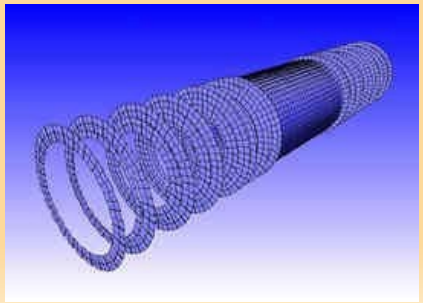
Can we measure charge at the SCT, ATLAS detector ?

Madalina Stanescu-Bellu (PhD student DESY), Stephen Mcmahon (CERN)

We want to check if the SemiConductor Tracker can actually

- *measure charge (as ionization energy dE/dx)*
- *discriminate particles*

even if it wasn't built for these.



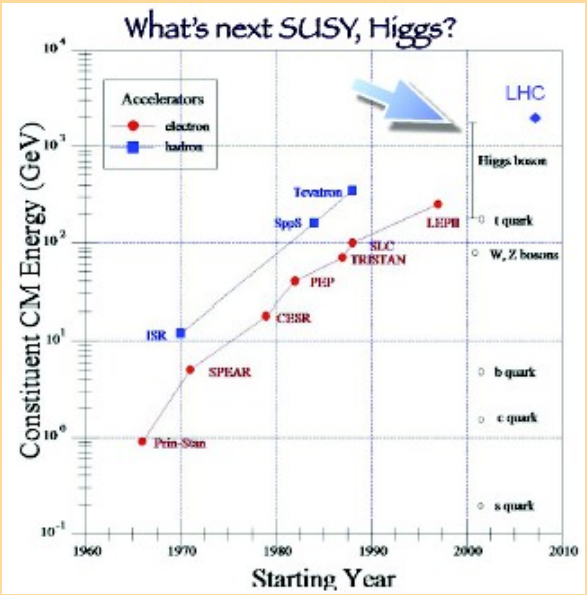
WORK IN PROGRESS

Graduiertenkolleg Blockcourse, 5 Oct 2011, DESY Zeuthen

Physics open questions - The Large Hadron Collider

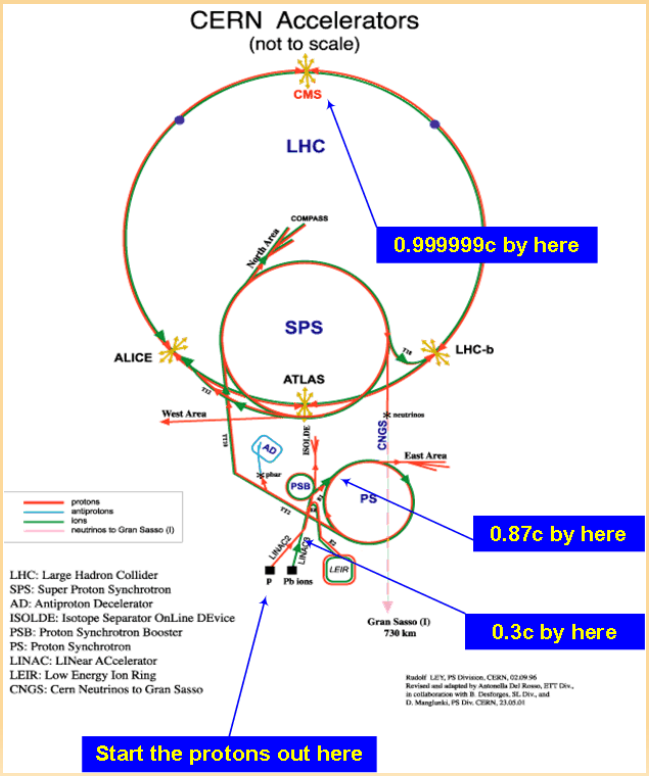
- Electroweak symmetry breaking
  - Does the Higgs field exist?
  - Does the Higgs boson exist? What mass?
- Can forces be unified at large energies?
  - Does supersymmetry exist?
- Extra dimensions?
  - Why 3 flavour families and not 4?

LHC is a probe at higher energies of these questions and of Standard Model



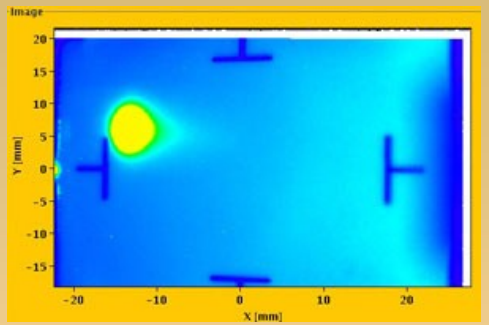
The Large Hadron Collider

- **Circumference 27km**, buried at 50-175m near Geneva
- **Energy 7+7 TeV** protons collisions (ATLAS,CMS,LHCb)
- **<u>Current energy 3.5+3.5 TeV</u>**
- Lead ions of 574 TeV / ion (ALICE)
- $\mathbf{T_{particles}=10^{16}\,K}$ (for Sun 16milions K) → 10^{-10} s after Big Bang



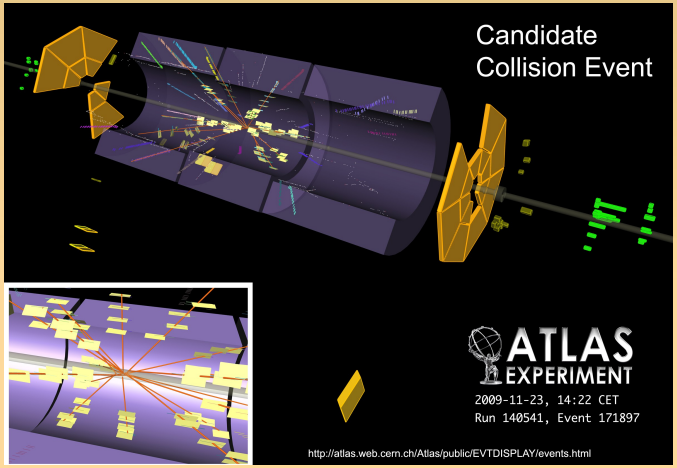
- **Bunches cross every 25ns**
- Peak instantaneous luminosity $\mathbf{L=10^{34}\,s^{-1}cm^{-2}}$
- **<u>Current luminosity $10^{33}\,s^{-1}cm^{-2}$</u>**
- Inelastic events xsection at designed lumi **σ= 60mbarn**
- $N_{events}=L*\sigma=$**600 milion collisions / second**

The Large Hadron Collider - History



← 10 Sept 2008 : proton beams successfully circulated for the first time, in stages, one in each direction, ~ 1h each

19 Sept 2008 : an electrical fault in the bus between magnets caused a rupture and a leak of 6t liquid He. operations halted.



- 20 November 2009 proton : beams successfully circulated again

  23 November 2009 : first proton–proton collisions → 450 GeV per beam

- After 2009 winter shut-down, LHC restarted and beams ramped to 3.5 TeV per beam (half its designed energy)

← 30 March 2010 : first collisions between two 3.5 TeV proton beams, new world record for the highest-energy man-made particle collisions.

- Until end 2012 :run at half energy
- From 2014 : run at full energy (7 TeV per beam), after luminosity&energy upgrade.

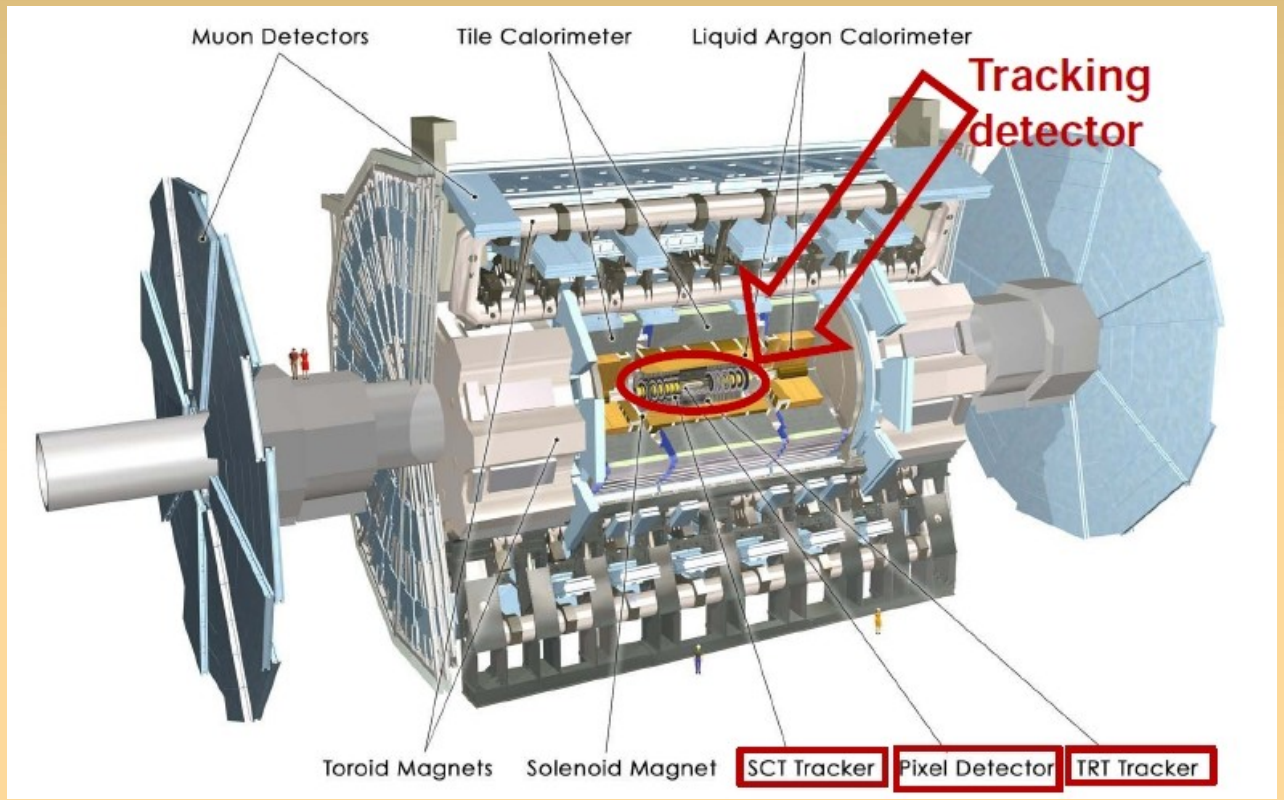
The ATLAS and CMS experiments

SM lecture at the BND school 2011, Pamela Ferarri, member of ATLAS Speakers Committee

