Track reconstruction in high density environment

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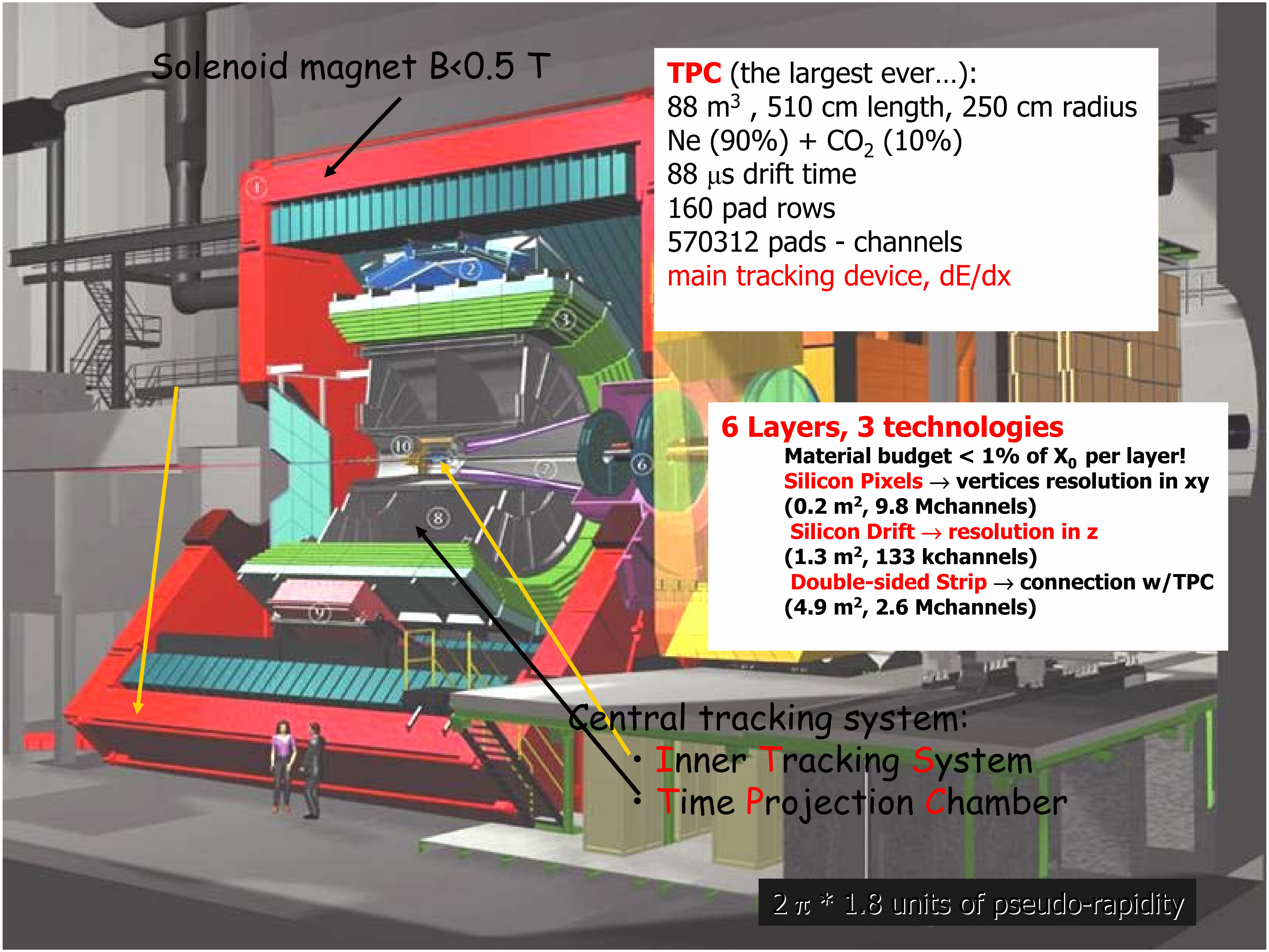
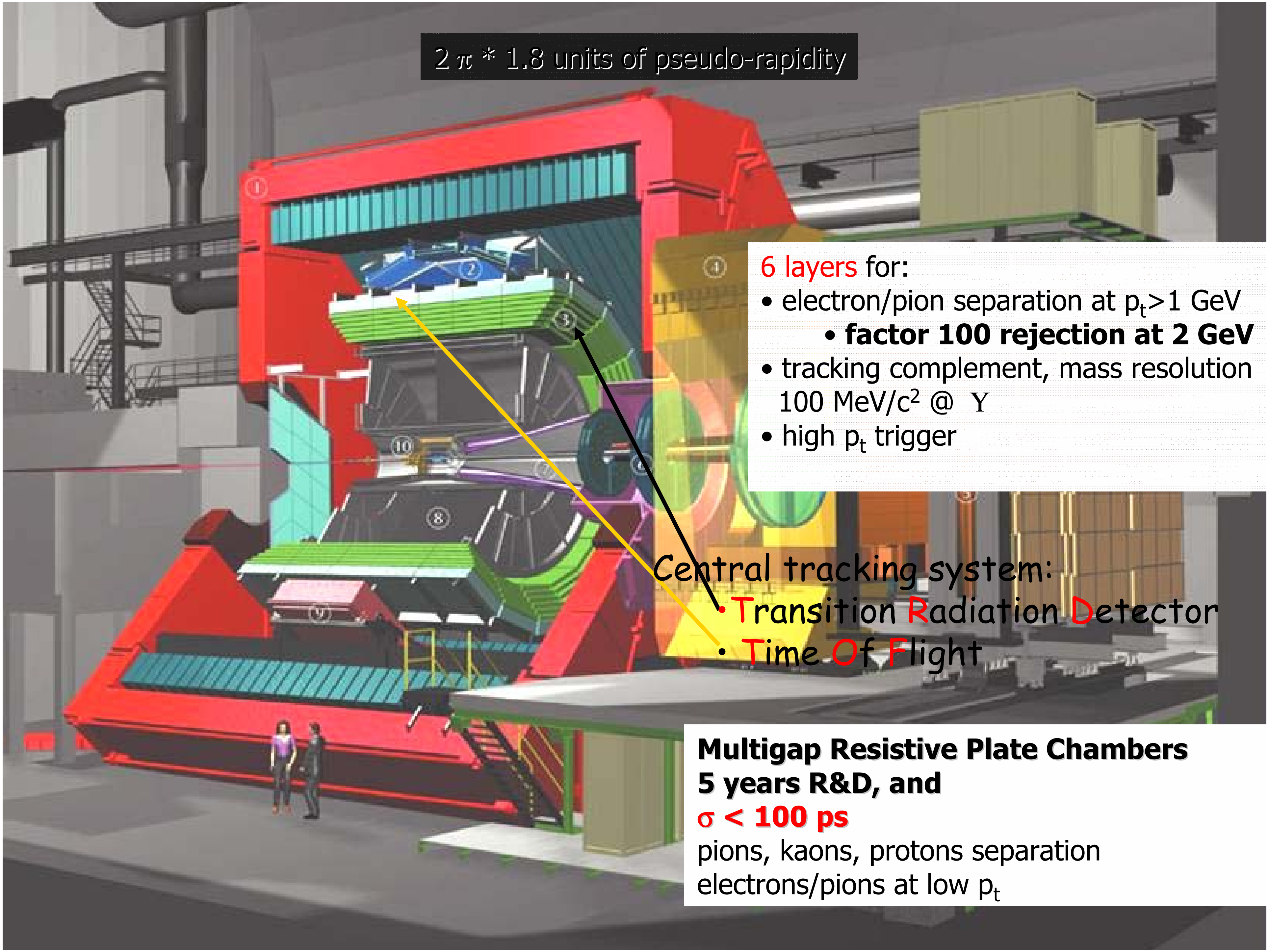

