve resolution for W/Z spectroscopy)

Assumption: momentum measured by central tracker ⇒ no need for magnetic measurement

∴ True? Background rejection for soft muons? Need studies

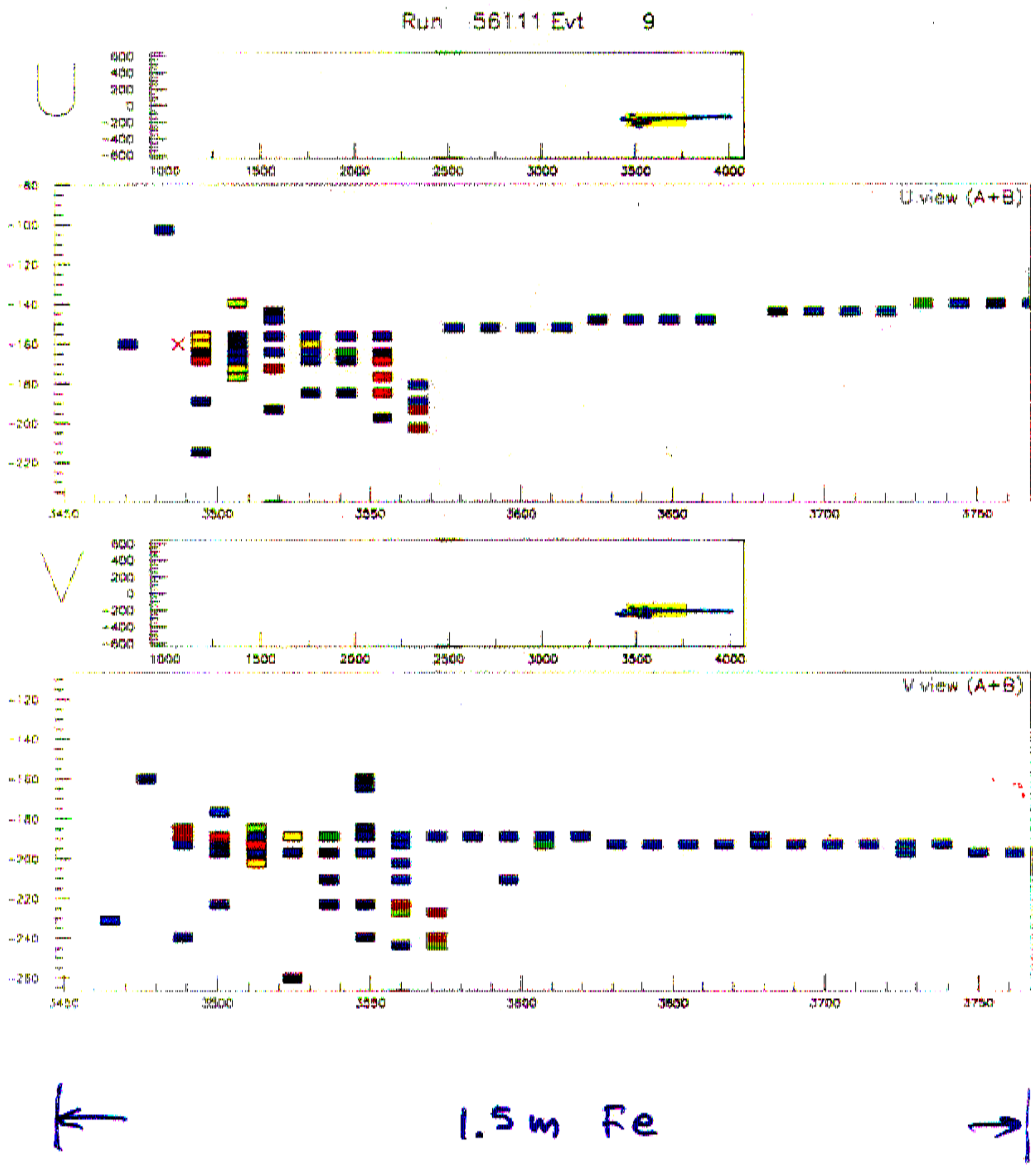
MINOS : an imaging calorimeter

Alternating planes

- 2.5 cm iron
- x - scintillator strips
- 2.5 cm iron
- y - scintillator strips
- ⋮

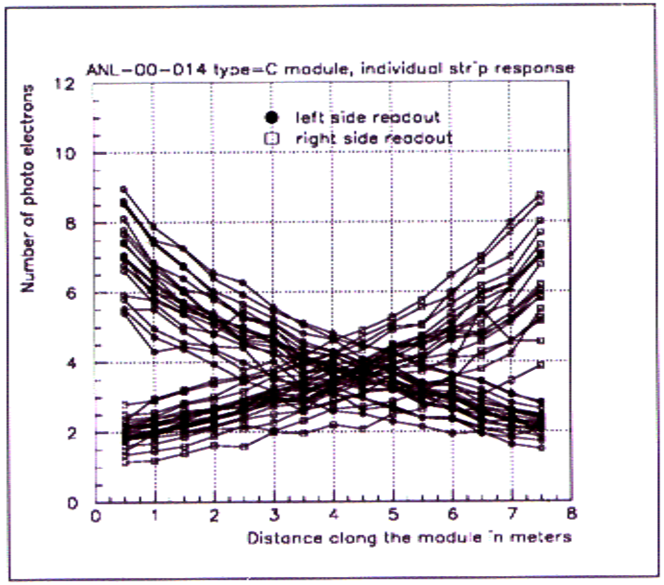
Magnetized iron : toroids (octagons)

