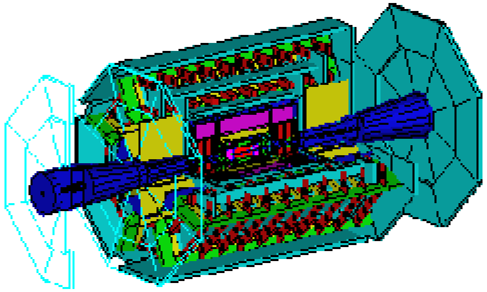
HIGHLIGHTS

of the

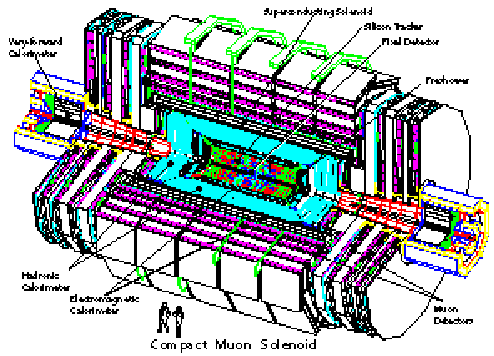
PARTICIPANTS ($\Sigma \approx 100$!)



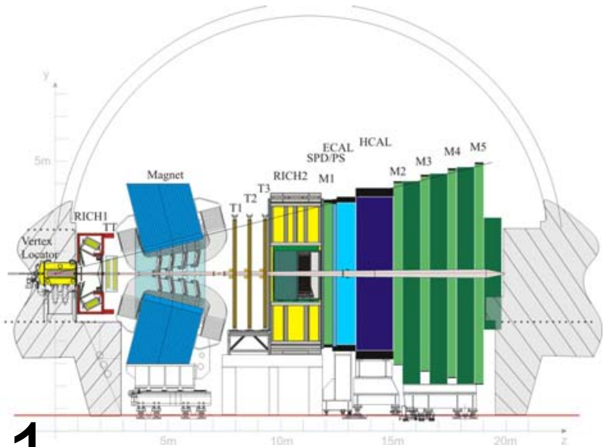
ATLAS

A Toroidal LHC ApparatuS

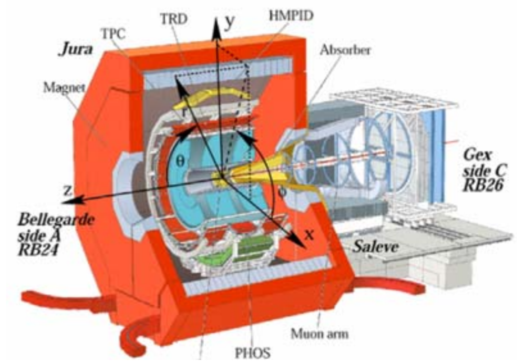
- ATLAS – 29
- CMS – 30



- LHCb – 18



- ALICE – 5 +1
- TOTEM - 4
- Others - ~ 10



PROGRAM

MONDAY

- Introduction – alignment challenges: ATLAS, CMS, LHCb, ALICE (by AJ)
- Mathematical methods & algorithms
  - Alignment algorithms (Volker Blobel)
  - Alignment using a Kalman Filter Techniques (Rudi Fruehwirth)
- Alignment experience from other experiments: STAR, BABAR, ZEUS/H1, SLD, CDF

TUESDAY

- Overviews of selected topics (covering all LHC experiments)
  - Detector description (geometrical modelers) (by Cvetan)
  - Tracking software & algorithms
  - Impact of misalignment on physics
  - Validation of the alignment

PROGRAM – cont.

- Alignment strategy for the LHC experiments
  - LHC machine plans (Mike Lamont, AB-OP)
  - Strategy from CMS
  - Strategy from ATLAS
  - Strategy from LHCb
  - Strategy from ALICE (Javier, Raffaele, Marian)
- Workshop dinner

  <u>**WENDSDAY**</u>
- Alignment survey data (Christian Lasseur et al. ,TS-SU)
- Workshop Summary (Dave Brown)
- Round Table discussion: workshop continuation ?, focus of the next meeting, documentation (Yellow Report ?), organization of the inter-collaborative work, lessons learnt …

LHC DETECTOR ALIGNMENT CHALLENGES

- **Detector** presentation: mechanics, granularity (# of degrees of freedom), hardware align. systems
- **Sources of misalignments**: mechanical precision and stability, sensitivity to B, thermal effects, aging etc
- **Methods and software tools** for realignment and alignment validation
- **Impacts of misalignment** on physics performance,
- **Goals** (20% degradation due to misalignment for ex.) expected problems (practical and numerical)

Tracking requirements

ATLAS ID TDR

Degradation due to geometry knowledge:
<20% on impact parameter and momentum

Reasonable goal:

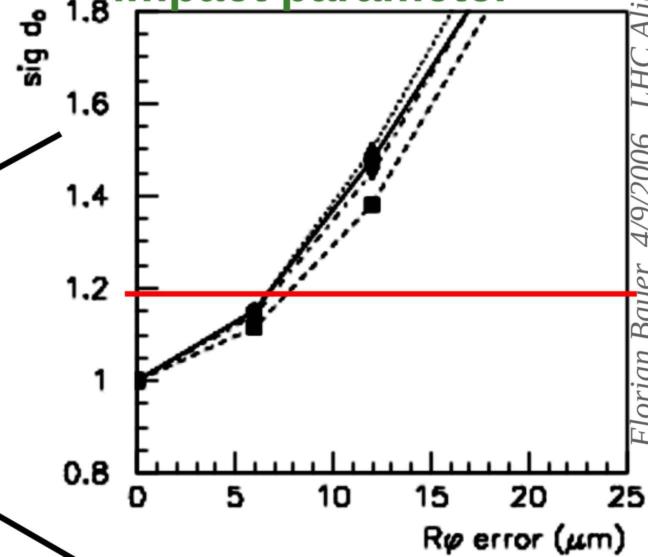
Pixel: $\sigma_{R\Phi}$= 7 µm
SCT: $\sigma_{R\Phi}$= 12 µm
TRT: $\sigma_{R\Phi}$= 30 µm

