“General” questions, comments on collider detector tracking setup. And proposal …

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On behalf of “MiniTPC working group”

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Questions, comments.

- Is there any collider (and fix target) experiments with Si ONLY tracking setup? { PHOBOS. 8 layers with limited acceptance }
- Kalman filter track finding / reconstruction “needs” >4 hits / track (!?)
- Is there any collider experiment with demands: very good tracking (finding, momentum reconstruction) and PID for 0.1 – 12 GeV/c limits in 3. T B-field?
- why SV(ertex)T (VXD) detectors at BaBar and BELLE were constructed as 5-6 layers, and with an “additional” Drift Detectors (in R)?
- why background MC simulation “dramatically” failed for e-machine?
- Magnet size?

High intensity E-machine has its own problem

From BaBar experiences and publications

- “The main problem – background”, personal communication.
- “During the first year of operation, it became evident that beam-related backgrounds were higher than anticipated and their origins were poorly understood. In particular, it was not known that radiative Bhabha scattering and the neutrons they produced were the dominant source of background in the DIRC.”
- “The main effect was a reduction of the collected charge and an increase in the noise, resulting in lower overall track reconstruction efficiencies.”

“Background at HERA”, Carsten Nieburhg, DESY

- “ Severe background problems in the year 2002 delayed significantly startup of HERA after luminosity upgrade”

- ==========

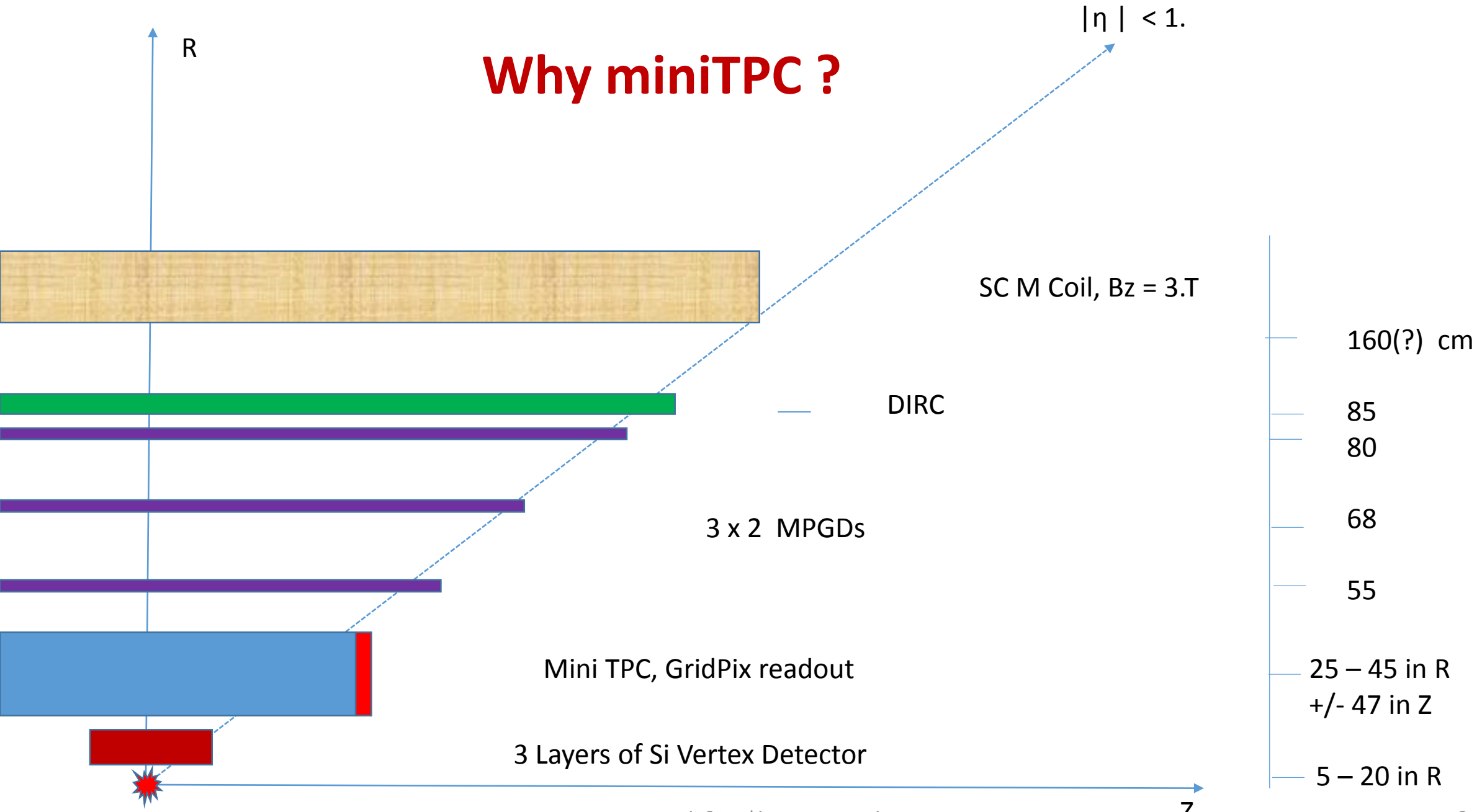
Jlab Experience

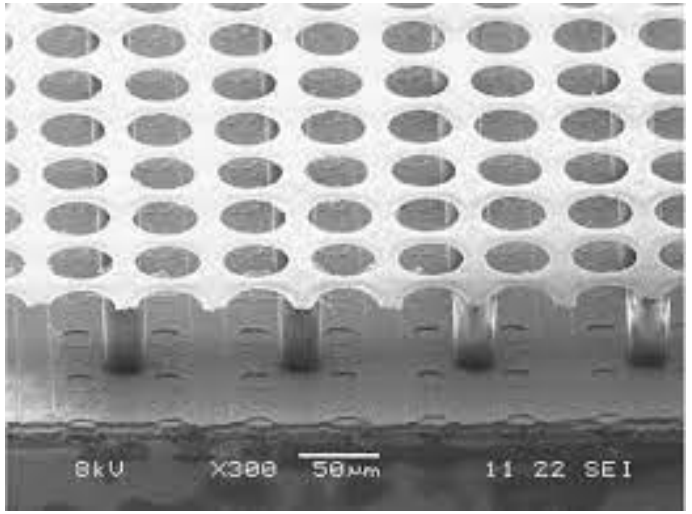
From BELLE experiment publications.