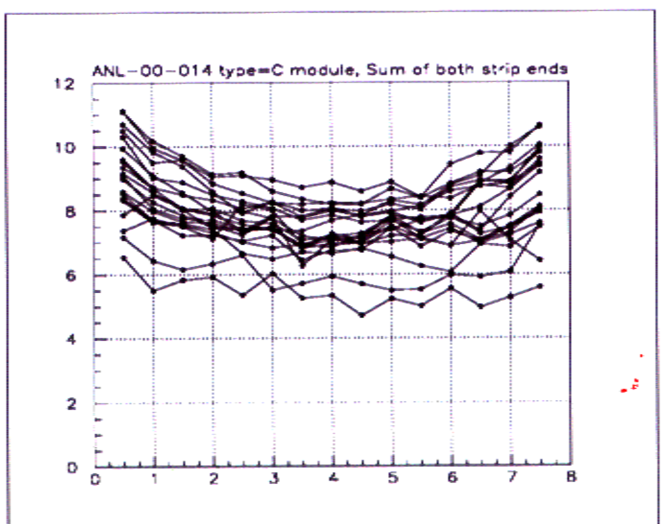
8 m across


Run 56111 Evt 9
U
U view (A+B)
V
V view (A+B)
1.5 m Fe

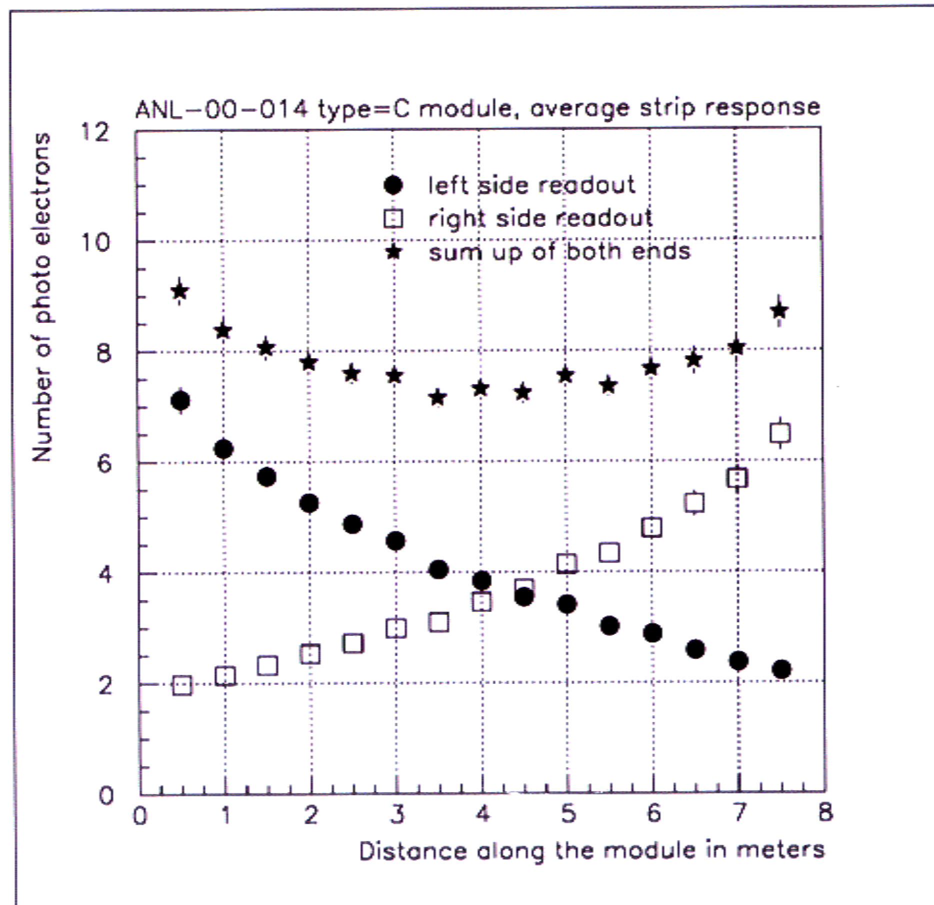
LIGHT OUTPUT
MAY 2000 MODULE PRODUCTION

MINOS



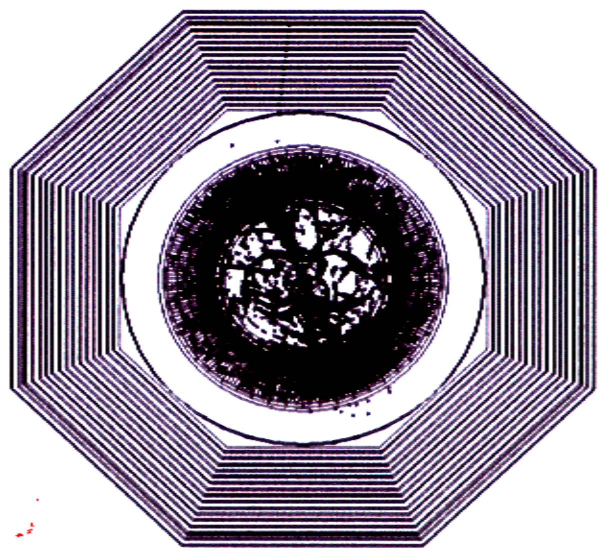


AVERAGE SUMMED LIGHT OUTPUT > 7.0 pe



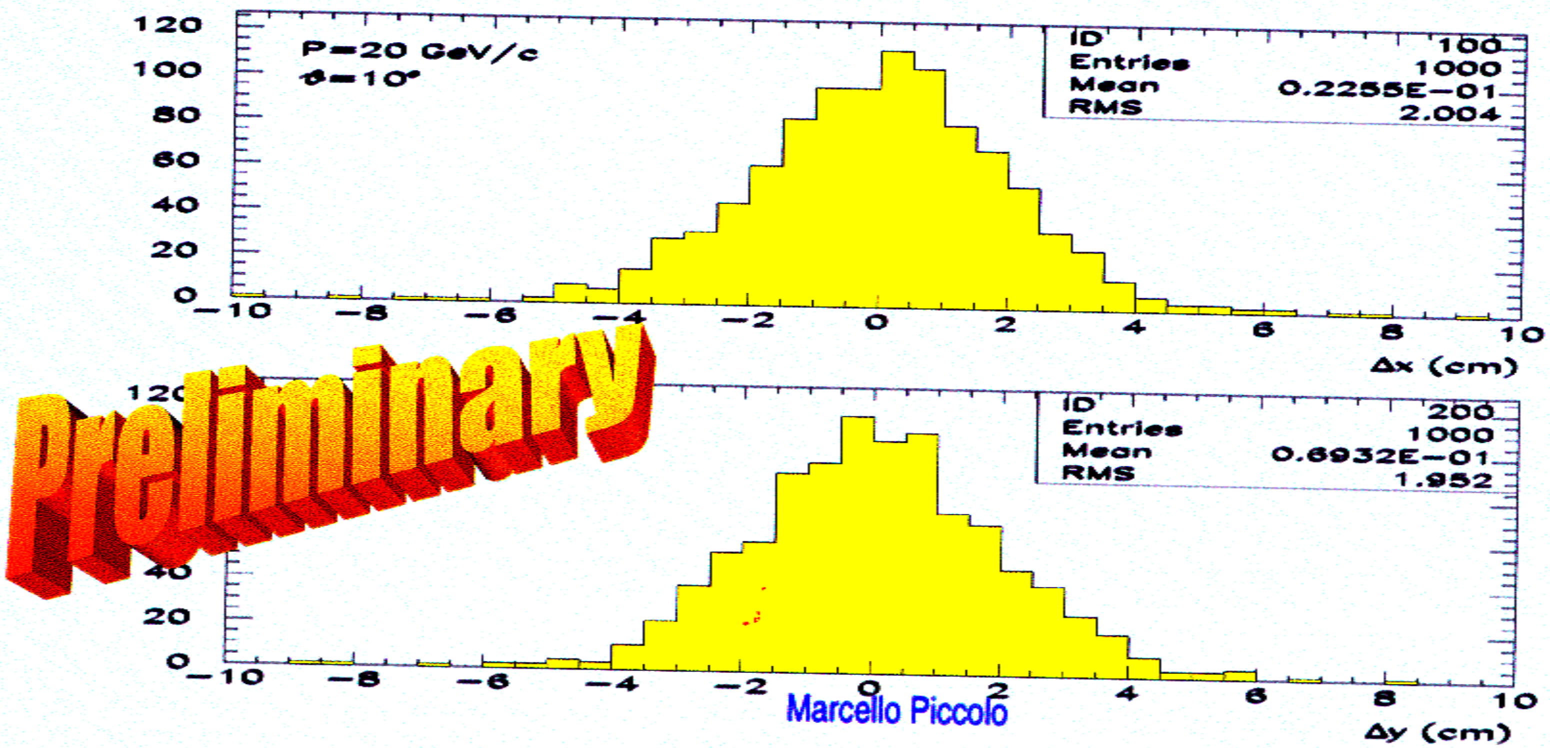
Identifying muons at an electron machine

- The cleanliness of an electron machine allows a relatively simple design for a muon detector.
- Muon systems at High Energy Hadronic Colliders usually operate on a stand-alone basis.
- The muon detector for an electron collider can profit of the momentum measurements coming from the inner detectors as associating inner tracks to muon stubs is easily doable in this environment.

