BEAUTY 2003

Calorimeter and Muon System

Lepton Identification

Pittsburgh, October 14 – 18, 2003

On Behalf of the LHCb Collaboration

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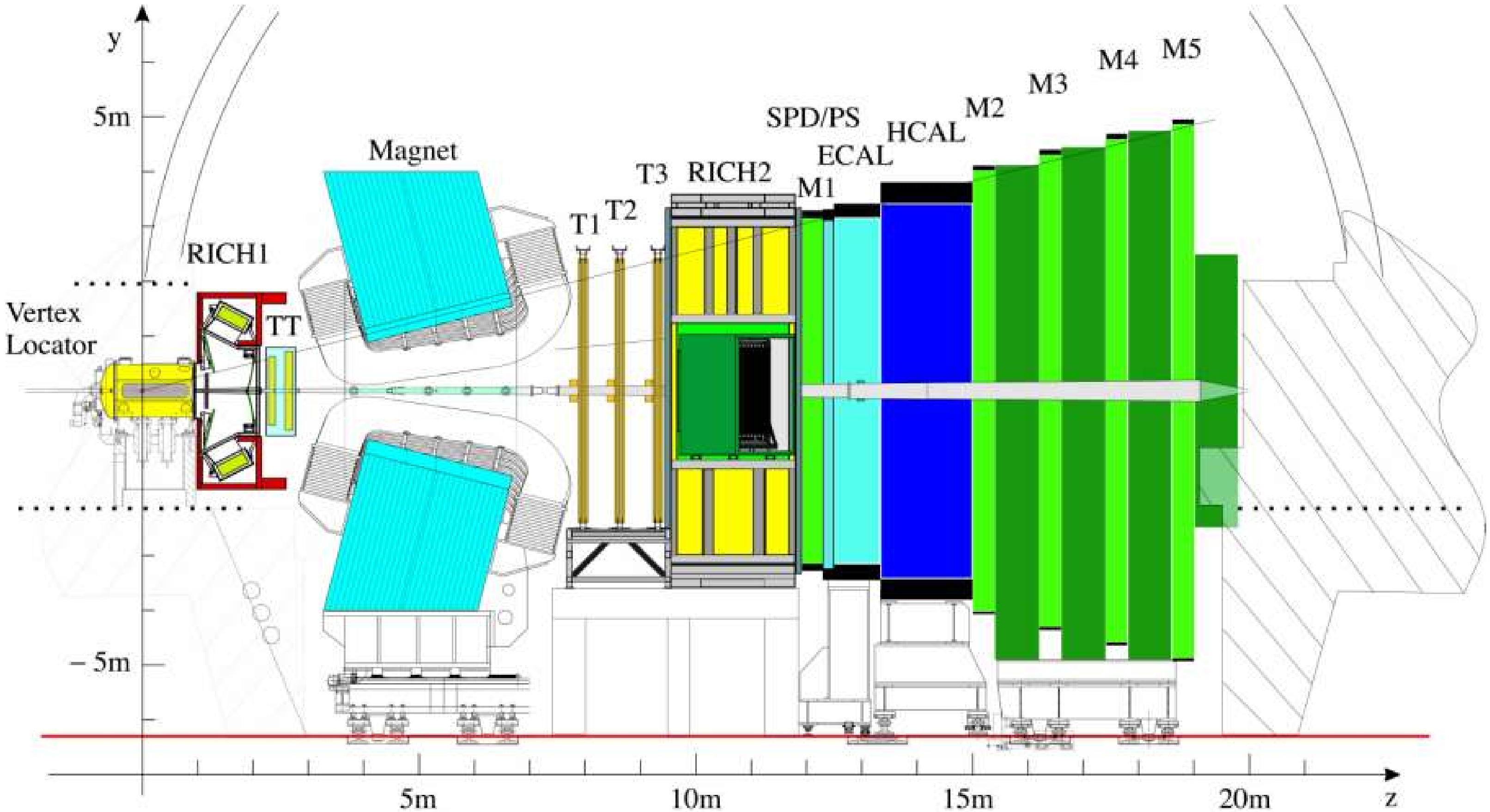
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

The LHCb experiment

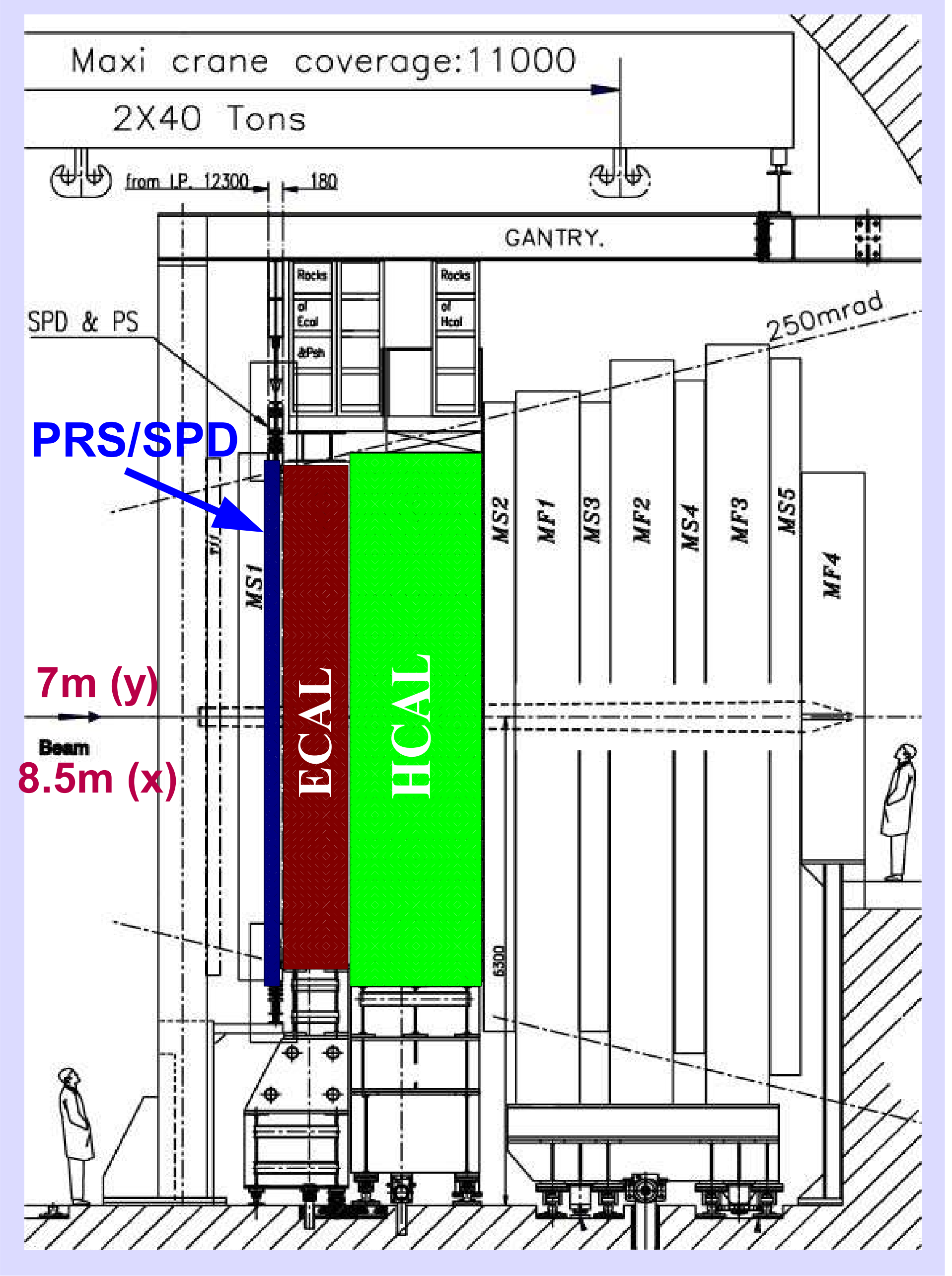
- LHCb is dedicated to the Study of CP violation in the B meson system



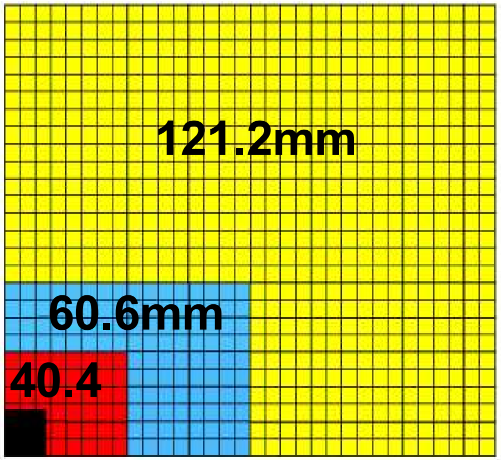
- recent reoptimisation
  - VELO, RICH1, Tracking
  - Less material before Calorimeter (~ 70%X_0)

