Identified charged hadron spectra from minimum bias p-p

Heavy Ions contribution to the QCD/HI pp-2007 paper exercise

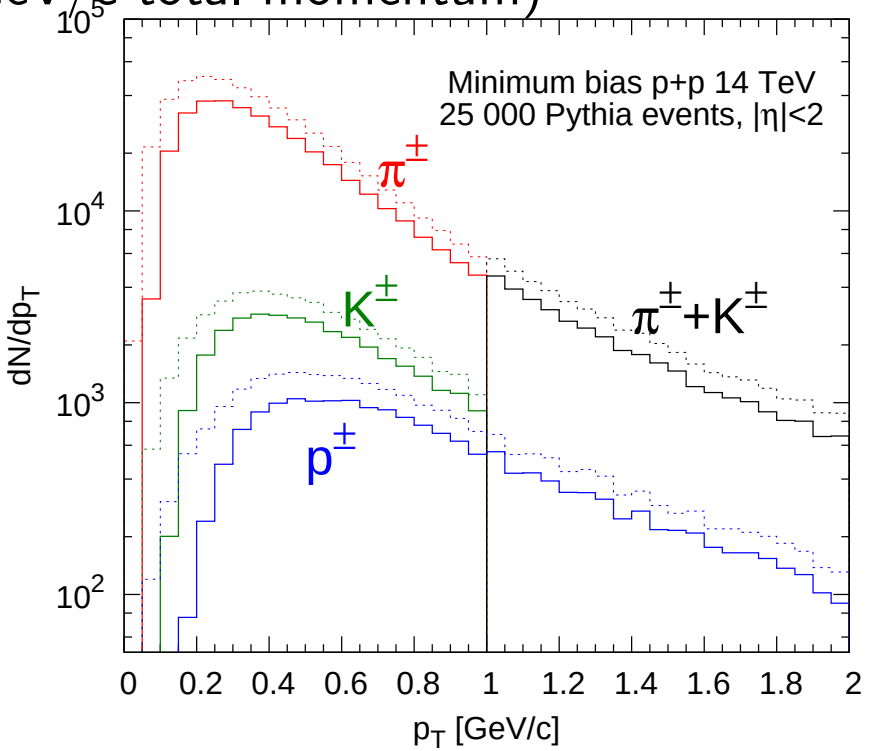
Ferenc Siklér
sikler@rmki.kfki.hu

KFKI Research Institute for Particle and Nuclear Physics
Budapest, Hungary

CMS HI Physics/Trigger week, April 27, 2007

Inclusive hadron spectra

- Goal: measure (η, p_T) spectra of
  - inclusive $h^{\pm}$
  - identified π, K and p (below 2 GeV/c total momentum)
- Tasks
  - Event generators
  - Detector simulation
  - ◦ Triggering
  - ◦ Charged particle tracking
  - Charged particle multiplicity
  - ◦ Vertexing
  - ◦ Energy loss analysis
  - ◦ Physical corrections



Available on twiki at http://twiki.cern.ch/twiki/bin/view/CMS/SoftPhysics
Workbook at http://twiki.cern.ch/twiki/bin/view/CMS/SoftPhysicsWorkBook

Development of algorithms and software is strongly physics driven

Hadron spectra – benefits, groups

- Benefits to CMS physics

  - Test and improvement of minimum bias event generators
  - Improvement on jet energy measurements by using reco'd low p_T particles
  - Contribution to particle flow studies by using reco'd low p_T particles
  - Significant improvement on vertex finding in minimum bias (pile-up) events
  - Particle identification in B decays and in other exclusive channels

- Groups

  - Budapest (**Ferenc Siklér, Krisztián Krajczár**, Gábor Veres, Gergely Patay)
  - CERN (**David d'Enterria**)
  - MBUE [QCD subgroup] (Paolo Bartalini, Livio Fano, et al)

Hadron spectra – working plan

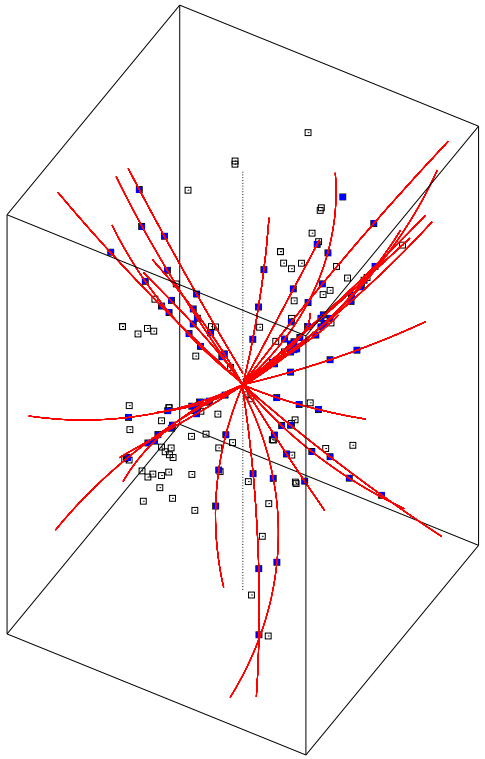
May	Look at pixel triplets and seed strips
	Gain p_T resolution and dE/dx (gives p+p and Pb+Pb tracking)
June	Finish dE/dx
	Public QCD/HI coordination meeting
July	Vertexing, physical corrections
August	Unfolding of dE/dx distributions
September	Public QCD/HI coordination meeting
October	Finish analysis
	Write the note