Solenoid magnet B<0.5 T
TPC (the largest ever…):
88 m^3 , 510 cm length, 250 cm radius
Ne (90%) + CO_2 (10%)
88 μs drift time
160 pad rows
570312 pads - channels
main tracking device, dE/dx
6 Layers, 3 technologies
Material budget < 1% of X_0 per layer!
Silicon Pixels → vertices resolution in xy
(0.2 m^2, 9.8 Mchannels)
Silicon Drift → resolution in z
(1.3 m^2, 133 kchannels)
Double-sided Strip → connection w/TPC
(4.9 m^2, 2.6 Mchannels)
Central tracking system:
• Inner Tracking System
• Time Projection Chamber
2 π * 1.8 units of pseudo-rapidity


2 π * 1.8 units of pseudo-rapidity
6 layers for:
• electron/pion separation at p_t>1 GeV
• **factor 100 rejection at 2 GeV**
• tracking complement, mass resolution 100 MeV/c^2 @ Υ
• high p_t trigger
Central tracking system:
• Transition Radiation Detector
• Time Of Flight
Multigap Resistive Plate Chambers
5 years R&D, and
σ < 100 ps
pions, kaons, protons separation
electrons/pions at low p_t

Reconstruction strategy

- Main challenge - Reconstruction in the high flux environments (occupancy in the TPC detector up to 40 %) requires a new approach to tracking
- Basic principle – **Maximum information principle**
  - use everything you can, you will get the best
- Algorithms and data structures optimized for fast access and usage of all relevant information
  - Localize relevant information
  - Keep this information until it is needed

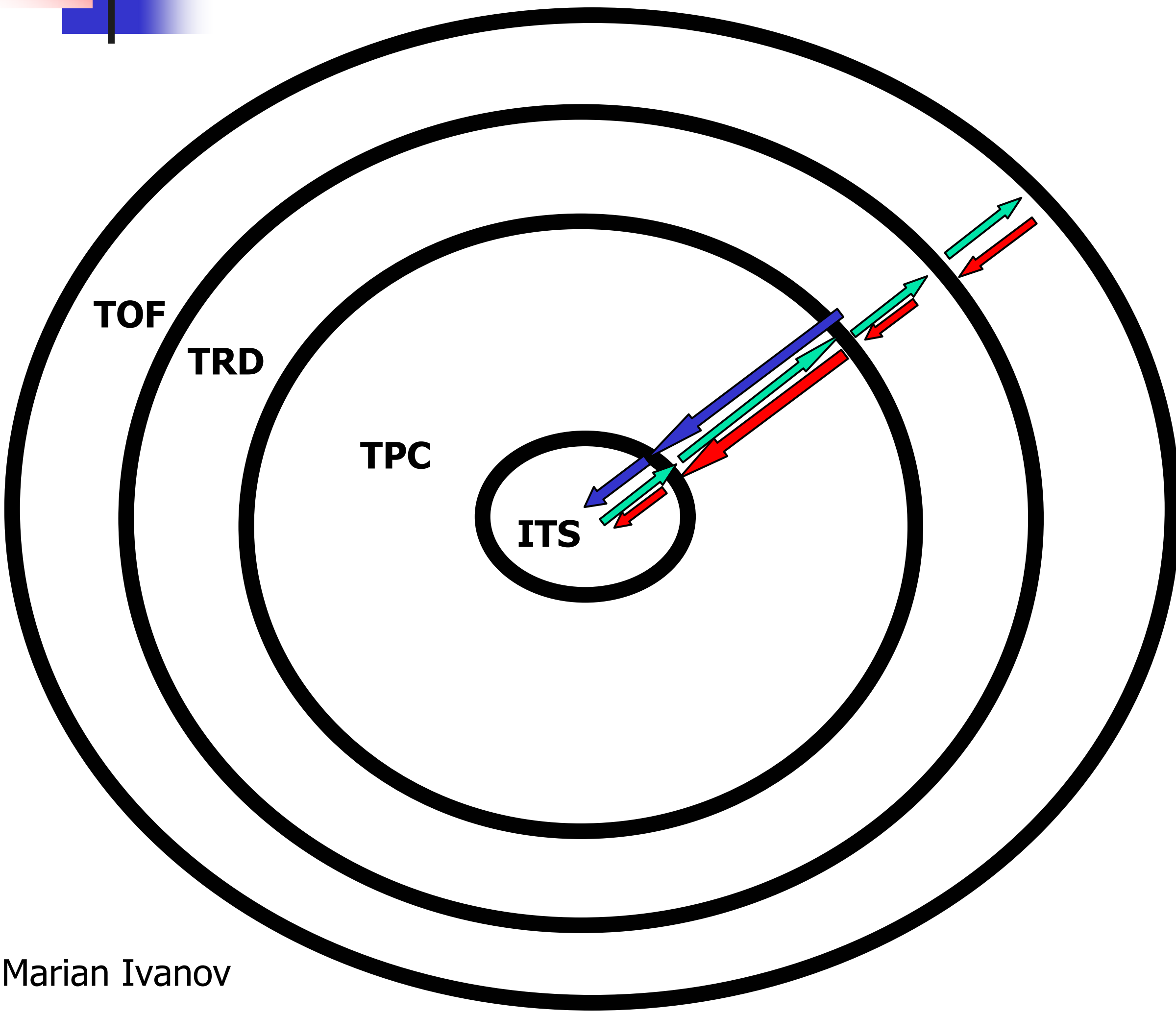
Kalman filter (0)