The ATLAS experiment

A Toroidal Lhc ApparatuS: 42m length, 22m radius, 7000t weigth, 10^8 electronic channels

EM Calorimetry: Pb-LAr Accordion, e/γ trigger, identification and measurement



Triggers:
3 levels, reduce the rate from 40 MHz collisions rate to 200MHz

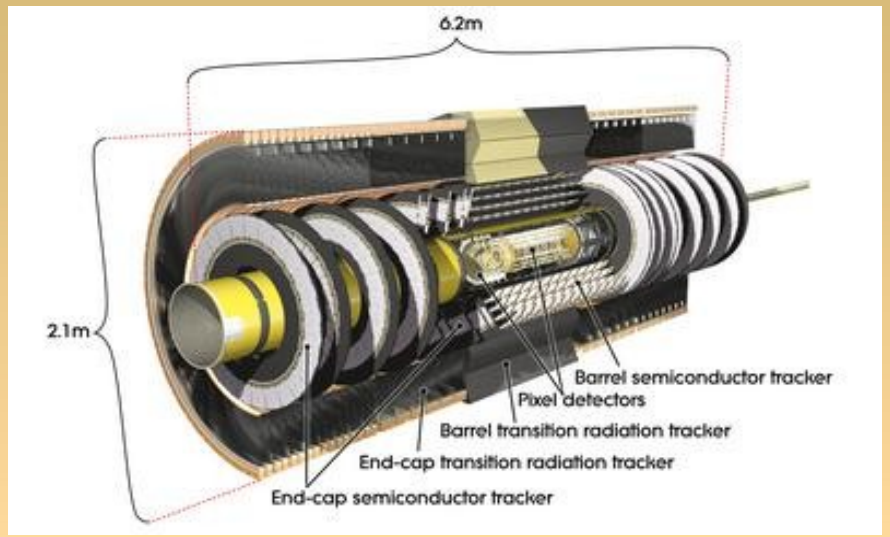
Hadronic Calorimetry: |η|<5, Fe/scintillator tiles (central), Cu-W-LAr (fwd), trigger and measurement of jets and missing E_T

MuonSpectrometer: |η|<2.7, air-core toroids with gas-based chambers, momentum resolution < 10%

Tracker (Inner Detector) |η|<2.7, B=2T

- Si pixels
- Si strips (**Semi Conductor Tracker)**
- Xe straws (Transition Radiation Tracker)
- Precise charge tracking, vertexing
- e/π separation
- Precise momentum resolution: σ/p_T=0.038%pT(GeV)+0.015

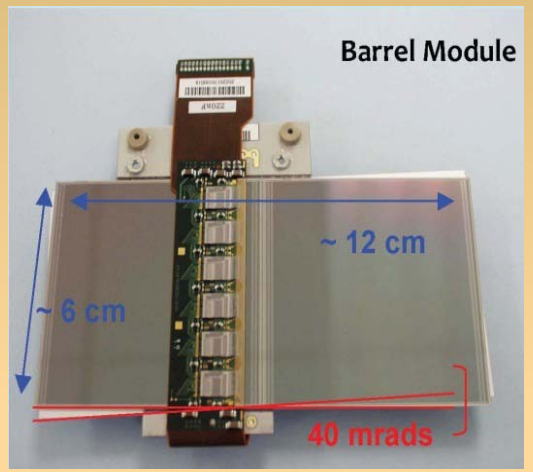
The SemiConductor Tracker (SCT)



Si strips modules each with 4 detectors (2 on each side), 6.3 million readout channels

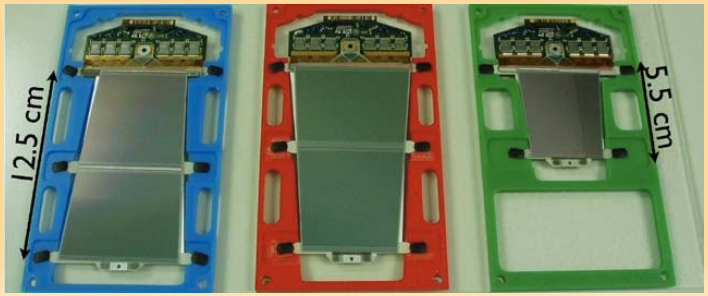
BARREL:

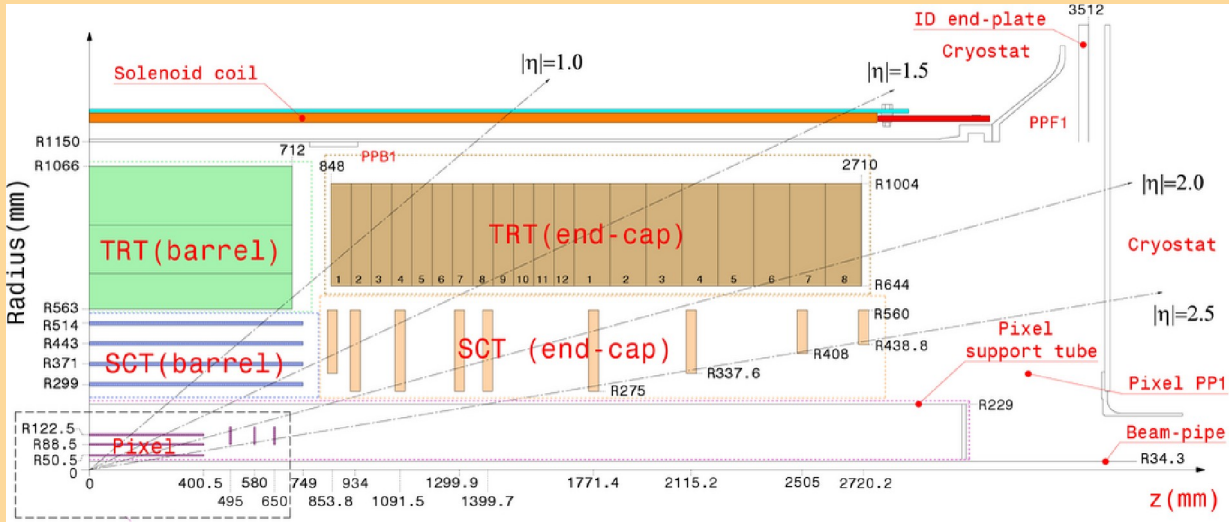
- 2112 modules of one type
- 4 layers
- $|\eta|<2.0$



2 END CAPS:

- 1976 modules of more types
- 9 disks/endcap
- $1.1<|\eta|<2.5$



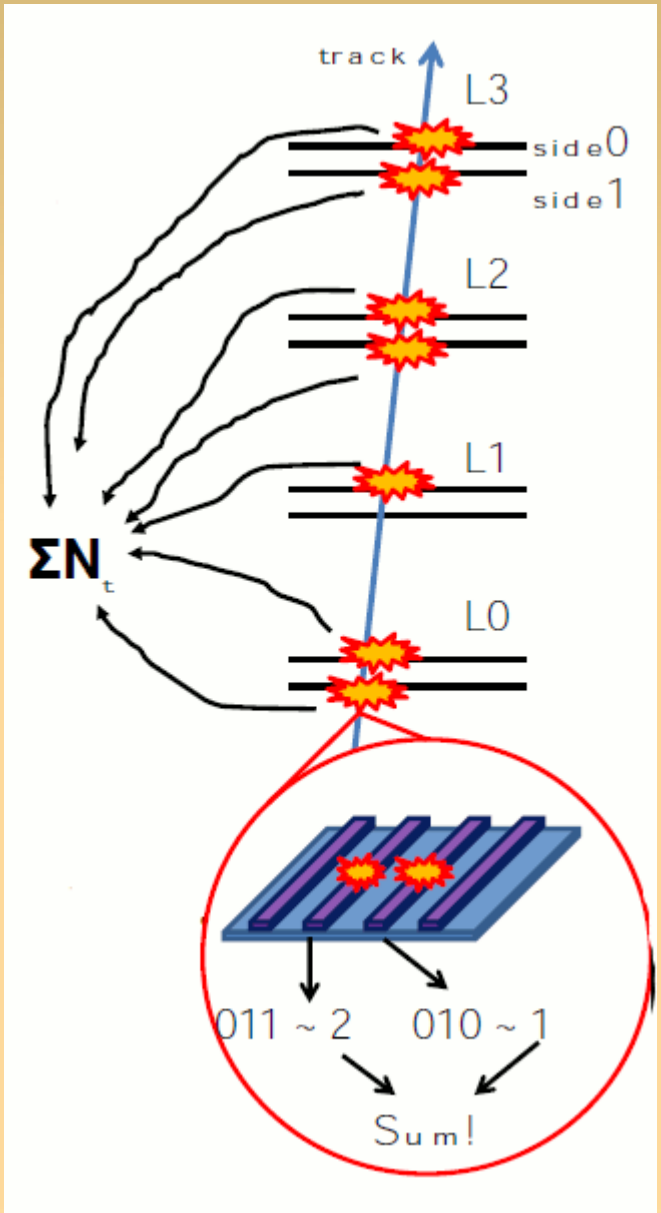


Motivation

- **Specific cluster energy loss dE/dx=QWcosα/(eρd) linear to charge Q. From now on we will identify dE/dx with Q.**
  - W = 3,68 eV/pair average energy to create an electron-hole pair
  - path in silicon x = d/cosα
  - silicon density ρ