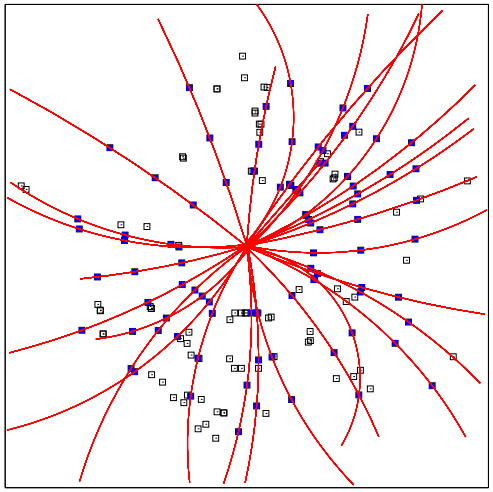
Work on topics in parallel

Things to follow: event generators, trigger

To be synchronized with QCD part

Introduction



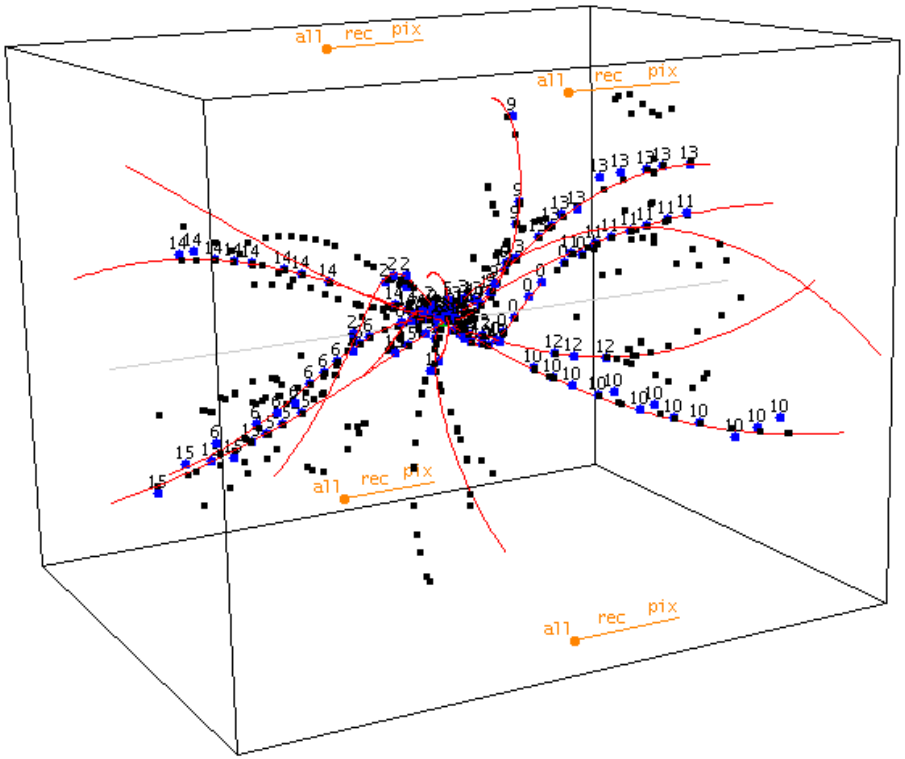


Minimum bias p+p @ 14 TeV

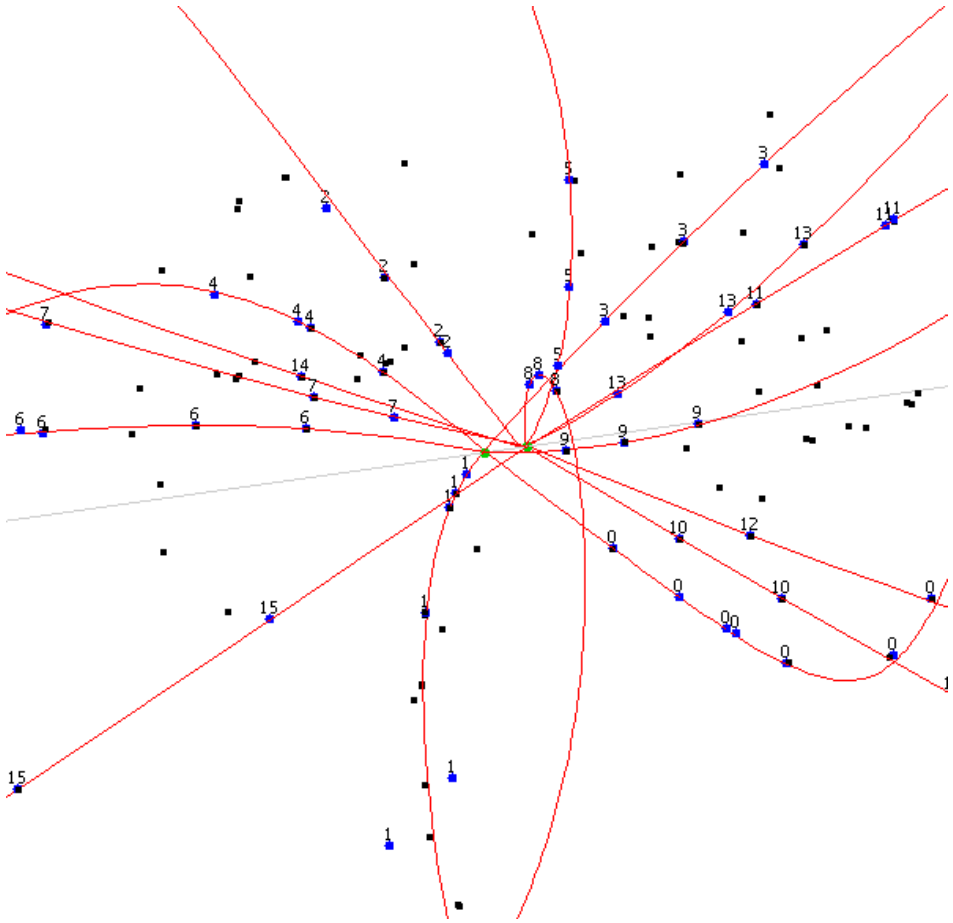
- CMS is better than previously thought
  - Particle tracking down to very low p_T with modified pixel triplet generation
  - Low fake track rate thanks to geometrical shape of the hit cluster
  - Particle identification using energy loss in silicon (low p), analog readout

Reconstruction of low p_T charged particles with the pixel detector CMS Note AN-2006/100
Reconstruction of V0s and photon conversions with the pixel detector, CMS Note AN-2006/101

Event display



Pixel+strip tracking



Close-up (2 piled-up events)

Gallery at https://twiki.cern.ch/twiki/bin/view/CMS/SoftPhysicsEventGalleryFull

Software used: CMSSW_1_4_0_pre1 with some additions (see SoftPhysicsWorkBook)
Sample: 25 000 min bias p-p events at 14 TeV from Pythia

Event generation

- Needs
  - 100k minimum bias events for analysis development
  - 1M minimum bias events for full analysis, depending on aimed p_T reach

- Informations from the MBUE group
  - Data cards
    CSA06 min bias, Spring07 production
  - Monte Carlo tuning
    Pythia 6.227 (with Tune DWT, that is, CTEQ5L PDFs) has
    σ_{ND}=55.22 mb, σ_{SD}=7.15+7.15 mb, σ_{DD}=9.78 mb

Triggering

- Minimum bias trigger

  Requiring a minimal number of HF towers ($>$10,15,20) on both sides
  Biased

- Specific hard triggers (high p_T, high energy)

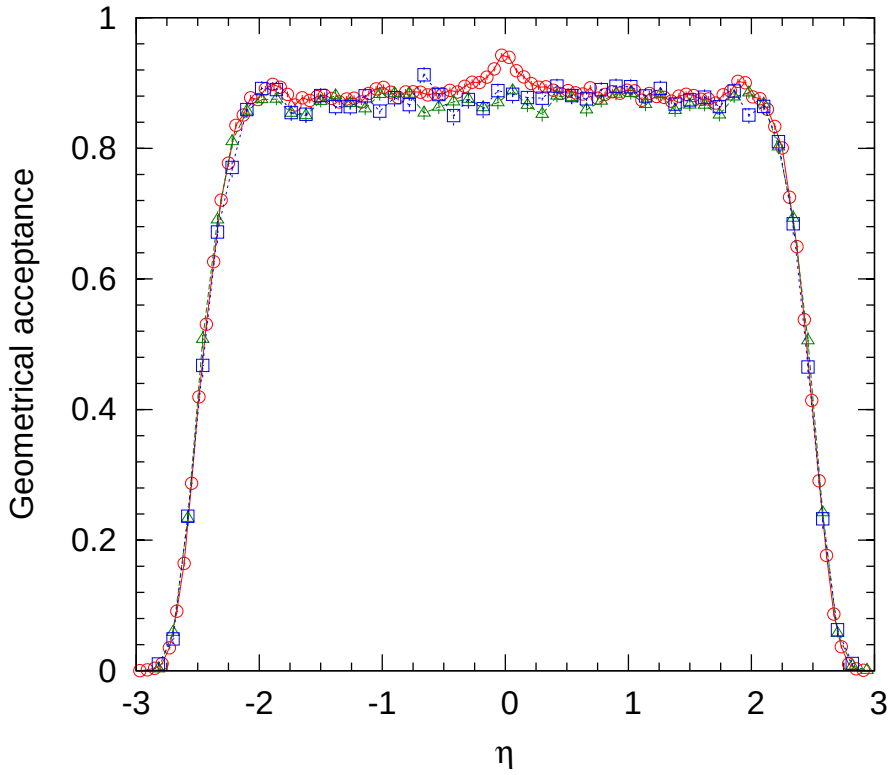
  Take events from pile-up
  Question: are those events really unbiased?
  Interplay with hard trigger?

