Tracking in ALICE

- **OUTLOOK:**
  - **Requirements**
  - **History**
  - **Tracking methods**
  - **Track finding**
  - **Tracking efficiency**
  - **Momentum resolution**
  - **Double-track efficiency and resolution**
  - **Track matching with other detectors**
  - **¡-mass resolution**
  - **Conclusions**

Tracking requirements

- **Environment**
  - dN/dy up to 8000 charged particle (about 4 times that foreseen for RHICH
- **Requirements**
  - good efficiency (above 90%) starting from pt 0.1 GeV/c
  - some efficiency also below (as low as possible)
  - momentum resolution (dp/p) on the level of 1% for low momenta and for high momenta few % at 5 GeV/c
  - good secondary vertexing capability (V0, charm ?)
  - particle identification capabilities, especially for low momentum electrons (which cannot reach other PID)
- **Principal solution**
  - silicon tracker at smaller radii (where affordable)
  - beyond a TPC with track length about 1.5 meter (for dE/dx)

History of ALICE tracking

The first ALICE design (1993)

- **Small magnet**
  - 1 meter diameter
  - 1 Tesla magnetic field
  - very thin (10% of X0) superconducting coil
- **Tracking devices**
  - 5 layers silicon tracker inside the magnet
  - outside the magnet TPC with no field (i.e. return yoke behind the TPC)
- **Two strategies for tracking**
  - do everything with silicon detectors
  - search for straight tracks in TPC (assuming a vertex constraint one has an estimate of momentum) then guided track finding through silicon detectors

Problems: change the design

- **Neither of the methods worked satisfactory**
  - **we had 90% efficiency above 0.4 - 0.5 GeV/c in pt but below the efficiency dropped drastically**
  - **magnetic field was to high, the low-pt tracks banded to much and were lost**
  - **the coil of the small magnet cannot be done thinner than 17 -- 20% therefore the low-pt tracks suffer from large multiple scattering**
  - **we try to put inside the magnet additional silicon layer with a marginal improvement**
- **We have to change the design**
  - **large magnet was needed to house both the silicon tracker and the TPC - problem with funding**
  - **therefore we reuse the largest LEP magnet L3 which has about 12 meter diameter and field up to 0.5 Tesla (we use 0.2 Tesla)**

ALICE tracking system

Two tracking detectors (maybe three ?)

- **ITS (Inner Tracking System)**
  - **six layers of silicon detectors**
    - **2 pixel layers at radii 3.8 cm and 7.4 cm**
    - **2 silicon drift layers at radii 14 cm and 24 cm**
    - **2 silicon strip layers at radii 39 cm and 45 cm**
- **TPC (Time Projection Chamber)**
  - **inner radius 88 cm, outer radius 250 cm**
  - **about 160 pad rows of three sizes**
    - **4x7.5 ; 6x10 ; 6x15 mm^2 from inner to outer**
  - **two different read-out chamber with different pad response function**
- **(TRD (Transition Radiation Detector)**
  - **6 expansion chambers, maybe use for tracking**

Tracking methods

Two large groups of algorithms:

- **Local methods**
- **Global methods**
- **Local methods**
  - ☹ decision taken step by step, when only partial information is available
  - ☺ no need for global track model
- **Global methods**
  - ☺ can operate directly on raw data
  - ☺ decision taken when all information is known
  - ☹ needs precise track model

We need to track down to p_t 100 MeV/c !

Prototyping

- **Strategy for local method**
  - start at outer part of the TPC
  - proceed towards smaller radii
  - extrapolate track to the outer ITS layers (at this step we usually need to use a vertex constraint)
  - proceed layer by layer through ITS
  - reverse the track and extrapolate to outer detectors (TRD, TOF, HMPID)
- **Stand alone tracking in ITS**
  - remove the hits assigned at previous step
  - special track finding in ITS only for low pt tracks
  - can work (with low efficiency) down to pt 60 MeV/c for pions and down to 30 MeV/c for electrons