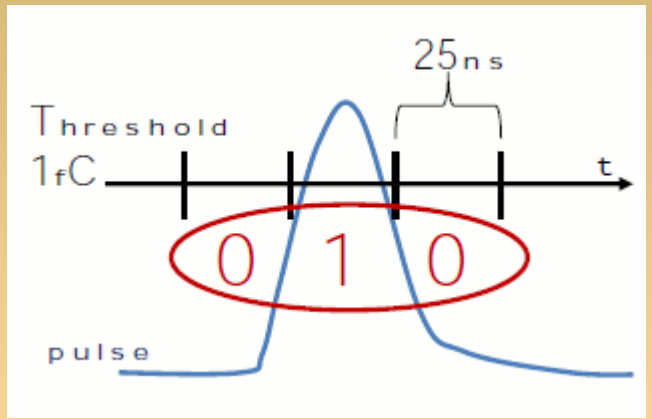
- **The Pixel detector provides analog dE/dx, SCT NOT, only Time Over Threshold → we try to see if we can deduct somehow dE/dx.**

- Measurements **inside each track**
  - **1 cluster**(=**hit**) for each 2 sides of each module
  - inside each hit , the number of **strips (RDO's)** with charge
  - for each strip, **3 Time-Over-Threshold values** (1 value for each consecutive bunch-crossing):
    - **0 if signal < 1fC**
    - **1 if signal > 1fC**

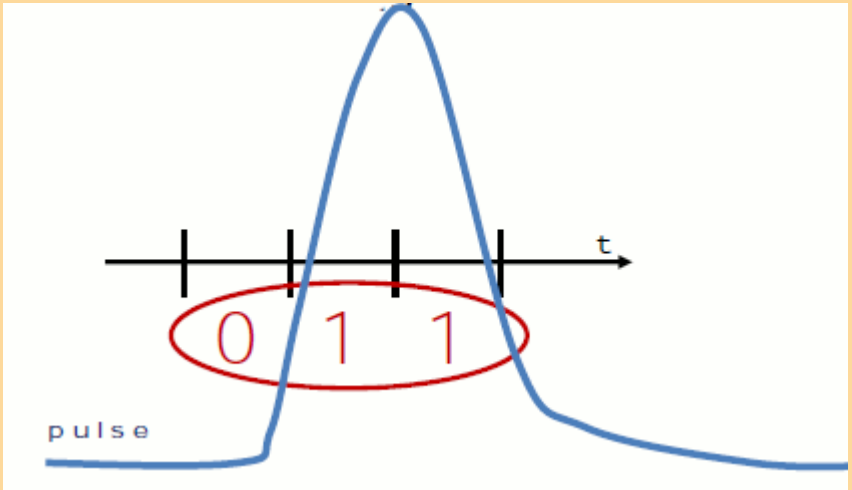


Analysis method: Time-over-threshold

- The signal pulse is correlated to the number of 1-bins: **the more consecutive #1-bins => the higher the signal.**



- **We use the <u>TOT method to approximate dE/dx in SCT</u>, by giving a <u>weight for each RDO</u> associated to the track, according to the timebin distribution:**
  - 101 (illegal bin), 000: weight=0
  - 001,010,100: weight=1
  - 011,110: weight=2
  - 111: weight=3



dE/dx for the track = Σweights

Datasets

We use SCT Ntuples:

- data10_7TeV.00167576.physics_MinBias.merge.NTUP_SCT.r1744_p327_p398
  - Run167576(Oct 24 2010 10:40:20 -21:09:57)
- data10_7TeV.00167607.physics_MinBias.merge.NTUP_SCT.r1744_p327_p398
  - Run167607(Oct 25 2010 00:15:58 -14:13:15)
- data10_7TeV.00167661.physics_MinBias.merge.NTUP_SCT.r1744_p327_p398
  - Run167661(Oct 25 2010 17:37:54 -Oct 26 08:13:49)
- data10_7TeV.00167844.physics_MinBias.merge.NTUP_SCT.r1744_p327_p398
  - Run167844(Oct 29 2010 01:51:46 –10:59:21)
- **#Events=1,892,815**
- **We use only the good Lumi Blocks (yields 99% of the total tracks)**

Run #	167576	167607	167661	167844
Good LBN	3-293	86-430	372-439	79-270

Track Selection and Classification

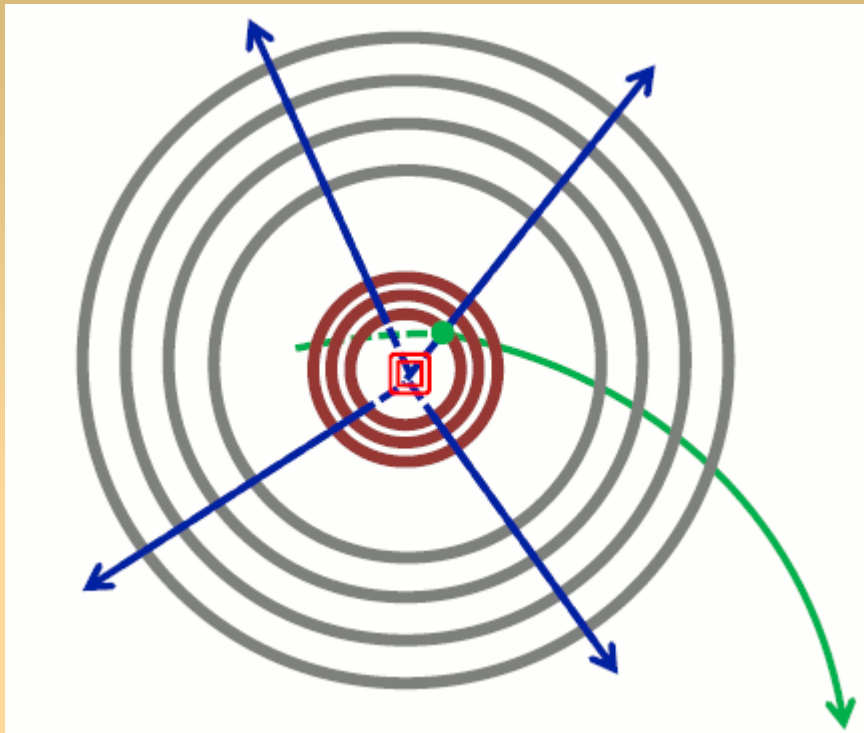
- **For each track #hits = #good_hits + #outlier_hits. Outliers** are hits far from the fitted track
- Condition: **#good_hits>7** so that the track is well measured

- Tracks are classified according to clusters location:
  - **Barrel Tracks** : all clusters associated with a track are in Barrel
  - **EndCap (EC) Tracks** : the other tracks

- **Sources of tracks:**
  - primary vertex PV (in the beampipe, very close to the Interaction Point IP)
  - gas interractions downstream in the beampipe
  - 2ndary vertex (outside the PV and IP, except gas processes, there are no more interractions until the first material layer, which is the BeamPipe wall)
  - noise