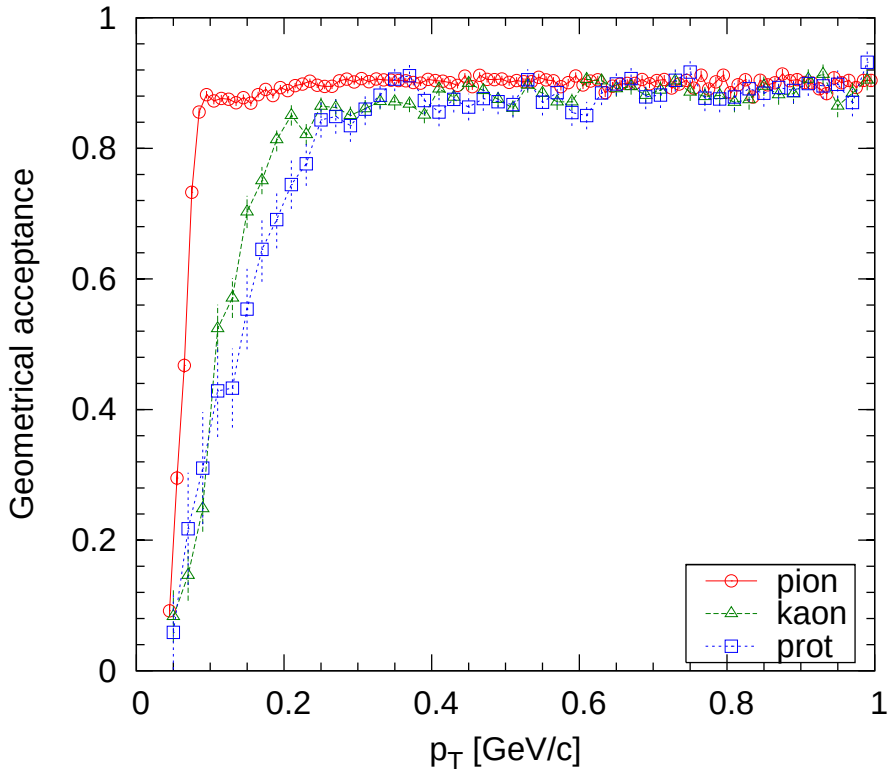
- Beam trigger

  Number of interactions per bunch crossing is $\mathcal{O}(1)$
  Unbiased, benefits for vertexing
  Have to be careful with beam-gas background

Several ideas
All of them should be considered

Charged particle tracking – acceptance



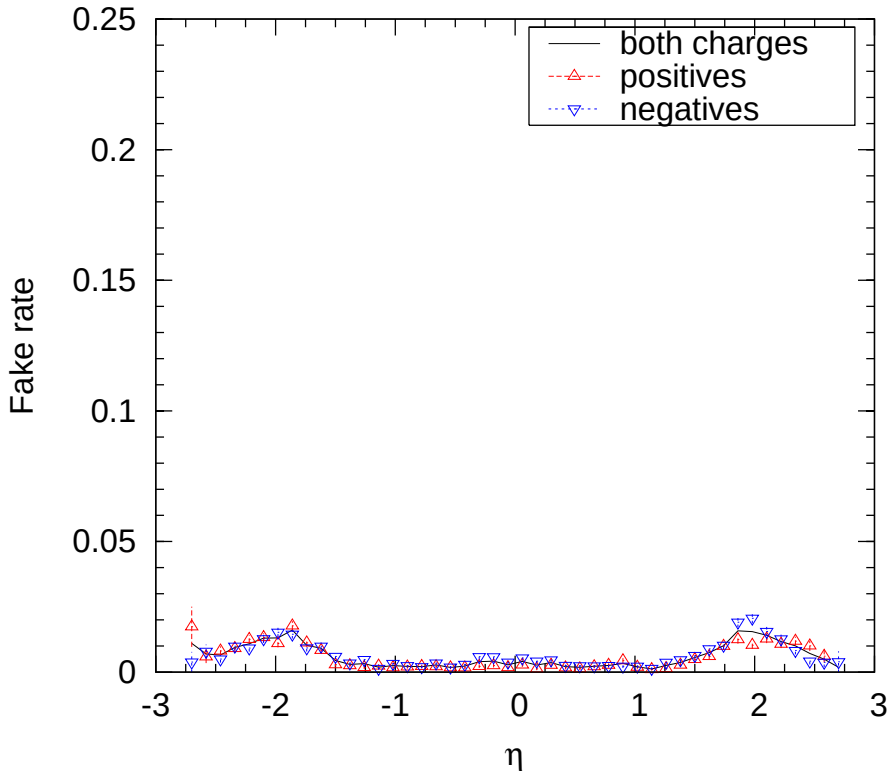


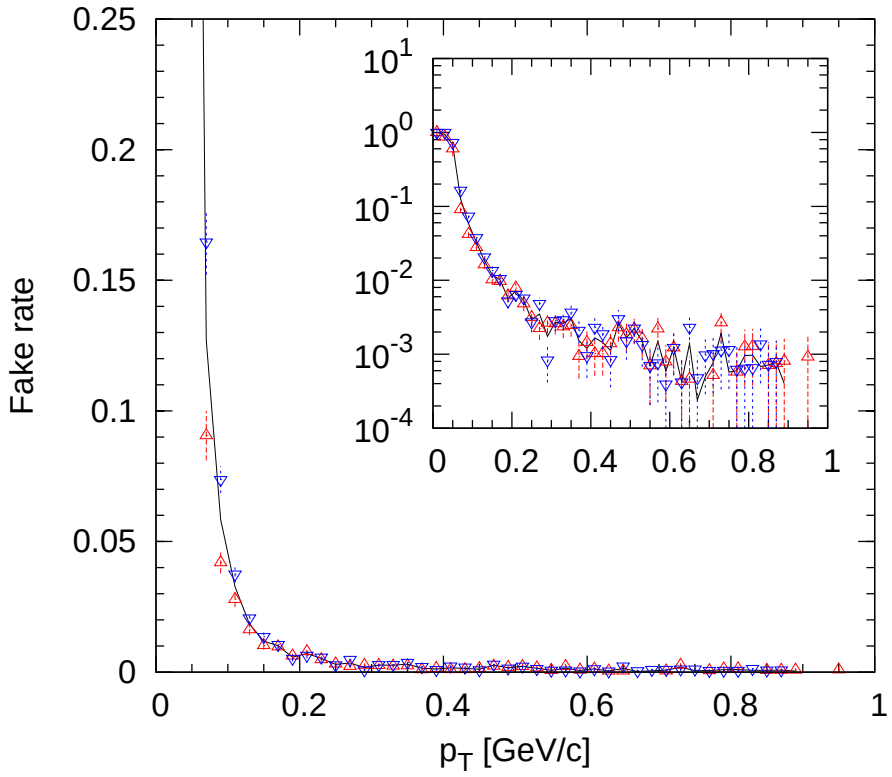
Flat acceptance for $|\eta| < 2$, difference as function of particle mass