- Parallel Kalman Filter tracking approach chosen
  - To use optimal combination of local and global information about track's and clusters
  - Space points - clusters reconstructed before tracking
- Advantages:
  - simultaneous track recognition and reconstruction
  - natural way to take into account multiple scattering, magnetic field unhomogenity
  - possibility to take into account mean energy losses
  - efficient way to match tracks between several detectors
- Main assumptions - Space points used for Kalman filtering
  - Gaussian errors with known sigma
  - Errors between layers are not correlated

Kalman filter (1)

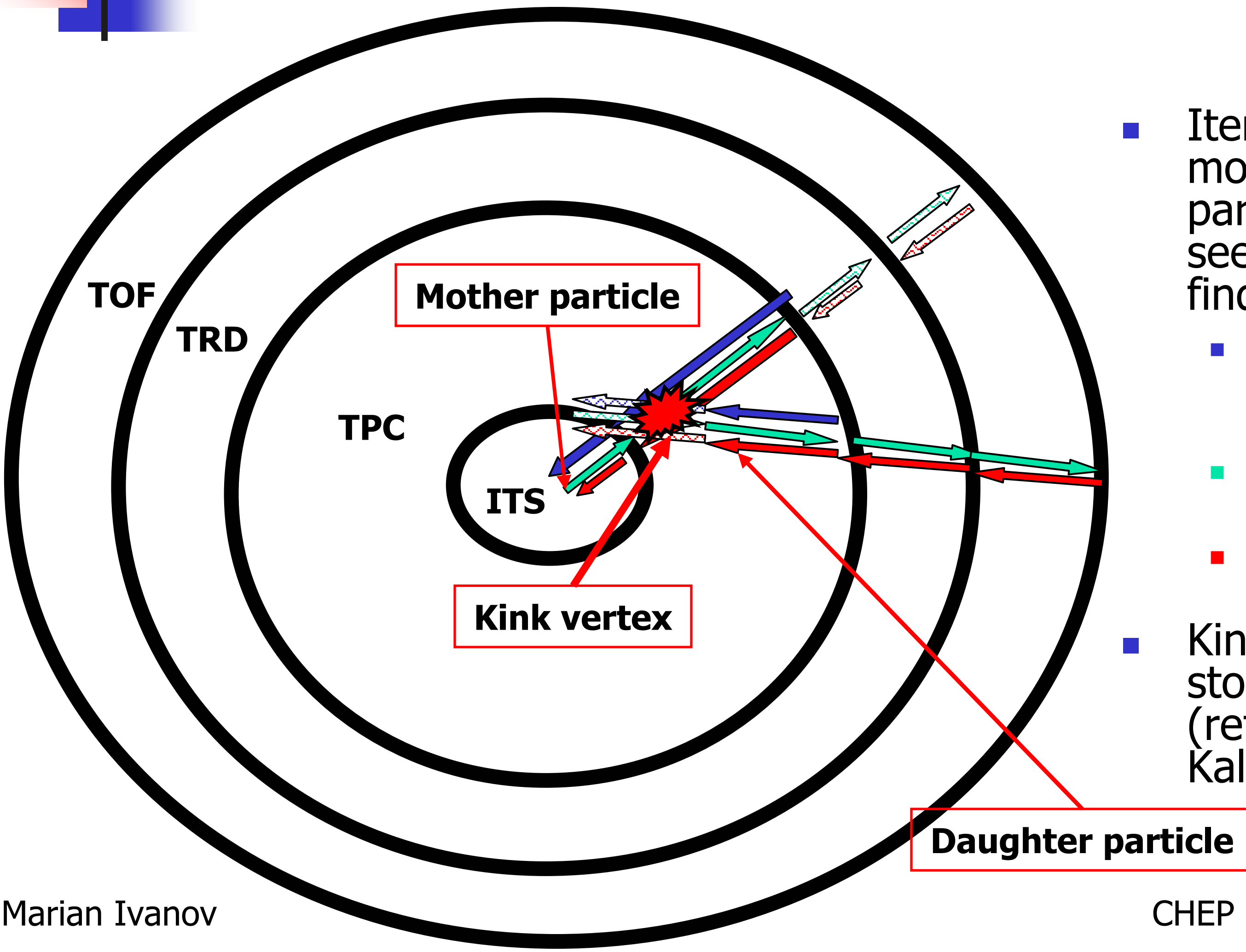
- To fulfill given assumption in the high flux environment
  - Cluster overlaps problem resolved:
    - Cluster shape parameterization depending on the track parameters
    - Cluster unfolding based on the cluster shape for clusters with extended shape
    - Multidimensional error parameterization in the space of observables
      - Space points characterized by the position, charge, shape characteristic and charge ratio for unfolded clusters
      - Space point errors assigned to the point only at the moment when the parameters of the tracks are known
    - Works for all detectors –**TPC, TRD, ITS**
  - Reduction of the influence of wrongly associated clusters on the track parameters
    - If the error of the prolongation comparable with the mean distance between of the clusters – building the tree of the hypothesis and choose the "best" - **ITS**
    - For Kink and V0 topologies refit the track towards the vertex found