Furthermore studies
of impact of SCT+Pixel random misalignment
on B-Tagging abilities show:

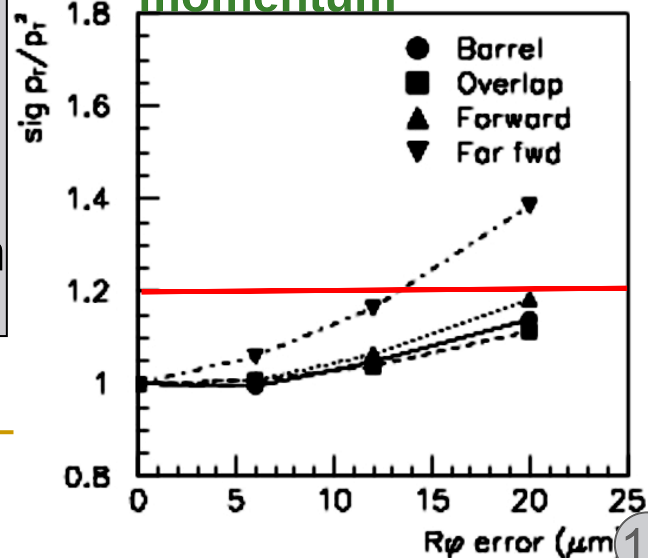
light jet reduction get worse by 10% for $\sigma_{R\Phi}$=10µm
light jet reduction get worse by 30% for $\sigma_{R\Phi}$=20µm

S. Corréard et al, ATL-COM-PHYS-2003-049

impact parameter



momentum



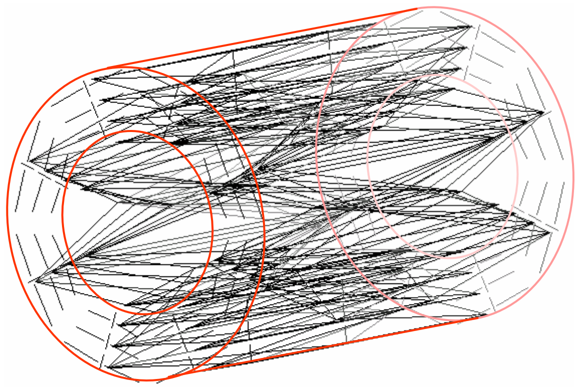
Florian Bauer, 4/9/2006, LHC Alignment Workshop

Software requirements

- ID consists of 1744 Pixel, 4088 SCT and 124 TRT modules
  => 5956 modules x 6 DoF ~ 35.000 DoFs
  This implies an inversion of a 35k x 35k matrix (Millepede)
- Use calibration as X-ray and 3Dim measurements to setup best initial geometry
- combine information of tracks and optical measurements like FSI.
  (frequency scanning interferometry)
- Reduce weakly determined modes using constraints:
  vertex position, track parameters from other tracking detectors, Mass constraints of known resonances, overlap hits, modelling, E/p constraint from calorimeters, known mechanical properties etc.
- ability to provide alignment constants **24h** after data taking
  (Atlas events should be reconstructed within that time)

Many approaches

- Global χ^2 minimisation (the 35k x 35k inversion)
- Local χ^2 minimisation (correlations between modules put to 0, invert only the sub-matrices, iterative method)
- Robust Alignment (Use **overlap residuals** for determining relative module to module misalignment, iterative method)



Furthermore work done on:

- Runtime alignment system (FSI)
- B-field

Alignment Software requirements

- Describe detector taking into account calibration for all optical elements, chambers. Description is 80% of the alignment software job…. Visualisation tools vital.

- Ability to combine optical information with straight or High Pt tracks

- Describe the 9 chamber **deformations parameters**: in the fit 6 + 9 DoFs per chamber.

- Handle up to 10.000 DoFs in the Barrel and roughly the same in the Endcap

- Run online (1 correction per hour) with a latency of 24h.
  ➔ robust algorithms, automated dataflow, monitoring, use of Databases as IO

Today we have 2 alignment softwares:
ASAP describing the Barrel alignment
AraMyS describing the EndCap alignment

ASAP: uses iterative χ^2 fit, segmentation into sub-alignments foreseen
AraMys: Minuit, segmentation into sub-alignments

Conclusion

(……………………………………………………………)

• Installation and validation of the Muon **hardware alignment** components on the way
• Muon: optical alignment software exists and validated at H8 test-beam
• Muon straight and High Pt track alignment still under development