Set of validation plots obtained

Results are very similar to those from ORCA

Charged particle tracking – fake track rate



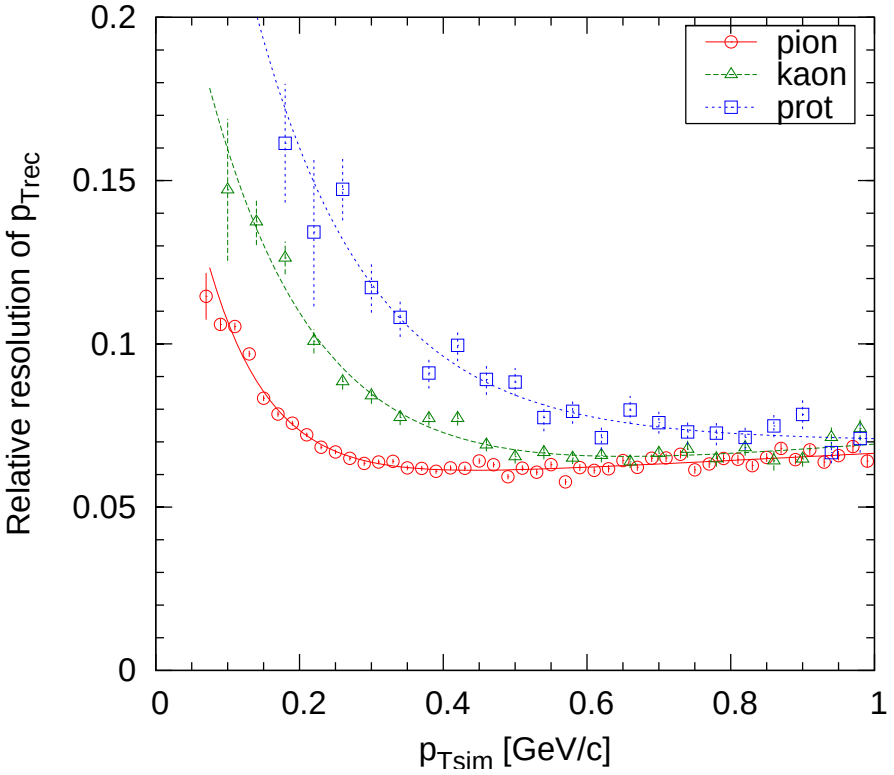


- Fake tracks
  - They are not real, only the reconstruction algorithm creates them
  - Central problem for high luminosity and multiplicity
  - Here solved with help of cluster shape filter

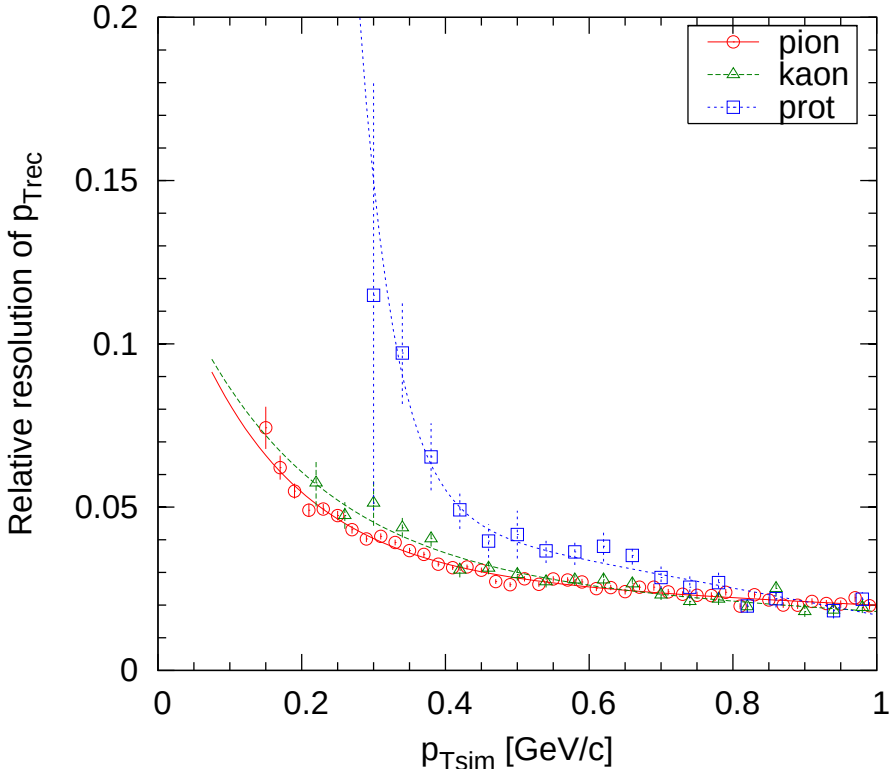
Small correction at the percent level, strongly p_T dependent