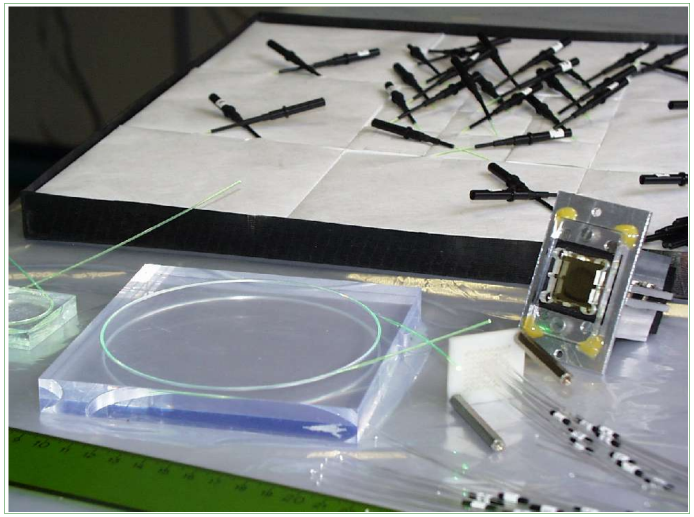
LHCb Calorimeters

- **Requirements :**
  - Identification of hadrons, electrons, γ, π^0
  - Energy/ Position measurement
  - L0 Trigger input : → see talk by O. Callot
    - High sensitivity
    - Fast response (40MHz)
- **Scintillator Pad Detector (SPD) Preshower (PRS) → L0**
  - γ / MIP separation (SPD)
  - Electron, γ / π (PRS)
  - Charged Multiplicity (SPD)
- **ECAL → L0**
  - Et of electron, γ
  - π^0 offline reconstruction
- **HCAL → L0**
  - Et of hadrons
  - Particle ID



SPD / PRS

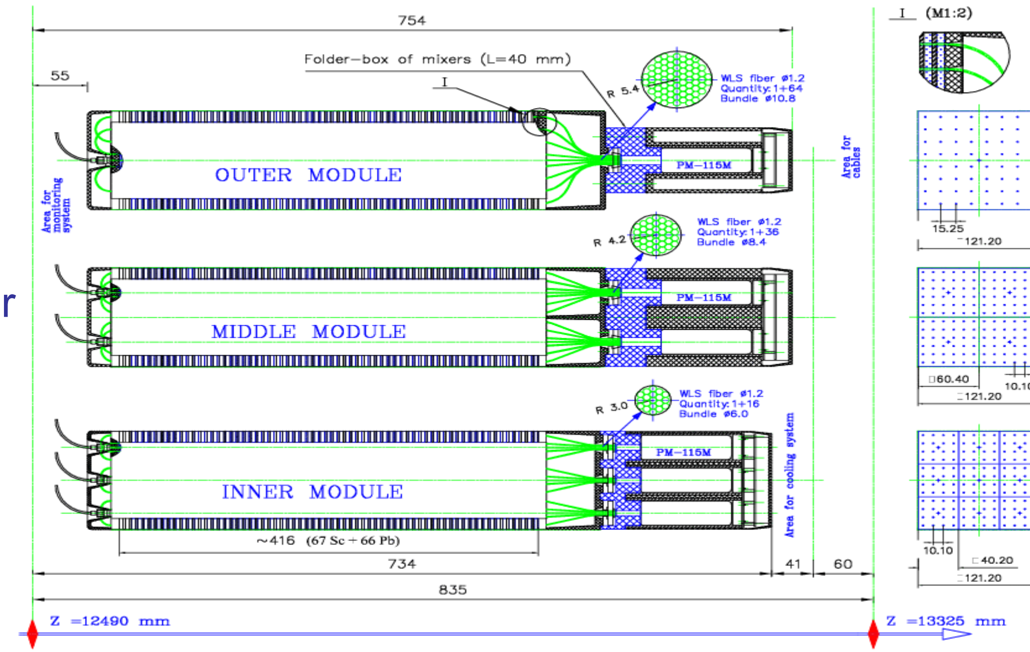


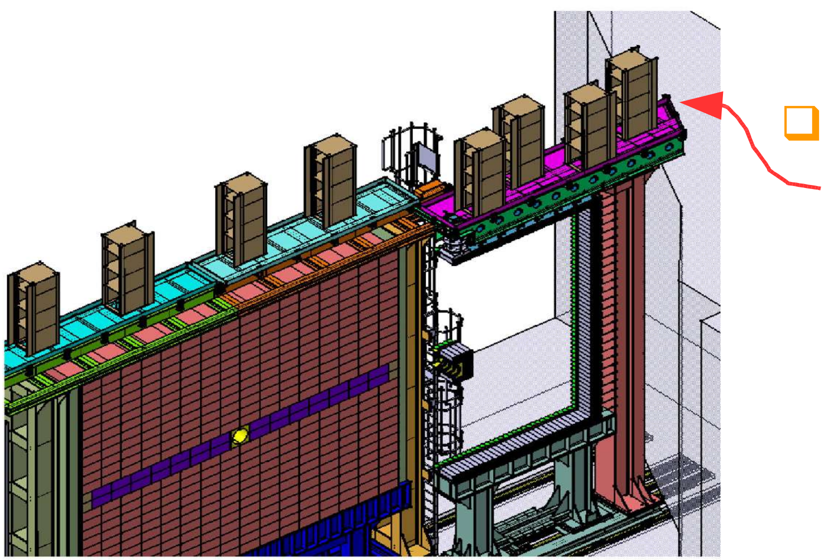


- **Scintillating detector**
  - 2.5 X_0 lead converter sandwiched between two scintillator planes (pads)
- **3 zones : granularity depends on the occupancy**
  - Cell size : 40.4 / 60.6 / 121.2 mm
  - ~ 6000 channels
    - Notice : 3 same zones for ECAL (HCAL : 2 zones)
  - Projective Calorimeters
- **L0 :**
  - ECAL finds local Et maxima
  - SPD/PRS determines electromagnetic nature of energy deposit
- **Signal read with MAPMT**
- **Dynamic range : 0 – 100 Mips**
  - 10 bits (PRS) + 1 bit (SPD)

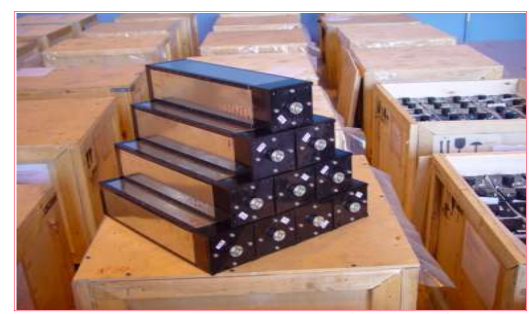
ECAL

- **Shashlik technology**
  - Radiation resistance
  - Fast response
  - 66 layers of 2mm Pb / 4mm scintillator
    - 25 X_0, 1.1 λ_I
  - WLS fibres transport signal to PMT





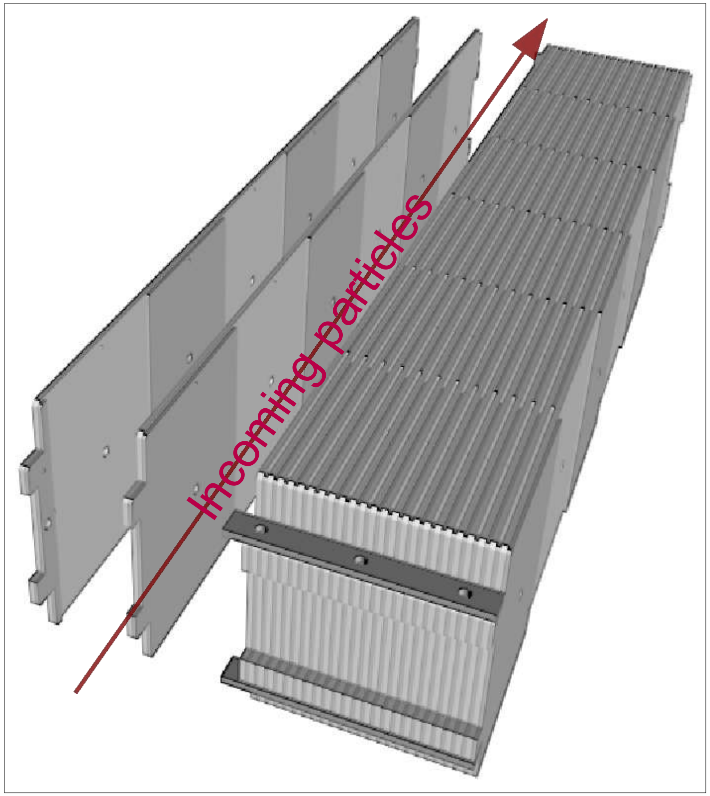
- **ECAL front-end/L0 electronics**
  - Installed on top of sub-detectors (200rad/y)
  - Low noise front-end integrator
  - Et range : 0 - 10GeV (12 bits)



- **90% of the modules delivered to CERN**

HCAL

- **Longitudinal tiles**
  - Iron and scintillator tiles
    - 6mm master, 4mm spacer / 3mm scintillator
    - 5.6 λ_I
  - 2 zones (1468 channels)
  - Signal propagates with WLS fibres to PMT