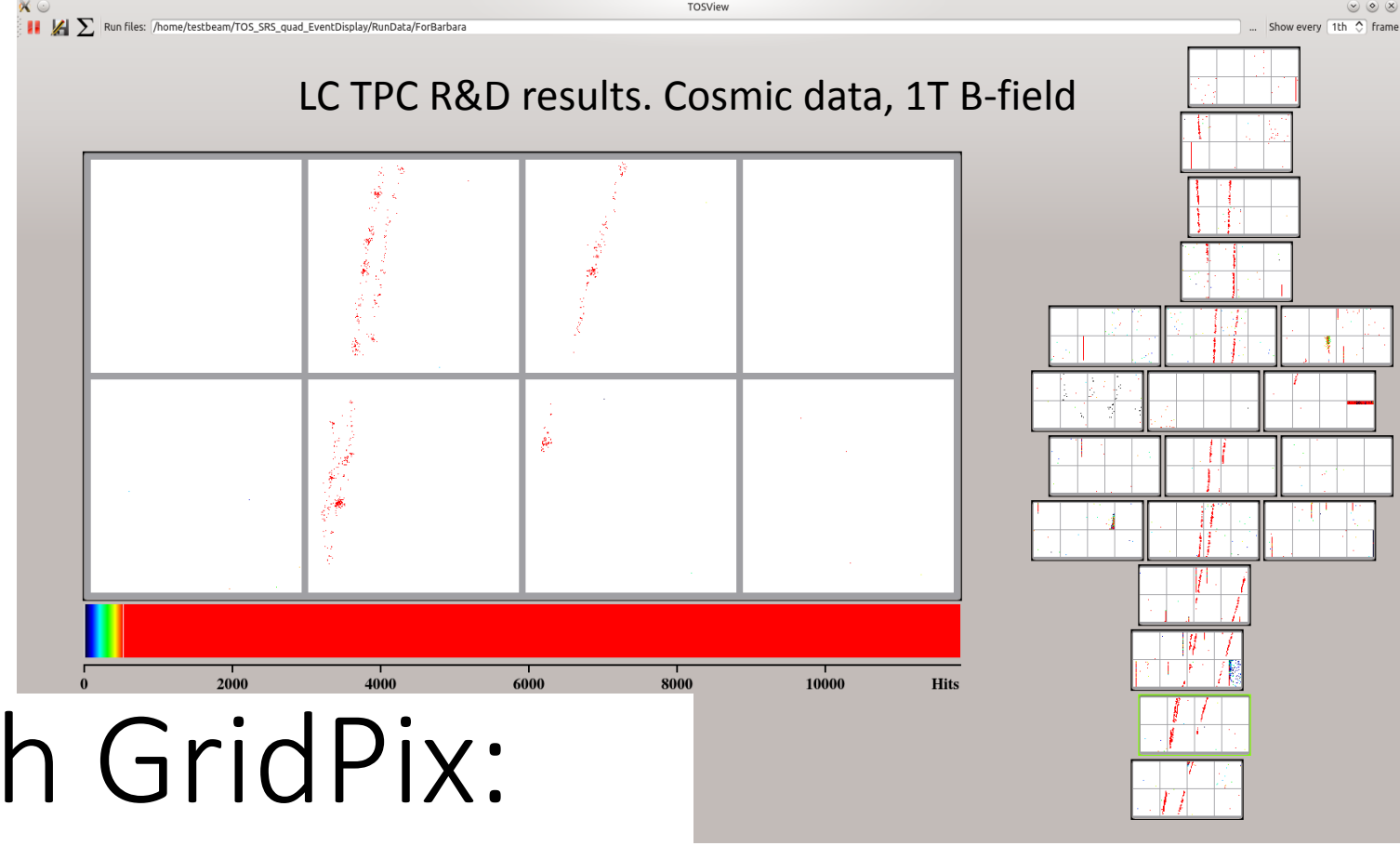
- “ Background from accelerator operation is a significant challenge for the experiment: {readout system, trigger decision, track finding and reconstruction, HV leakage current in the drift chamber, radiation damage}”
- “The beam induced background affects the VXD in two ways: radiation damage to the sensors and degradation of tracking performance due to fake hits”
- “Indeed disagreements were observed between beam induced background simulation prediction and experimental rates”
- “We observe moreover a huge data/MC discrepancy” (Factor 20 for LER (e+) and 1300 for HER (e-))
- Neutron “contribution”: from a few Hz/cm2 to 10**6 Hz/cm2

- It can be a very serious problem for EIC Si-only barrel tracking setup.
- 4 hits / track – huge challenge for track finding / reconstruction
- As realistic as possible background should be included in MC detector simulation with hits reconstruction and track finding.
- Setup: Si VXD + miniTPC + MPGDs can be significantly more robust as a tracking and momentum reconstruction (3. T B-field).
- Plus: h-PID for momentum <0.6 GeV/c and the pointer for DIRC. (track direction).
- Additional topic: “forward – back tracking”, and h-PID for particle momentum (6. – 12.) GeV/c

Why miniTPC ?


R
|η | < 1.
SC M Coil, Bz = 3.T
DIRC
3 x 2 MPGDs
Mini TPC, GridPix readout
3 Layers of Si Vertex Detector
Z
160(?) cm
85
80
68
55
25 – 45 in R
+/- 47 in Z
5 – 20 in R





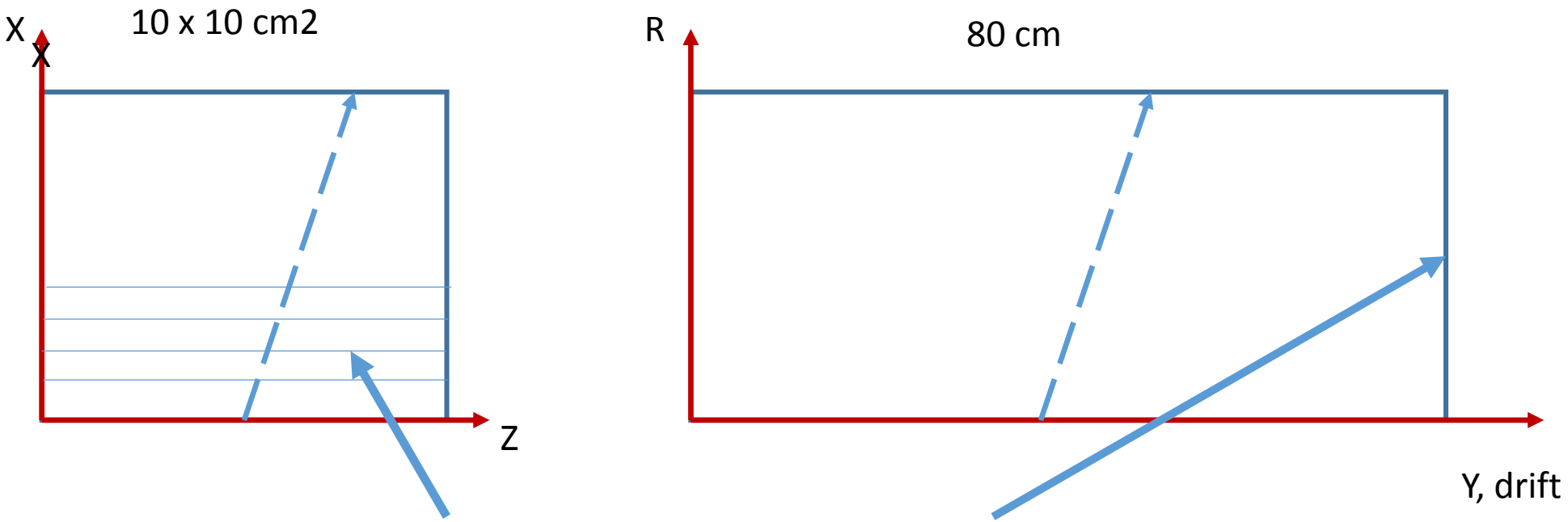
miniTPC with GridPix: Tracker and a PID

TK Hemmick, K Dehmelt, G Prakhar(SBU)
N Smirnov, (Yale), J Kaminski (Bonn)

- GridPix is a 55 µm × 55 µm pixel readout for a gaseous TPC
- First Timepix3 based GridPix test beam (2017)
- Quad module performance from test beam (2018)
- Investigations of the 8 quad detector (2020)

MiniTPC GridPix response, “toy MC”