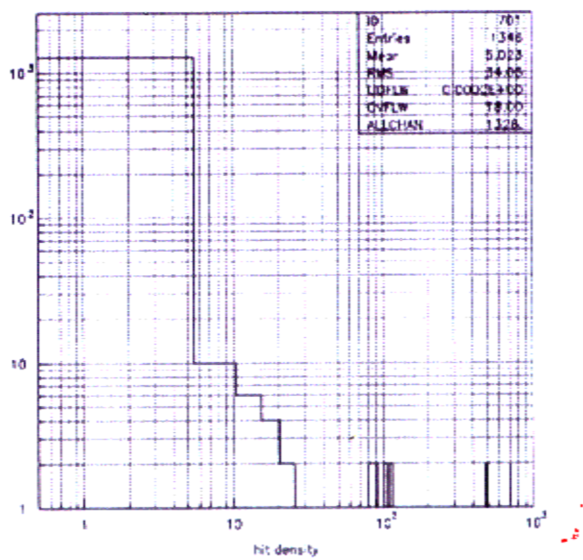


20 GeV/c μ

- The distribution of Δy and Δy from the extrapolated tracks at the entrance of μ identifier for 20 GeV/c muons.

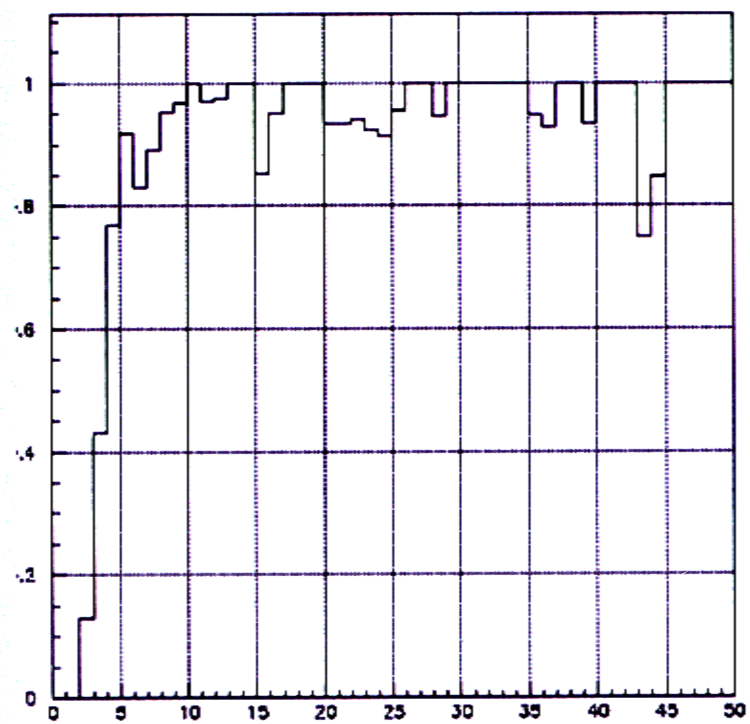


An other ingredient: hit density



- Important to choose active detectors
- ...or operational properties

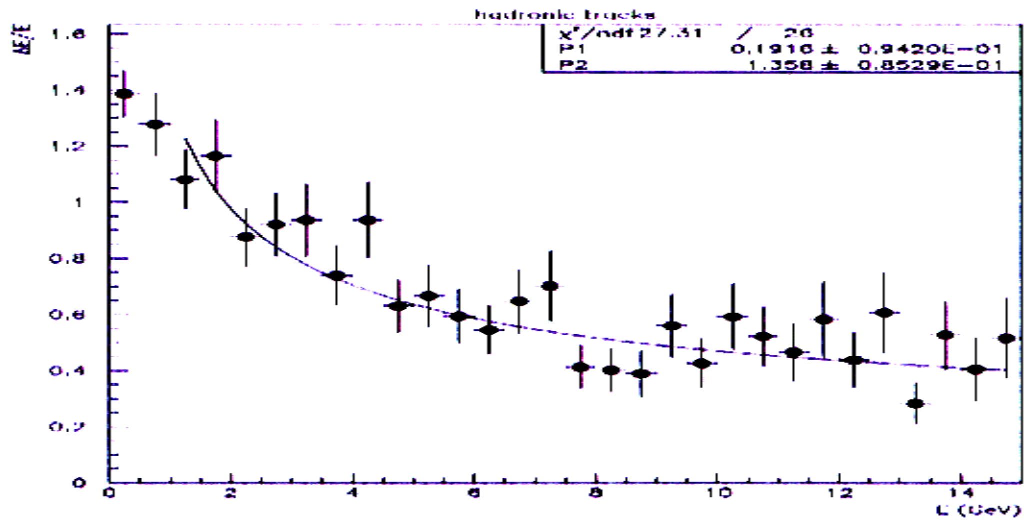
Performances



- Here is the efficiency vs. p of a configuration that uses 150 cm Fe.

- Here the efficiency for detecting m is shown for the 12/11 active planes configuration.

Energy resolution



Now for particle (hadron) identification

- Since last year not an enormous amount of work done.
- The attitude up to now was ….probably it won't be there ,so I better do without.
  - Not completely correct in my opinion

- Two very interesting talk:
  - The first one: what is available (almost) for free from a TPC detector
  - The second: a brave attempt to see whether particle id would buy some B^0 tagging capability in topologically complicated events.

M. HAUSCHILD
CERN
26-Oct-00

dE/dx Particle ID at the TESLA-TPC

- estimated dE/dx resolution
  (based on running detectors experience)
- toy Monte Carlo results
  (study by Magali Gruwe)
- particle separation power

Do we need Particle ID ?

- Physics studies show
  - only "weak" physics cases, e.g.
    background reduction at heavy flavor tags
  - no need for dedicated particle ID detector

↪ dE/dx of TPC sufficient ("for free")
↑ not compromizing other detector performances

- Different situation at "Giga Z" option
  $= 10^9\ Z^0$ at 2x 45 GeV

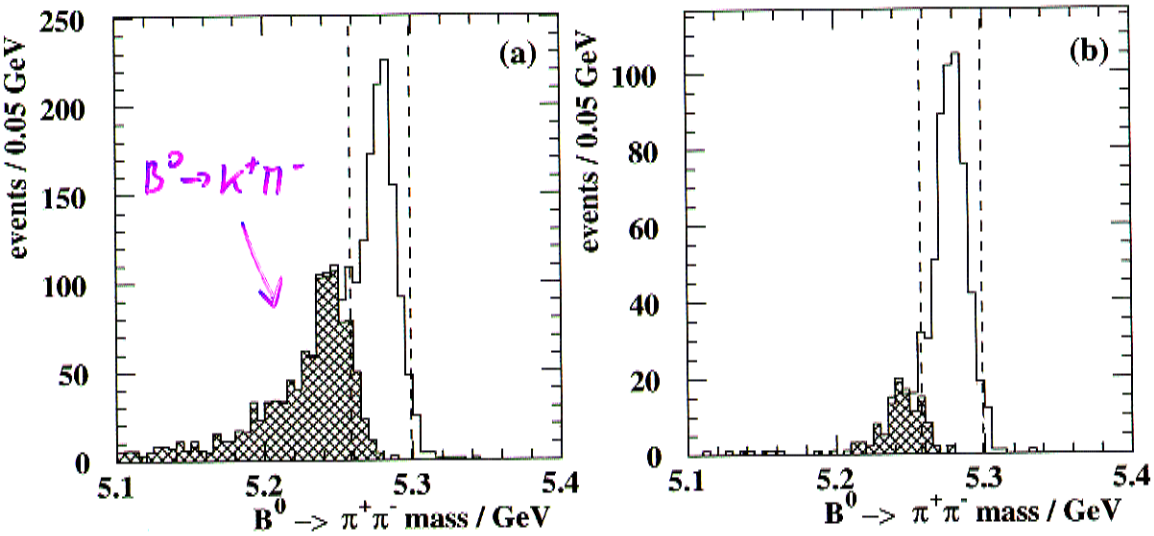
↪ Z^0 physics largely profits from particle ID