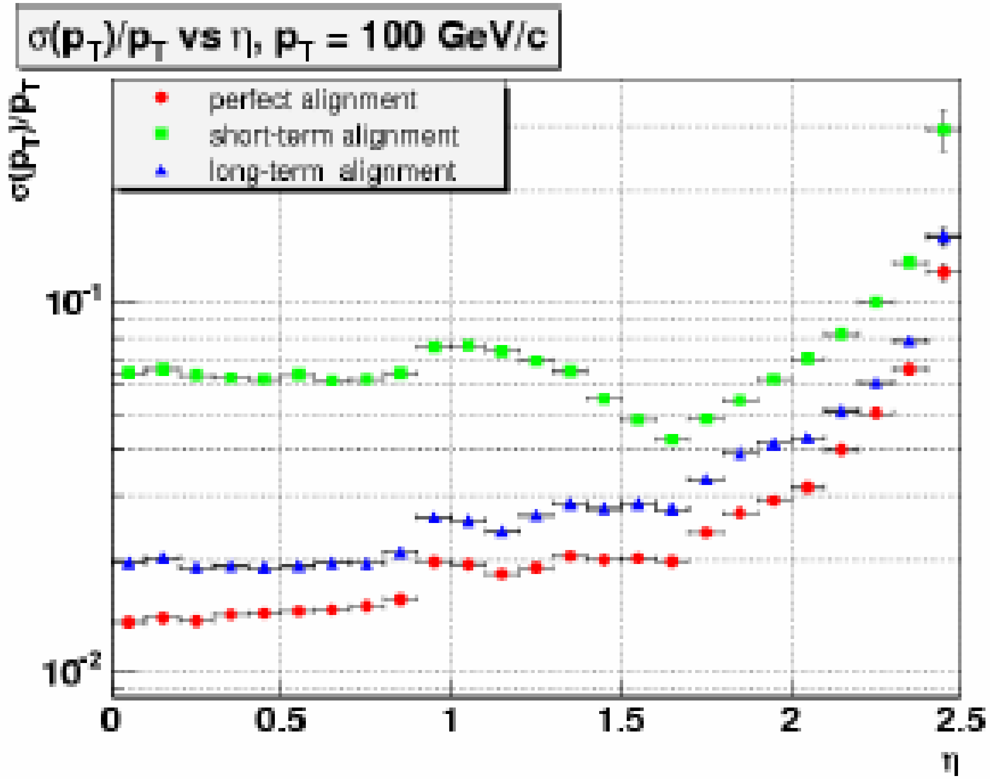
• Inner tracker alignment: many algorithms exists today
• Validation in the H8 test beam done

Between ATLAS Inner Tracker and Muon Spectrometer many synergies can be gained !

This should be even more true on LHC level !

- Misalignment is due to
  - Precision of assembly
  - Stress from magnetic field or thermal stress
  - Changes due to humidity and gas evaporation (from carbon fiber support)
- Misalignment will be time dependent!

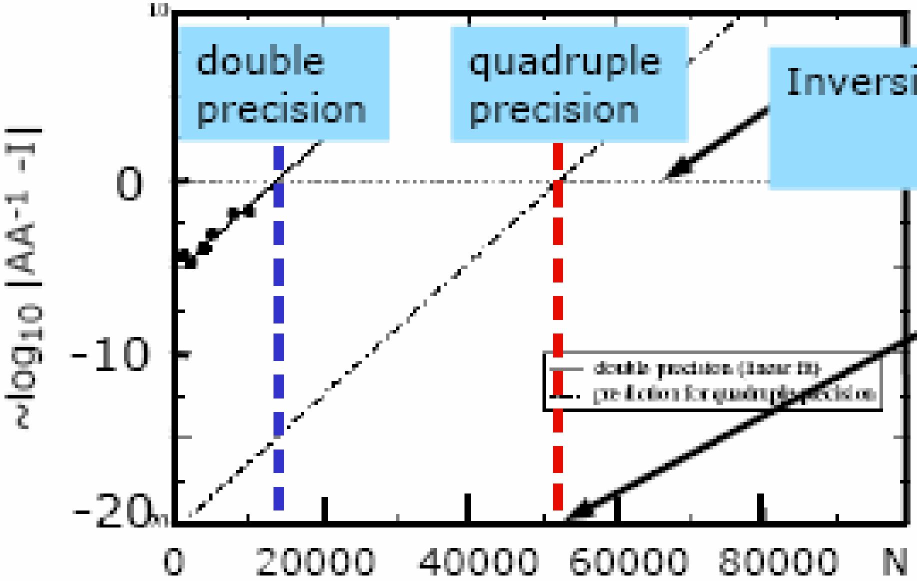
G. Steinbrück, Tue 10:00



- Ideal geometry
  - No misalignment
- Short-term (<1 fb^{-1})
  - First data taking
  - Hardware alignment used
- Long term (1-5 fb^{-1})
  - First alignment with high-statistics tracks, for first physics analysis
- Final alignment
  - Do not deteriorate detector res.

Strip tracker: Algorithmic challenge

- Estimate ~6 parameters per strip tracker module
  - CMS strip tracker is built of 15148 modules → alignment parameter covariance matrix E or matrix to be inverted $A^T W A$ are sized (15148*6)^2 = 90888^2
  - Store E or $A^T W A$ in memory (~32 GB for double precision → sparse storage)
- Experience from ATLAS (COM-INDET-2004-011)
  - Matrix inversion and Diagonalization algorithms break down at ~50000 parameters due to CPU time limitation and floating point precision:



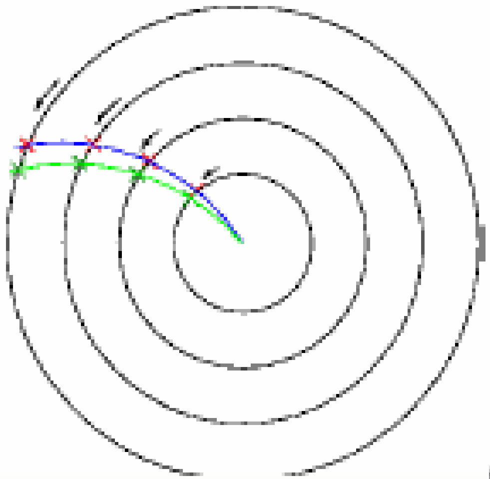
Not more than ~50000 parameters possible even with quadruple precision! (ATLAS: 34992)

→ We need more clever algorithms!