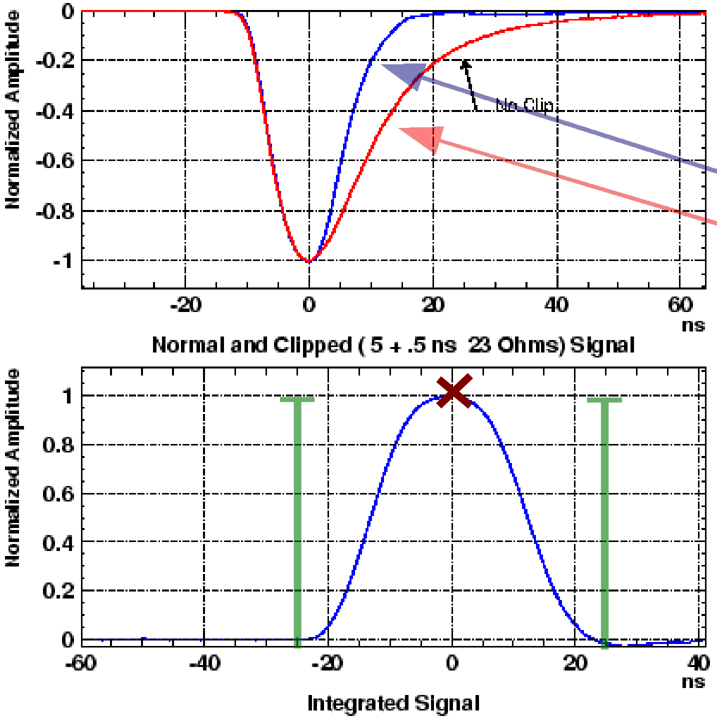


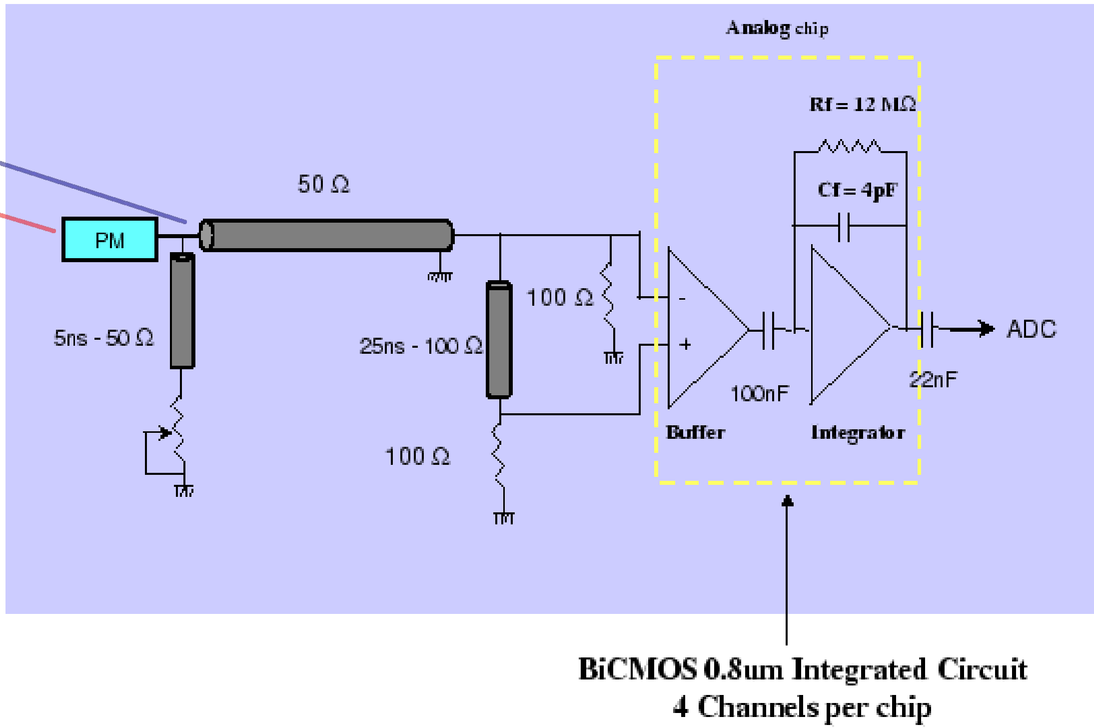
- Same front-end electronics as ECAL

- **30% of the modules already delivered**

ECAL-HCAL Electronics

- **Scintillator + WLS fibre : fast system**
  - Try to measure every bunch crossing : no pileup effect (residue after 25 ns : < 1%)



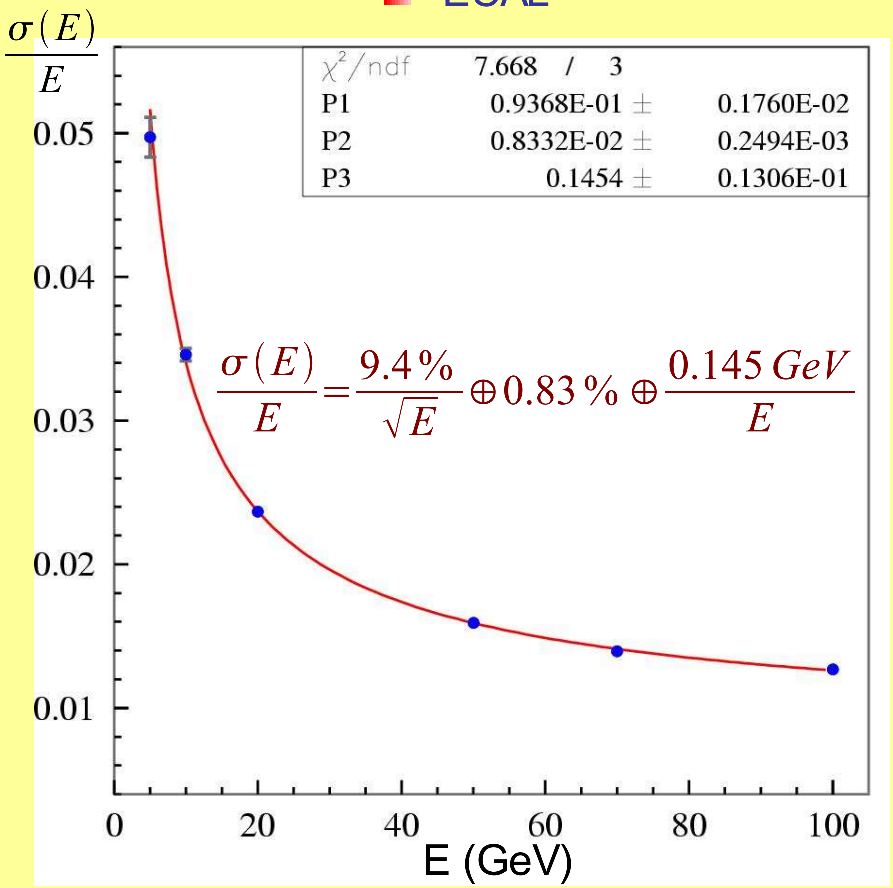


- **Digital electronics based on Actel anti-fuse technology**
  - FPGA configuration insensitive to Single Event Effects
  - Protection by Parity code and Triple Voting
- **All components have been tested in proton and ion beams**

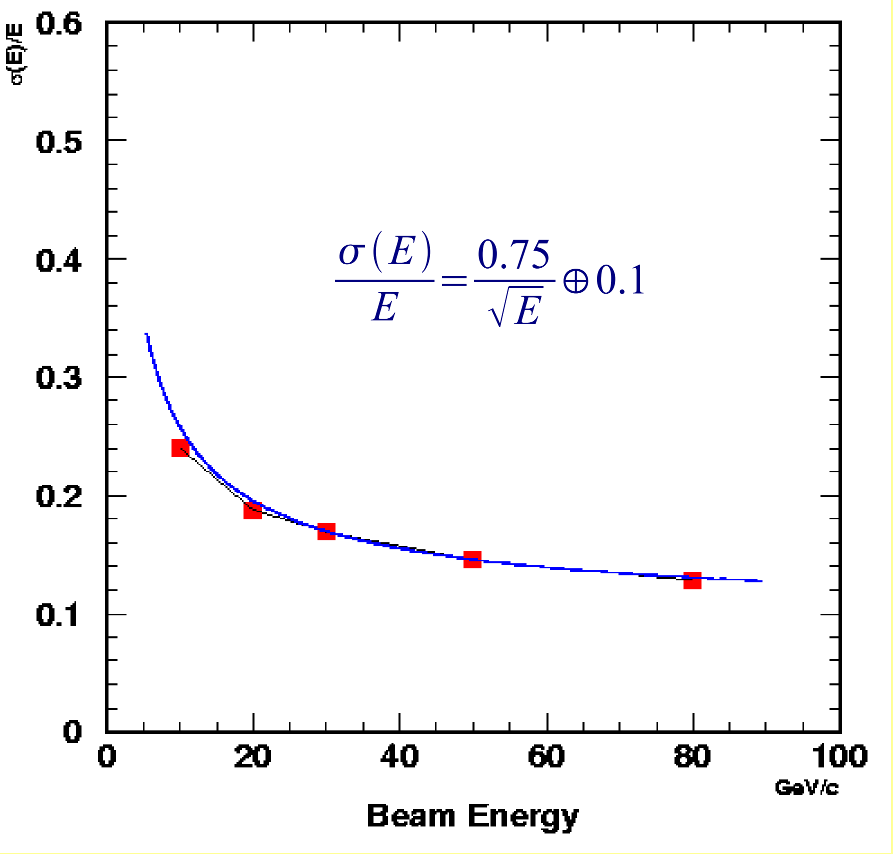
Energy Resolution

- Energy Resolution of series modules (test beam measurements)