Charged particle tracking – p_T resolution

Pixel triplets



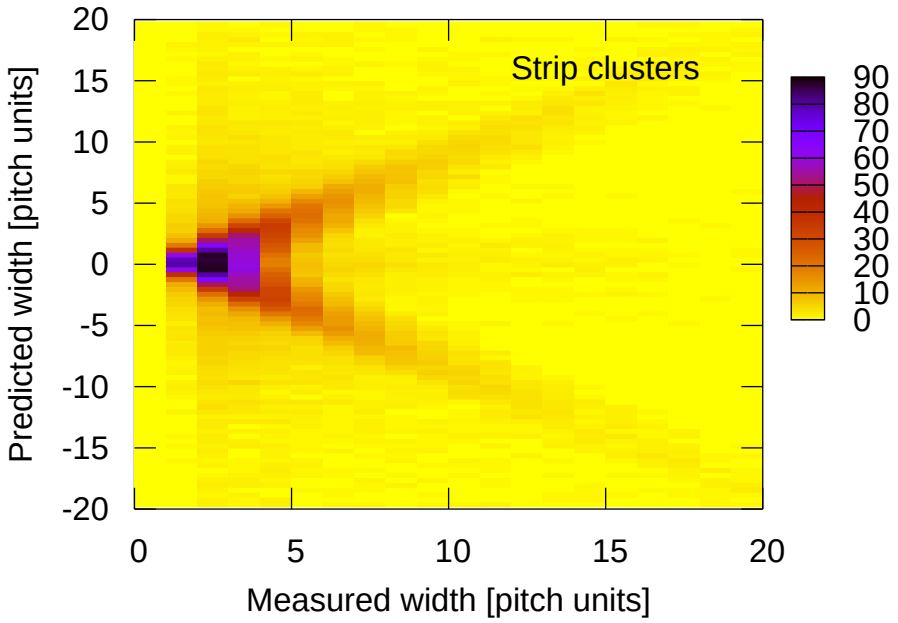
Pixels+strips



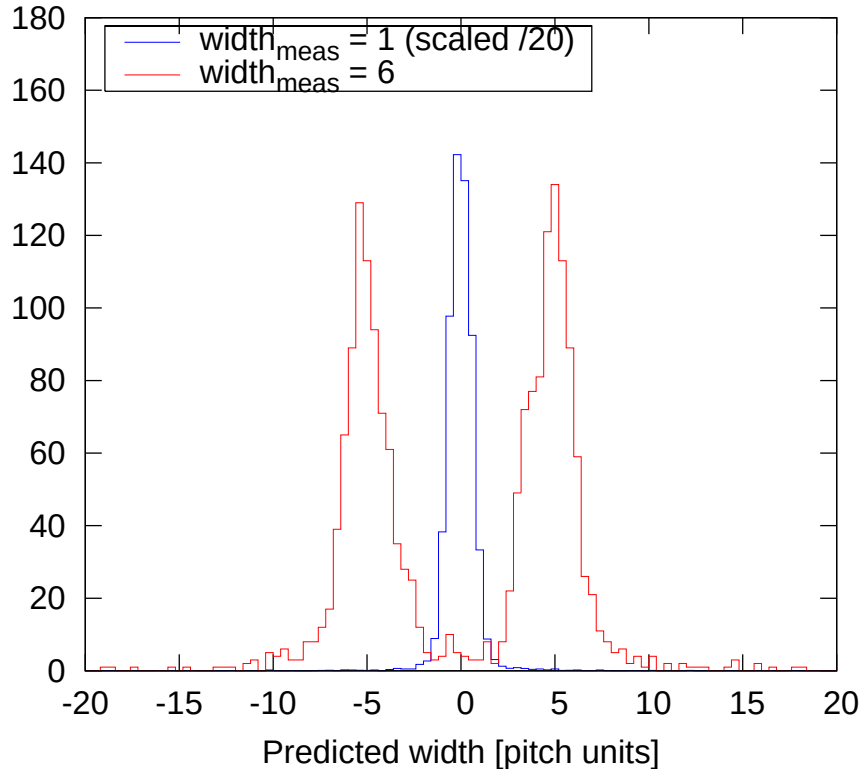
Pixel triplets only give 6% resolution asymptotically

Pixels+strips tracking brings resolution down to 2%

Cluster shape filter – width of the strip cluster



Cluster width is correlated to the angle of incidence

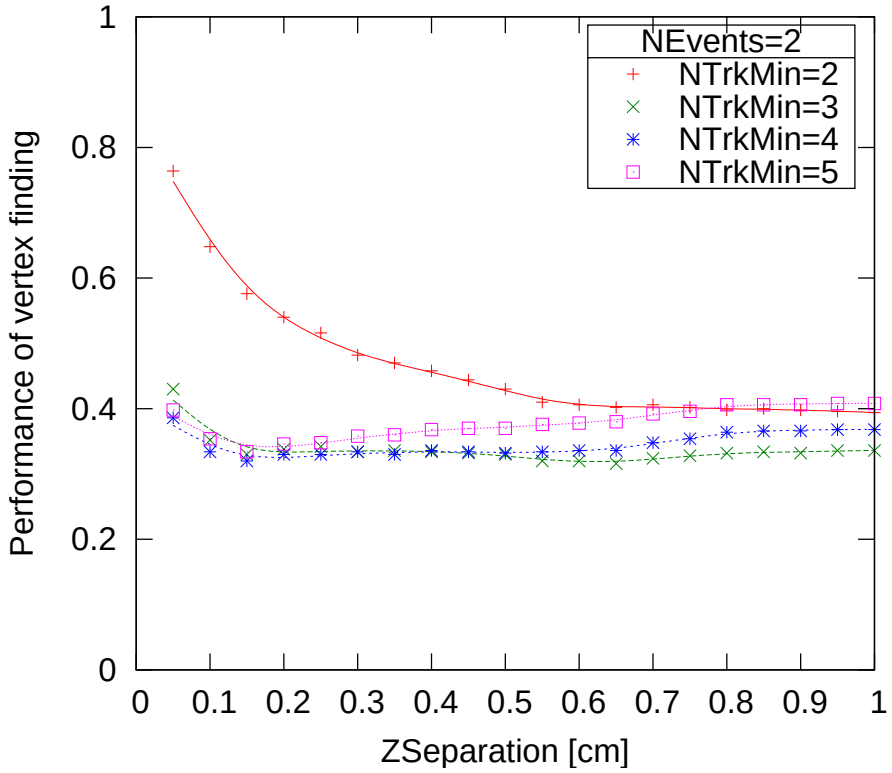


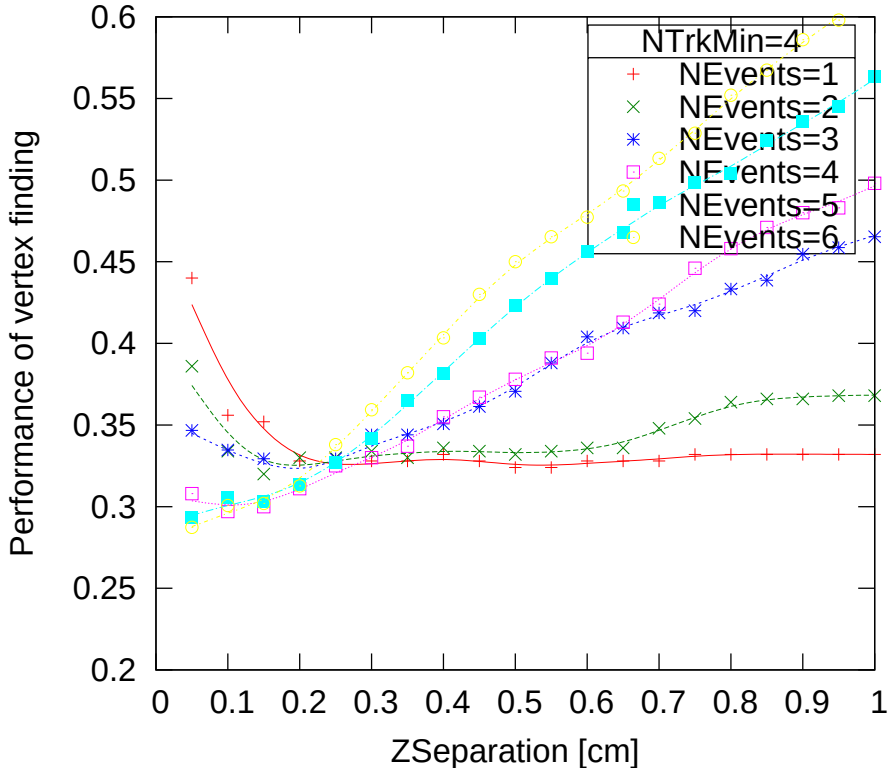
Discriminating power between width=1 and 6

Usage similar to the pixel case

Another tool for trajectory cleaning

Vertexing – optimization (1)