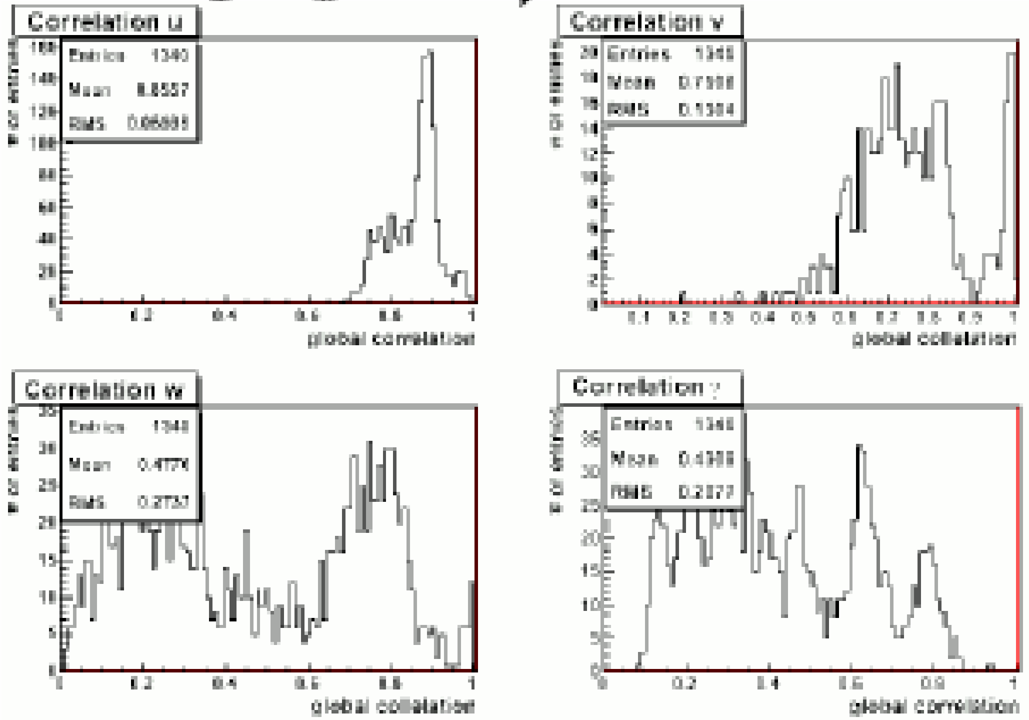
V. Blobel, Mon 10:45

R. Frühwirth, Mon 11:45

- Certain transformations leave χ^2 unchanged
  - Simplest: Layer rotation by angle α
    - Distorts p_T spectrum and inv. mass
  - A lot more higher modes...
  - High global correlation observed by using single tracks without any constraint
- Use constraints (under study)
  - Laser Alignment System
  - $Z \rightarrow \mu\mu$ with Z mass (helps)
  - Cosmics (helps a lot in the barrel)
  - Beam halo (useful for endcaps)
  - Implement global & survey constraints in χ^2
- Best use of all available data!



Alignment of barrels, layers, rods:
Example using $Z \rightarrow \mu\mu$ with mass constraint, cosmics, survey information



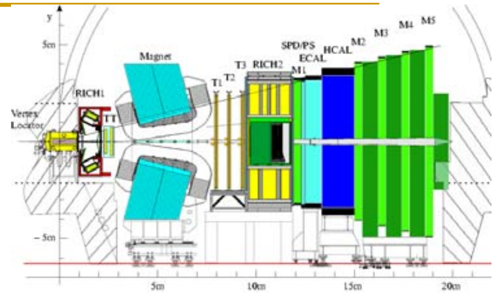
Conclusion

- Many challenges in front of CMS
- Some are more challenging than others, but all need to be met
- Alignment only possible after many other detector effects are understood
  - Non-uniform magnetic field, material budget, time dependent effects, algorithmic challenge (number of parameters), position & orientation of sensors, module topology, combining different alignment data sources, ...

Alignment is "The Art of Calibration"