Tracking strategy – Primary tracks



- Iterative process
  - Forward propagation towards to the vertex –TPC-ITS
  - Back propagation – ITS-TPC-TRD-TOF
  - Refit inward TOF-TRD-TPC-ITS
- Continuous seeding –track segment finding in all detectors

Tracking strategy – Kink topology



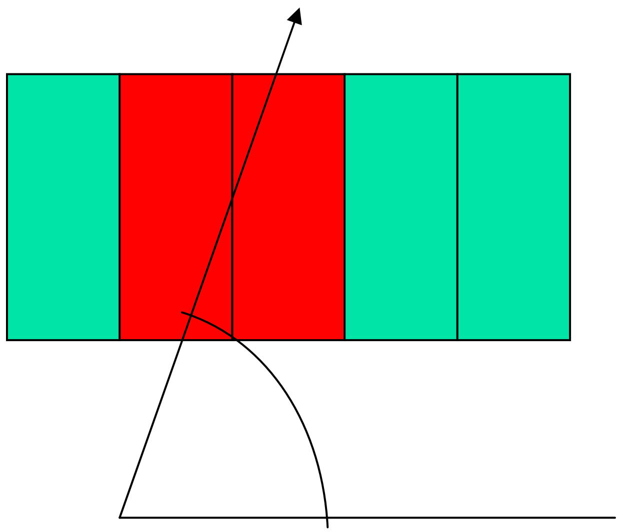
- Iterative process for mother and daughter particles (Continuous seeding –track segment finding in all detectors)
  - Forward propagation towards to the vertex – TPC-ITS
  - Back propagation –ITS-TPC-TRD-TOF
  - Refit inward TOF-TRD-TPC-ITS
- Kink topology finding, storing and updating (refitting) with the best Kalman parameters

Sources of information

- spatial characteristic of a track and sets of tracks
  - px,py,pz,y,z parameters and covariance
  - chi2
  - number of points on the track
  - number of shared clusters on the track
  - overlaps between tracks
  - DCA for V0s, Kinks and Cascades
  - …
- dEdx
  - mean, sigma, number of points, number of shared points… reliability
- TOF of a track and sets of tracks
- derived variables
  - Mass
  - Causality - Probability that particle " really exists" in some space interval (used for causality cuts)
    - Based on clusters occurrence, and chi2 before – after vertex
  - Invariant mass
  - Pointing angle of neutral mother particle
  - …

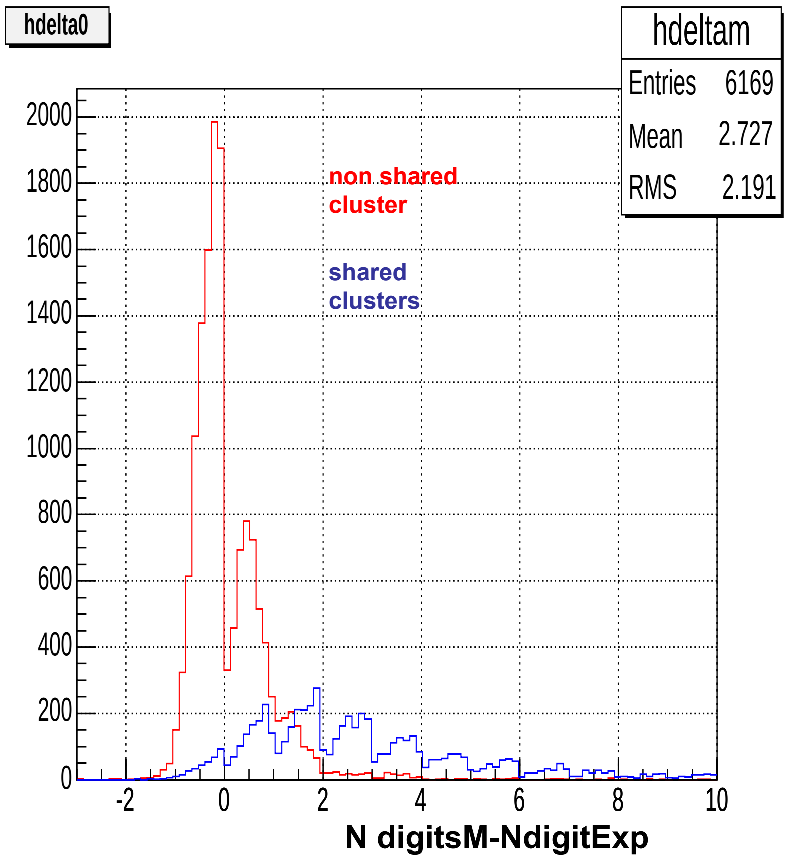
ITS - Cluster shape parameterization

- Cluster shape parameterization
  - linear dependence on the local track angle in θ and φ (known only during tracking procedure)
  - dependence on the layer width and the granularity – different for each layer