Prototypes

- **Prototype 0 (1993-1995)**
  - **simple road tracker in the TPC, using smeared GEANT hits as input (starting from ALEPH TPC reconstruction)**
  - **merging with the ITS done by forcing vertex constraint when leaving the TPC (into two outer silicon strip layers)**
- **Prototype 1 (1996-1997)**
  - **taken the experience from prototype 0 first `real' reconstruction program was written (in C++ !)**
  - **still using only smeared hits as input, not a detector response simulation**
- **Prototype 2 (1998-2000)**
  - **TPC crisis (somebody said that TPC will never work for particle densities foreseen)**
  - **use very detail detector response and digitization**
  - **see talk by Yu. Belikov**

Track finding prototype

We choose and prototype Kalman filter for tracking (see Yu. Belikov talk)

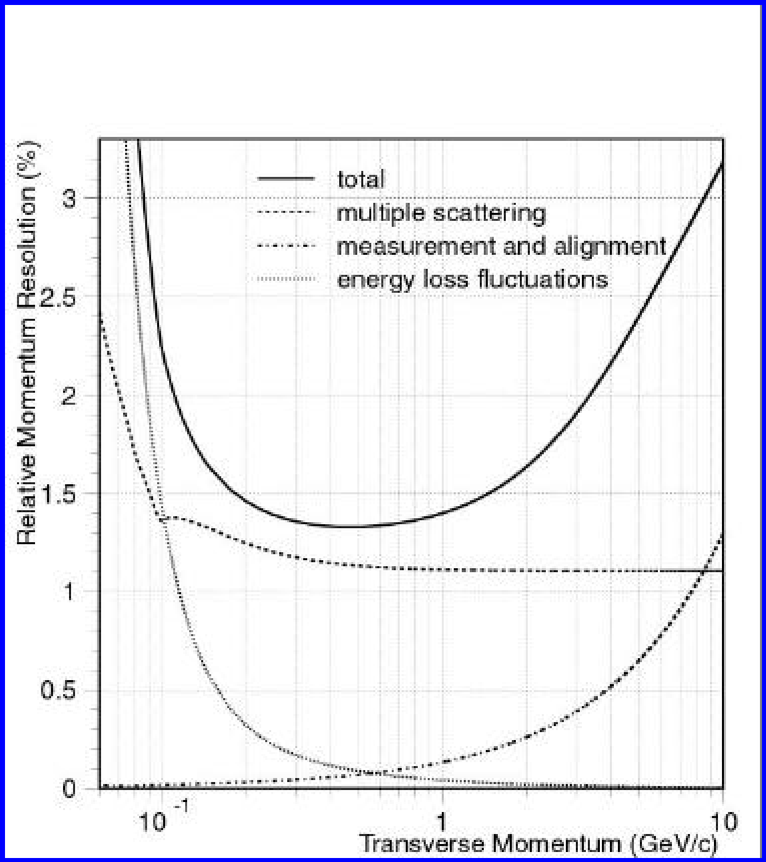
- ☺ no track model needed
- ☺ easy to take into account stochastic processes
  - multiple scattering
  - fluctuations in energy losses
- ☺ gives simultaneous track finding and fitting
- ☺ faster fitting for correlated space-points
- ☺ natural way to connect with other detectors

- ☹ needs cluster finding in advance
- ☹ needs track seeds to start with

We had no serious attempt in prototyping of global tracking method (only not serious)

Momentum resolution (ITS)

Momentum resolution from ITS TDR



Question: **Why the total error is so large compare to the contributions due to multiple scattering and measurement error ?**