Just to get some “impression” on GridPix PID and tracking performance



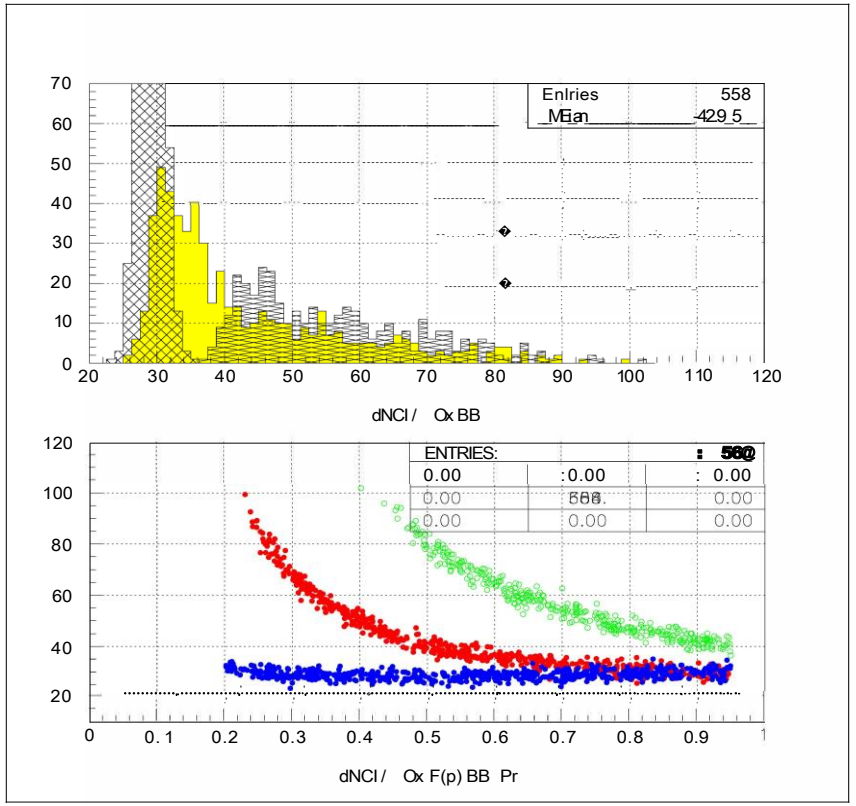
"artificial pad-rows": 0.1 or 0.3 cm

Simulation approach

- Simulate GridPix response using both BB and PAI models (“home edition”) with P10 gas, no B-field, but diffusion parameters as T2K gas with 3 T B-field
- PAI option includes “secondary's” production. The electron range was tuned in “high B-field”.
- For each primary / secondary electron: drift with diffusion parameters, gain simulation (Polya), add noise, find pixel (with 90% geom. efficiency), check threshold, convert drift time to cm and get a 3d-hit.
- Calculate an average values for hits in an “artificial pad-row” (0.1 or 0.3 cm in X)
- Then reconstruct back “track” in (X,Z) and (Y,R) planes
- Everything should be done in a “real” simulation (GEANT4, HEED, GARFIELD, …)

Using Bethe-Bloch and experimental data for the number of electrons per cluster. P10. 10-12 cm tracks length. 0.2 – 0.9 GeV/c