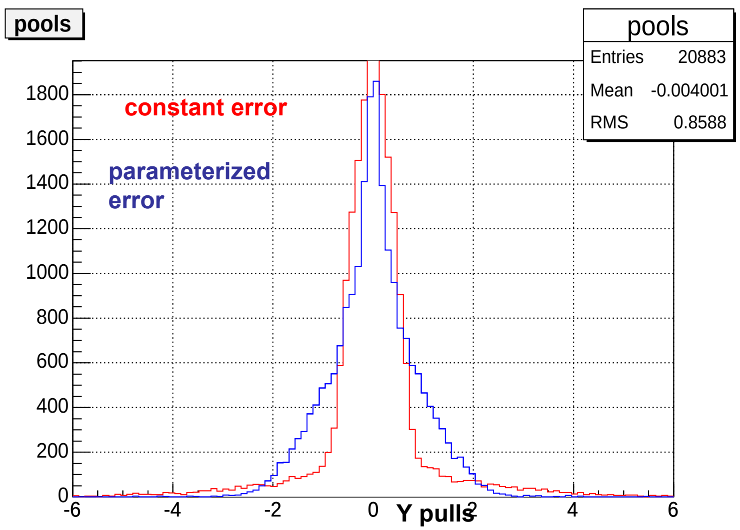


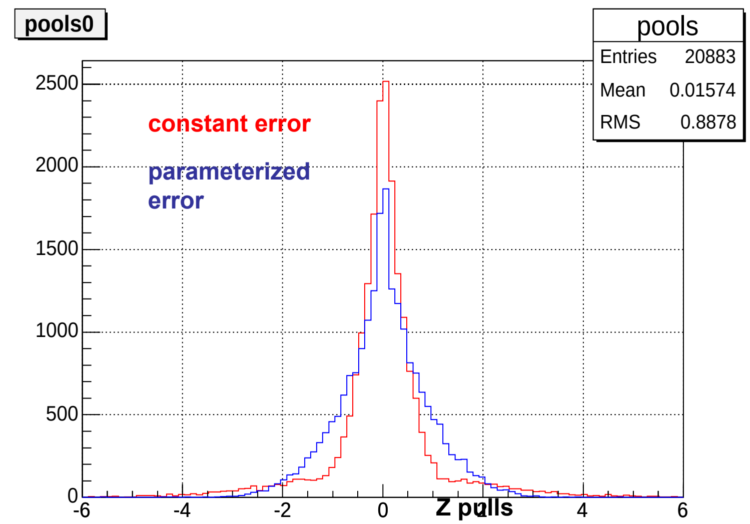
ITS - Cluster sharing probability parameterization

- cluster can belong to more than one track
- probability as a function of distortion from the expected cluster shape parameterized



ITS - Cluster error parameterization



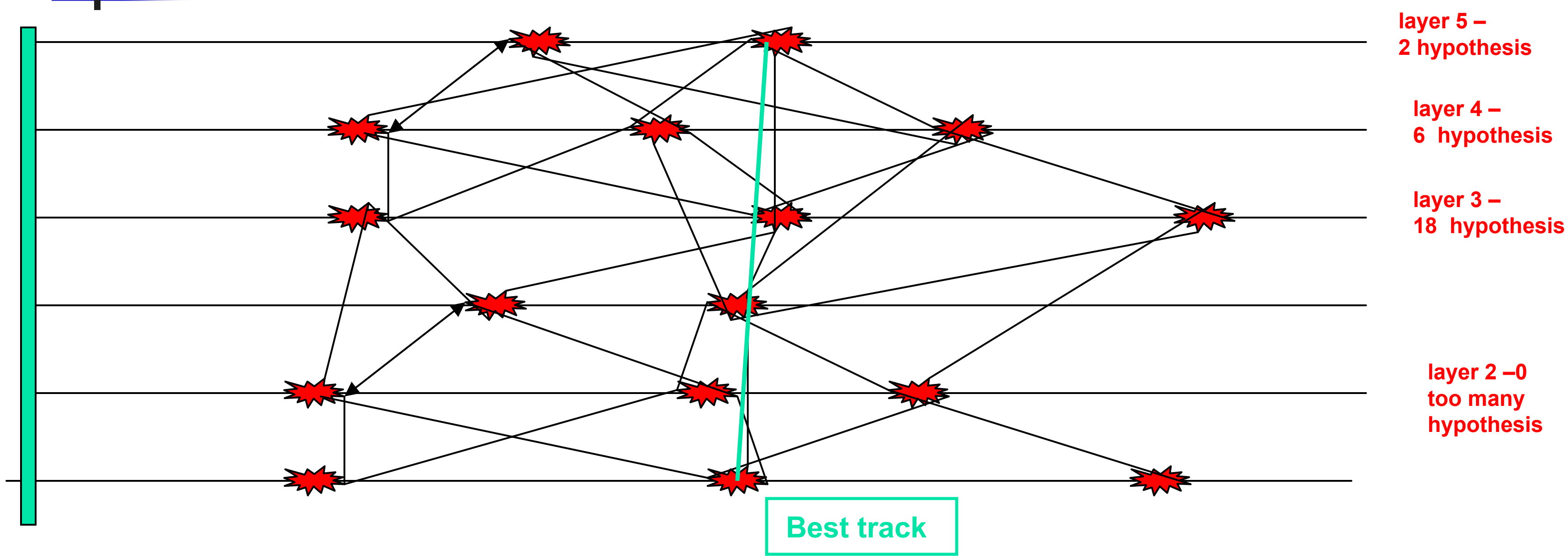


- If a constant effective errors are used - pulls have long tail – χ^2 criteria for the selection of the best track candidates is not optimal
- using the information about the distortion of the measured cluster shape from the expected one, and about the distortion of the measured cluster charge from the expected one
- different types of the parameterization for each layer and cluster types

ITS tracking

- starting point
  - track seeds from the TPC
- follow the tree of track hypotheses connecting reconstructed clusters
- following cases taken into account
  - track in dead zone
  - missing clusters
    - track crosses dead ITS channel – (map of dead channels still not available)
    - cluster below threshold
  - track crosses noisy ITS channel – (not yet in the simulation)
  - secondary tracks not cross ITS layer as function of impact parameter in z and r-φ
  - probability of the cluster to be shared as a function of the cluster shape