e.g. CP violation studies in b decays
(Richard Hawkings)

reconstruction of $B^0 \to \pi^+\pi^-$ decays

no dE/dx — $S/B = 10:1$

with dE/dx (moderate res.) — $S/B = 40:1$



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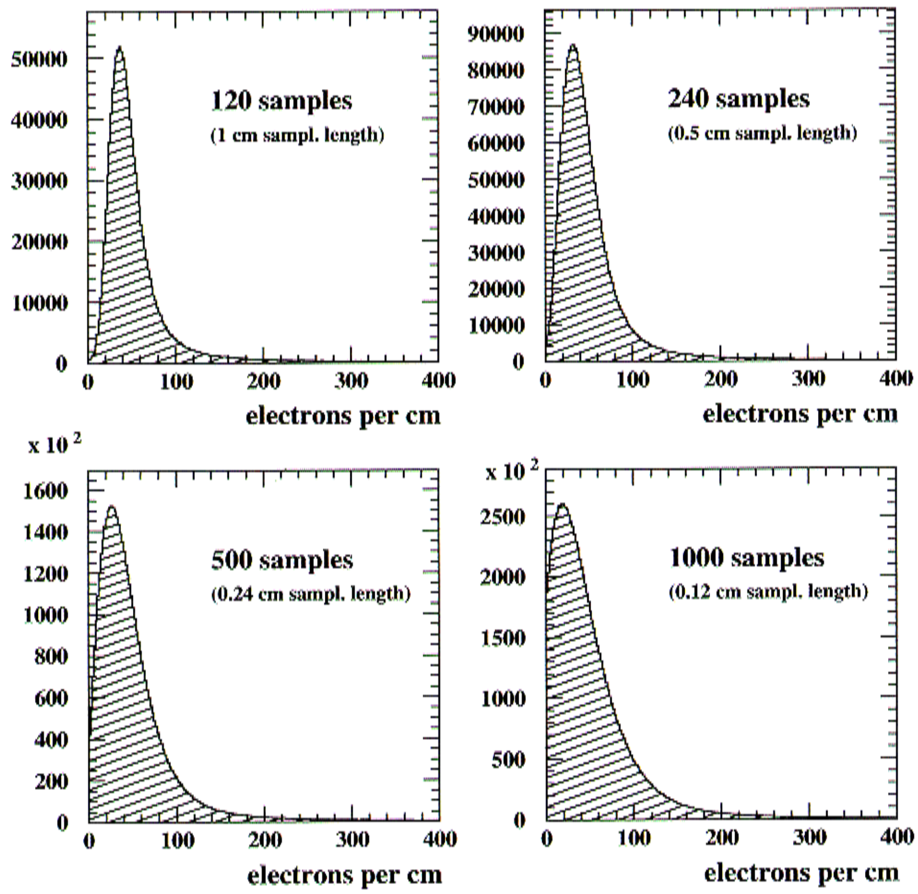
Landau Distributions

- Keep track length constant (120 cm = TESLA-TPC)

  ↳ vary sampling length (or number of samples)

track length = 120 cm, Ar/CH_4 (90/10)



Landau distributions, 600 e^- noise, Cross-talk

↖ ALEPH pre-amps

- More (shorter) samples → better resolution ?

  e.g. $\sigma(dE/dx) \sim N^{-0.43}$? ← valid for constant sampling length only

  ↳ Not true in general !

  ↳ Many empty samples if sampling length too short

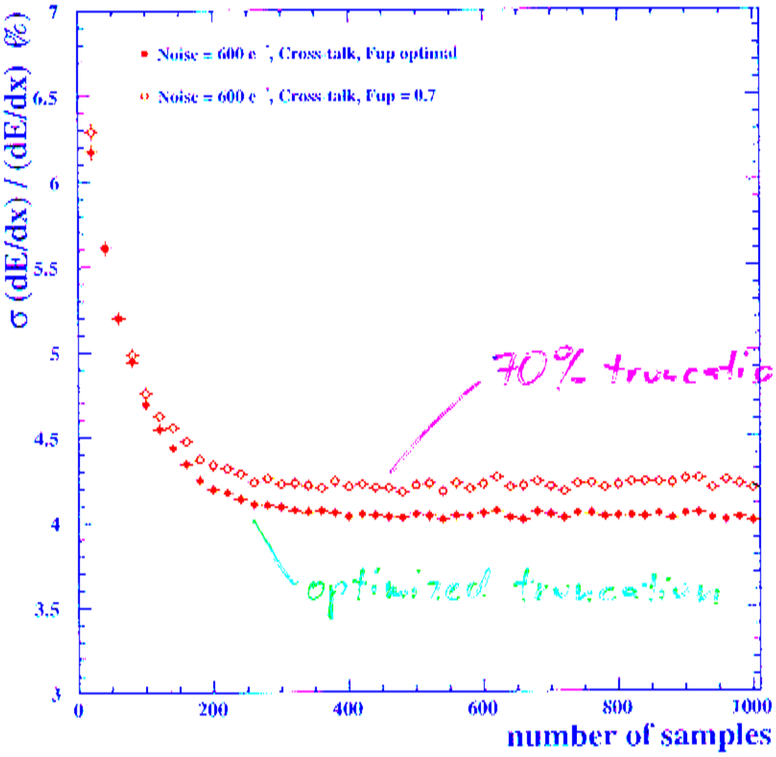
  ↖ difficult to handle in later dE/dx reconstruction

⇒ Sampling length needs optimization

(9)

dE/dx Resolution (opt.)

- Saturation reached at ~ 200 - 300 samples (~ 4 - 5 mm sampling length)

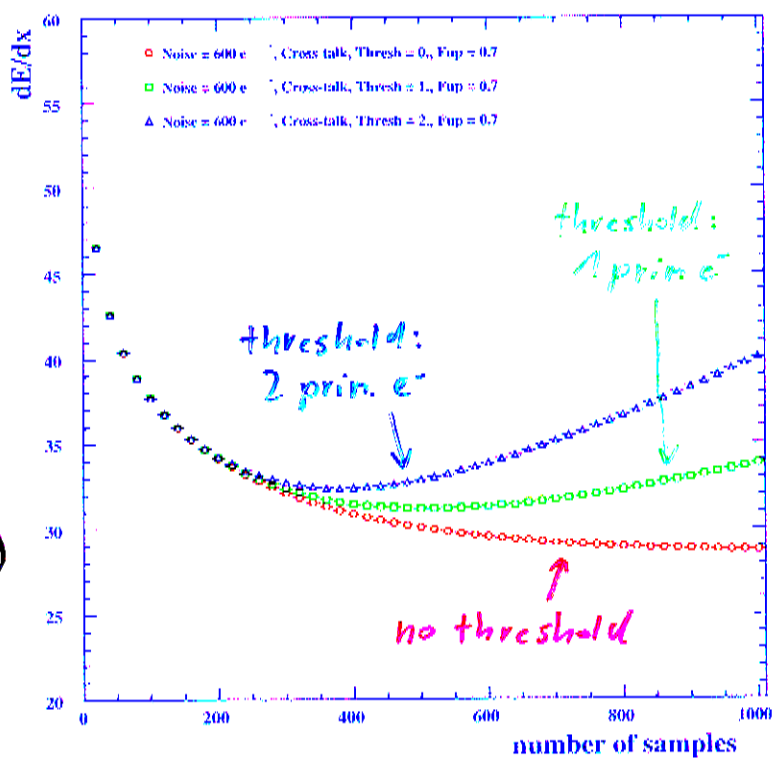


gain up to 0.2% resolution using optimized truncation

- Again: Do not use too many samples (too short sampling length)

reconstructed dE/dx becomes very sensitive to hit detection threshold for > 300 samples (< 4 mm sampling length)

BIAS!