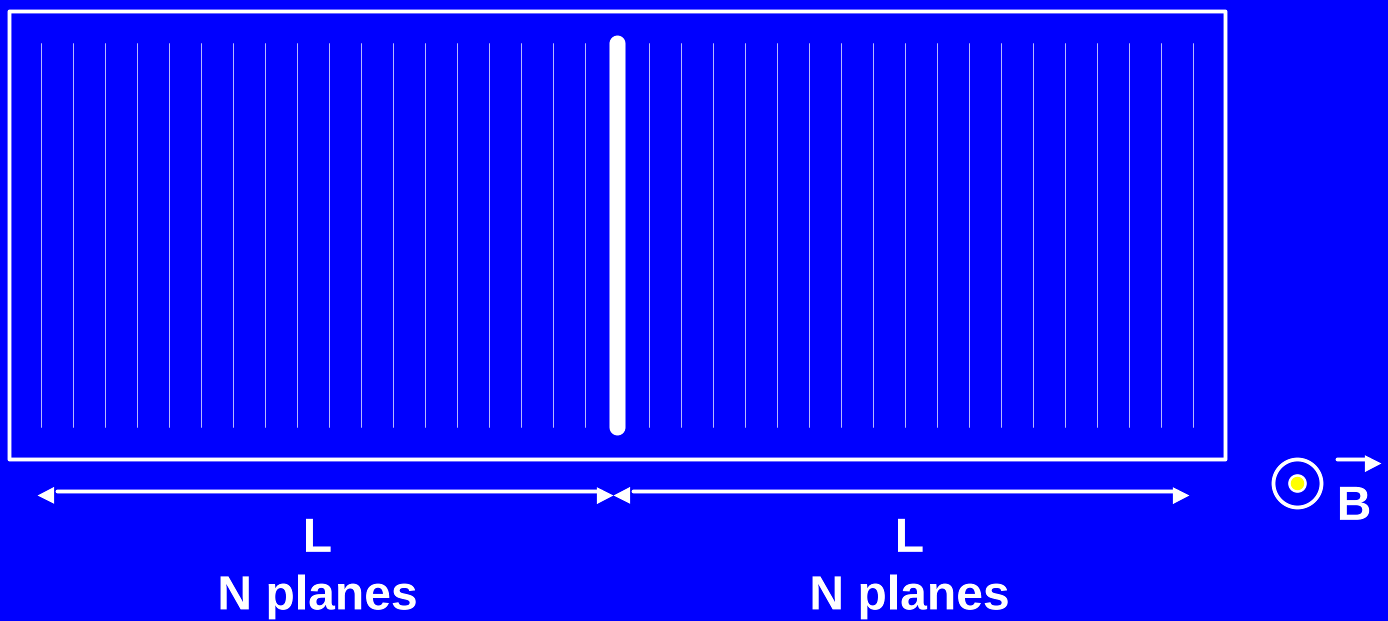
Because of correlation.

Even larger than the linear sum of the two !

Only sum of the norm of covariant matrices has to be larger, not a diagonal term.

Example of BAD detector

- Imagine detector like this one:



detector thickness infinitely small

detector thickness infinitely large

Total error and contributions

- **Total error**

  first half of detector $\quad$ **Dp/p = s_L µ s_p / (L^2 ÖN)**

  the measurement in two halves are independent !