ITS - Track tree building algorithm



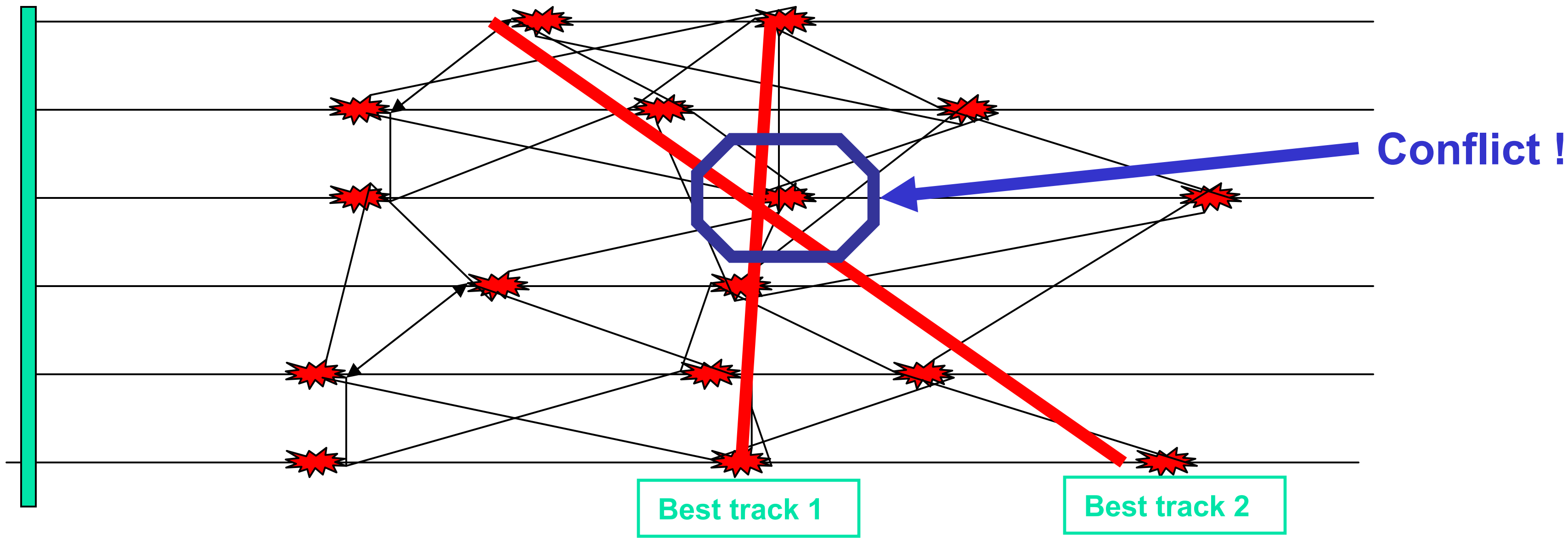
Algorithm –

- after each layer track hypothesis sorted according to $\chi 2$
- only gold track branches and a restricted amount of non gold tracks prolongated further down

ITS -Parallel tracking

- for each seed, tree of the track hypotheses constructed
- current best track according to $\chi 2$ chosen
  - restricted amount of tracks kept for further parallel tracking procedure
  - for secondary tracks also short best tracks kept, for further V0 study
- best track is registered to all the clusters which belong to that track
- overlap factor between the best track and all other tracks is calculated
- if the overlap factor is higher than a critical value, $\chi 2$ of the pair of tracks is calculated

ITS - Parallel tracking (2)

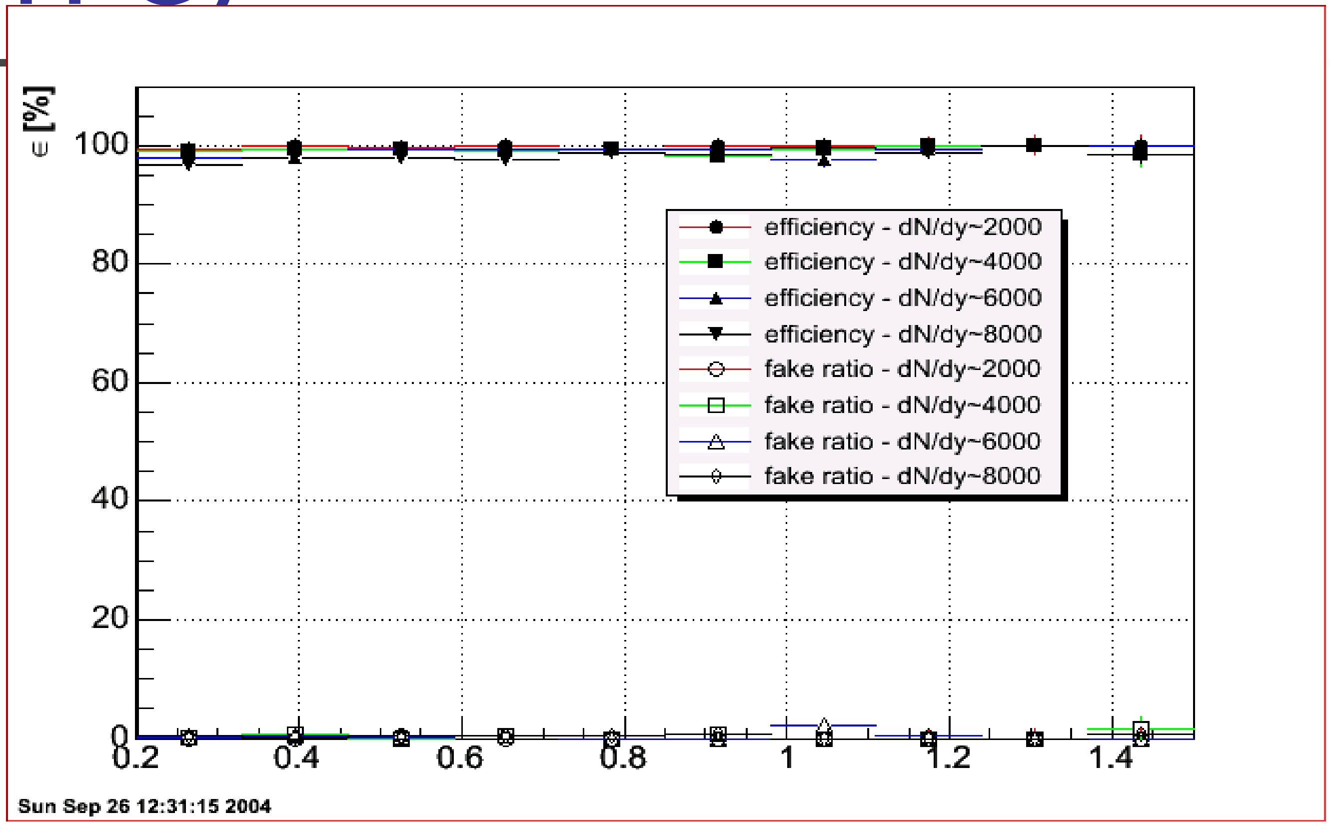


- double loop over all possible pair of branches
- weighted χ2 of two tracks calculated
  - effective probability of cluster sharing and for secondary particles the probability not to cross given layer taken into account