Number of Interaction / 0.5 cm



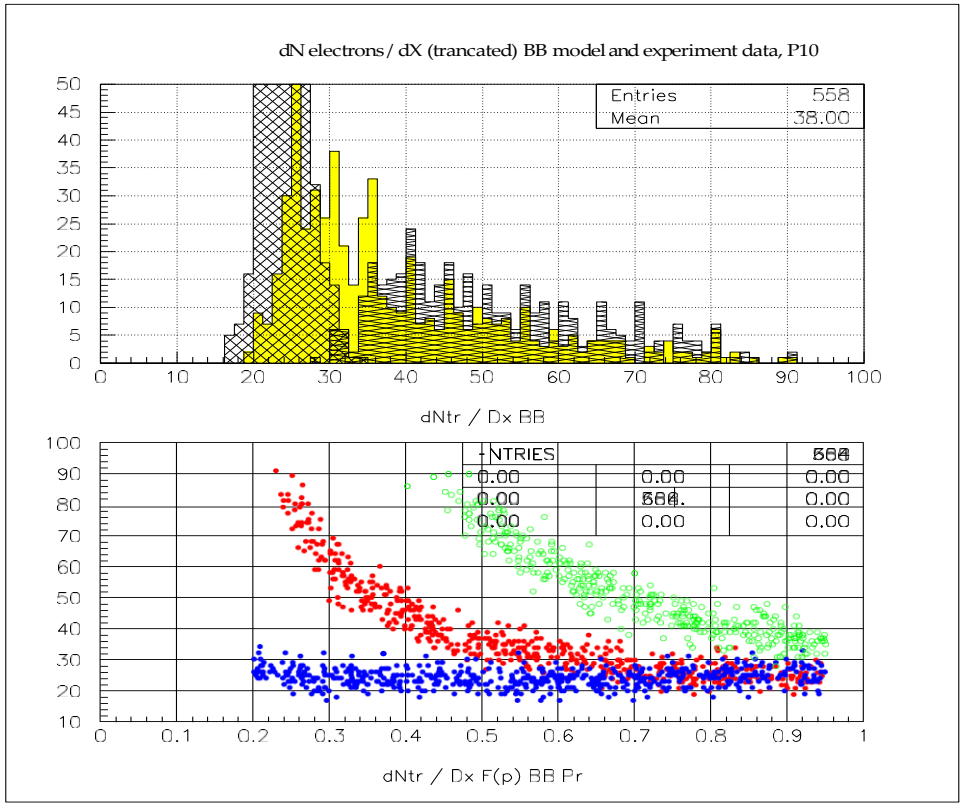
P, GeV/c

π

K

P

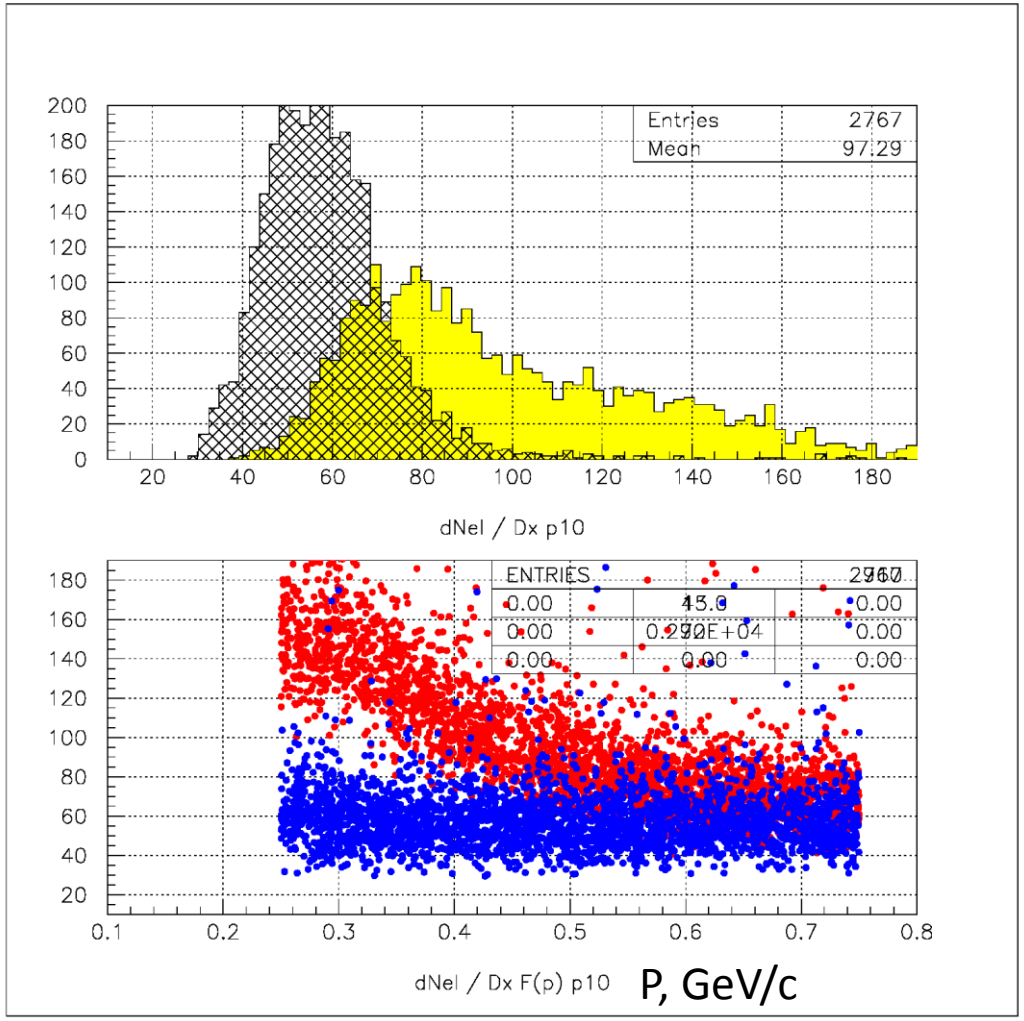
Number of electrons / 0.5 cm



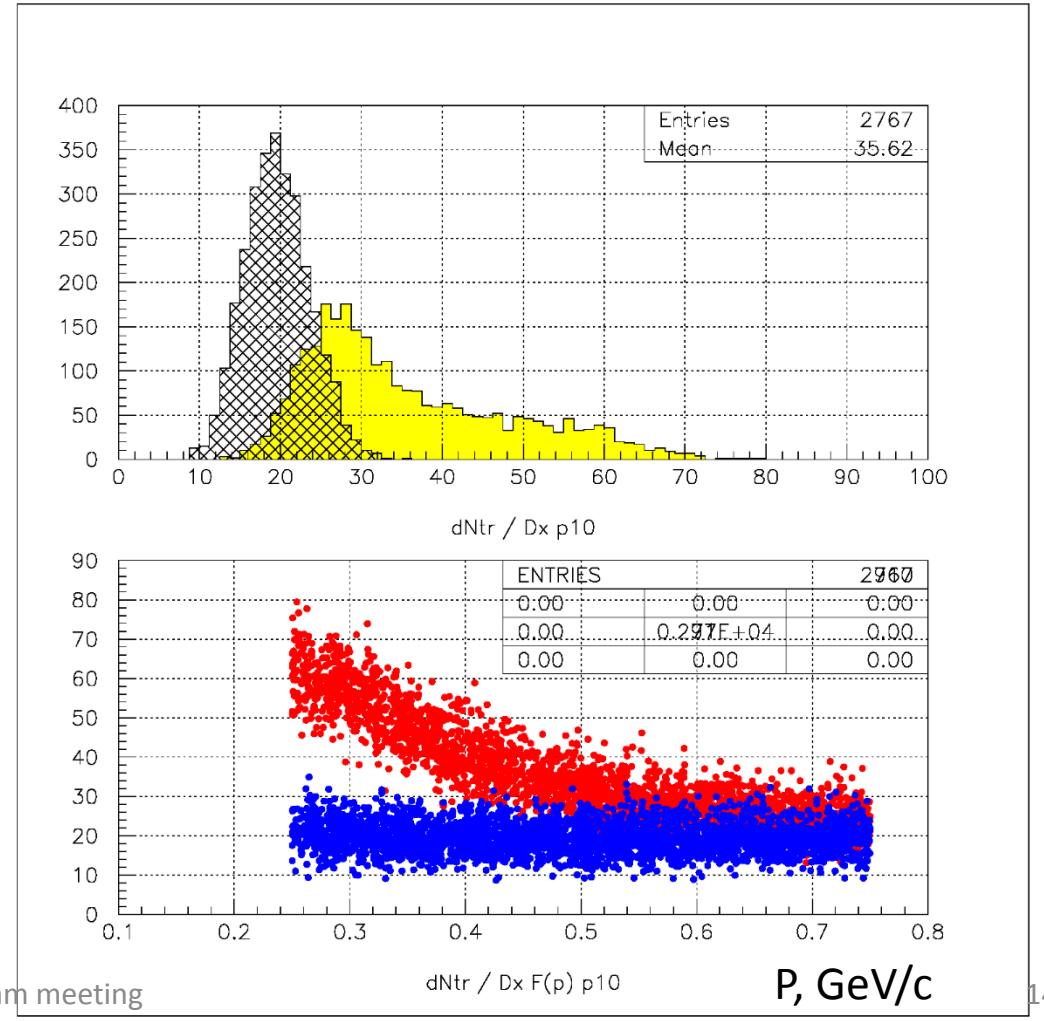
P, GeV/c

“PAI” model, p10, number of electrons / 0.5 cm, ~ 10-12 cm tracks length

“Full” numbers



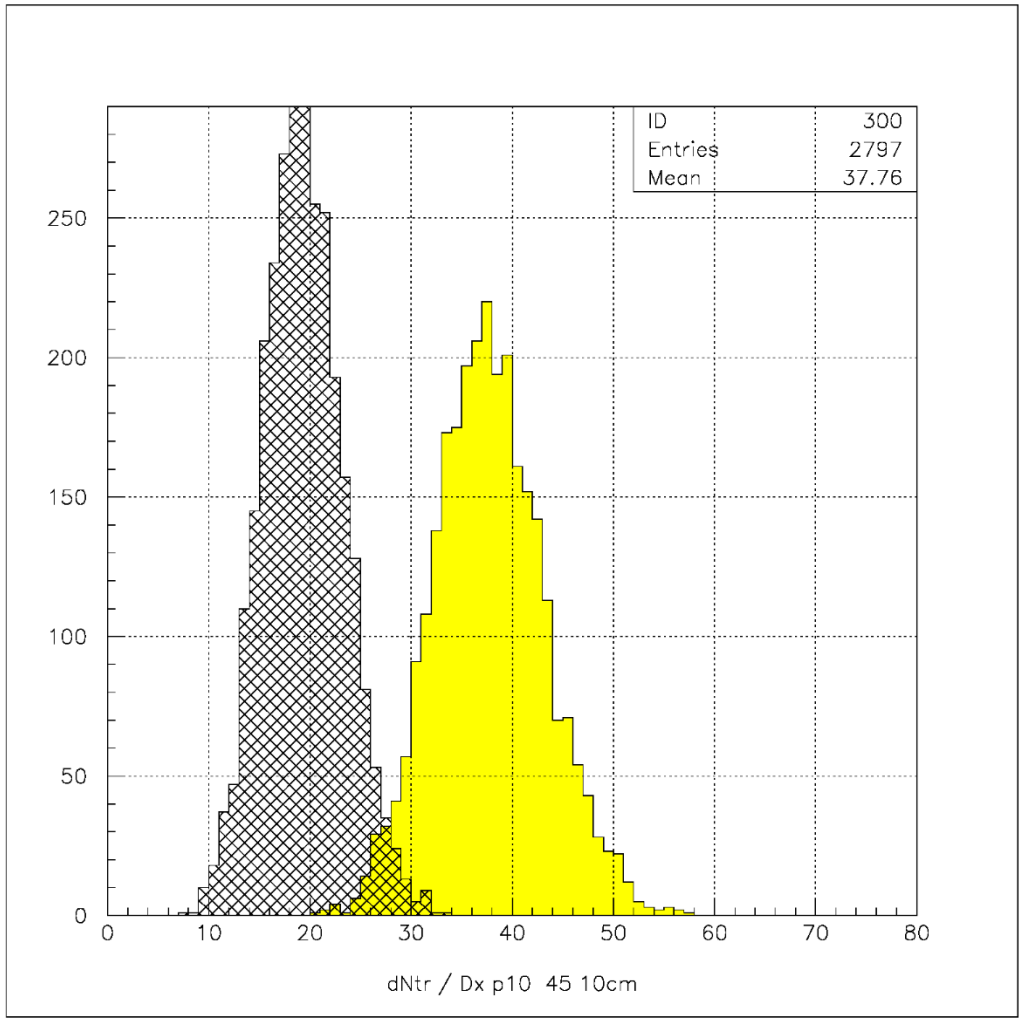
After truncated procedure (60%)