Thank you for your attention

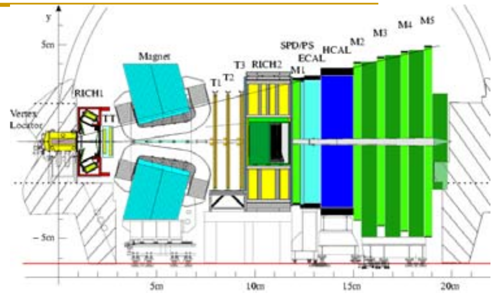
Tracking System Challenges

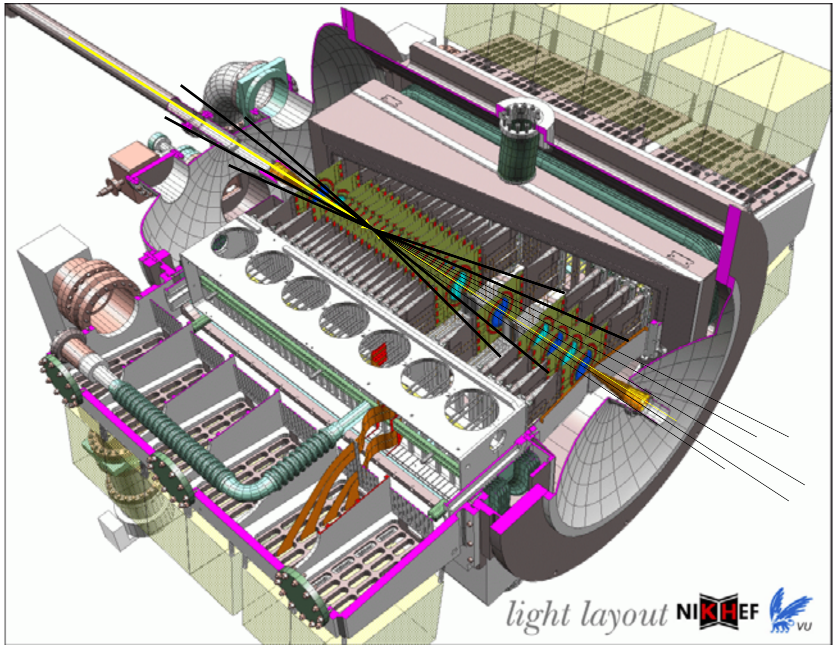


(LHCb , by Steve Blusk)

- ❑ Large track density
- ❑ Trigger uses tracking info
  - ❑ Requires good alignment
  - ❑ Online updating of constants if needed.
- ❑ Tracking algorithms need to be FAST, as they are executed online. Want offline pattern recognition very similar to online version, except for fine tuning of alignment & calibrations.
- ❑ Minimize material (no surprise here)

Vertex Detector Challenges

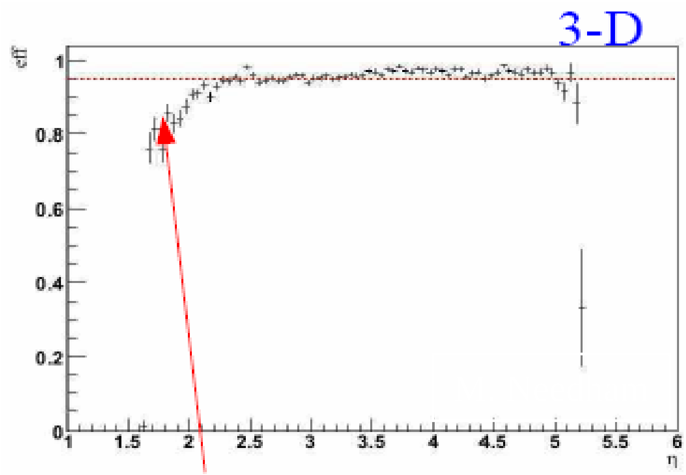




- Most precise device in LHCb <u>moves</u>
  - Retracted by ~ 3 cm in-between fills
  - Reinserted to ~ 8 mm after stable beams

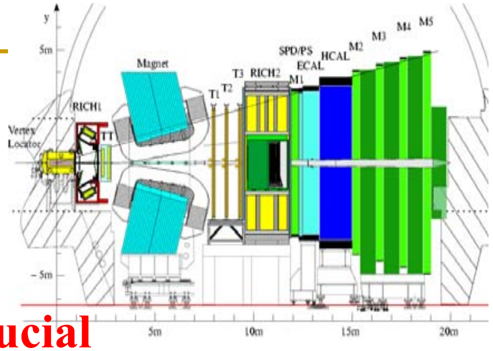
- Integral part of the trigger
  - RZ (2D) tracking/trigger scheme requires transverse alignment between modules < **20 μm**.
  - Internal alignment monitoring/updating as necessary (online vs offline), 2D vs 3D
  - Rest of tracking system (online vs offline)
    - Momentum estimate using VELO-TT in HLT.

- Need for "same" tracking in HLT and offline:
  tradeoffs of speed/efficiency/ghost rate

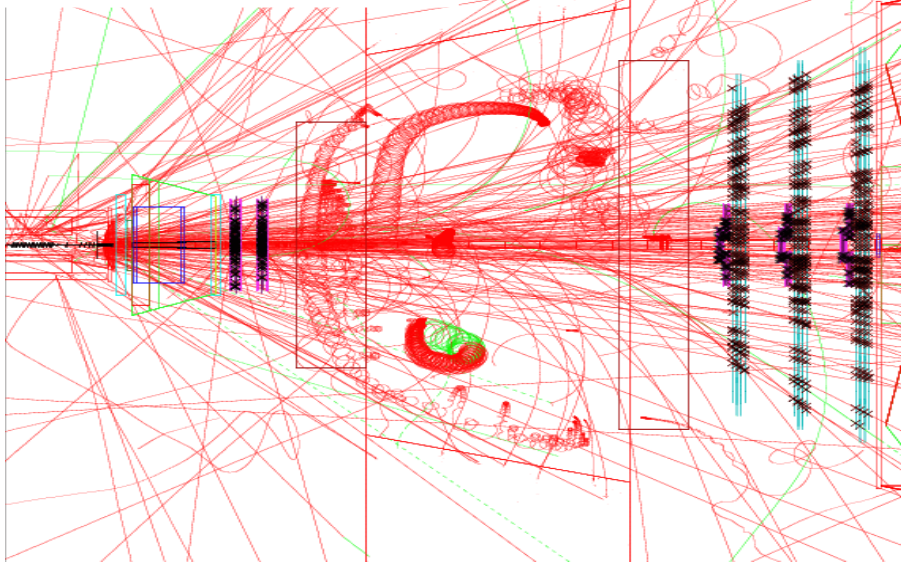


~4% ghost rate (3D)
~7% ghost rate (2D)