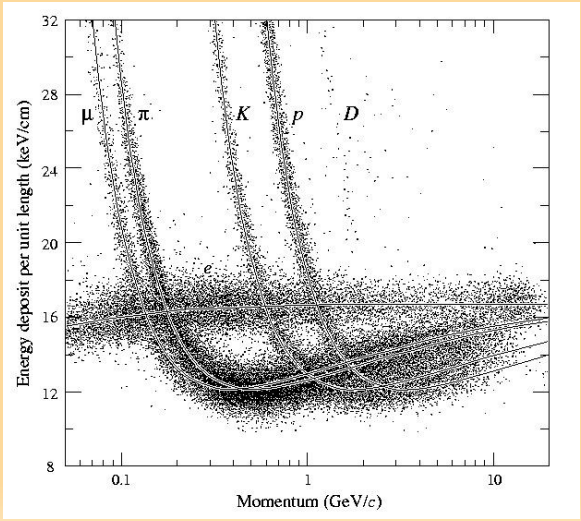
Track Selection and Classification

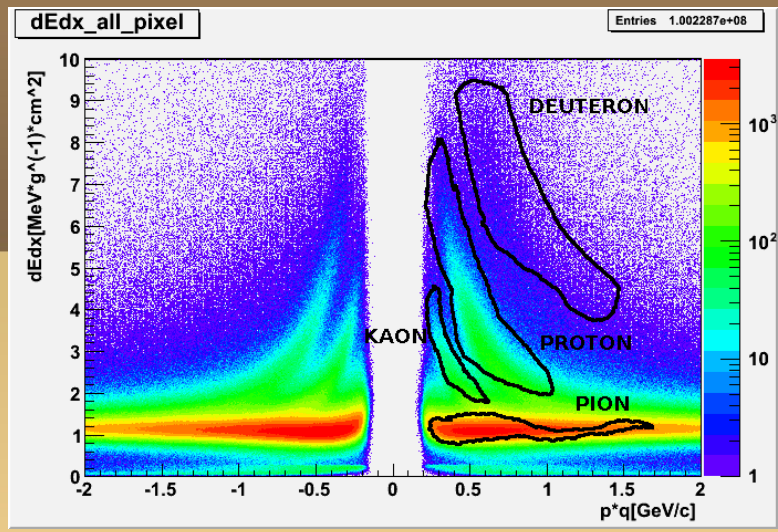
- **BLUE**: tracks coming from the Primary Vertex **(PV tracks)**
  - **Small D0: D0<2mm (transversal cut)**
- **GREEN**: tracks coming from a 2ndary interaction in the material, usually the BeamPipe wall **(BP tracks)**
  - **They project a high D0: D0>2mm**
  - **These interactions should be rich in protons/ deuterons because of taking place in material**
- Both require **Z0<100 mm** (**longitudinal cut**, to be inside the beamspot and avoid gas interractions)

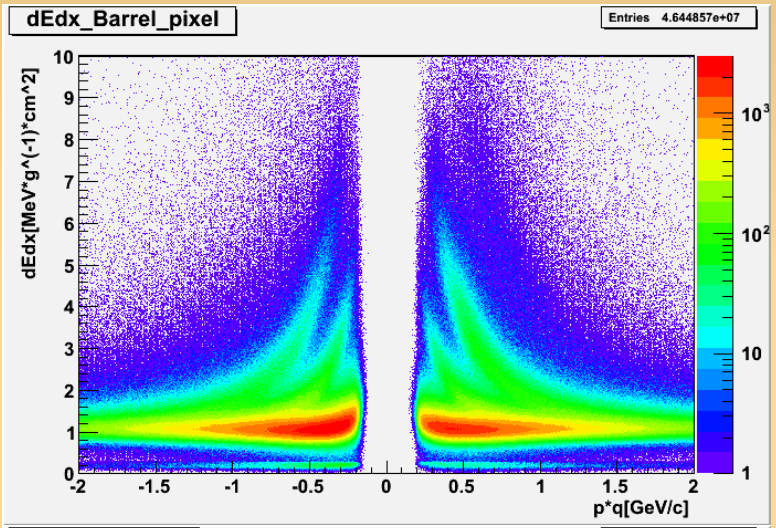


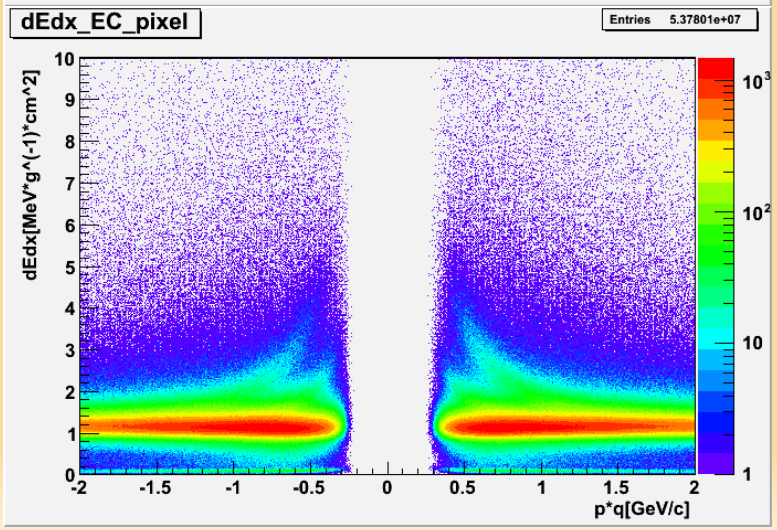
Pixel dEdx vs p*q

- The Pixel Detector provides their dEdx measurements, which we correlate with p*q.
- **Q is usually +1 or -1** (Protons, Deuterons, Pions, Kaons, Electrons)
- We associate the theoretical Bethe-Block curves with the Pixel dEdx (where they are bands, because of low resolution) and identify the particles.
- **Deuteron comes from nuclear interactions. Negative Deuteron comes from fragmentation, therefore is unstable and less represented.**
- We want to obtain some similar shape in SCT .



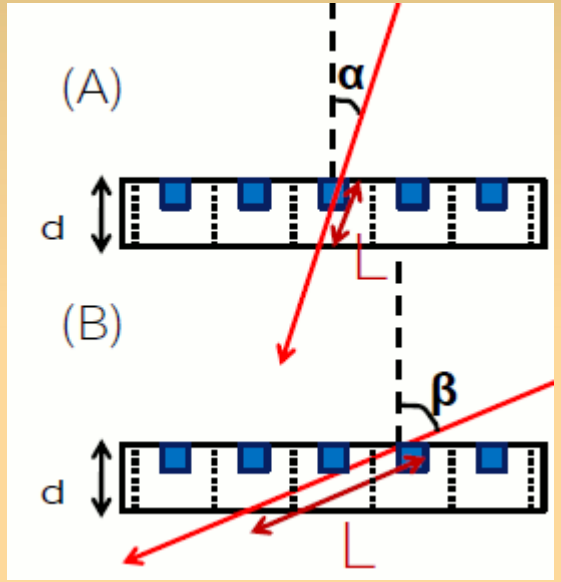






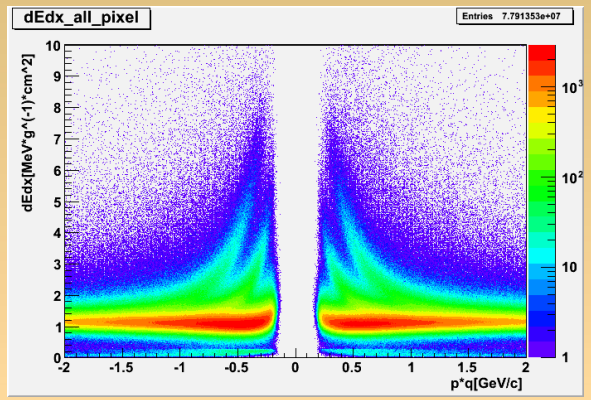
Path correction at TOT method

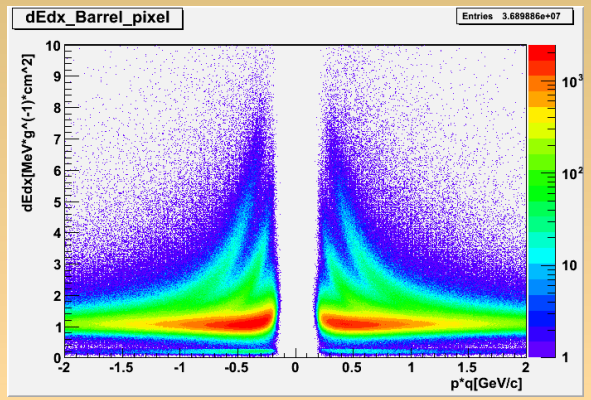
- If a track passes obliquely across one module, the path length L = d/cos(α).
- Corrected weight is weight`=weight*cos(α)
- Corrected **dEdx=Σweights*cos(α)**
- α = the compund angle for angle correction
- **cos(α)= cos (theta) * cos (phi) where theta and phi are in the module(local) coordinates**

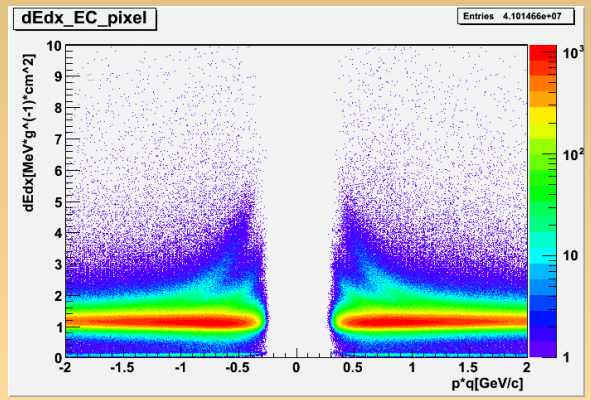


SCT dEdx vs p*q TOT method PV

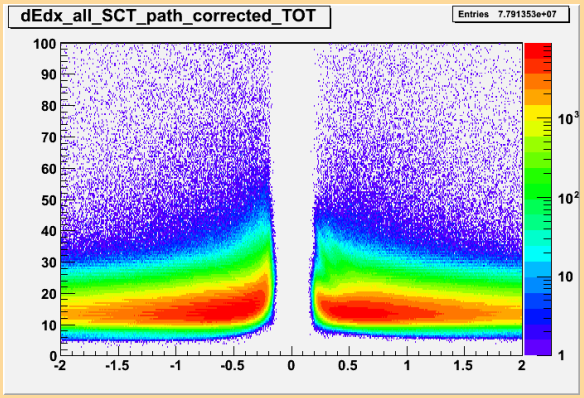
- PIXEL dEdx:

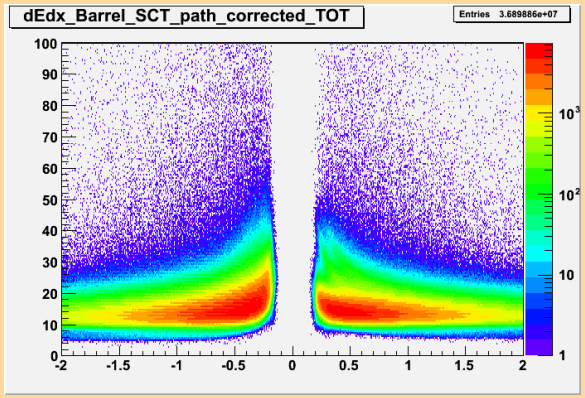


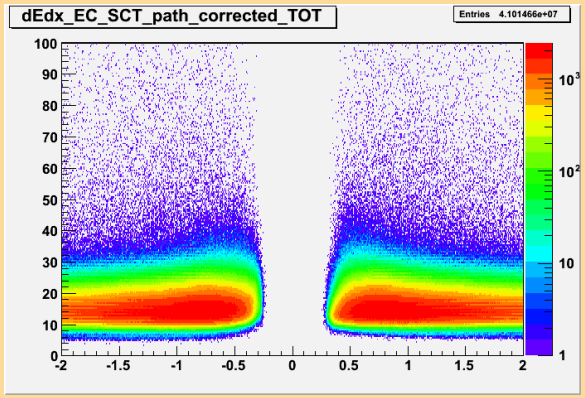




- SCT dEdx with path correction:



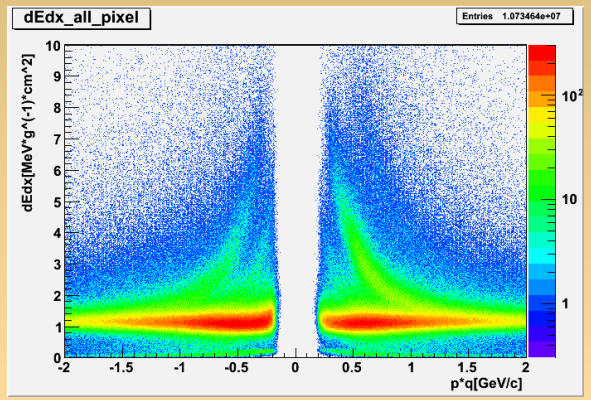


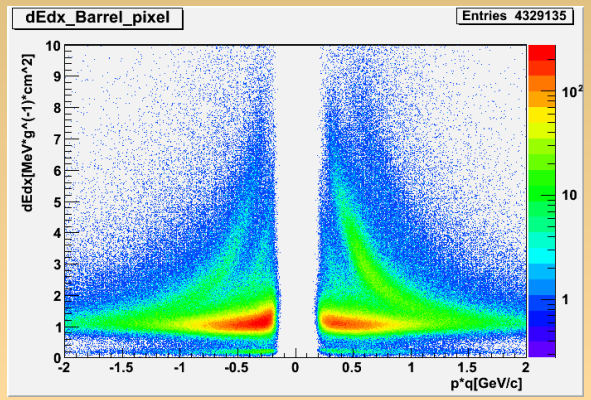


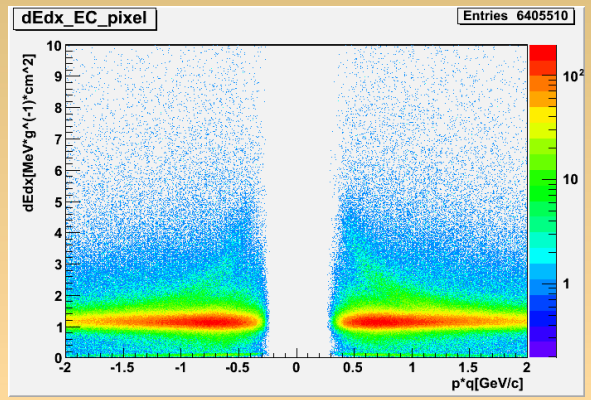
- The bands are not clear yet

SCT dEdx vs p*q TOT method BP

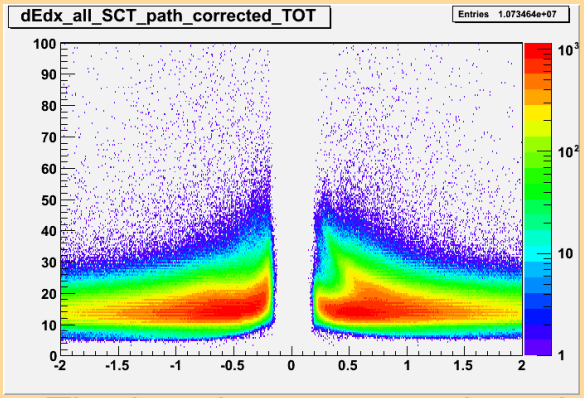
- PIXEL dEdx (we can see more pronounced Proton-Deuteron bands, because of the material interractions)

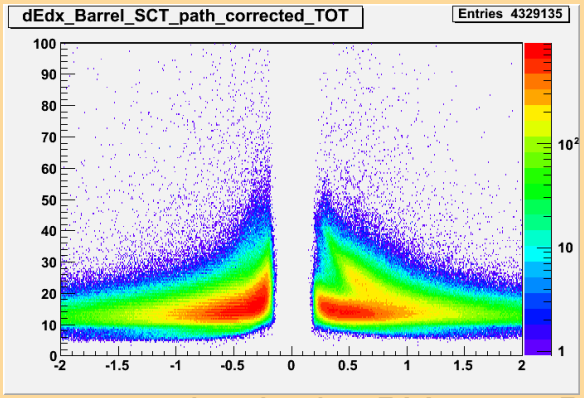


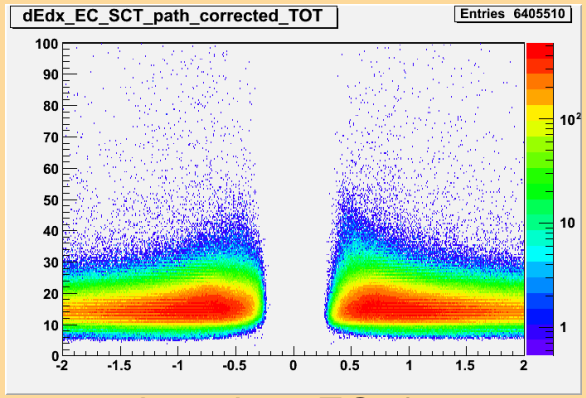




- SCT dEdx with path correction:

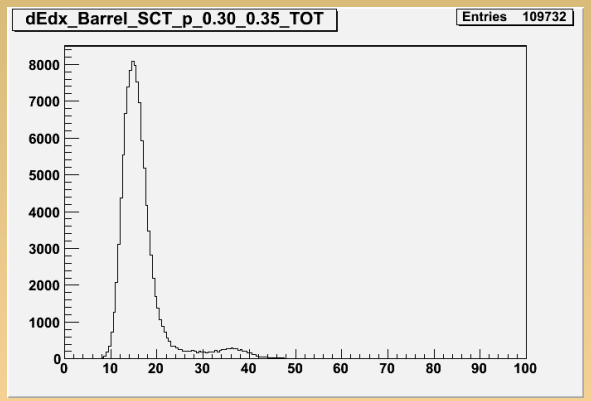


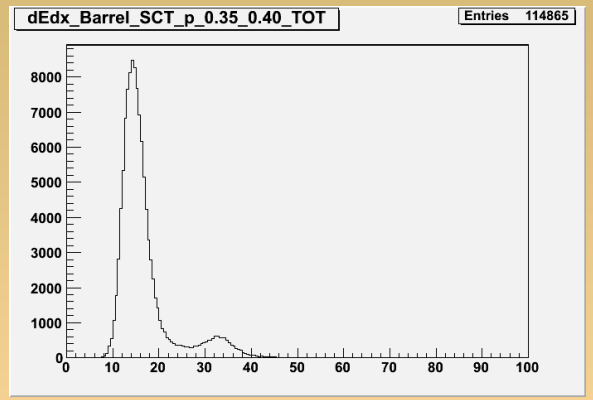


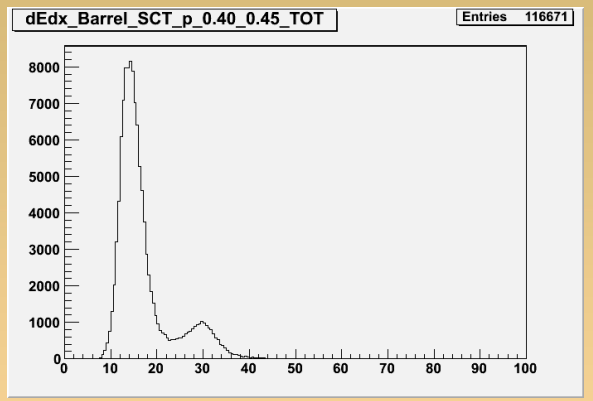


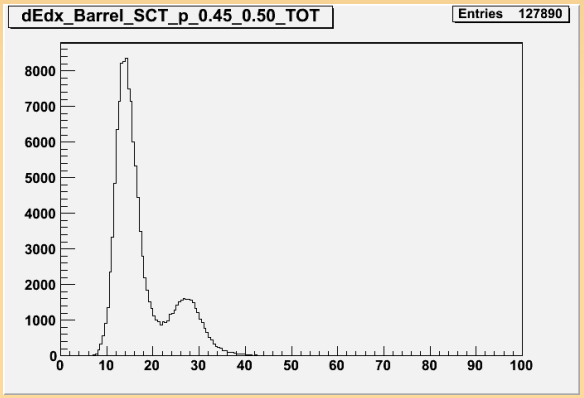
- The bands are more clear that the reconstruction in the PV case. Barrel is more clear than EC, for Q=+1 .