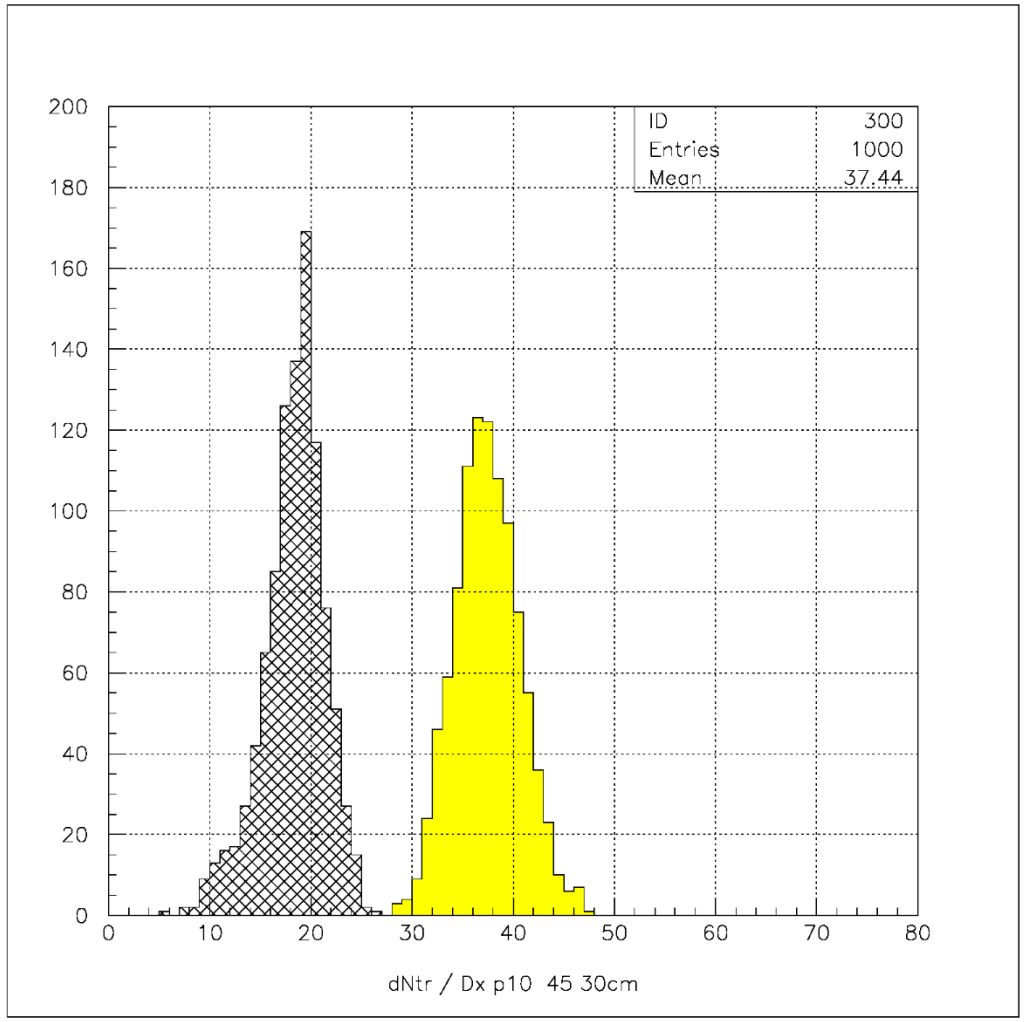
π / K separation. Number of electrons / 0.5 cm. Select momentum 0.45 GeV/c