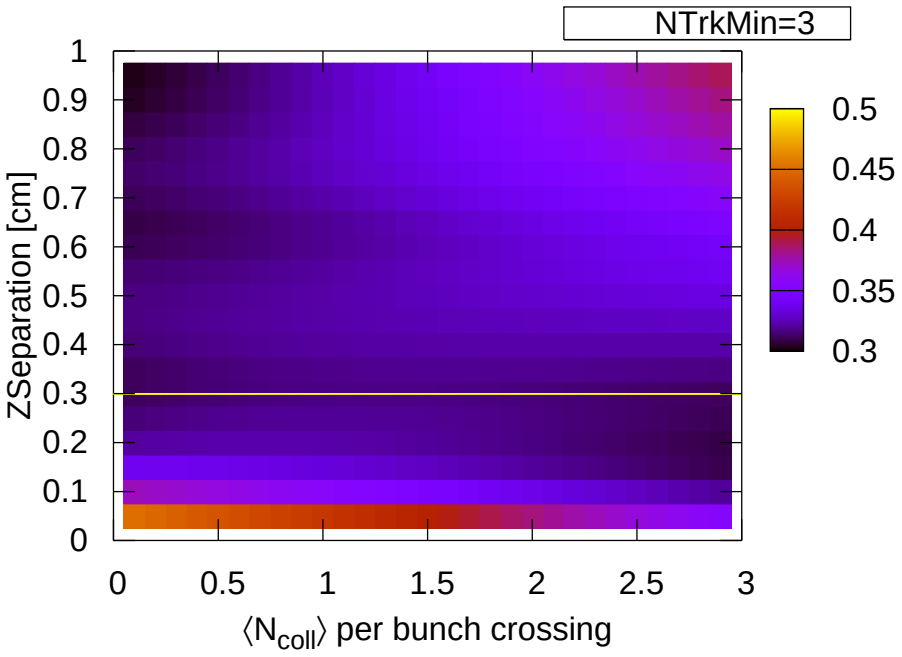


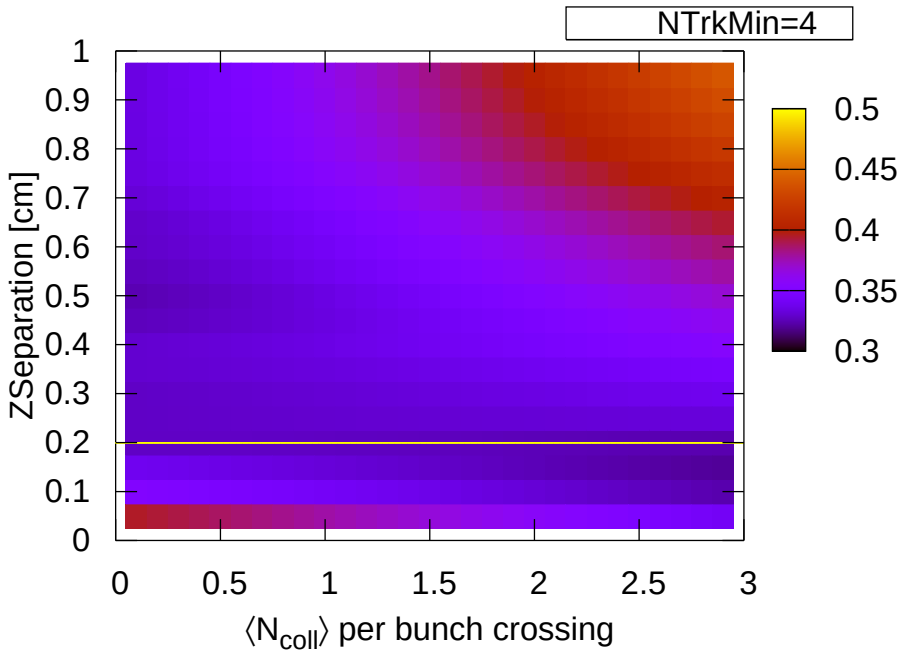
- Parameters
  - NTrkMin : minimal number of tracks for forming a vertex
  - ZSeparation: minimal separation of vertices in z direction
  - PtMin : minimal track p_T, now lowered to 0 GeV/c

Several expressions for measuring performance considered

The relative deviation is measured by $\chi = |n_{recvtx}/n_{simvtx} - 1|$

Vertexing – optimization (2)



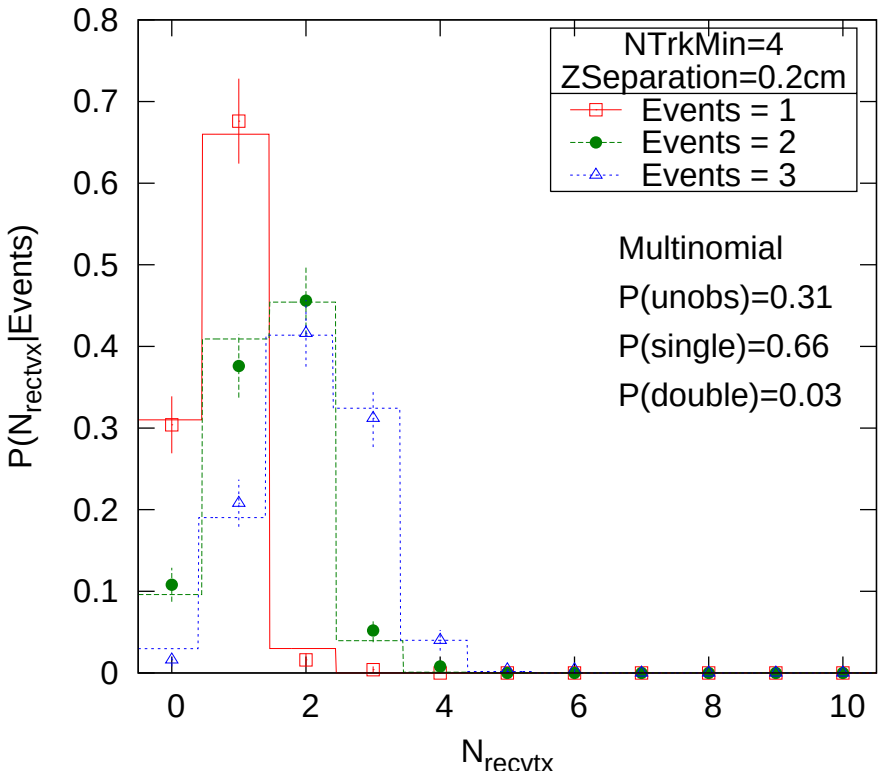


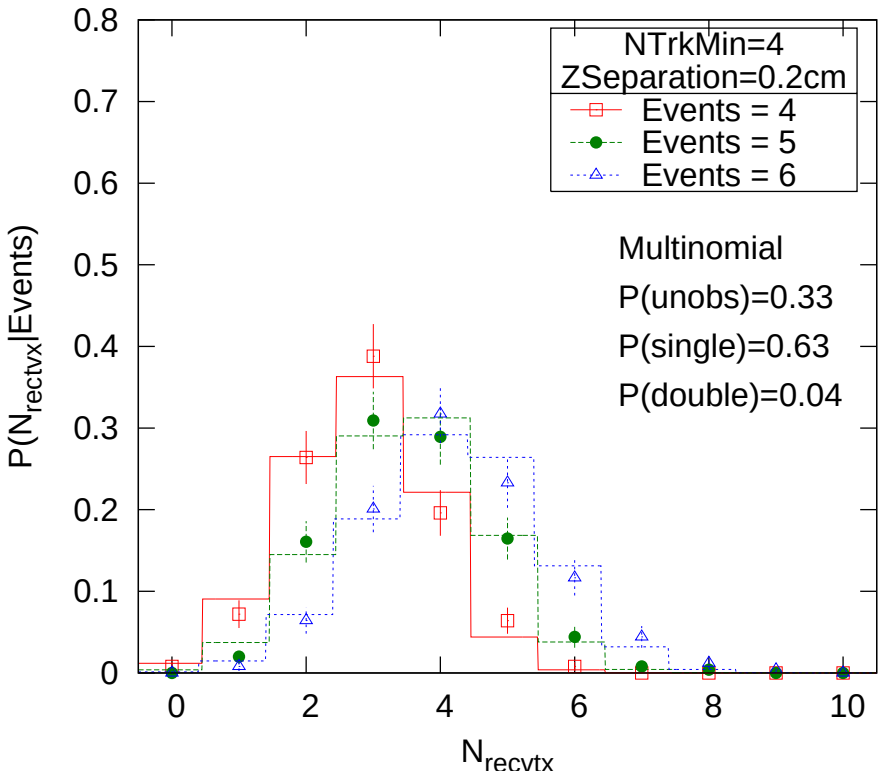
Results are weighted according to Poissonian with average $\langle N_{coll} \rangle$
Look for minima as function of $\langle N_{coll} \rangle$