  therefore $\quad$ **s_T = s_L / Ö2**

- **Multiple scattering contribution**

  point error s_p = 0 therefore s_L -> 0

  m.s. contribution $\quad$ **s_{MS} = 0 / Ö2 = 0**

- **Point error contribution**

  thickness of middle plane goes to zero

  the two halves are correlated $\quad$ **Dp/p = s_{PE} µ s_p / [$(2L)^2$ Ö2N]**

  therefore $\quad$ **s_{PE} = s_L / (4Ö2)**

Finally: $\quad$ **s_T = 4 (s_{PE} + s_{MS}) > s_{PE} + s_{MS}**

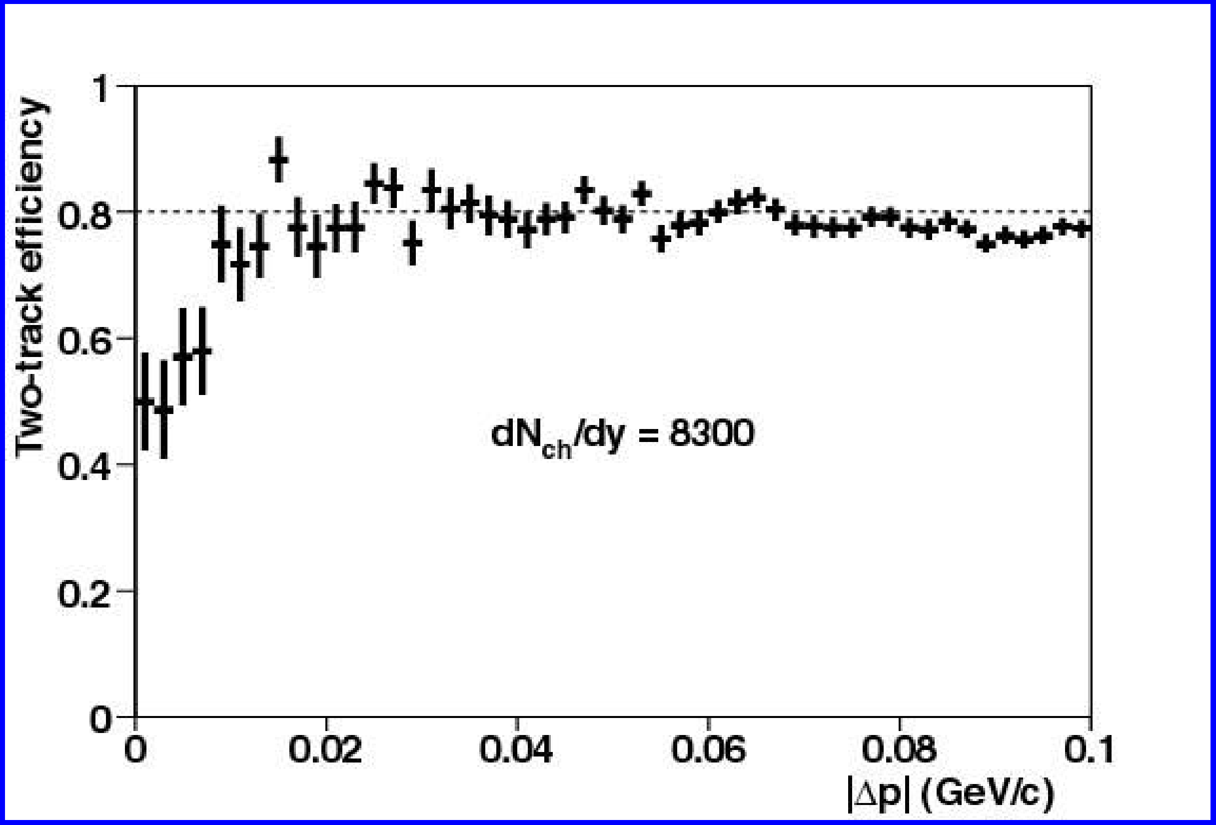
What about real detectors ?

- Formula with quadratic sum of contributions (see PDG) is valid only for uniform distribution of scattering material (bubble chamber formula)
- For modern detectors it is not more true
  - even for high momenta !
- Typical example is ALICE combination of ITS and TPC
  - there is obviously non negligible material in between
  - this material is responsible for loss of correlation !
  - once again: the interface between ITS and TPC is crucial place to be optimized and watched
- Another example: muon detectors with measurements in front and after absorber

Two track efficiency

Two-track efficiency for dq -> 0 goes down to » 40 %

not to 0 ! (here helps multiple scattering in ITS material !)