ECAL

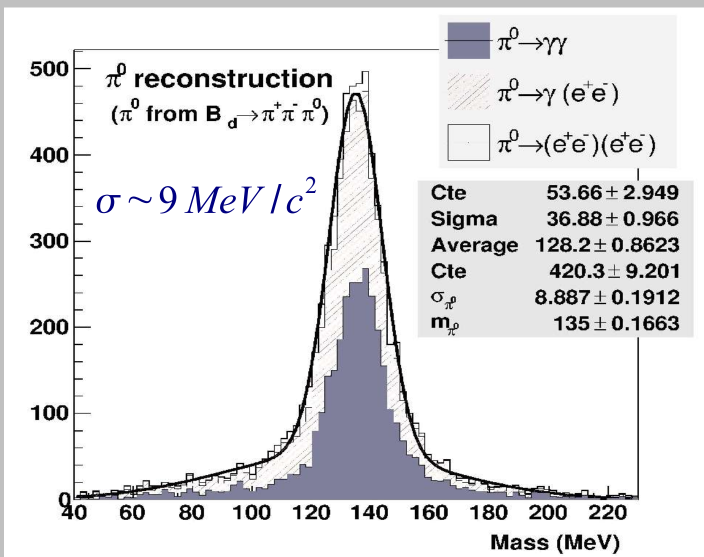


HCAL

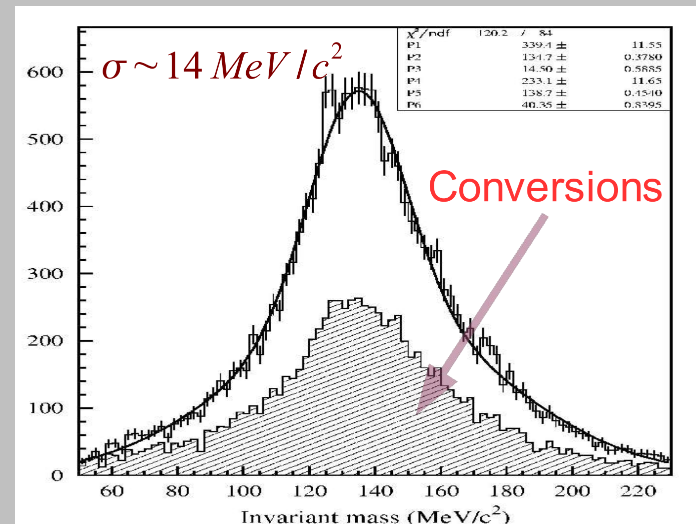


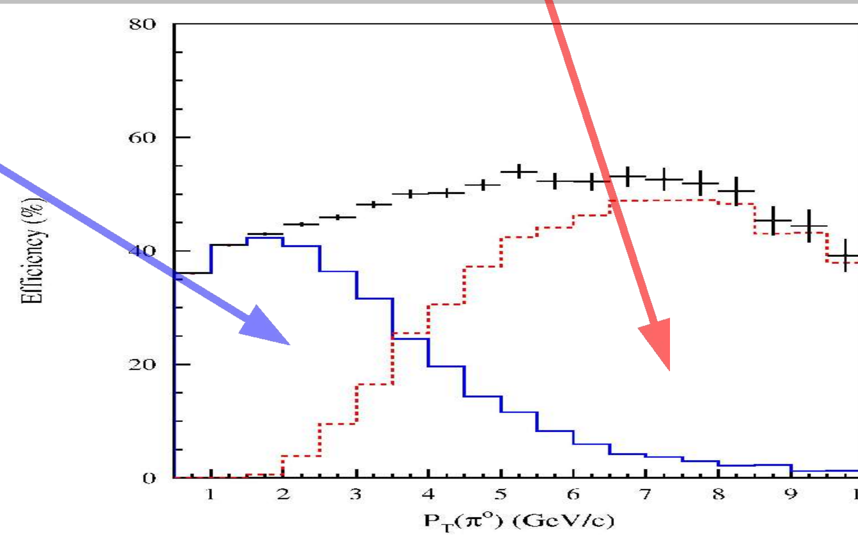
Calorimeter Performances : π^0 reconstruction

- **π^0 reconstruction efficiency**
  - Resolved π^0 (2 clusters)



- Merged π^0 (1 cluster)

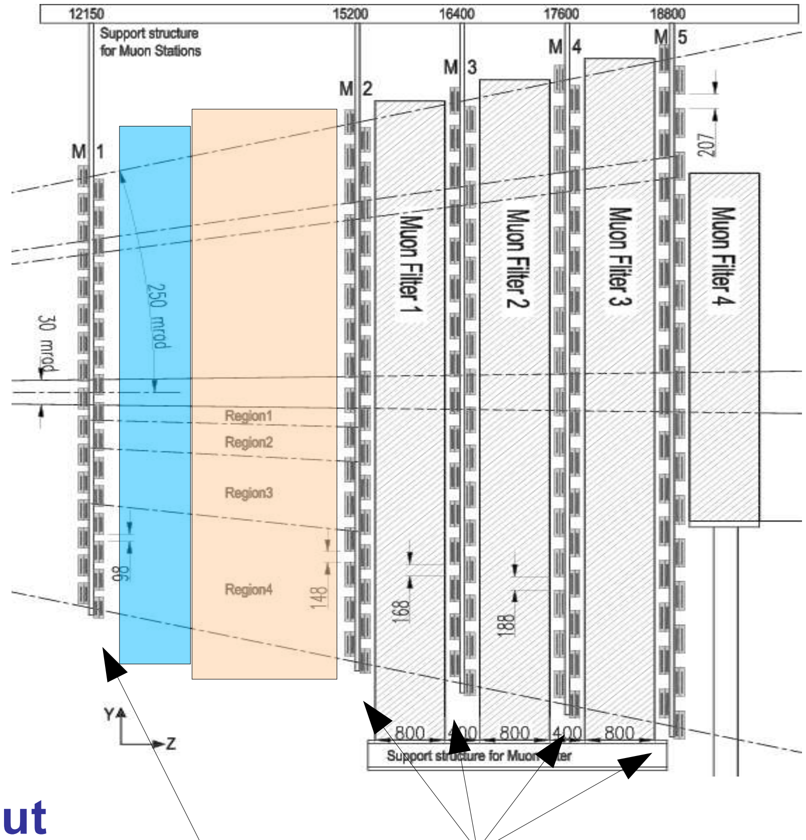


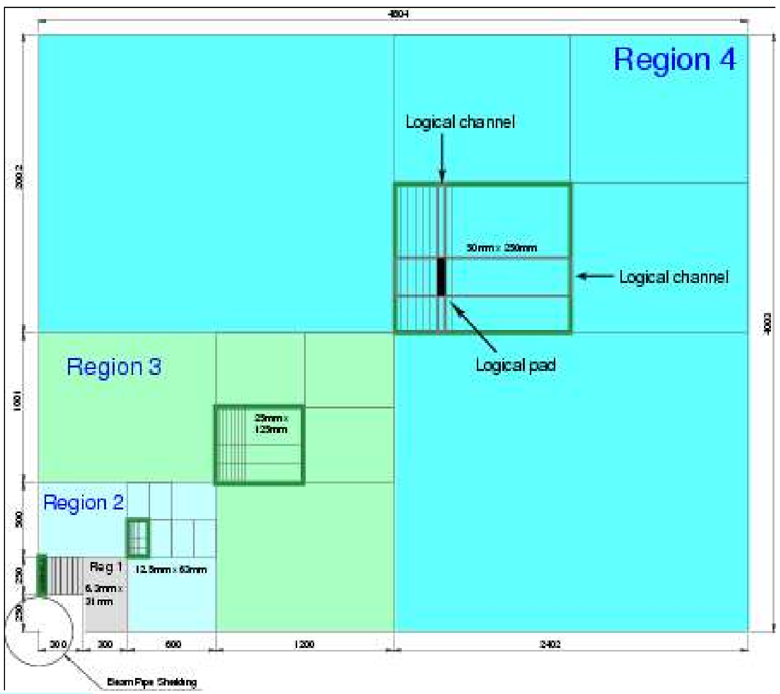


π^0 efficiency inside detector acceptance ~ 50%

Muon System

- **Requirements**
  - Muon triggering (L0)
    - Fast measurement / Bunch crossing id.
    - High efficiency (down to p=5GeV/c)
    - Pt resolution ~ 20%
  - Muon offline identification
    - Tagging + reconstruction
      - ε>90%, mid-id<1.5%

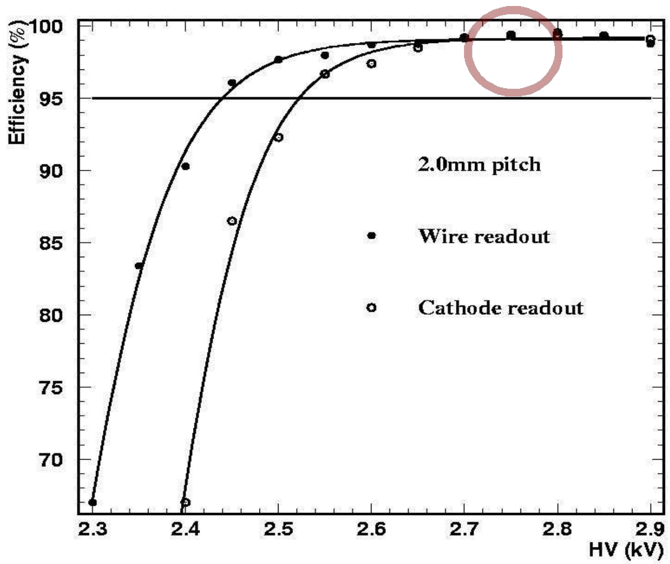




- **Layout**
  - 5 stations : 1x(2 layers)+ 4x(4 layers)
  - Projective geometry
- **Granularity : Stations divided in 4 regions**
  - X-dim : L0 pt resolution
  - Y-dim : background rejection
  - Logical pads from logical channels
- **435m² – 1380 chambers – 26k channels**