(12)

Expected Separation Power

- Simulation + measured dE/dx resolutions based on
  - isolated, clean tracks, full number of samples

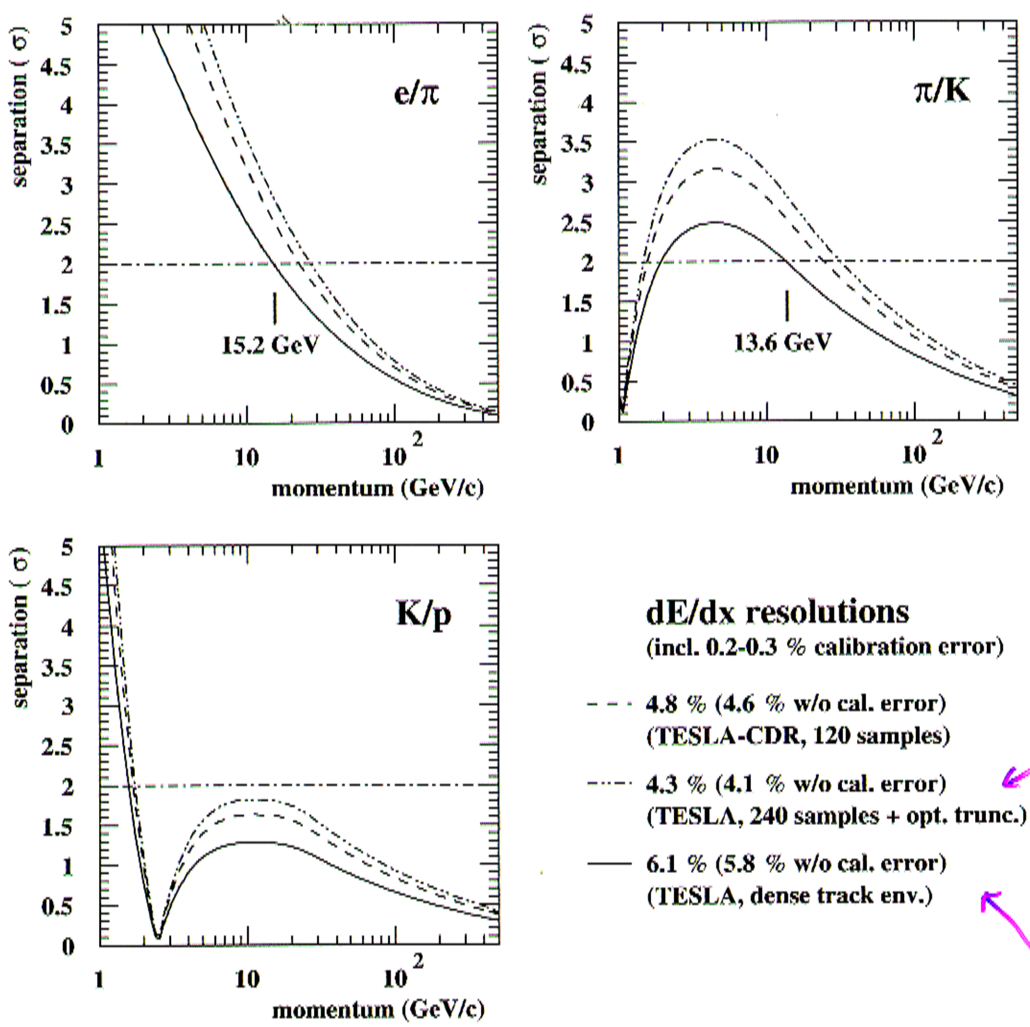
  ➔ "testbeam like"

- Particle ID in physics analysis use tracks in dense track environments (multihadronic jets)
  - reduced no. of samples (limited by double hit res.)
  - samples less clean (additional corrections)