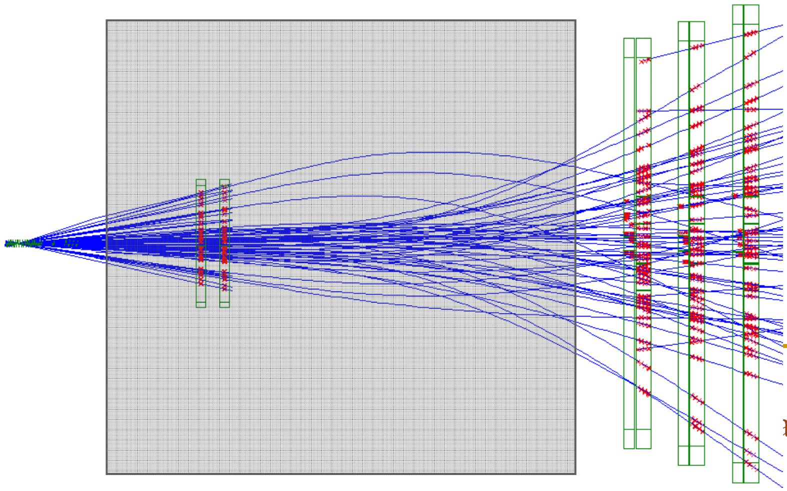
Software Alignment at LHCb



Generated MC Particles



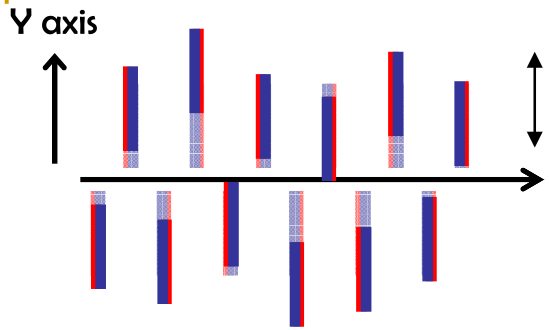
Reconstructed Event



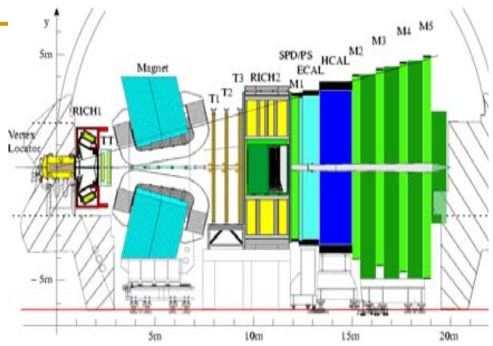
General Strategies

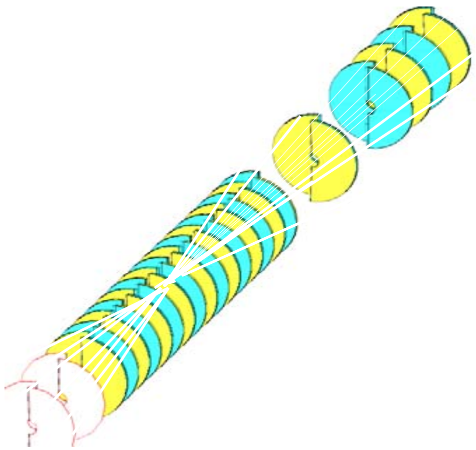
- ❑ **Magnet OFF data crucial**
  - ❑ Separate magnetic field effects from geometrical ones.
  - ❑ Commissioning
  - ❑ After access to service tracking system
  - ❑ Otherwise, periodically, based on unexplainable change in alignment
- ❑ Pre-selected track samples
  - ❑ Low multiplicity events
  - ❑ Isolation requirements around track (if necessary)
  - ❑ Magnet OFF: Use energy from calorimeter
- ❑ Magnet ON data
  - ❑ Tweak alignments from Magnet OFF
  - ❑ Cross-check with K_s, J/ψ, Y, $D \rightarrow K\pi$, Z^0, *etc* (after *dE/dx* corrections and B field map validated)