For low intensity the best parameters (lowest χ) are

(NTrkMin=3, ZSeparation=0.3 cm) or (NTrkMin=4, ZSeparation=0.2 cm)

Vertexing – measurement of σ_{pp} non-single-diffractive



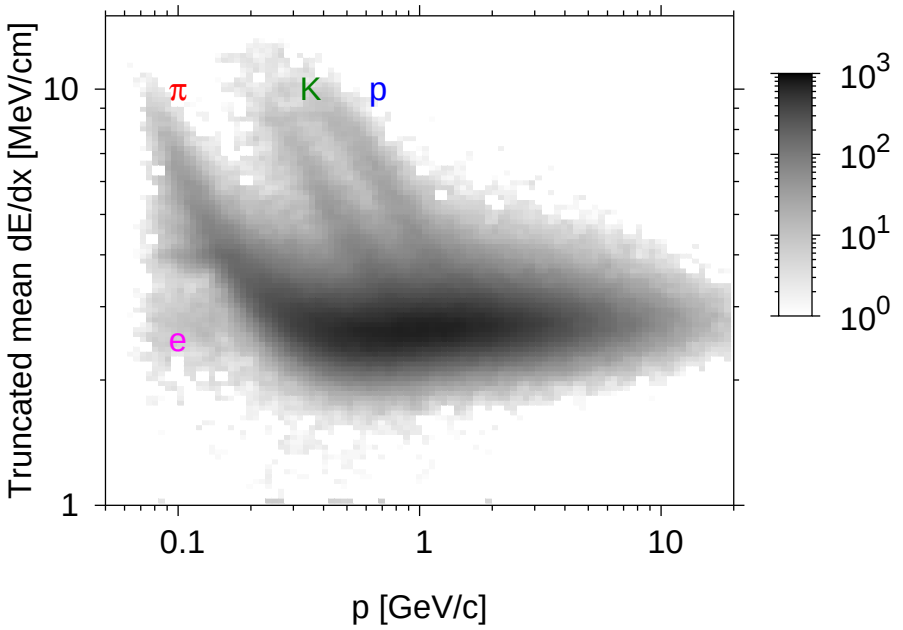


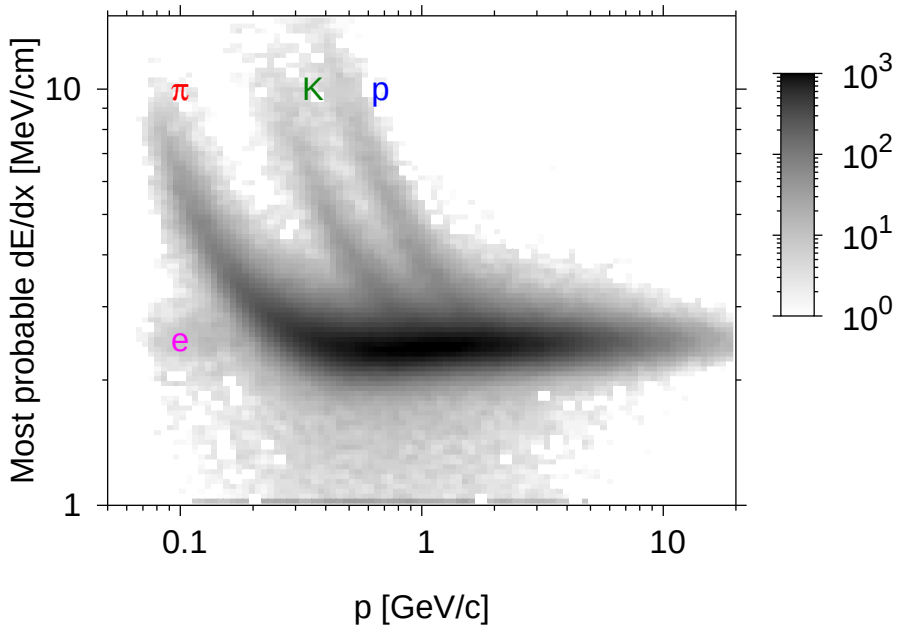
- We can count interaction vertices when on beam trigger
  - They are either unobserved, singly or doubly observed
  - This can be considered as independent process, multinomial
  - Almost 70% of the inelastic p-p vertices are detected

The non-single-diffractive p-p cross section can be measured: $\Delta N/\Delta t = \sigma_{pp} \cdot L$