  ➔ at ALEPH, DELPHI, OPAL typically ~ 60 - 70% of full no. of samples used

⇓

$\sigma(dE/dx)_{AVERAGE} \approx \sqrt{2} * \sigma(dE/dx)_{ISO.}$

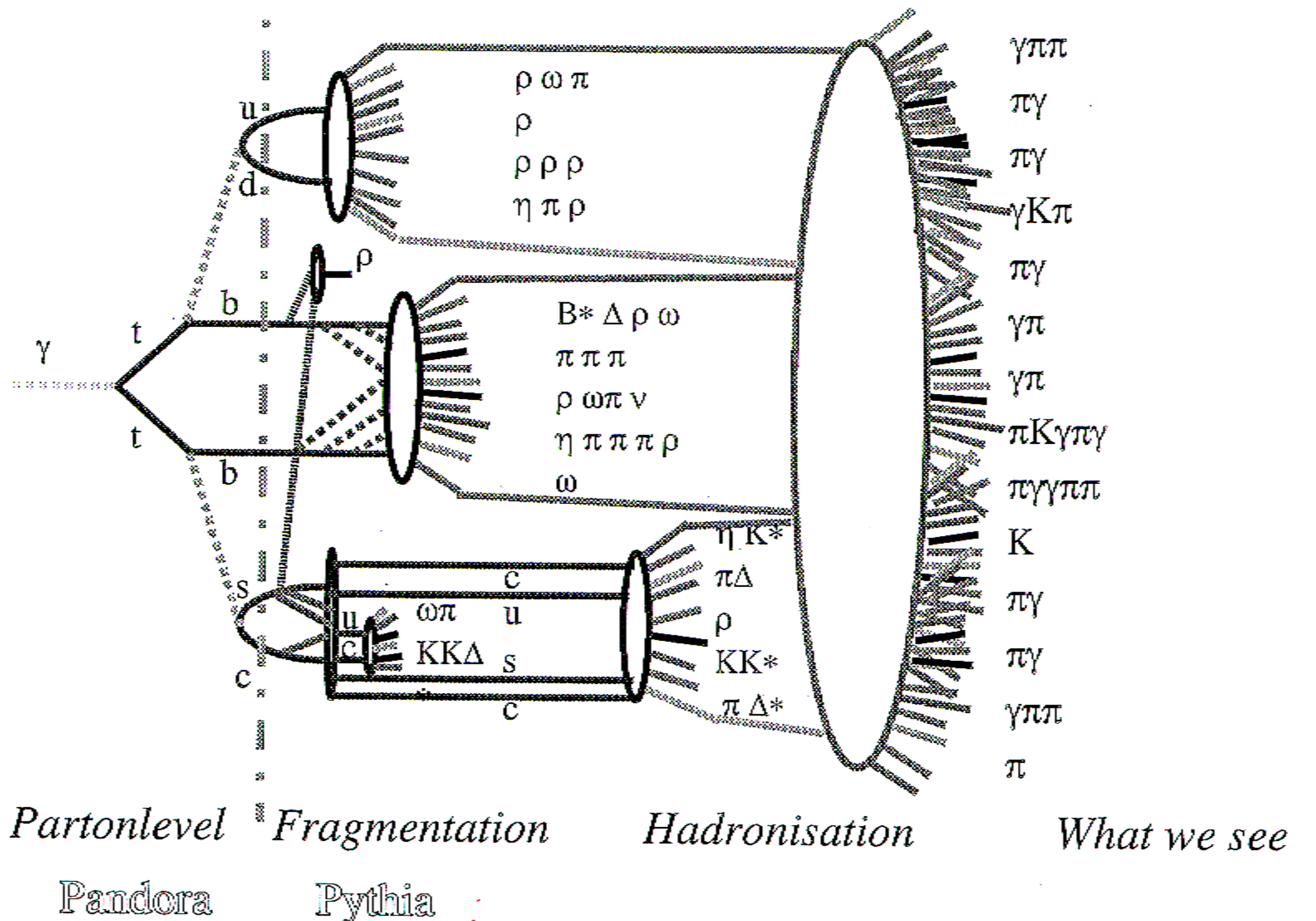


4.3 % best

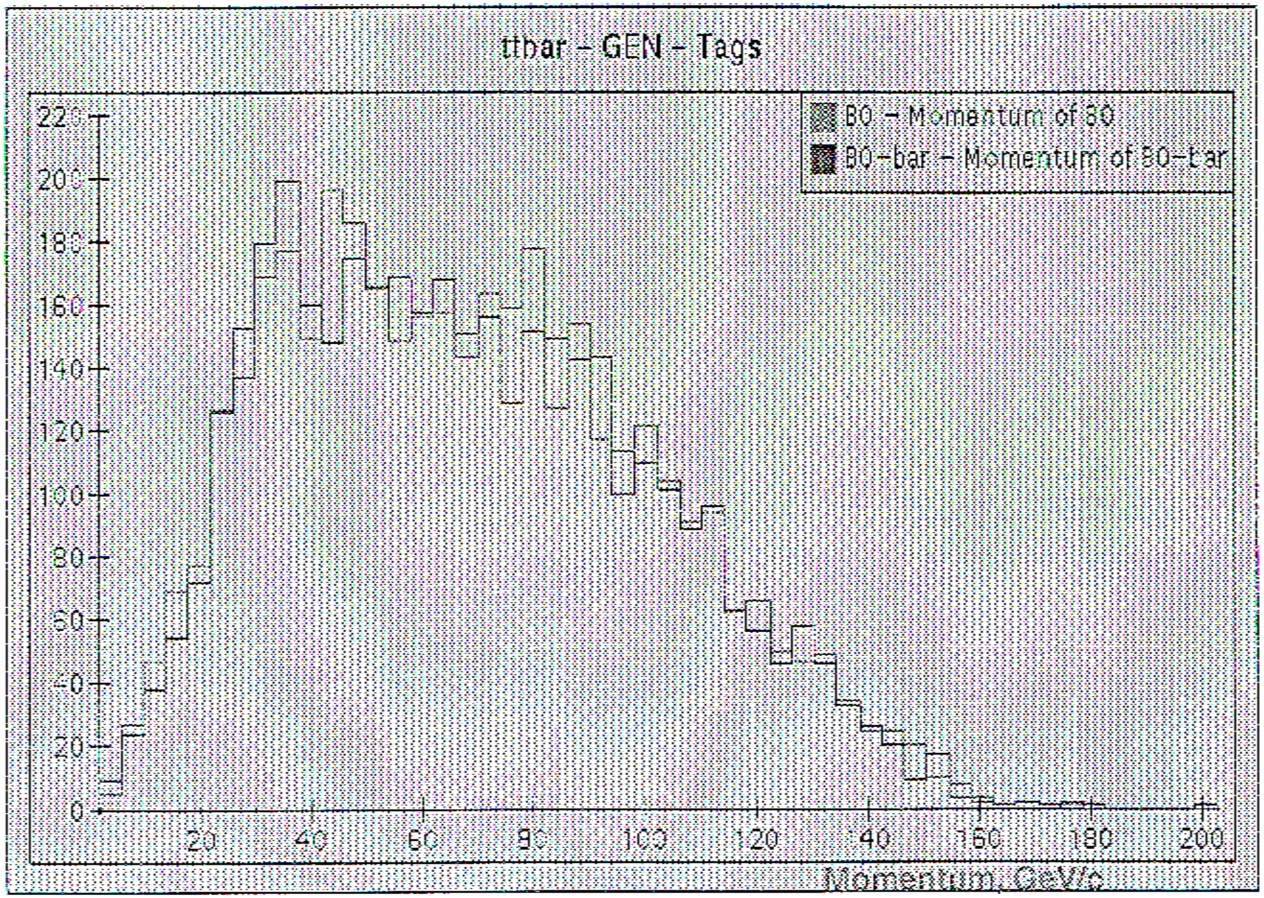
6.1 % average

dE/dx particle separation power

The Challenge: “typical” t–tbar decay ...



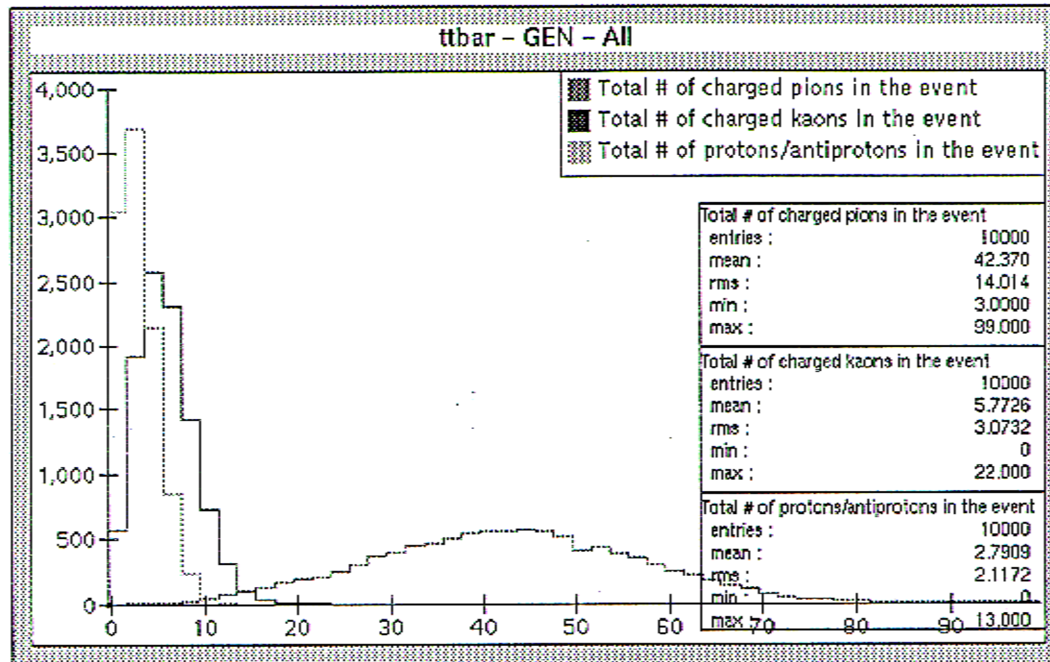
Spectra (Pandora check):