Random Velo Misalignment

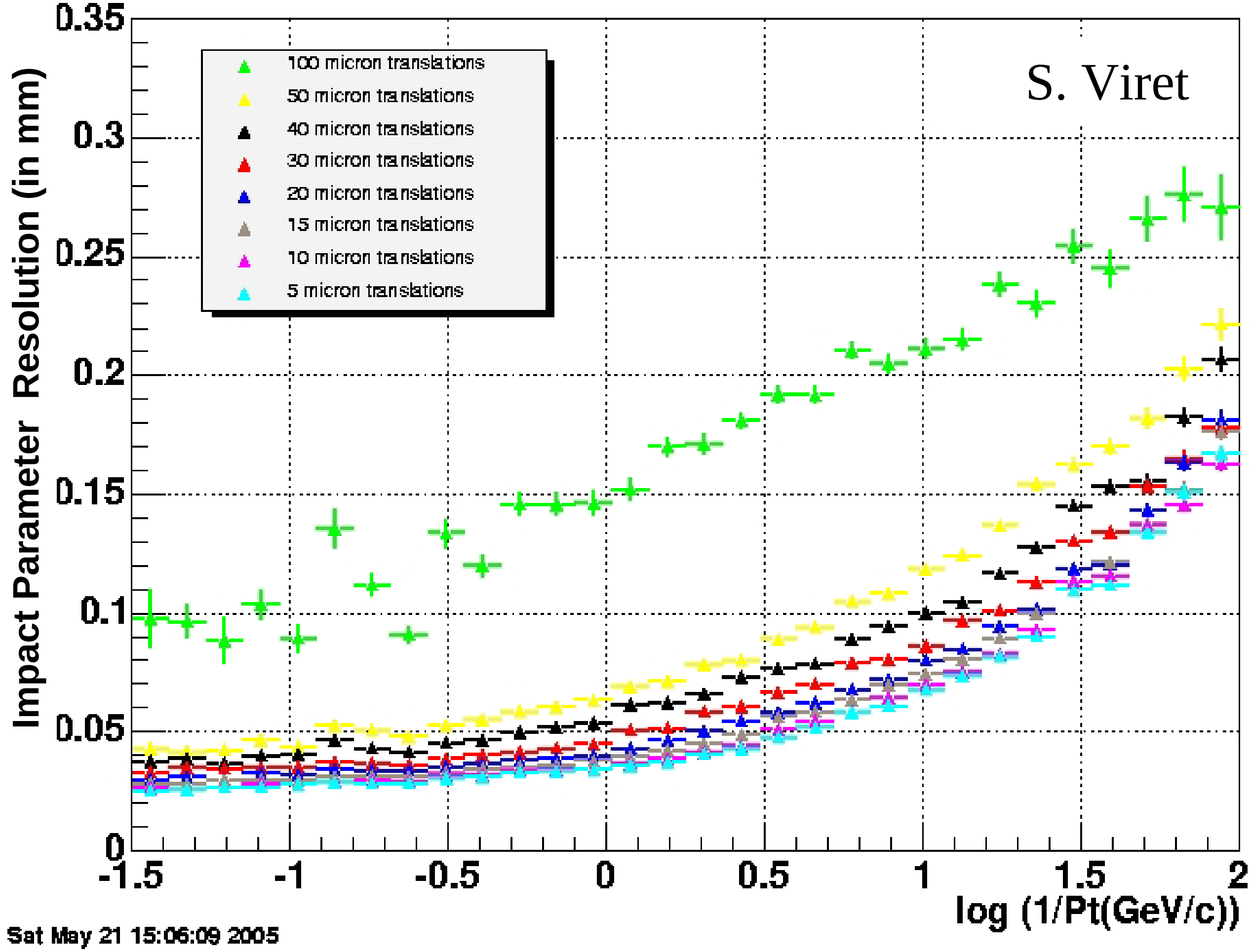


Mechanical placement, σ < **20 μm**,

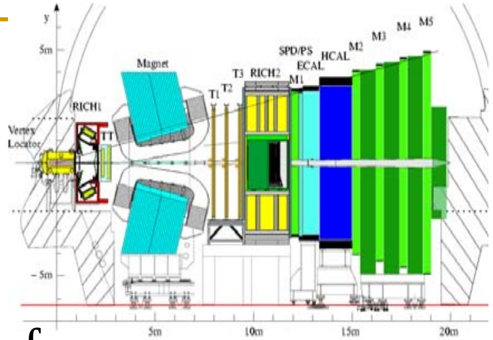




(Velo = Vertex Locator)



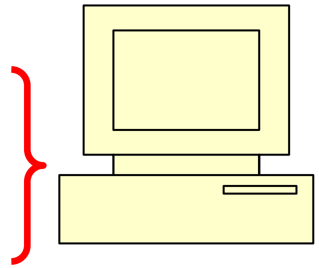
(LHCb challenge) Summary



- LHCb Trigger requires "good" online alignment.

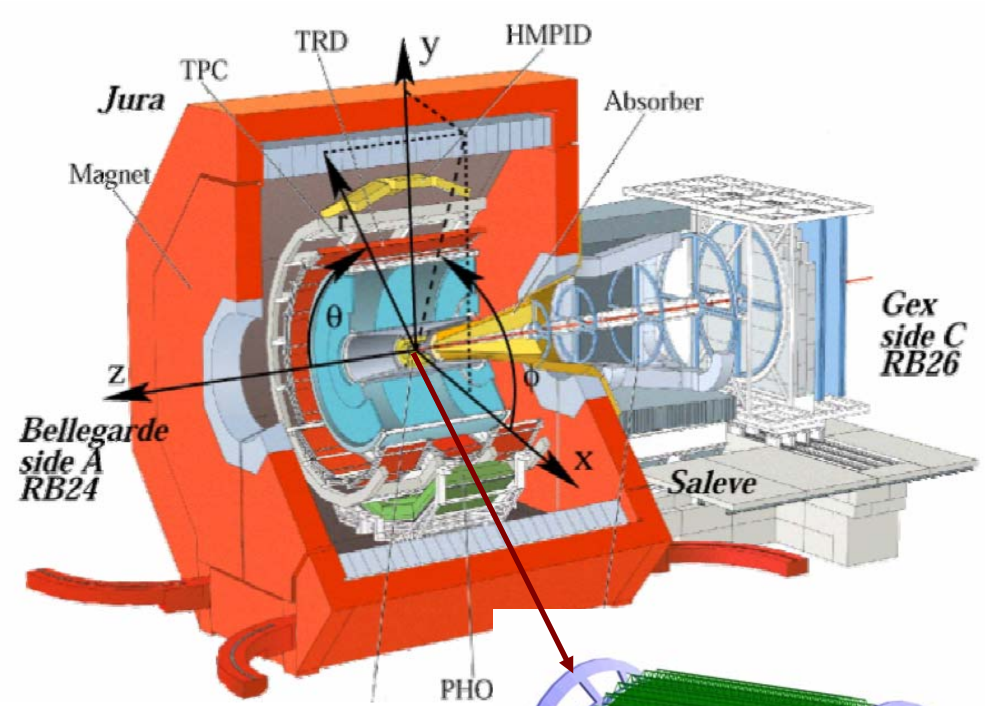
- Extraction/re-insertion of VELO every fill requires updating of some subset of alignment constants
  - Probably default alignment constants from previous run to start off (aside from an overall ΔX (ΔY) from VELO motion controller between fills)
  - Always update ? Or only when significant change?
- Large number of planes and overlap regions facilitate alignment between detectors
- Magnet OFF data critical to decoupling geometry from B field effects
  - More work needed on proving that dE/dx and B field mapping "issues" can be de-convoluted.
- Fine tuning of alignment for final offline analysis.