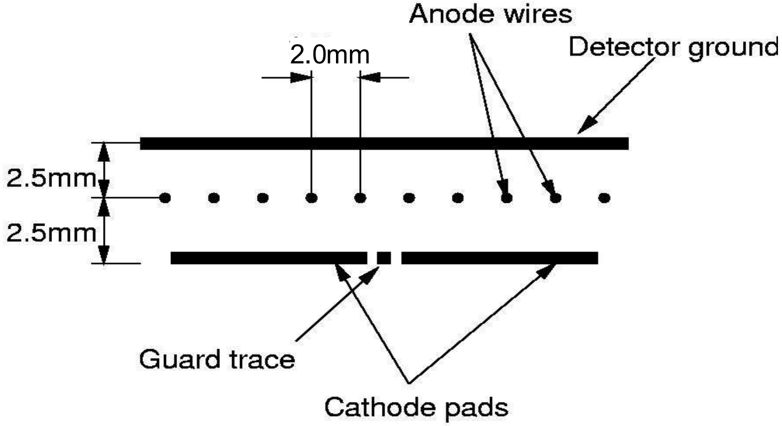
MWPC

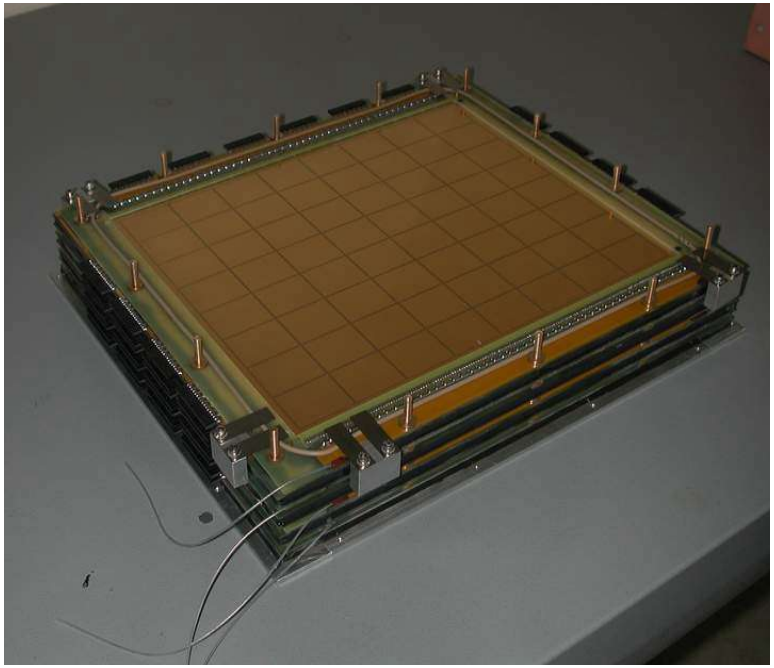
- **MWPC**
  - Wire/cathode reading
  - 2mm wire pitch ε=99% (20ns-2 gaps)
  - Time resolution : 4ns
  -



  - M1 radiation length : $0.15X_0$

(Nomex Honeycomb)



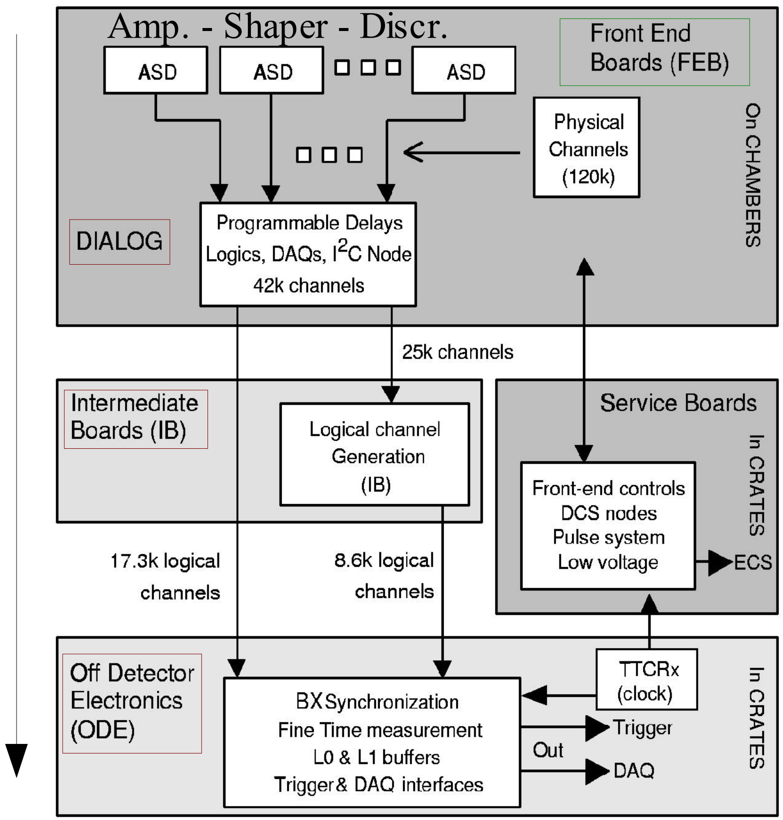


Pre-series MWPC

- **Central Part M1 ($0.6m^2$) : Triple-Gem ?**

Muon system electronics

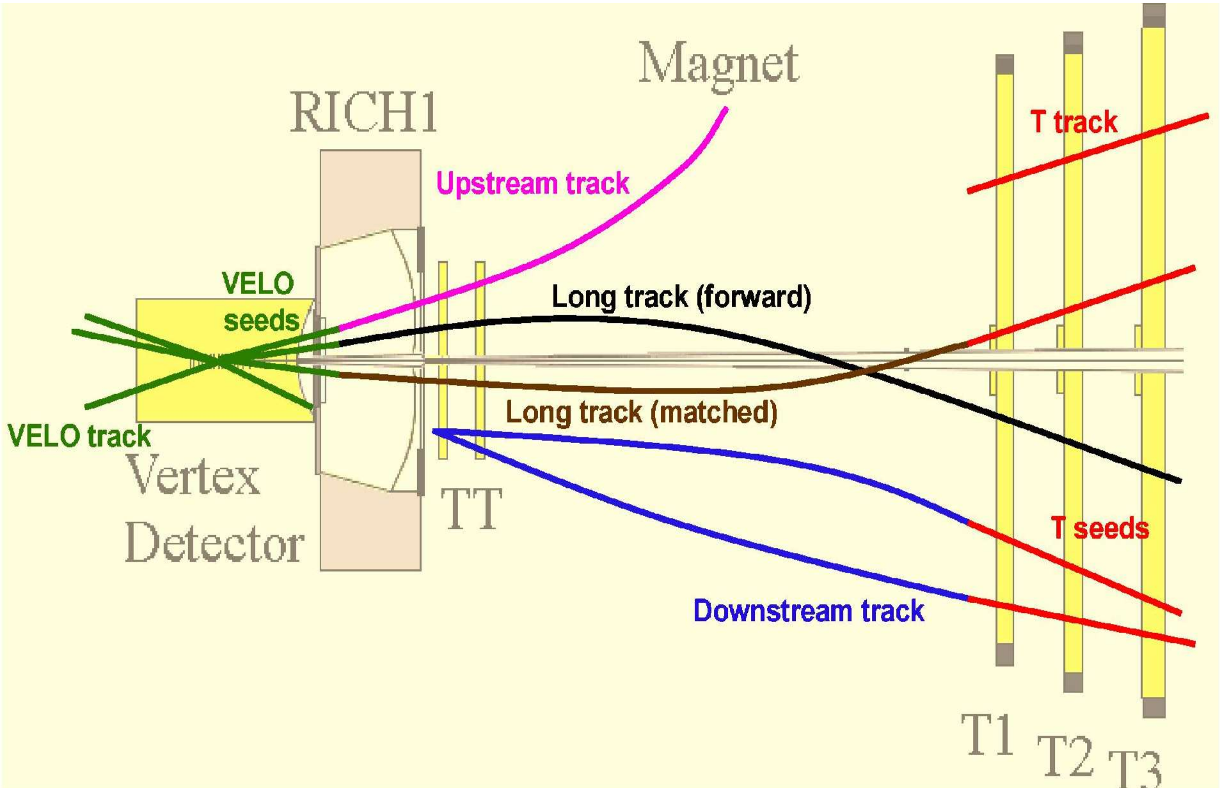
- **Muon electronics Architecture**
  - Physical Channels : 120k
  - Logical pads : 26k
    - Made from
      - strip crossing
      - physical pads
  - L0 / L1 / DAQ



- **MWPC pre-series production started**
- **Several sites are ready (tooling and clean room) for production**
- **Electronic Architecture has been reviewed and approved**
  - Final version of most chips has been received