Two-track resolution

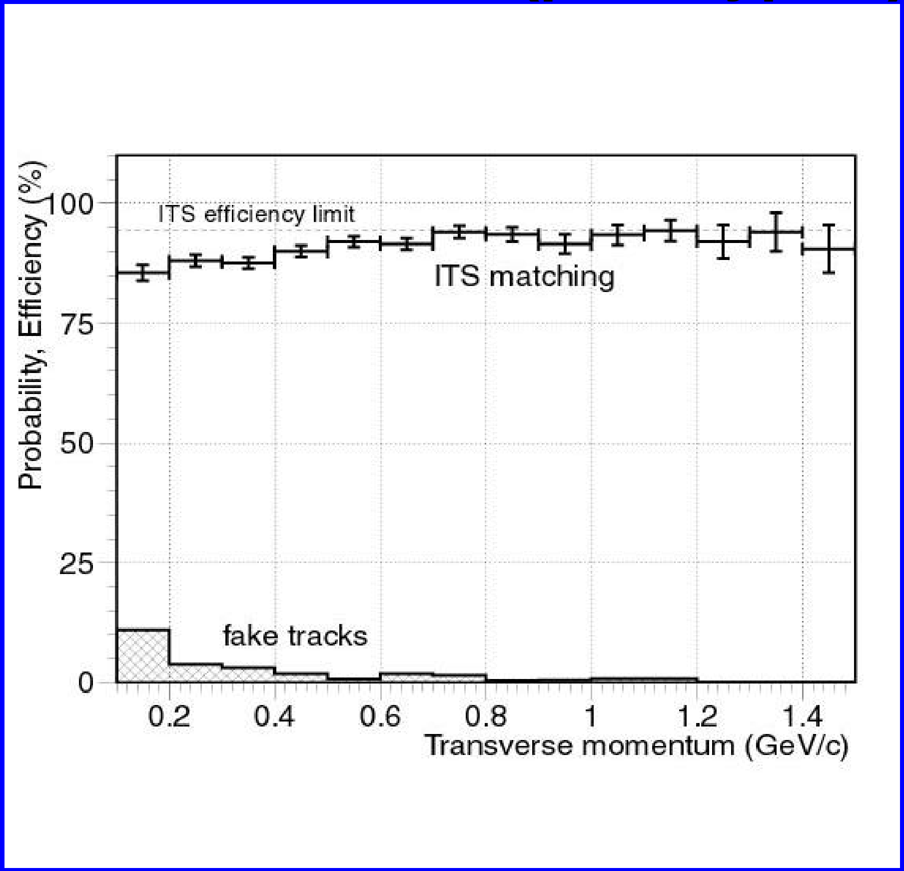
- dq_{long} and dq_{side} do not depend on momentum and on charged particle density
  - their resolutions is determined by angular resolutions
- dq_{out} does depend on both momentum and charged particle density
  - its resolution is determined by momentum resolution itself

Two-track resolutions in MeV/c:

dNch/dy	dq_{long}	dq_{side}		dq_{out}	
		p_t(GeV/c)	0.2	0.5	1.0
1000	1.0	1.1	3.7	7.4	13
6000	1.1	0.5	3.9	9.5	16

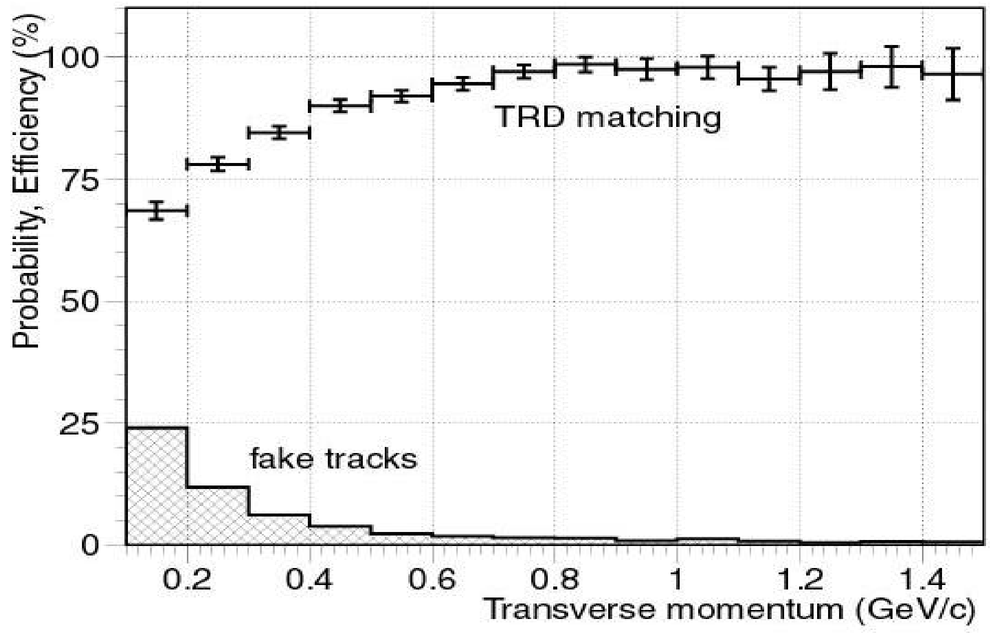
Track matching with ITS

Extrapolation of Kalman filter to ITS with tighter vertex constraint (prototype 1)