I. Dawson, K. Prokofiev, arXiv:hep-ex/0702041

Energy loss analysis – particle identification

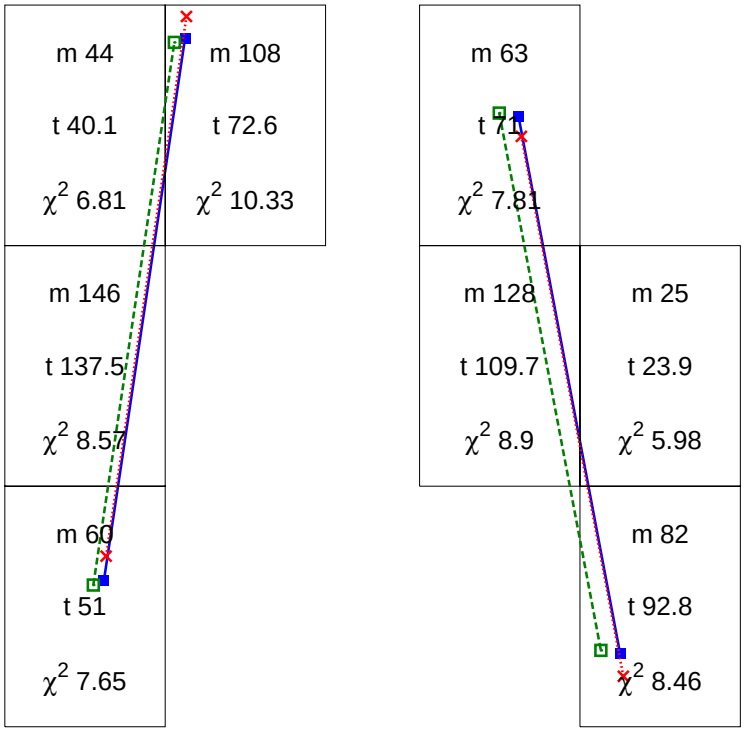


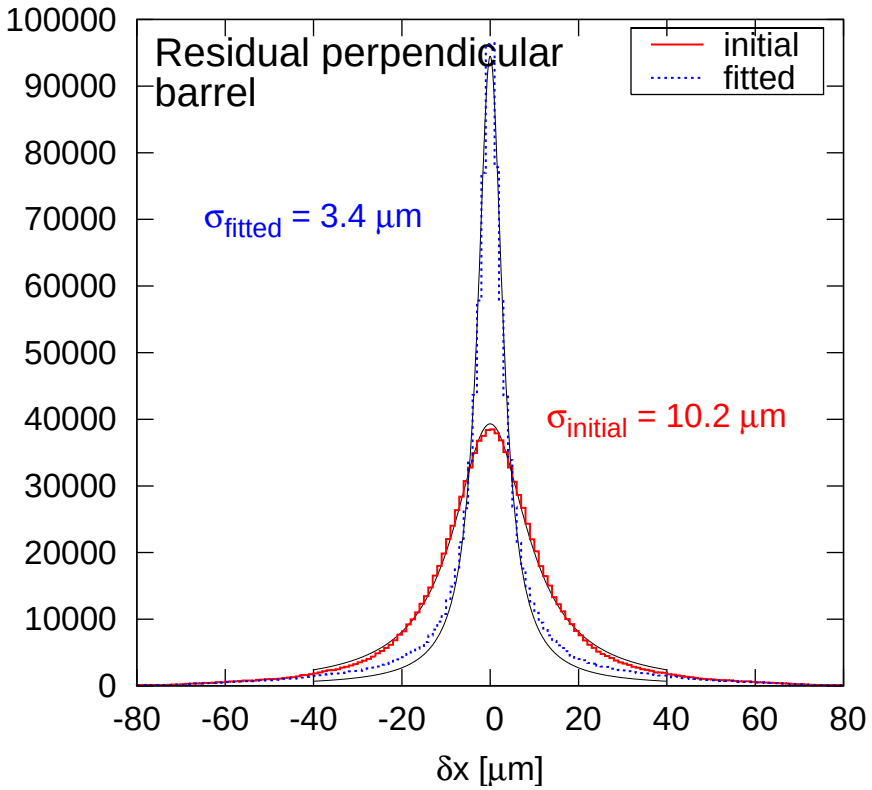


- Estimators, model
  - Use maximum likelihood estimator (right plot)
  - Resolution around 10% with pixels only (note the logscale)
  - Energy loss in silicon by Geant4 to be replaced by a more accurate one
  - Model of Hans Bichsel, known to be good within a percent

Separation at lower, unfolding of distributions at higher momentum

Energy loss analysis – improved residuals



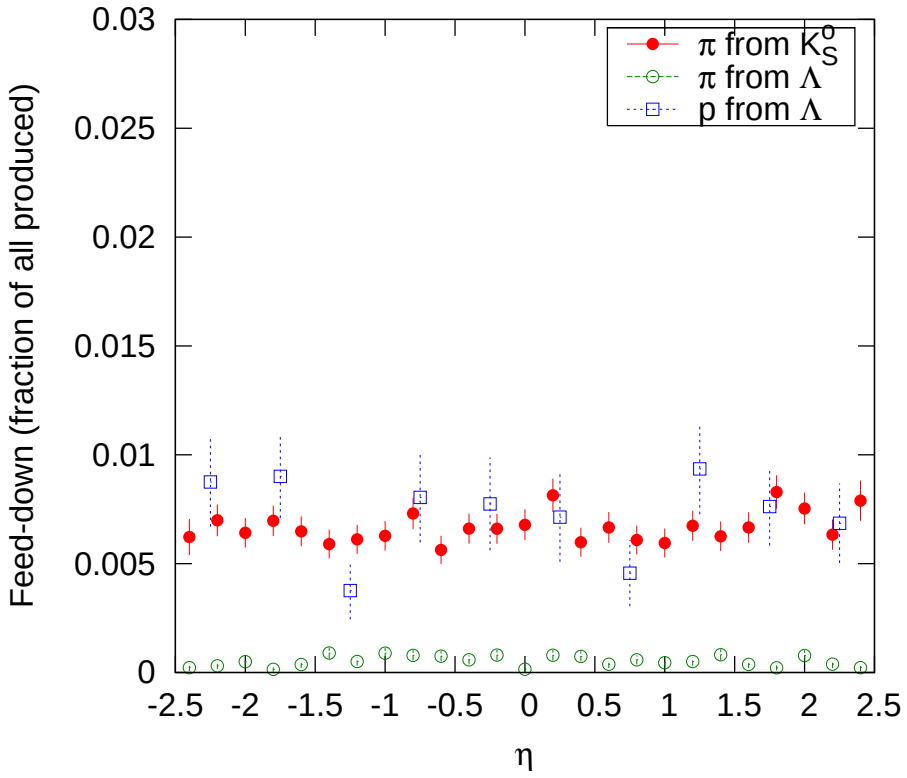


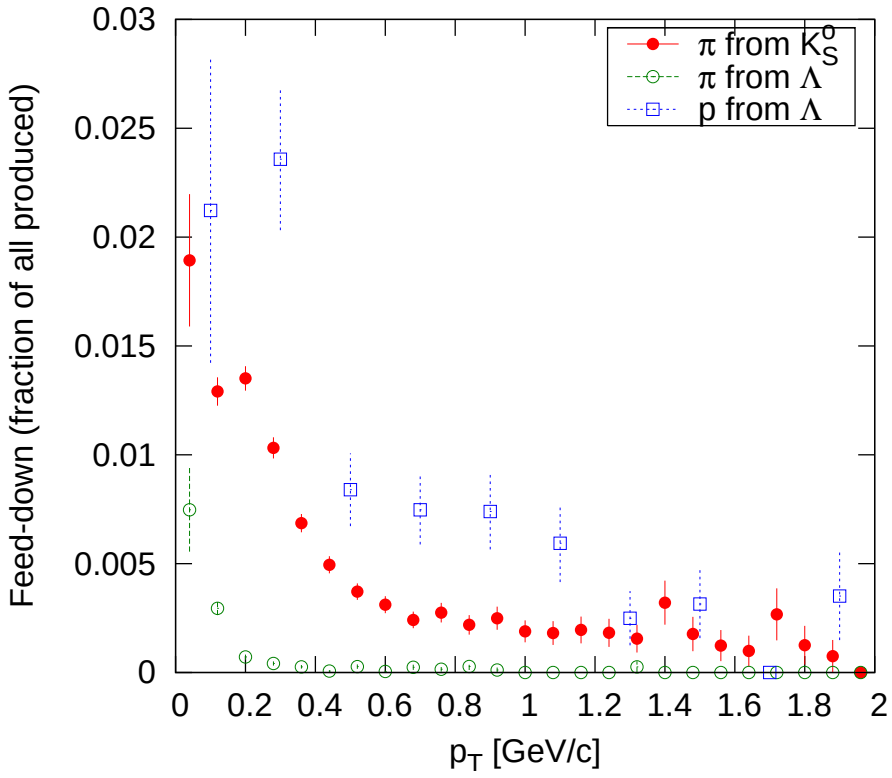
Particle identification using energy loss in the pixel detector, CMS Note in preparation

A by-product of particle identification work
The cluster position is fitted taking in account individual pixel ADCs

Almost threefold improvement in the direction perpendicular to the path of the track in the barrel

Physical corrections – feed-down





- Feed-down
  - Hadron spectra are traditionally corrected for weakly decaying resonances
  - The relative amount of feed-down is below the percent level overall
  - Why so small? Thanks to impact parameter cut $d_0 < 0.2$ cm
  - It is a strong function of p_T, reaches 2% for both pions and protons

Small correction

Hadron spectra – summary

- Tasks
  - Event generators
  - Detector simulation
    - Triggering
    - Charged particle tracking
  - Charged particle multiplicity
    - Vertexing
    - Energy loss analysis
    - Physical corrections
  - Comparative analysis

We are moving forward on many fronts in parallel