~60% truncated

Track length ~10 cm



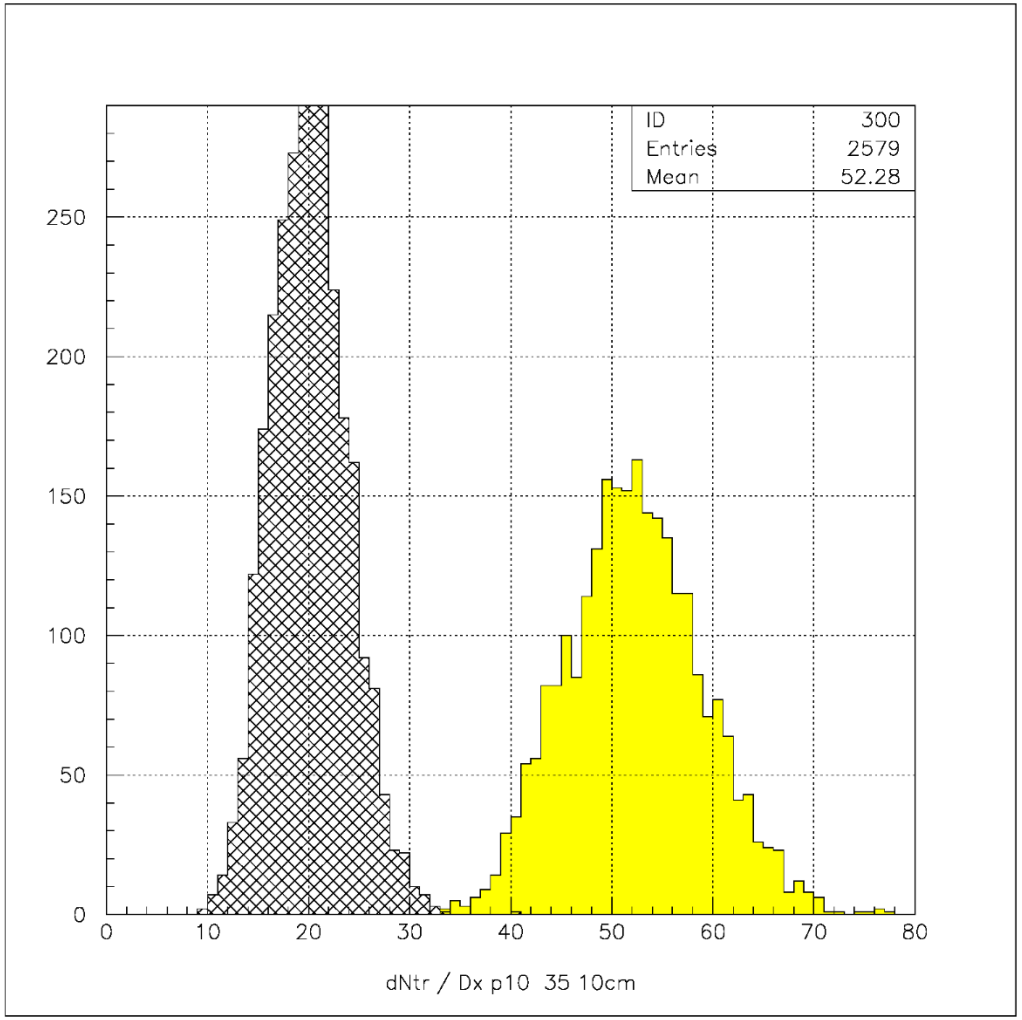
Track length ~ 30 cm



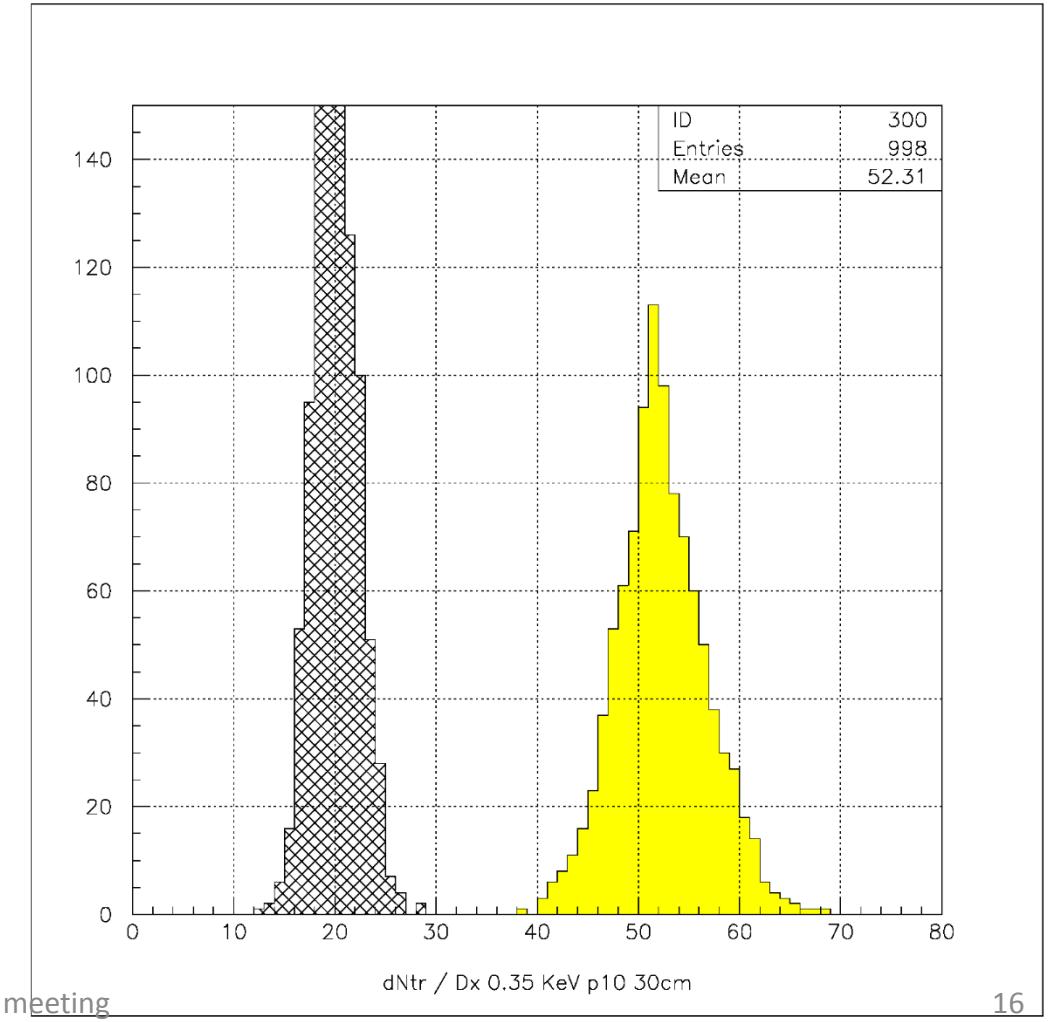
π/K separation. Number of electrons / 0.5 cm. Select momentum 0.35 GeV/c