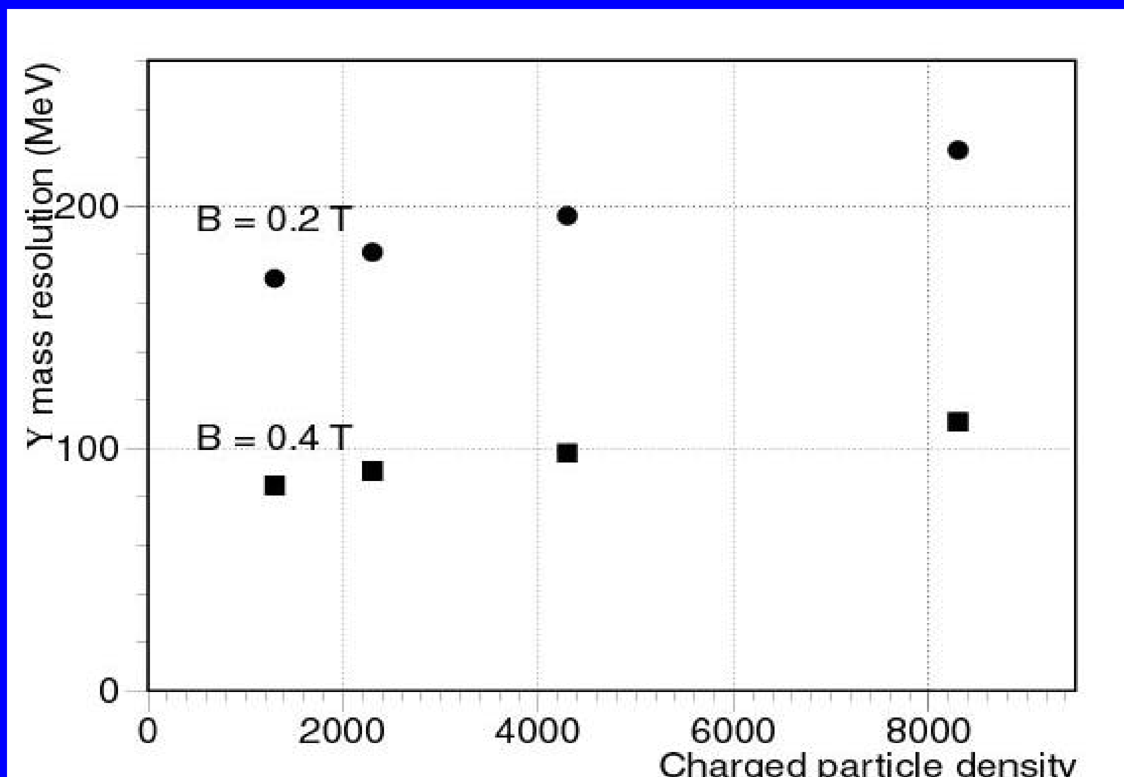
Track matching with TRD

- Extrapolation of TPC tracks to TRD - simple simulation - preliminary estimate (prototype 0)



¡ -mass resolution

- Depend on charged particle density
- Momentum resolution at ‘nominal’ filed (0.2T) is insufficient to achieve ¡’ and ¡’’ separation



0.4 T

Conclusions

- We have well defined strategy for tracking - maybe we will still do some `global’ prototype
- Results from TPC prototype 2, see Yu. Belikov talk
- Two-track efficiency is very good, but
  - ‘out’ component of dq is worse then required
- Track matching to other detectors - satisfactory
- ¡ resolution practically within requirements if we increase magnetic field to 0.4 T
- Finish prototype 2 through the ITS and TRD - end of this year