Lepton identification : Tracking

- Tracking performance

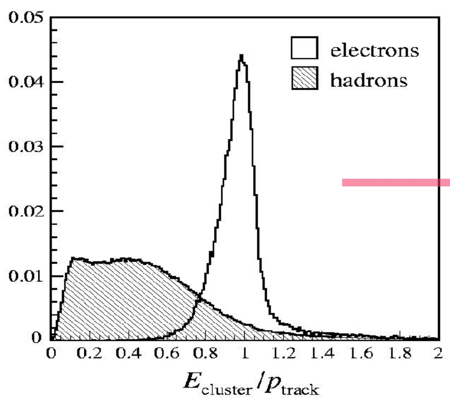


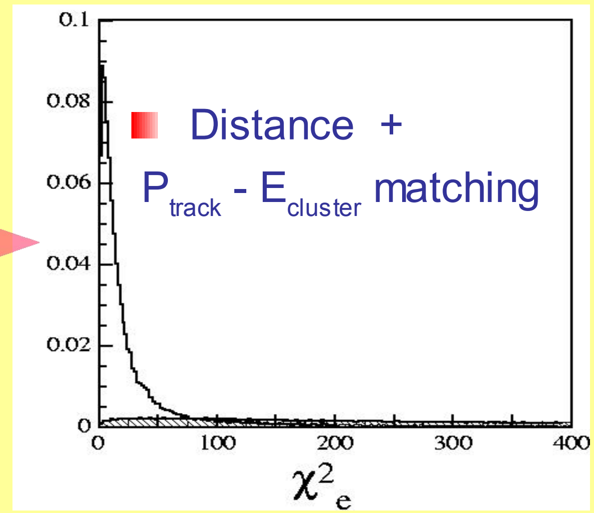
- ε=94 % - P>10GeV

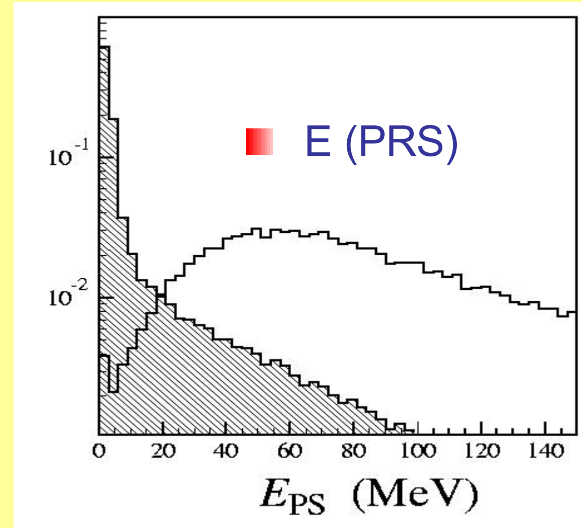
- R_{Ghost} ~ 3% - Ptcut=0.3GeV

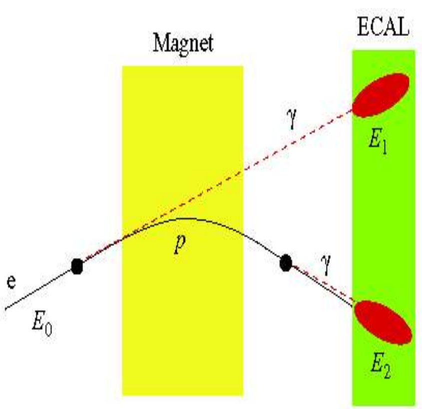
Electron Identification (I)

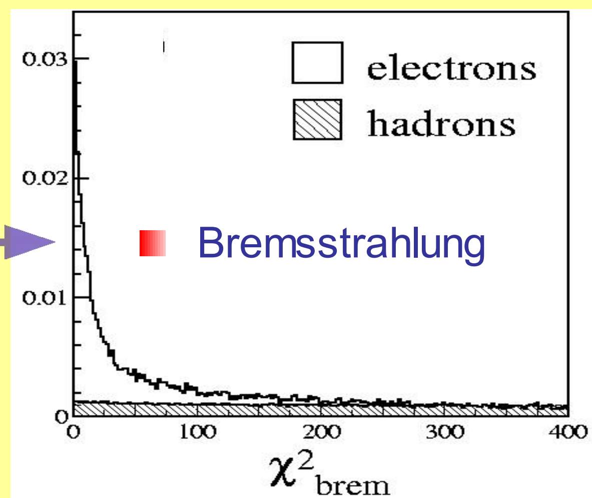
- Require impact of a track near a calorimeter cluster
- Build 4 parameters :