ITS V0 finding strategy

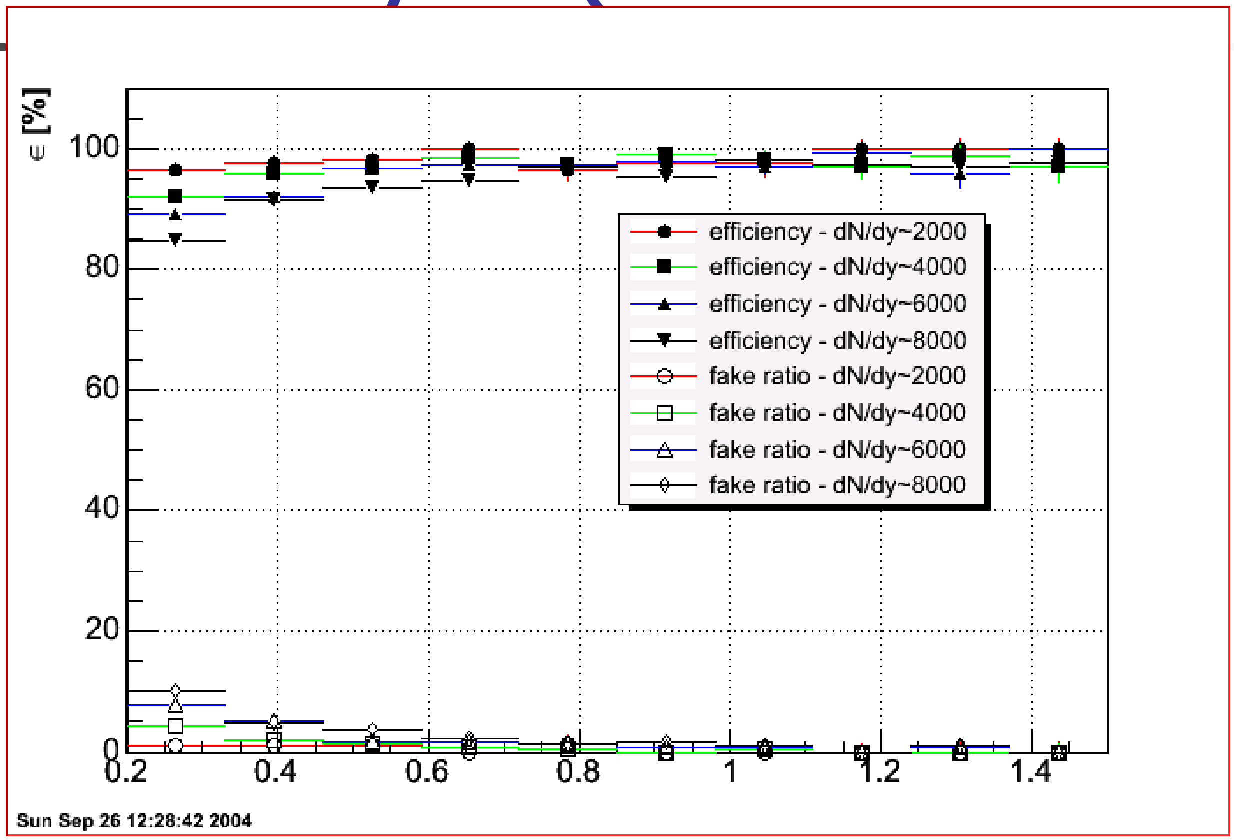
1) Before deletion of the tree of the hypotheses
    1) DCA calculation in the ITS for best "tracks" defined by parallel tracking
    2) Application of rough cuts
        1) DCA, pointing angle, causality (defined by chi2 of the clusters found before the vertex)
    3) Take the best pair of track candidates at the point after V0 vertex obtained in the first approximation
    4) Application of stronger cuts
    5) V0 object registration
2) Deletion of the tree of the hypotheses
3) V0 refitting in the 3rd reconstruction iteration

Results – Tracking efficiency (TPC)



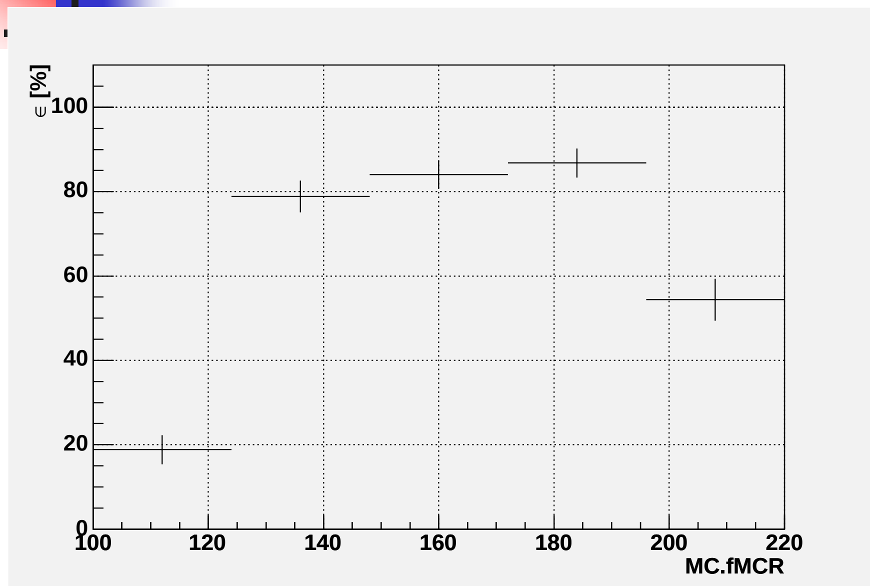
- Efficiency and the fake ratio as the function of the particle momentum
  - Almost 100 % for all multiplicities – old non MIP algorithms ~89%) -(for details see CHEP03)