~60% truncated

Track length ~10 cm

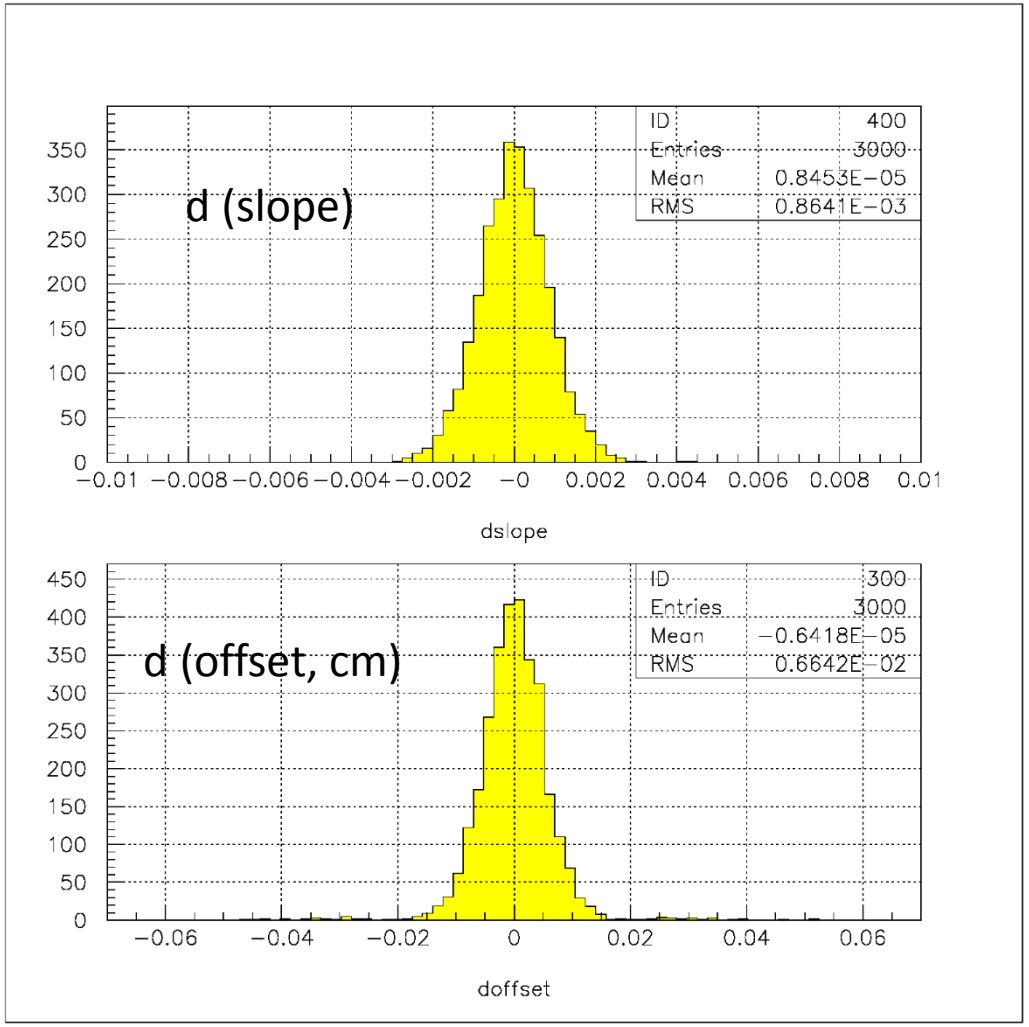


Track length ~ 30 cm

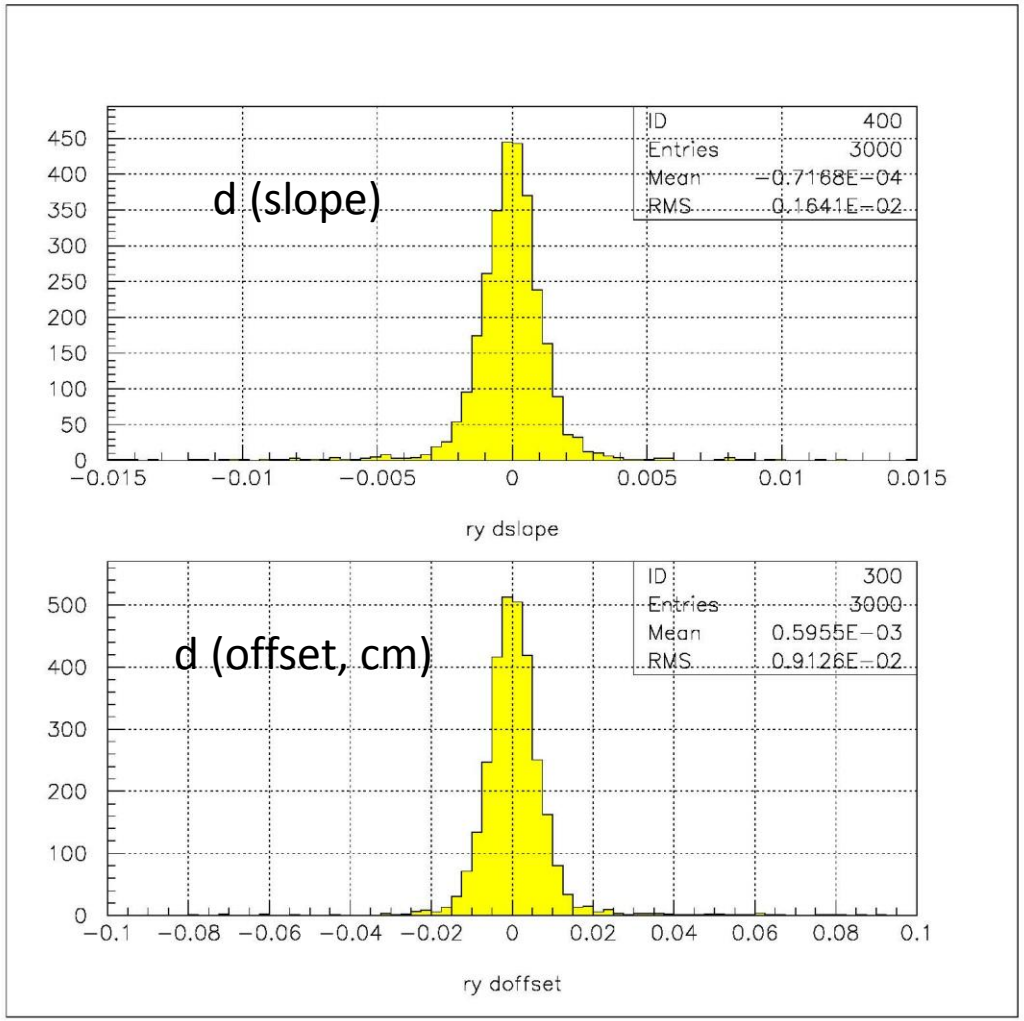


Reconstruct back track parameters and compare with simulated ones

d(XZ) slope and offset, 0.1 cm “pad-row”, PAI

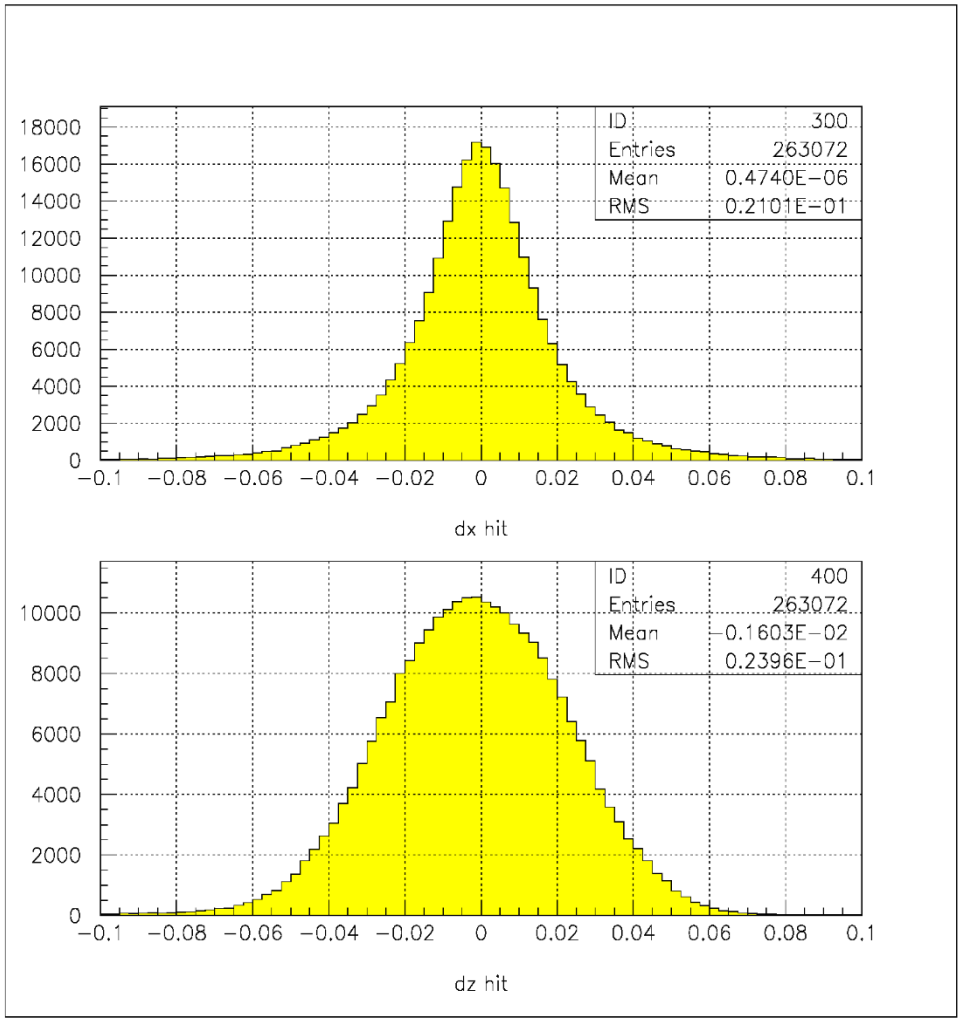


d(YR) slope and offset, 0.1 cm “pad-row”, PAI



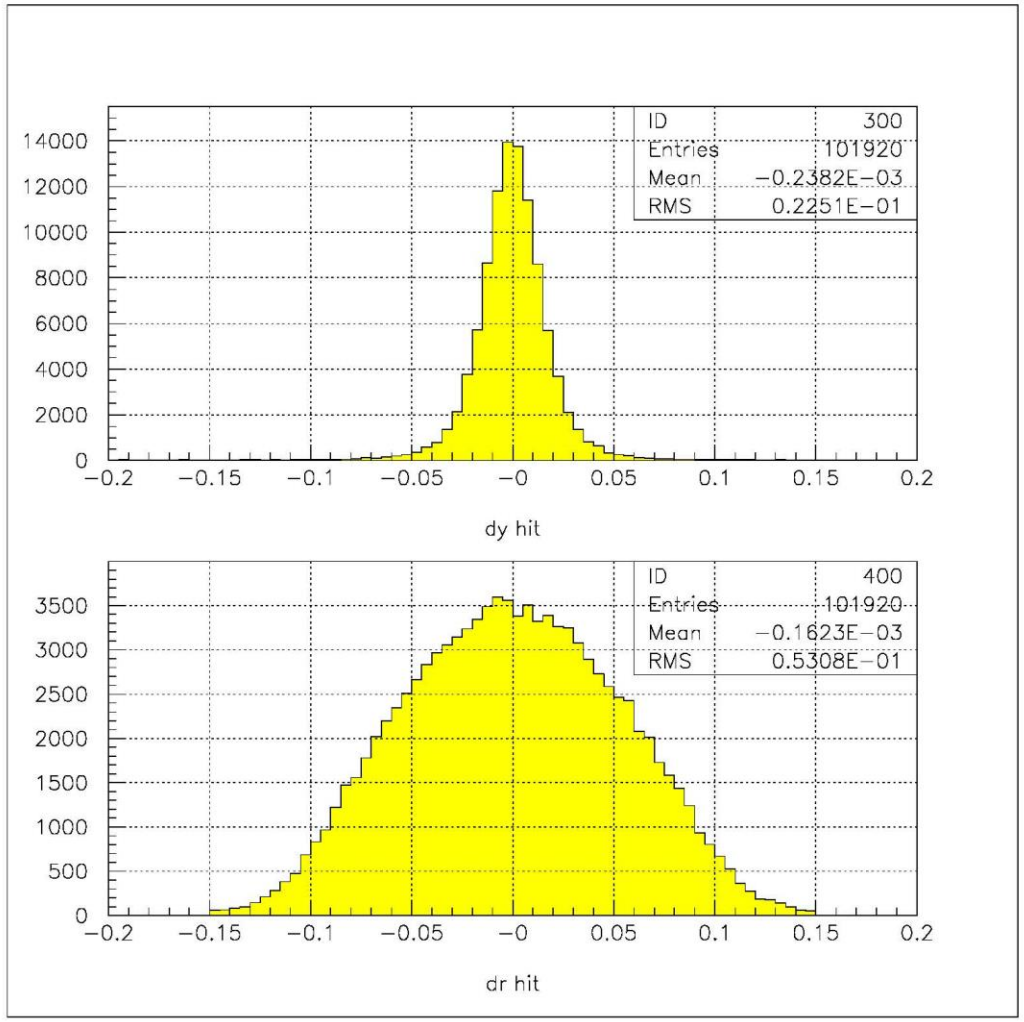
PAI model, 0.1 cm pad-rows

"Individual contributions". dX and dZ (cm)