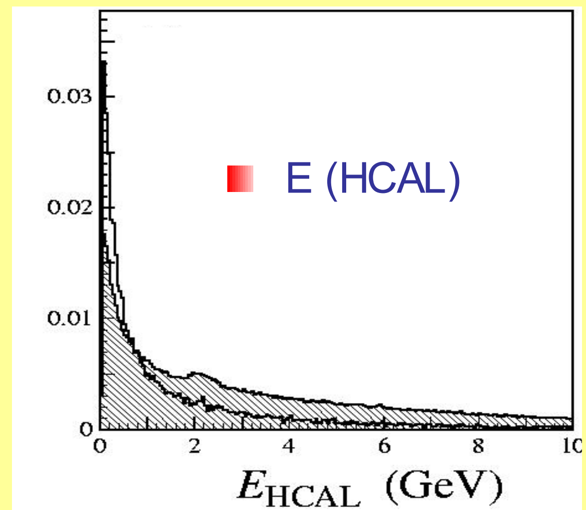






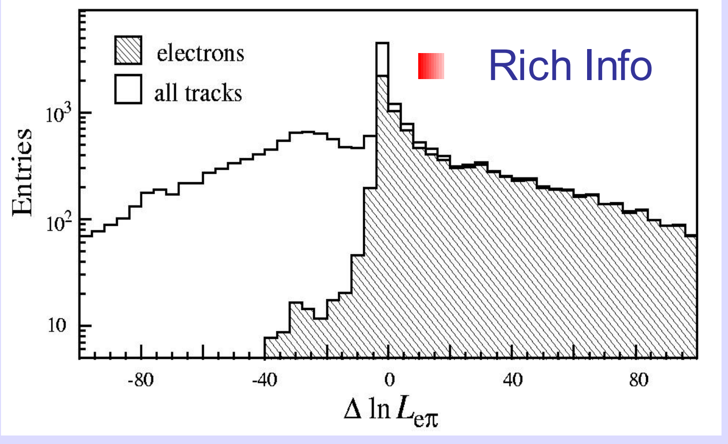


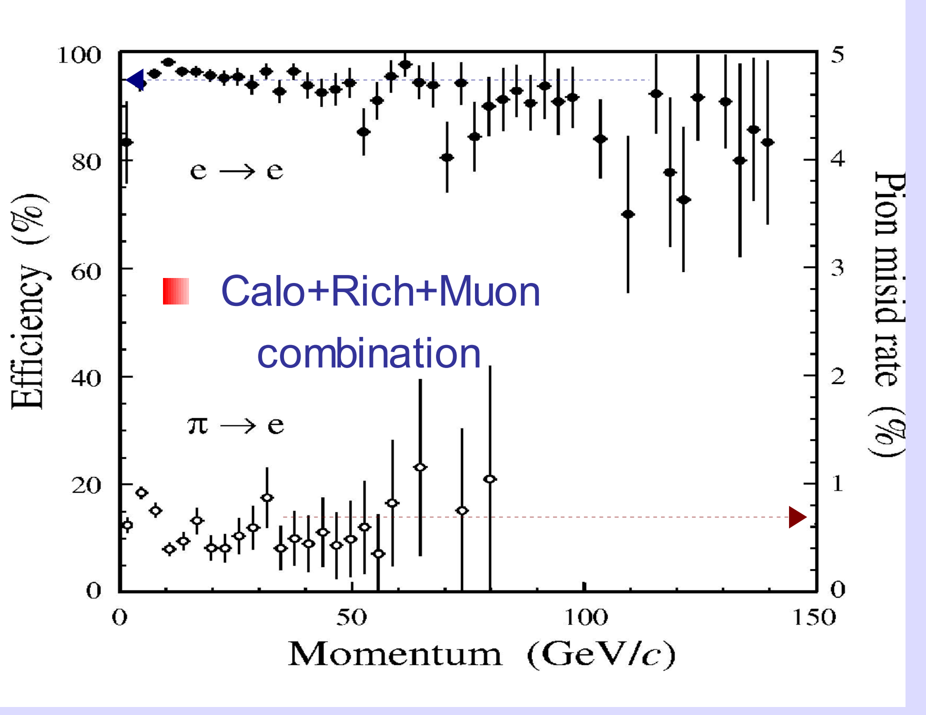


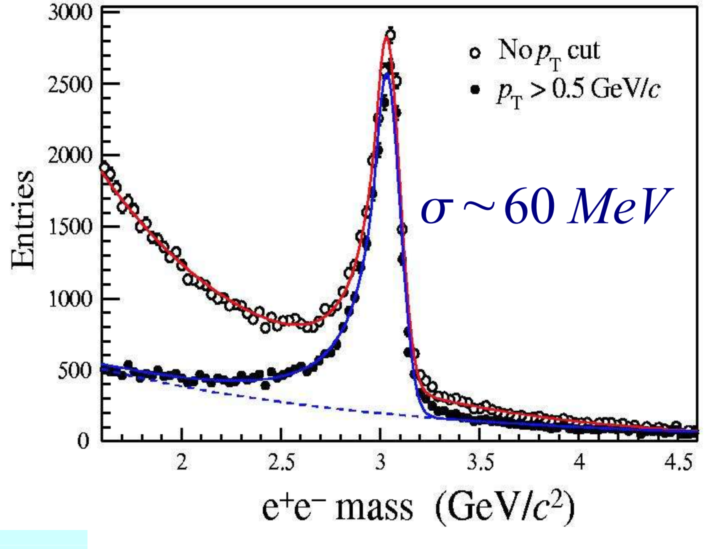


Electron Identification (II) : combined analysis

- Combine Calo + Rich + Muon





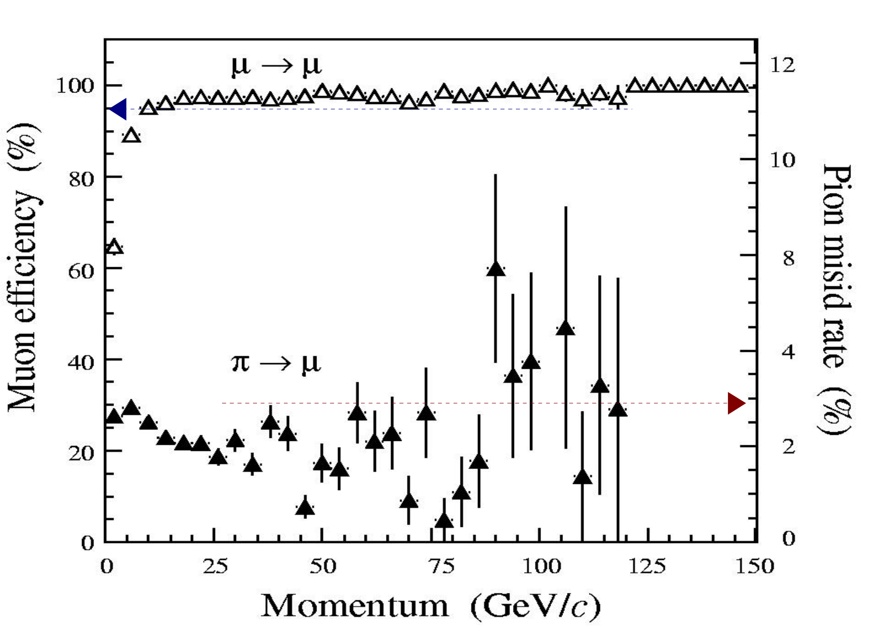


- $J/\Psi \rightarrow e^+ e^-$ ($B_s^0 \rightarrow J/\Psi\ \Phi$)
  - $\varepsilon(e)=95\%$ - $\varepsilon(\pi \rightarrow e)=0.7\%$

Muon Identification (I)

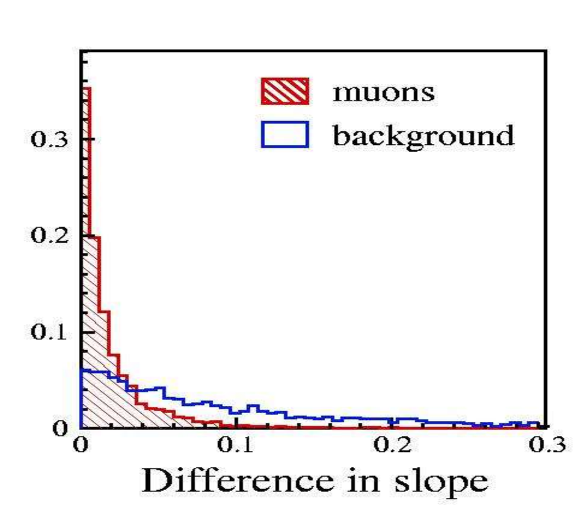
- Definition of Fields of Interest around track extrapolation
- Require hits in # stations in FOI

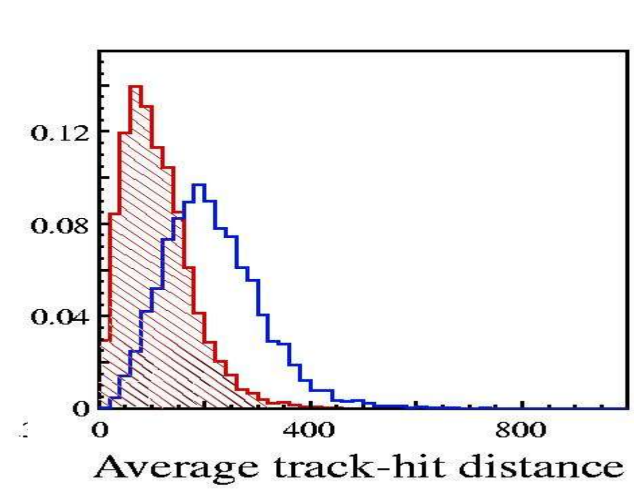
Momentum (GeV)	Muon Stations
3 < P < 6	M2 + M3
6 < P < 10	M2 + M3 + (M4 or M5)
P > 10	M2 + M3 + M4 + M5



- ε(μ)=94.3% - ε(π→μ)=2.9%

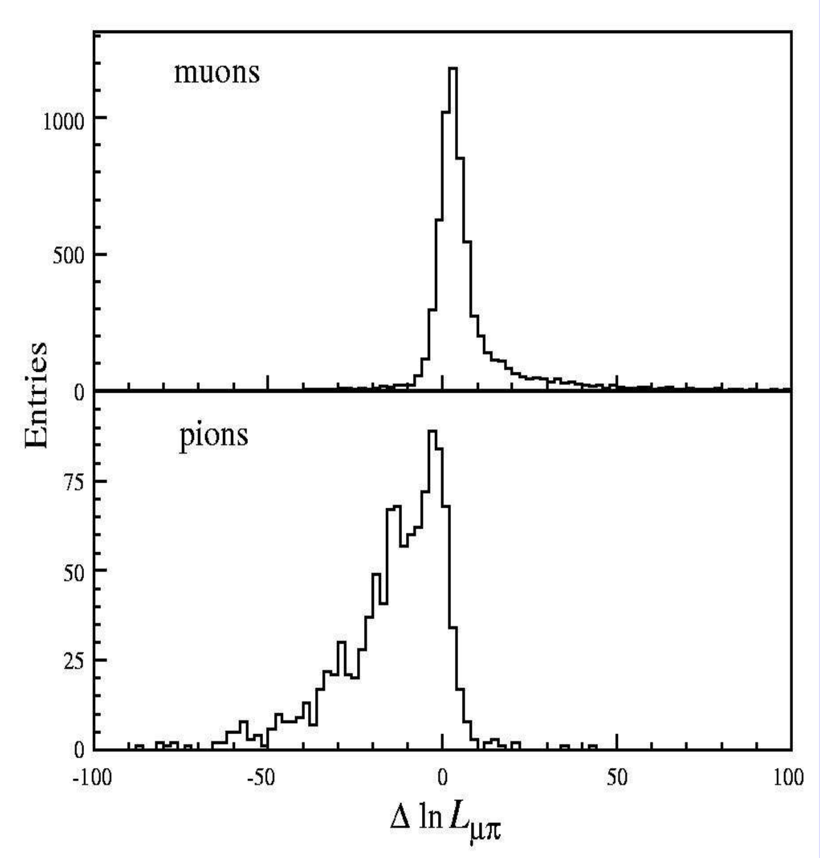
- Estimator to further reject pions



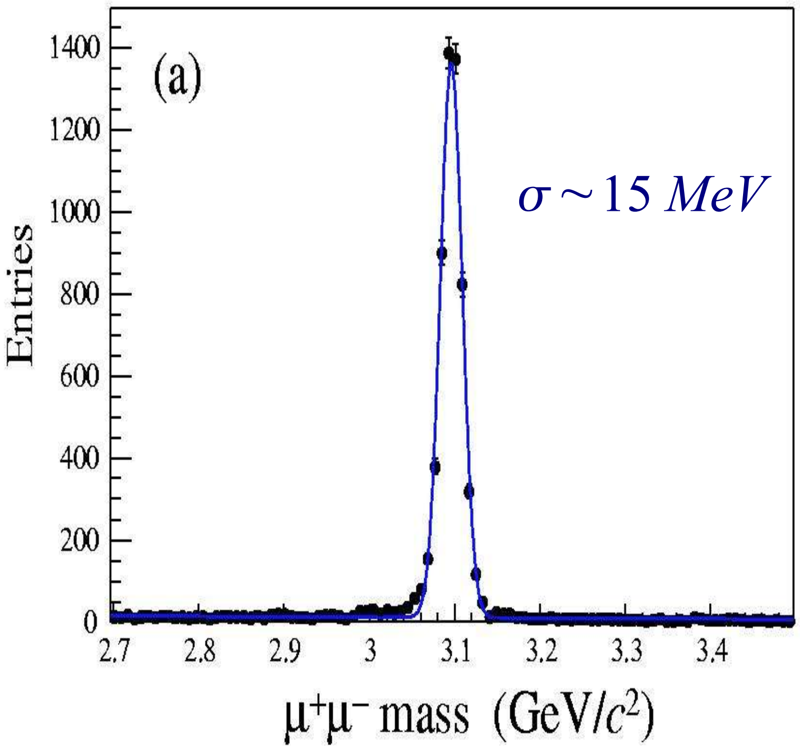


Muon Identification (II)

- **Combine Muon+Rich+Calo**
  - Further improves selection wrt FOI only



- **$J/\Psi \rightarrow \mu^+ \mu^-$ $(B_s^0 \rightarrow J/\Psi\ \Phi)$**
  - $\varepsilon(\mu)=93\%$ - $\varepsilon(\pi\rightarrow\mu)=1\%$



Conclusion

- **Calorimeter**
  - Complementary systems
    - SPD / PRS / ECAL / HCAL
  - L0
  - Fast / sensitive / efficient / robust

- **Muon system**
  - Simple (all MWPC) / robust
  - L0
  - Logical channel : no geometrical ambiguity