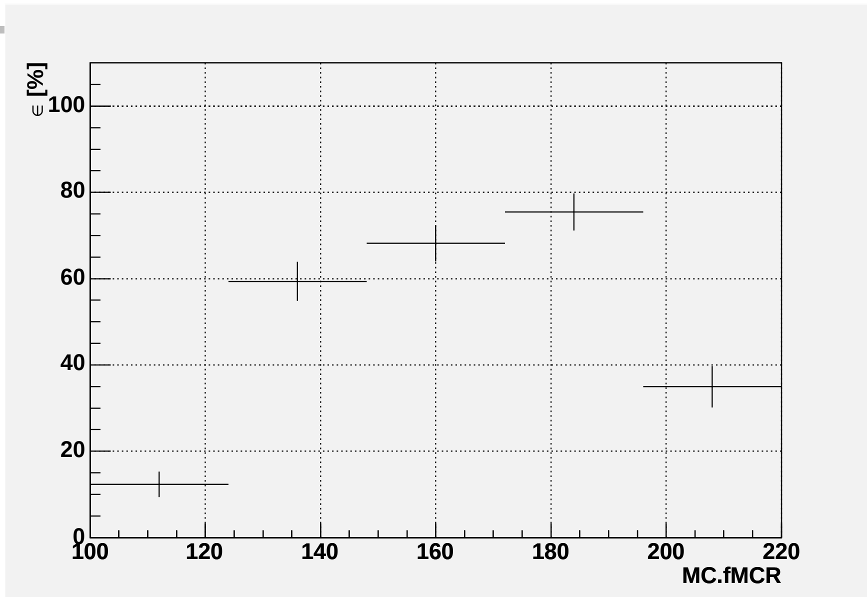
Results – Combined tracking efficiency – (TPC and ITS)



- Efficiency and the fake ratio as the function of the particle momentum

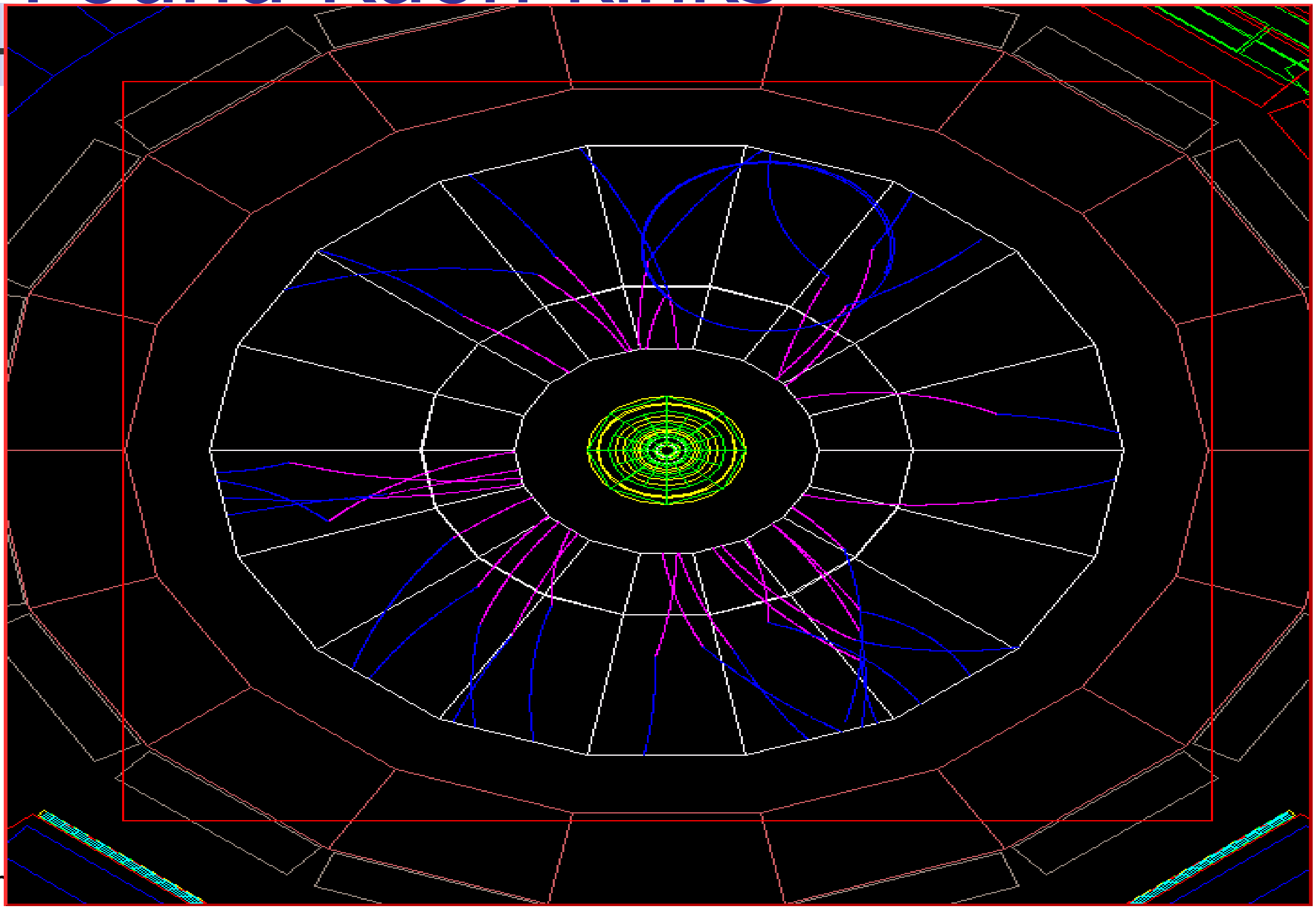
Kink finder efficiency





- Efficiency for Kaons as a function of decay radius
- Left side – low multiplicity (dN/dy~2000) – 2000 Kaons
- Right side – same events merged with central event (dN/dy~8000)

Found Kaon kinks



Tracking performance

- Procesor – Pentium IV 3000 MHz – (dN/dy – 6000)
  - TPC tracking - ~ 40s
  - TPC kink finder ~ 10 s
  - ITS tracking ~ 40 s
  - TRD tracking ~ 200 s

Conclusion

- Alice reconstruction based on MIP implemented
- Performance of the reconstruction greatly improved
  - acceptable also in the highest expected multiplicities (dN/dy~8000)
  - Kink finder efficiency improvement by factor 2.5
  - TPC tracking efficiency from 89% to 99%
  - TPC dEdx resolution improved from 9.5% to 6.9%
  - ITS tracking efficiency also improved
- ALICE experience from combined tracking in the high flux environment indicates that the maximalist approach leads to considerable improvements compared with tracking based on zero-level approximation