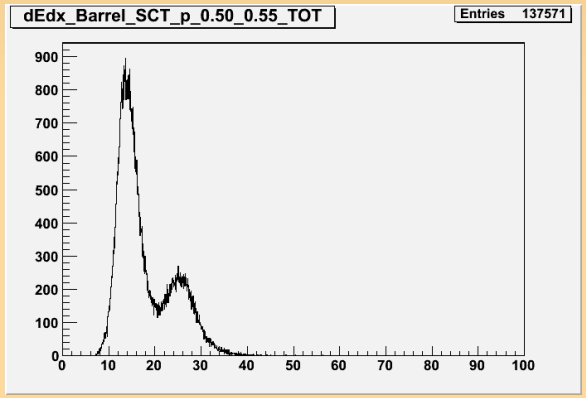
SCT dEdx TOT method BP Barrel





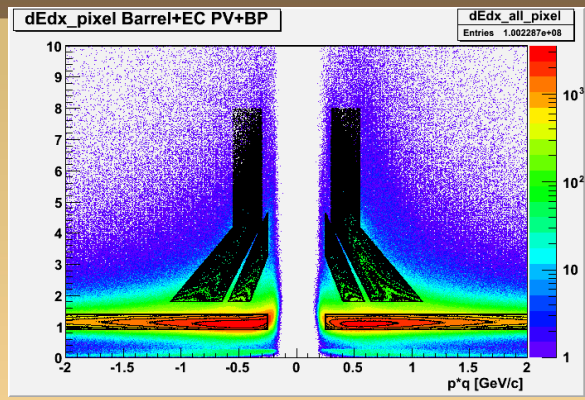






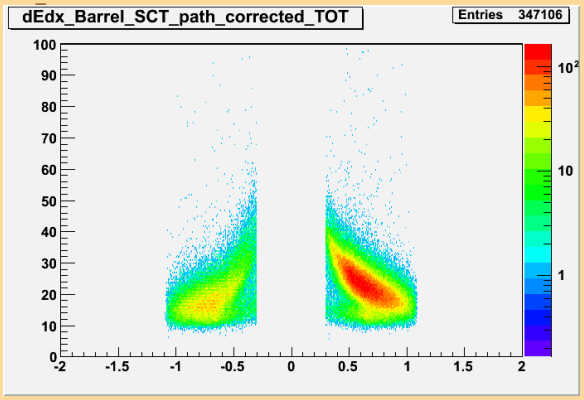
- Distributions of SCT reconstructed dEdx for Barrel, BP, Q=+1, for each momentum slice
- **WE SEE VERY CLEARLY 2ND BUMPS, INDICATING THE PROTON BAND! ENCOURAGING RESULT!**
- **We focus on BP analysis, in the Barrel**

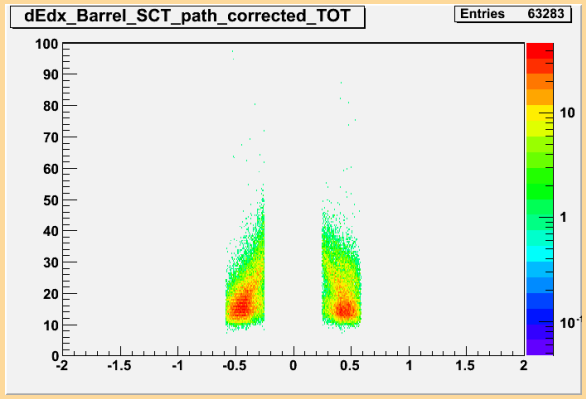
Bands separation, Barrel, BP

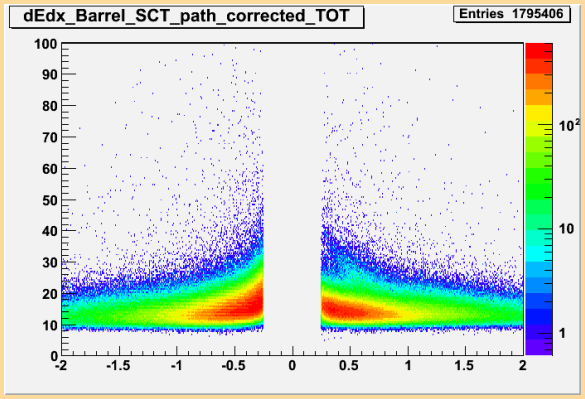


- We take the tracks from the bands of the pixel dEdx and reconstruct them for SCT, with the TOT-path corrected method.

- PROTON KAON PION

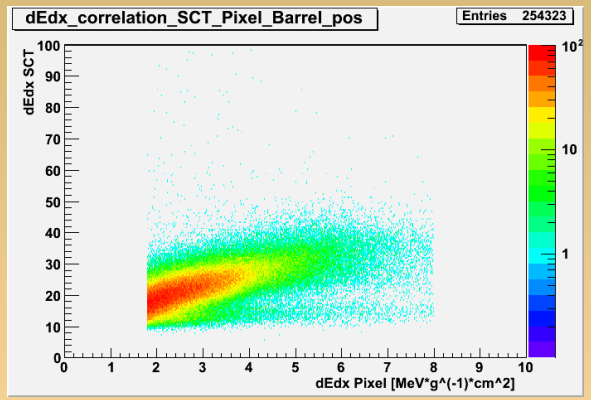


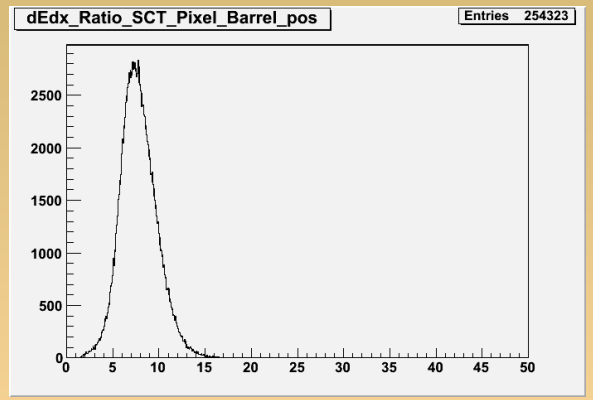


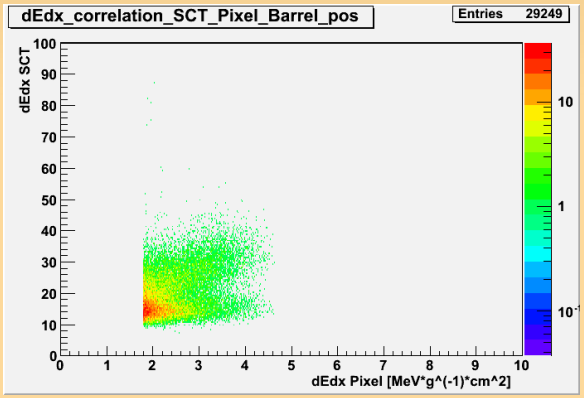


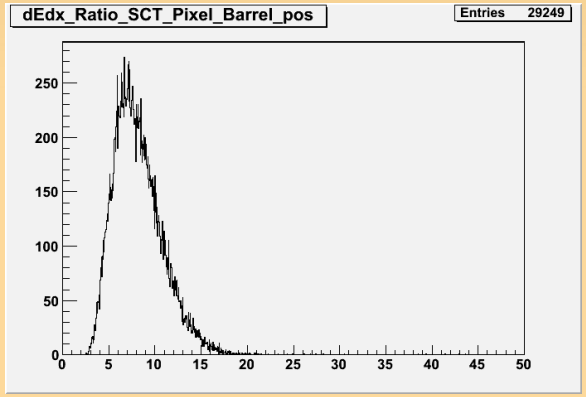
- We can see all 3 reconstructed bands clearly separated and rising !