PAI model, 0.3 cm pad-rows

"Individual contributions". dY and dR (cm)



Status and request for R&D

- I would like to stress once more:
- 1. Background can be more serious problem than we expect just now. BELLE experience should be careful checked.
- 2. 3-4 hits / track is extremely unreliable from track finding point of view
- 3. Barrel PID for P < 0.6 GeV/c in 3 T B-field
- 4. ToF (ps) is very delicate, complicated and expensive option (including T0 problem)
- 5. miniTPC ***will solve ALL problem***, is not costly, and (most probable) “allows” to minimize number of Si layer to 3. SVT only.
- 6. miniTPC end-cap material. GridPix readout option – significantly minimizes this problem. Cooling approach is a “hot topics” and need R&D in our case.
- 7. R&D points: Gas selection. Demonstrate the tracking and PID performance in 3T B-field, demonstrate cooling performance and the temperature stabilization. Small TPCs (SBU sPHENIX test, BNL and Yale options) are available, a few GridPix chips and DAQ – from Europe. For cooling test – new chips should be prepared.
- 8. Cost estimation and production time schedule spreadsheet was prepared (published by PID group)

  It will need < 3.1 M$ including R&D, and 3 years production / test time.

Any committee to review ip6 barrel tracking setup can ask these questions:

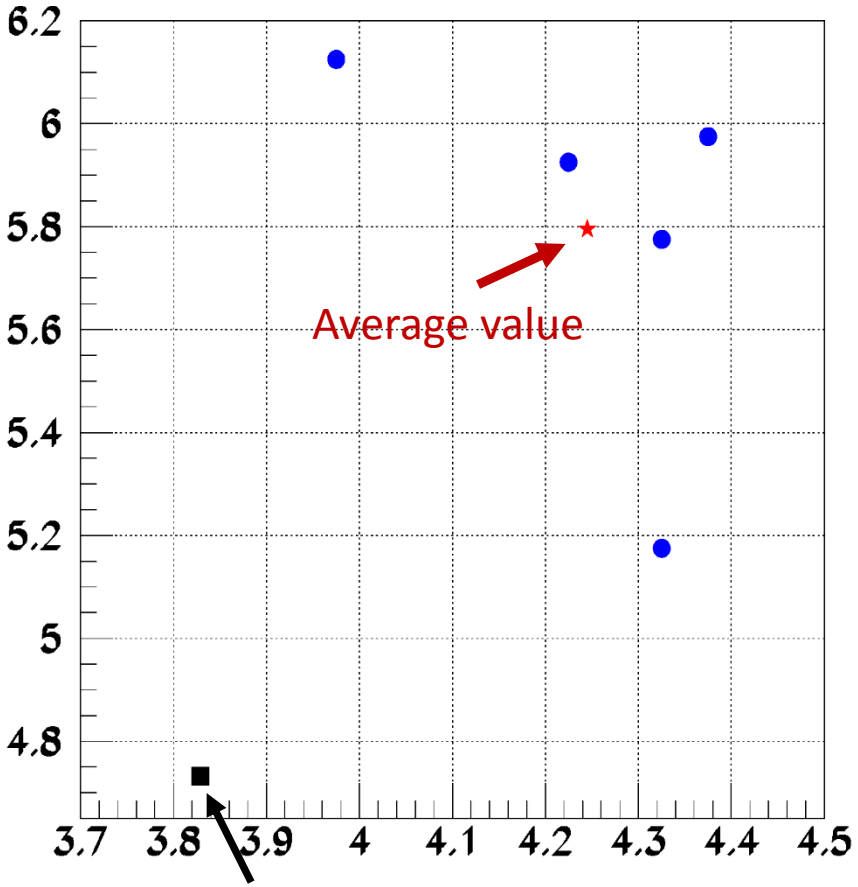
- ***If reliable and comprehensive machine background simulation will demonstrate:***

- A. Background is small and can be ignored
  -- Si only tracking option
  -- compact design
  -- “small size” magnet
  -- money would be saved to install expensive ps TOF and dedicated EMCAL with TOF.

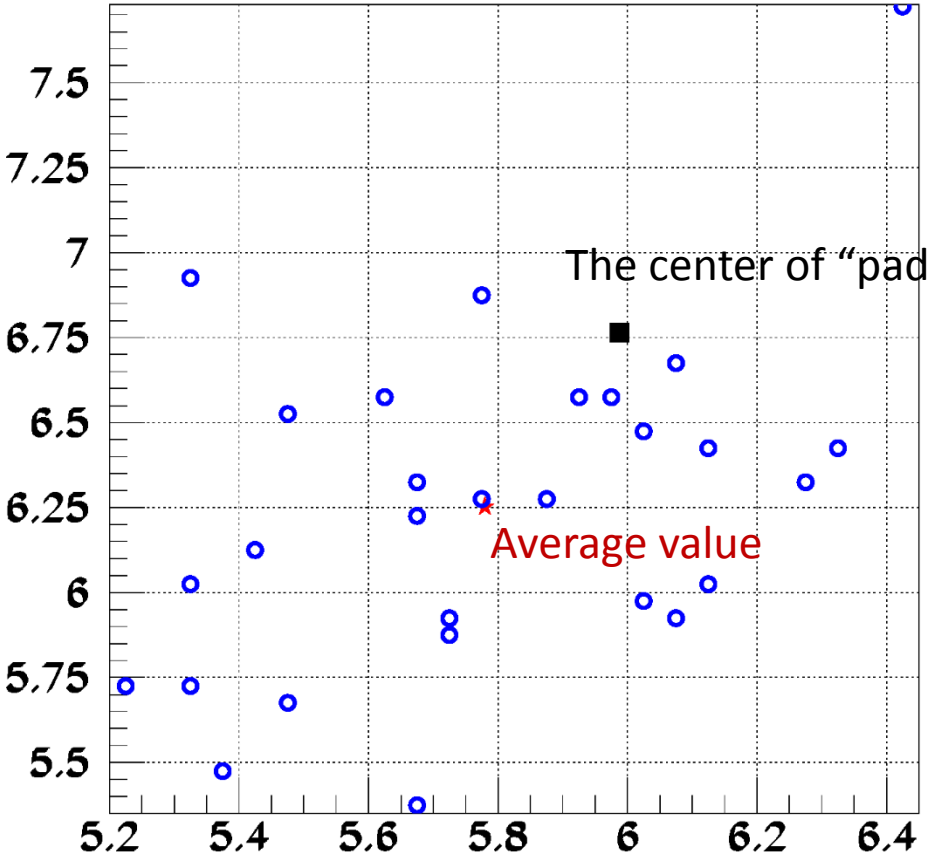
- B. Background is essential and should be taking into consideration
  -- “classical“ and tested approach
  -- main tracker – gas detectors with PID
  -- Si – additional tracking and Vertex detector
  -- “large size” magnet with the possibility “high P PID”.

Special selected the response for two “pad-rows” with the worth reconstruction precisions

Scale in mm



The center of “pad-row” (0.3 cm)



From BELLE experiment publications.

- 4. (LER e+) – 7. (HER e-) GeV/c SuperKEKB collider. L ~ 5. e35 cm-1 s-1 (Mass energy in the bottomonium region like Y(4s) resonance -> to couple of B-mesons)
- VXD 6 layers of Si detectors, 3.5 – 13.5 cm in R
- Drift Chambers up to 110 cm in R. ToF (SC) and Quartz TPD For Hadron PID
- EMCal
- 1.5 T B-field