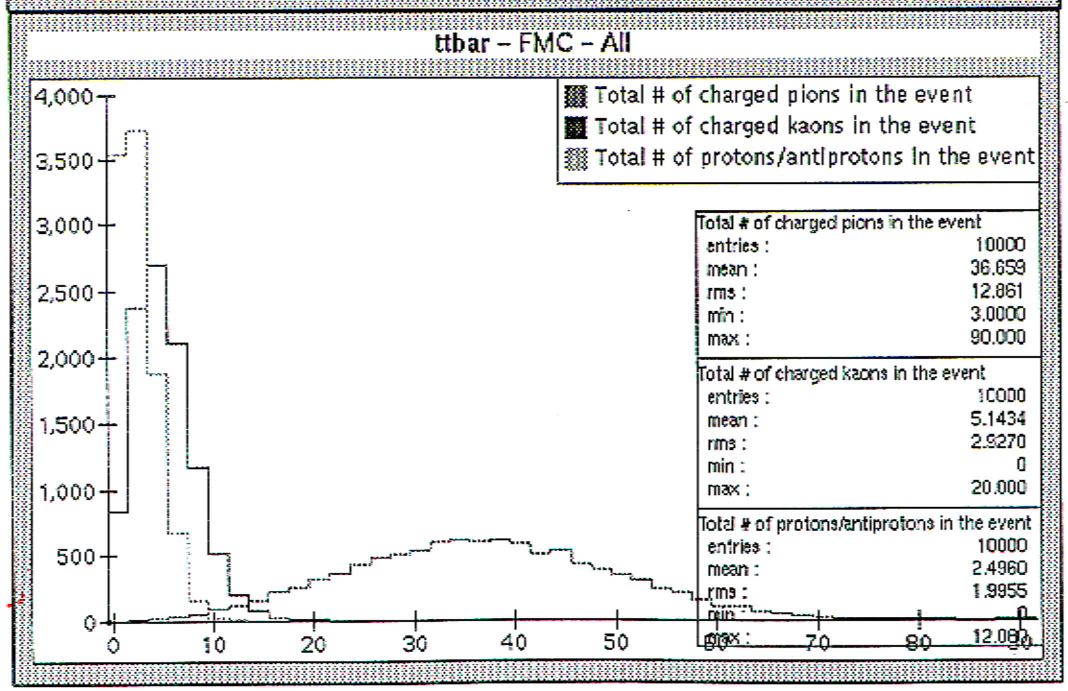


Assume these will be well reconstructed by tracking/vertexing...

π/K/p multiplicity:

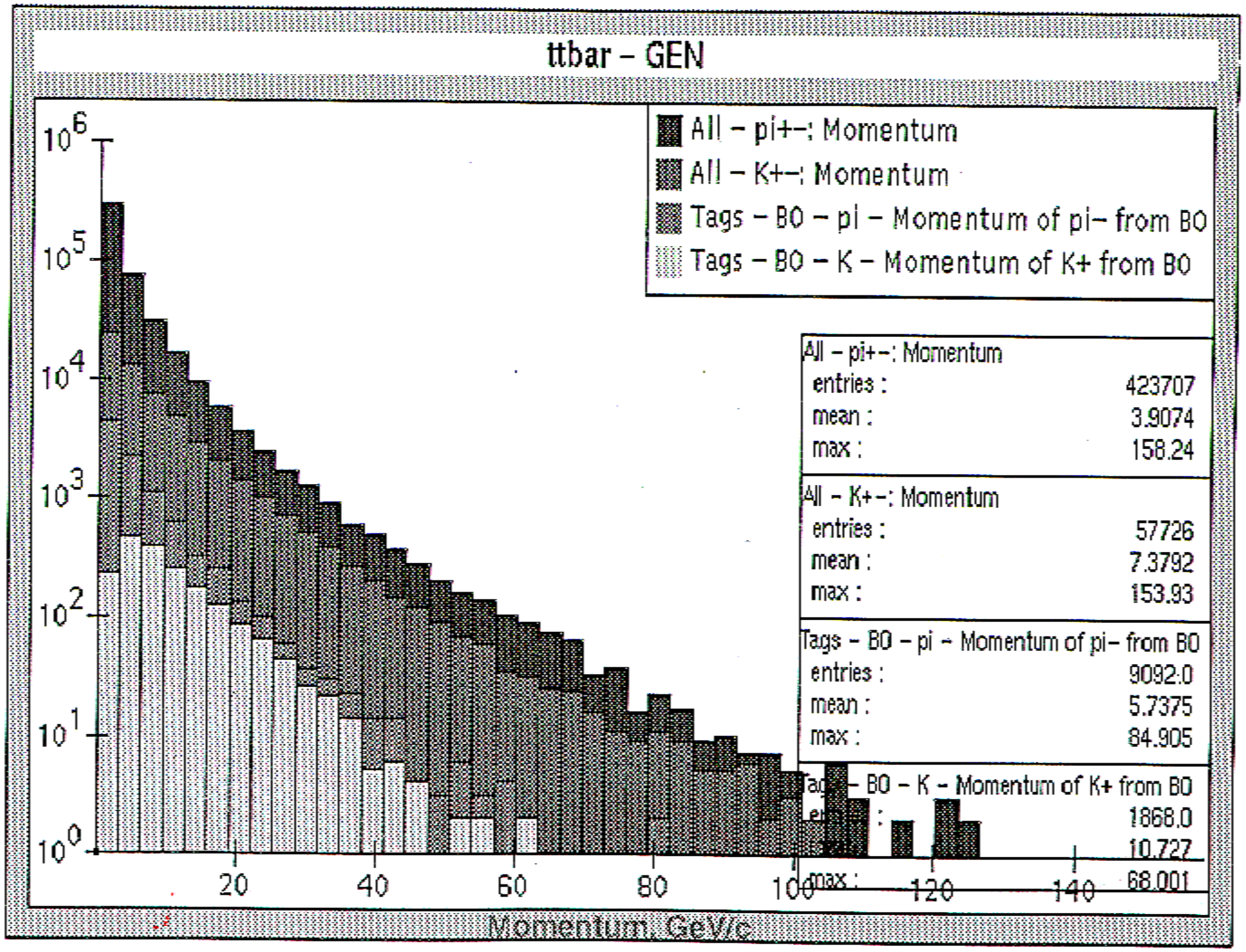
10,000 ttbar	<Nπ>	<NK>	<Np>
GEN	42	6	3
FMC/L2	37	5	2.5





π/K momenta:

	$<p(\pi)>$	$<p(K)>$
All	3.9	7.4
Tagged B0	5.7	10.7

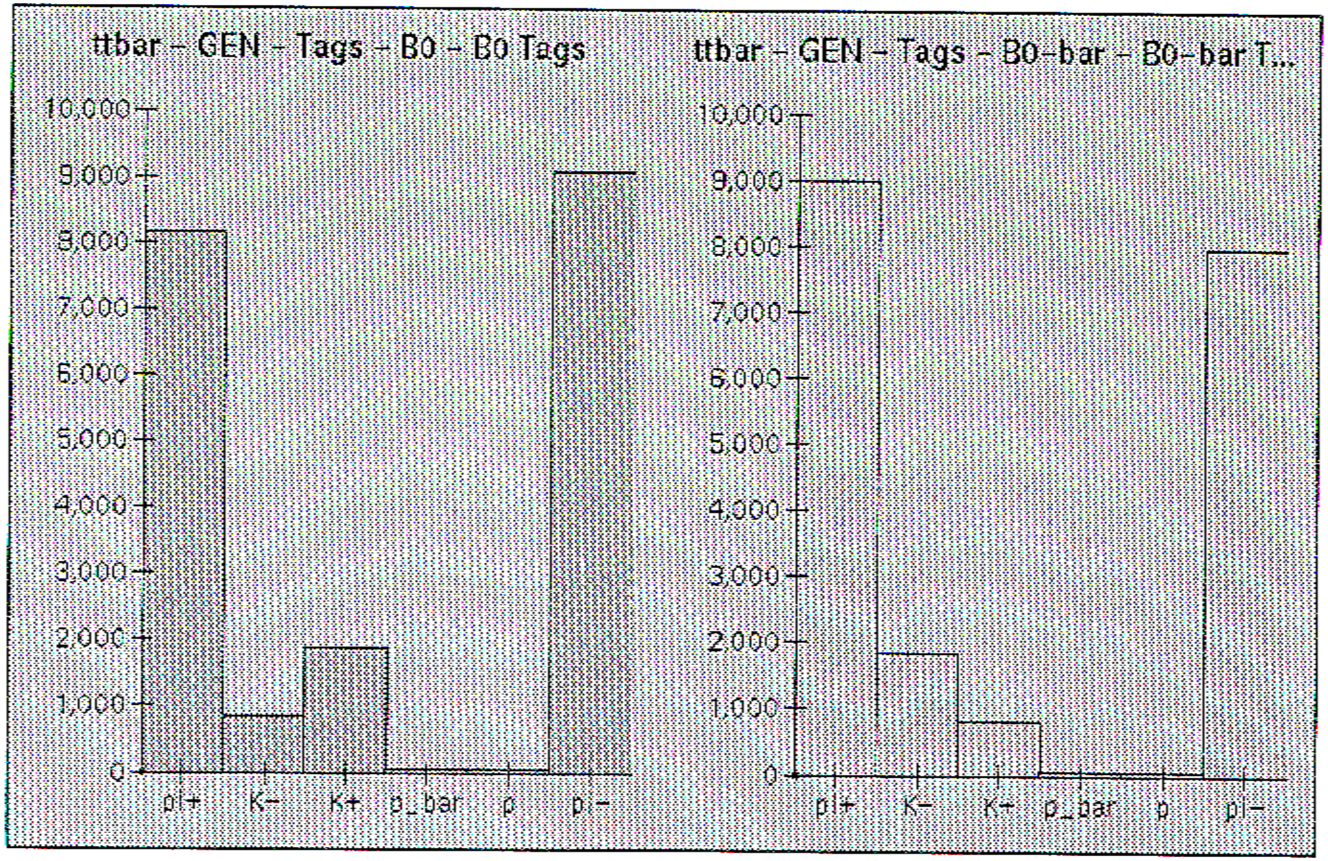


Note: TPC dE/dx roughly

1σ π/K sep. 1.5<p<20 GeV/c

2σ π/K sep. 2<p<8 GeV/c

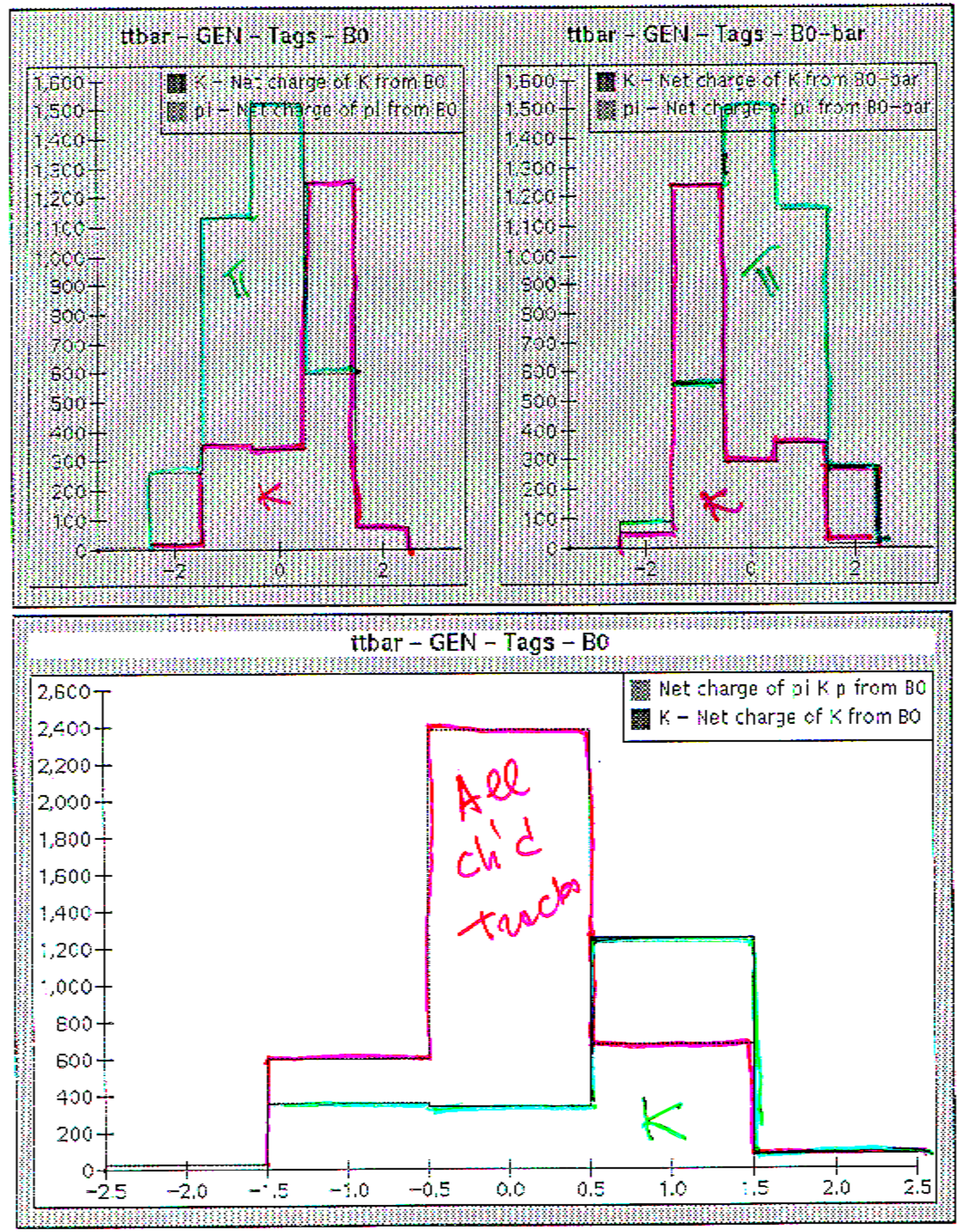
B0/B0bar Charged Hadron Tags:



Net charge:

Perfect hadron ID –
note opposite asymmetry for pi & K

... so no hadron ID ==>
almost zero asymmetry



Bottom line: μ-system

- Muon detectors at a LC would be required to perform tagging; they can be designed with today technology without much R&D .
- There is a reasonable choice of detectors that can be used.
- Tesla design relies on RPC's, other proposals could be worked out.
- My personal opinion is that gas devices are economically preferable.

Bottom line: Particle id

- A clear case for the H.E. has not been presented jet:a complete attempt to assess benefit and cost is still to come.
- The situation in the low energy regime (Giga Z) is in my opinion a bit clearer: here we have something to gain as exclusive processes are important.
- Apart from the CP asymmetries, (not so) rare B decay would benefit a lot from PID.

Conclusions

- The design and optimization of the μ-identifier for a general purpose LC detector is proceeding: for Tesla the RPC option has been chosen, other groups might explore other possibilities.
- Particle i.d. does require a definite effort in order to state, on solid bases which ratio benefit/cost this subsystem would imply.
- The Giga Z physics program would clearly benefit, in my opinion, from hadron identification capabilities.