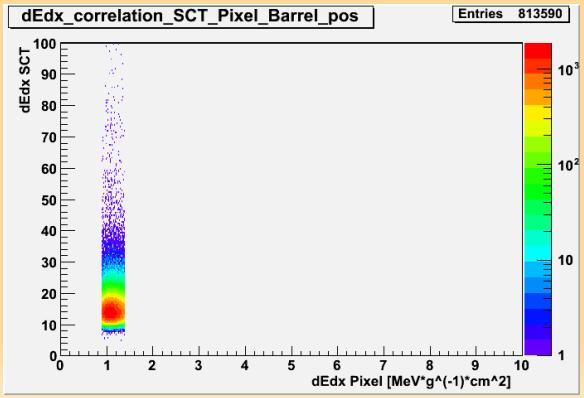
Correlation SCT-Pixel dEdx for bands, BP, Barrel

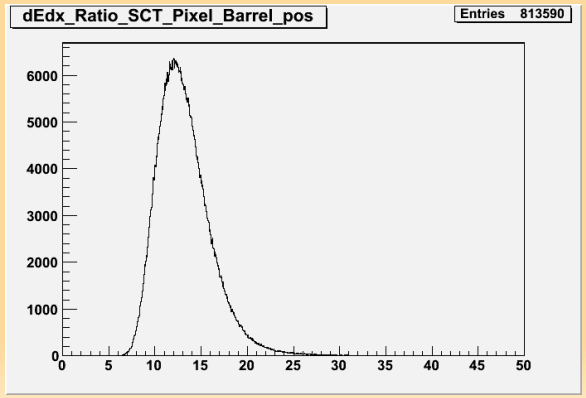










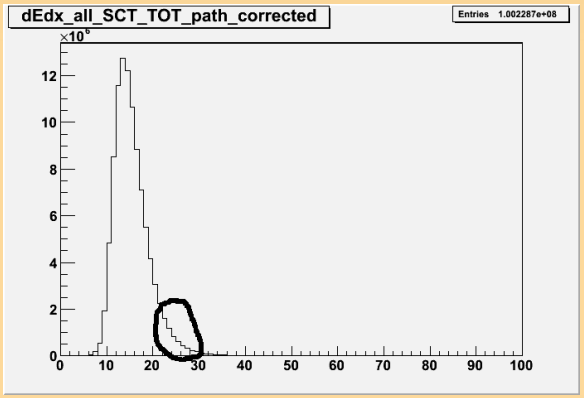


- PROTON correlation and Ratio SCT/Pixel. **CLEAR LINEAR CORRELATION !**
- KAON correlation and Ratio SCT/Pixel
- PION correlation and Ratio SCT/Pixel
- **We want to make the correlation more linear , and the Ratio width smaller.**

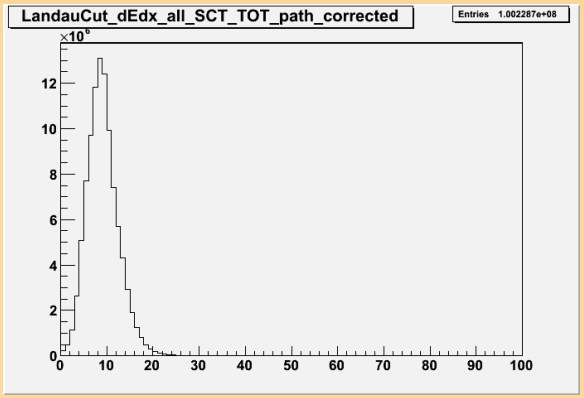
Landau cut

- The Pixel dEdx was actually provided after removing for each track 30% of the highest dEdx clusters, because they are on the dEdx Landau tail => we do the same for SCT reconstruction and **cut for each track 2 hits with the highest already calculate #TOT.**

- **SCT-TOT path corrected dEdx, for all regions, no PV/BP cut:**

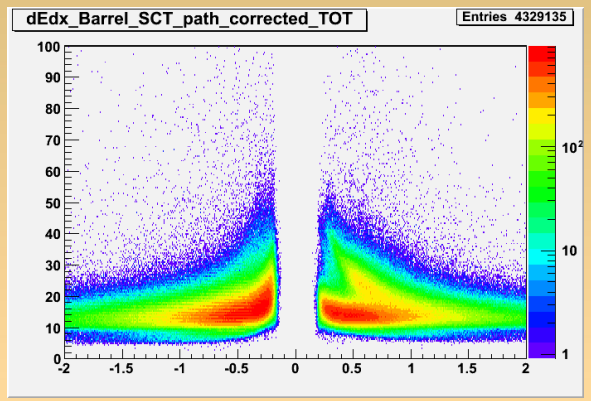


Landau tail Cut =>

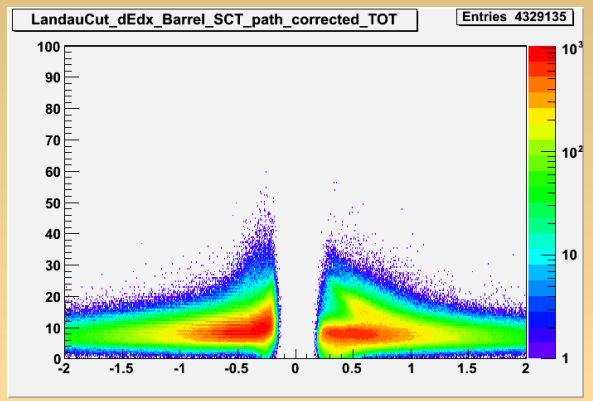


SCT dEdx vs p*q after Landau cut, BP, Barrel

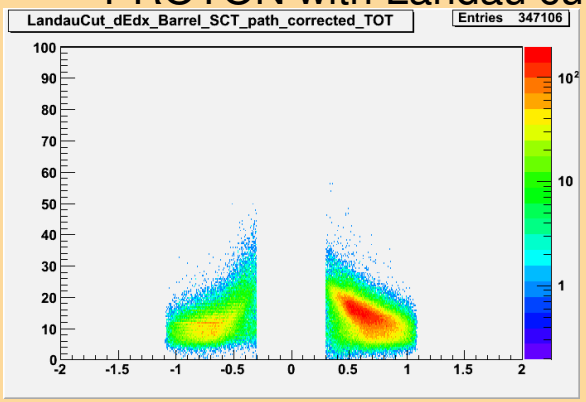
- SCT dEdx



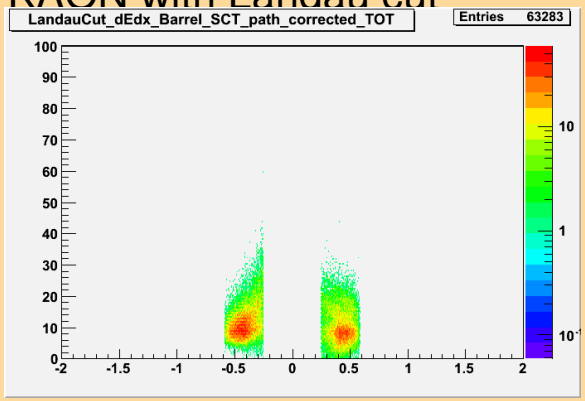
- Landau Cut=>
  (not much difference, so let's see for each band)



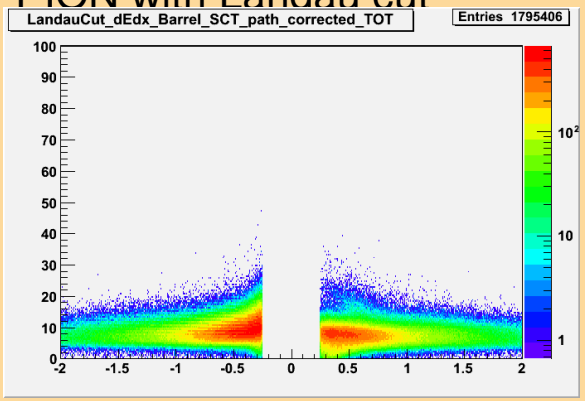
- PROTON with Landau cut



KAON with Landau cut

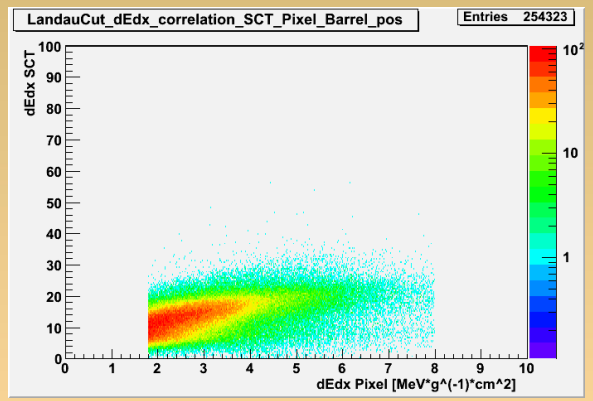


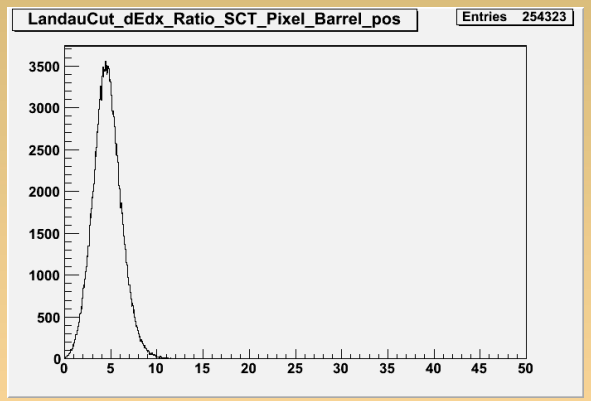
PION with Landau cut



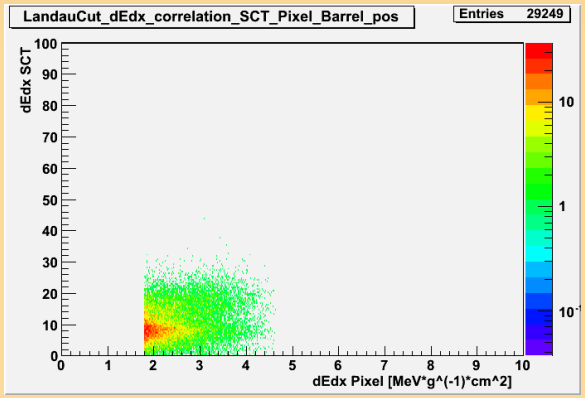
- We can analyse the bands better again with the correlations:

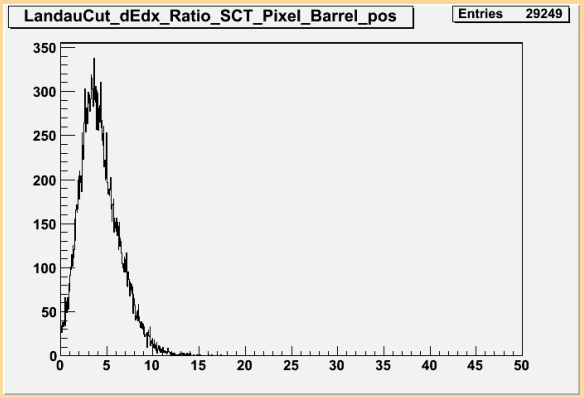
Correlation SCT-Pixel dEdx for bands, BP, Barrel, after Landau cut



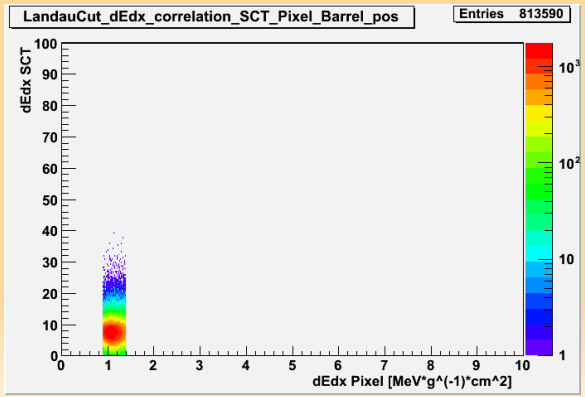


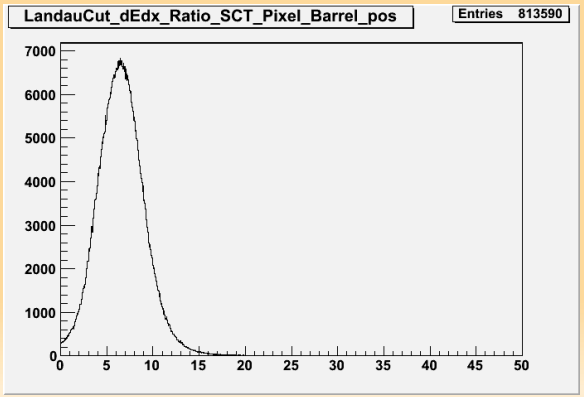
- PROTON correlation and Ratio SCT/Pixel. **THE WIDTH OF THE RATIO IS SMALLER THAN WITHOUT LANDAU CUT!**





- KAON correlation and Ratio SCT/Pixel





- PION correlation and Ratio SCT/Pixel

Conclusions and future studies

- The first results on dEdx reconstruction for SCT are very encouraging, **BUT**
  - **Measuring dE/dX in a strip detector is still speculative**
  - **Long term goal is to track changes in the collected charge and NOT to do particle ID**

- More investigations:
  - Monte Carlo
  - Cosmics
  - Angle and strip corrections (if the track goes through multiple strips, the charge gets distributed to each strip, becomes too small and below threshold for each stripand gets undetected)
  - Check other dEdx reconstruction methods, and see which has better particle discrimination power (#strips, #strips/#tot, #tot/#strips)
  - Pick up the tracks in resonance state($K \rightarrow \pi^+\pi^-$, $\Lambda \rightarrow p+\pi^-$)

Thank you for your attention :)

http://lhc-machine-outreach.web.cern.ch/lhc-machine-outreach/lhc-interesting-facts.htm

When the 27km long circular tunnel at CERN was excavated, between lake Geneva and the Jura mountain range, the two ends met up with just one centimetre of error.

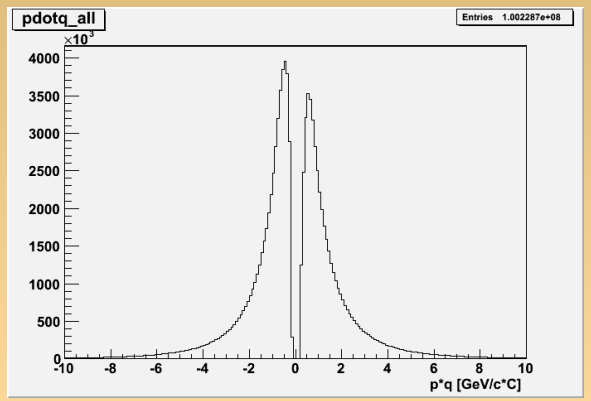
LEP was sensitive to the departure of the TGV from Geneva train station.

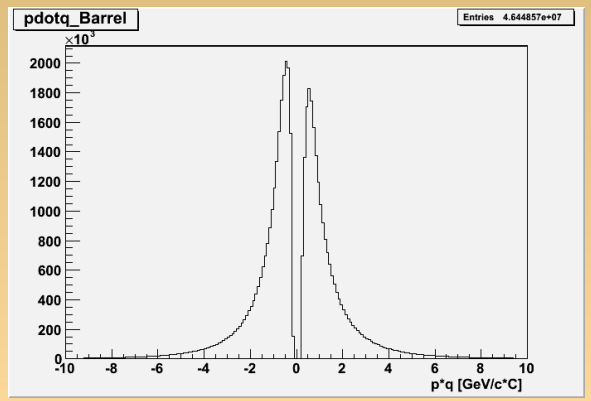
In the 1960's CERN's main data network was the famous bicycle on line. Tapes of data were loaded into a basket on the bike and then rushed over to the computer centre.

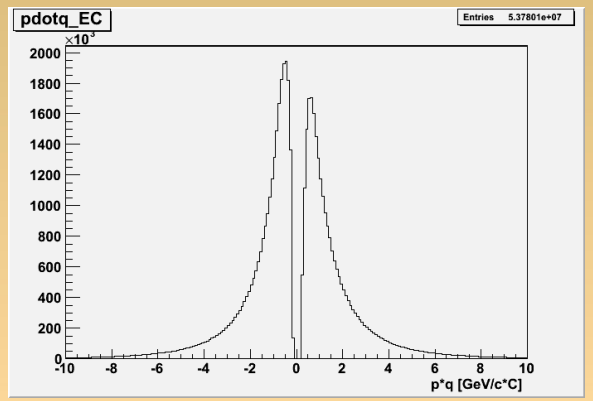
Particle accelerators are used to dry the paint on soft drinks cans.

Backup - A little about P*Q distribution

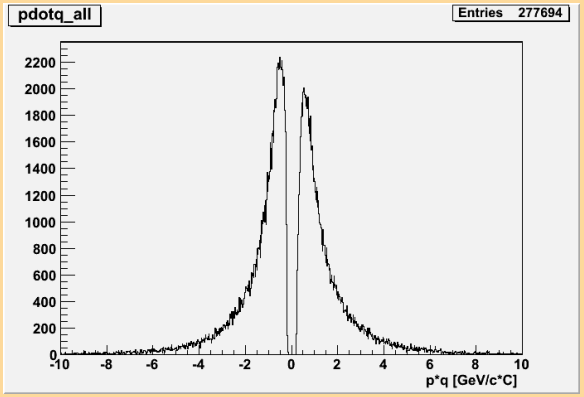
- P*Q distribution from Data:

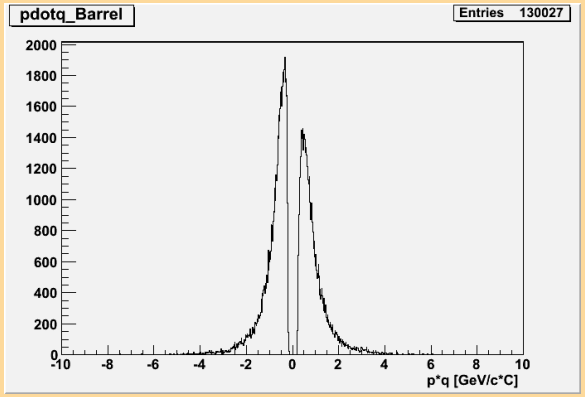


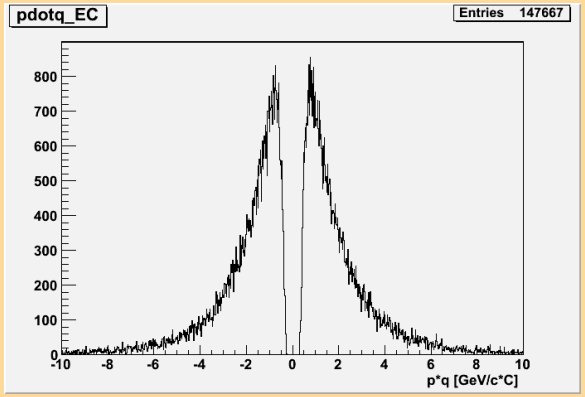




- P*Q distribution from Monte Carlo:







- **In both cases we see assymetry in the Barrel region. We don't know why yet.**
- Could do further: Monte Carlo analysis for each type of particle.