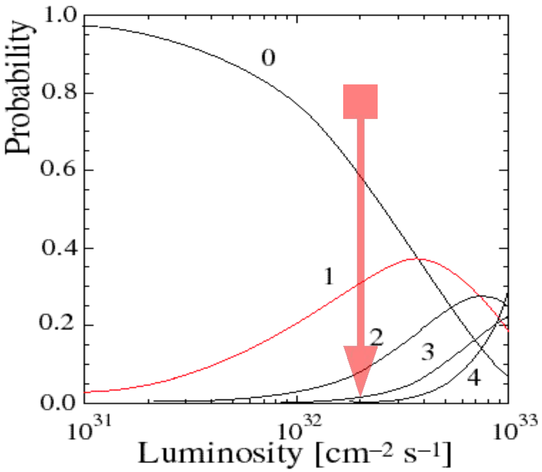
- **Lepton Identification ($B_s^0 \to J/\Psi\ \Phi$)**
  - Electrons : $\varepsilon(e)$ = 95% - $\varepsilon(\pi \to e)$=0.7%
  - Muons : $\varepsilon(\mu)$ = 93% - $\varepsilon(\pi \to \mu)$=1%

- **LHCb will be ready for data taking in 2007 at LHC start-up**
  - Detector production is on schedule
  - Detector installation starts at the end of next year (magnet installation ongoing)

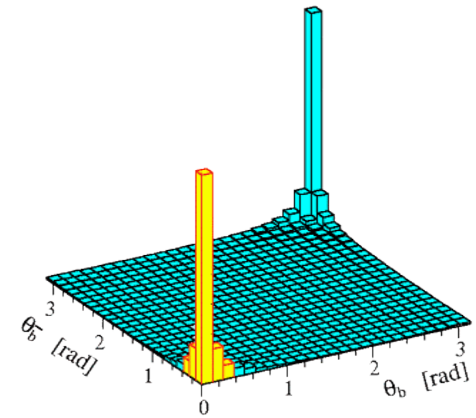
Backup Slides

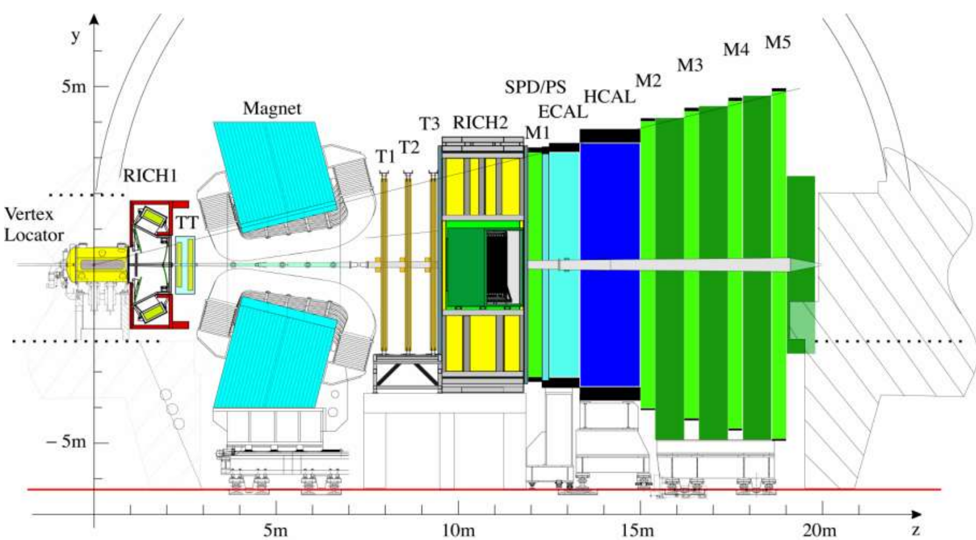
The LHCb experiment

- LHCb is dedicated to the Study of CP violation in the B meson system



- pp collisions at $\sqrt{s}$ = 14 TeV
- forward $b\bar{b}$ production correlated
- σ_{total} ~ 100 mb → Int. Rate : $2x10^7$Hz
  - σ_{bb} ~ 500 μb, σ_{inel} ~ 80 mb
  - S/B~1%
- 10^{12} $b\bar{b}$ pairs per year



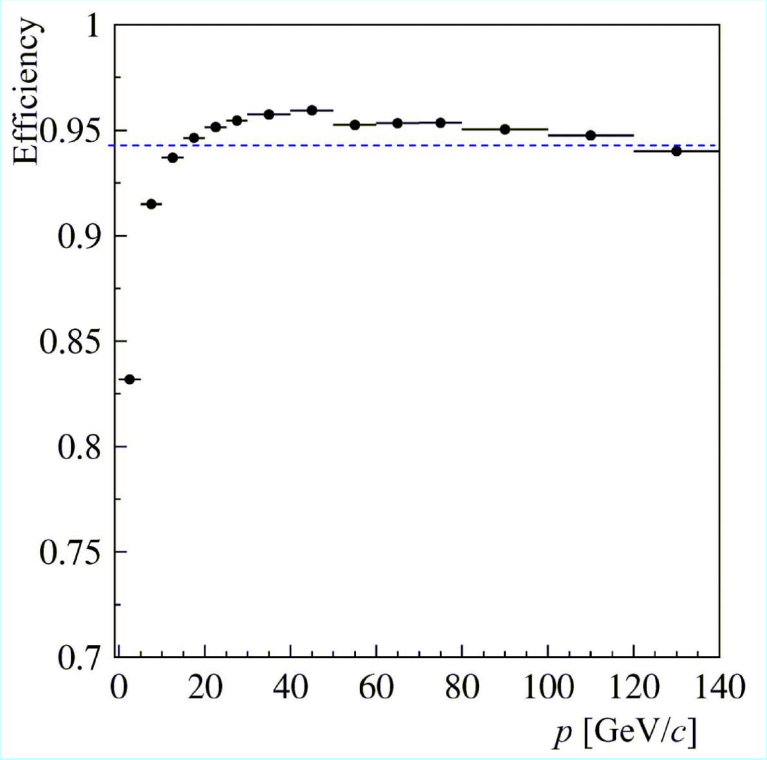


- LHCb
  - Mostly single interactions (PileUp Veto)
    - $L_{nom.}=2x10^{32}cm^{-2}.s^{-1}$
  - 12 mrad < θ < 300 mrad
  - efficient trigger (L0~1MHz, L1~40kHz)
  - recent Re-optimisation
    - VELO, RICH1, Tracking
    - Less material before Calorimeter

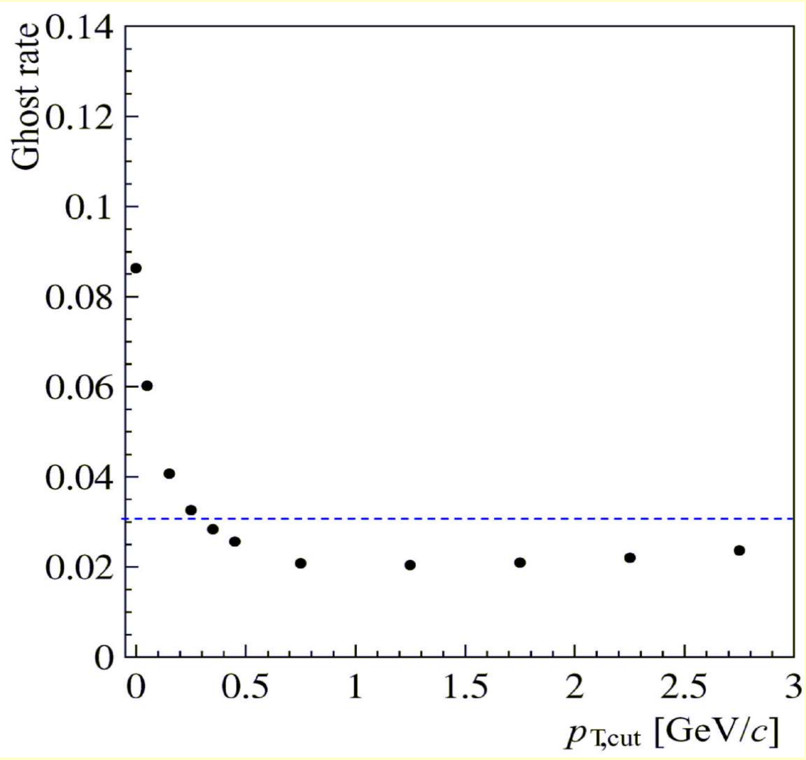
Lepton identification : Tracking

- Tracking performance

Efficiency



Ghost Rate



- ε=94 % - P>10GeV

- R_{Ghost} ~ 3% - Ptcut=0.3GeV

Lepton Identification Robustness

- **Electrons (Calo effects)**
  - Coherent / incoherent noise increase
    - +50 up to +100%
  - Dead channels
    - 1%(PRS/SPD) – 0.2% (ECAL/HCAL)
  - Channel gain error
    - +50%
  - No re-tuning (nominal reference histo)

ε(e) loss of 2.5%

ε(π→e) = 0.7% → 1%

- **Electrons (ex. of track multi. Effect)**
  - Increase track multiplicity by x2

ε(e) unaffected

ε(π→e) = 0.7% → 1%

- **Muons (Muon system effects)**
  - Increase low energy background by x5
  - No re-tuning

ε(μ) = 94 % unaffected

ε(π→μ) = 2.9 % → 11.7 %

- After algorithm re-tuning

ε(μ) loss of 7%

ε(π→μ) back to 2.9 %