- Software Alignment Monitoring:
  - Low-level: #Hits/track, χ^2, IP, residuals, #tracks/event, etc
  - High level: Masses, mass resolutions, relative particle yields.



ALICE Alignment Challenge

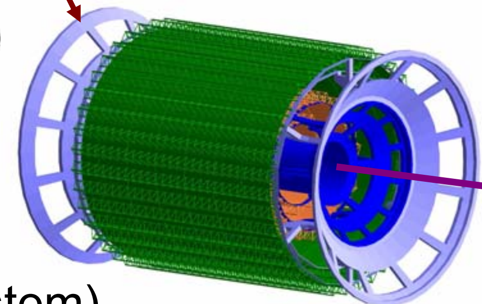
(A Large/LHC Ion Collider Experiment)



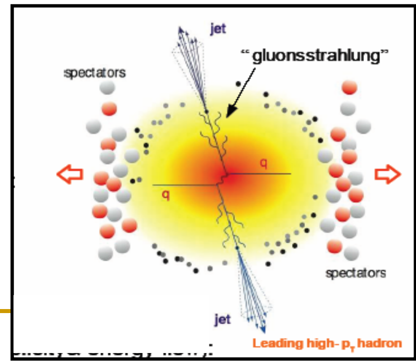
OUTLINE

- physics @ ALICE
- ALICE detectors
- software framework
- tracking & vertexing
- alignment aspects and challenges

ITS



(Inner Tracking System)



Impact of misalignment on Physics

- All physics performance figures obtained with the perfect geometry (same for the ALICE Phys. Progress Report)
- γ mass resolution as a function of misalignment (in Muon Arm) studied (see talk by J Castillo)
- This summer Physics Data Challenge (PDC06)
  - (hypothetical) **residual misalignment in**
  - part of the simulation with the ***full misalignment*** (expected Day-1 misalignment)
- Analysis of the PDC06 data ➔ assessment of the physics quality degradation due to misalignment (underway !)

Alignment Challenges

- Initial misalignment within specifications (50 – 200 μm)
- Inner Tracking System

  → robust track based alignment

  10 micron alignment precision goal

Alignable elements:
SPD -- 240
SDD -- 260
SSD - 1698
Total – 2198

- TPC calibration & alignment (ExB effect !)
- Muon Arm & TPC ←→ ITS alignment
- TRD,TOF, RICH(HMPID)... → inter - detector alignment
- Fast alignment and validation procedures (during data taking!) → **C**ondition **D**ata **B**ase
- Alignment stability monitoring (hardware & software)

Mathematical Methods and Algorithms

- **Alignment algorithms** (V. Blobel), overview of the most frequently used algorithms, more detailed presentation of the Millepede algorithm and its developments (Millepede II) ➔ http://www.desy.de/~blobel
- **Alignment using a Kalman Filter technique** (R. Fruehwirth) – a novel approach in which Kalman Filter is used alternatively for tracking and alignment parameters update

Summary and Outlook

- Kalman filter for sequential estimation of alignment constants
- Successful test on small-scale setups
- Advantages
  - No solution of large systems of equations
  - Depth of correlations can be taylored to setup
  - Errors of estimated alignment constants are always available
  - Can be used for stopping criterion

R. Frühwirth, E. Widl LHC Alignment Workshop 38

Summary and Outlook

- Disadvantages
  - Larger computational expense per track
  - More bookkeeping required
- Outlook
  - Extend to full set of angles and shifts
  - Study alternative approaches to correlation lists
  - Speed optimization
  - Large-scale examples

R. Frühwirth, E. Widl LHC Alignment Workshop 39

Alignment experience from other experiments

- STAR (S. Margetis)

Alignment/Calibrations affect everything

DCA-XY ~ 140μm / p(GeV) ← Remember this number

Drifting complicates the Alignment process

↓

If you have drift detectors make sure you have plenty of redundant monitoring systems (lasers, charge injectors etc.

Summary

(S. Margetis for STAR)

- **Recent interest in charm physics re-focused STAR's interest in its vertex detectors**

- **The presence of drift silicon technology (like in ALICE) complicates the task of Alignment**
  - **but also presence of non-drifting detectors (strips or pixels) will prove invaluable**

- **Our Global Alignment approach and techniques were successful to overall shifts better than 20 mkm**
  - **which for this device is sufficient**

- **The Self-Alignment methods are still under development.**

- **STAR has a funded R&D active pixel effort for an ultra thin device @ 2cm from the vertex**

Overview talks for selected topics (all LHC experiments)

- **Detector Description** (Cvetan) – different systems but large (logical) similarities
- **Tracking software & algorithms** (A. Strandlie) – including input from ALICE (from Marian)
- **Impact of Misalignment on physics** (G. Steinbrueck) – a lot of study in other LHC experiments, from ALICE only MUON results on Y family resolution
- **Validation of the Alignment** (T. Golling) – private discussions (Raffaele and me with Tobias), many ideas, some experiment dependent features

Alignment Validation

Tobias Golling on behalf of

ALICE ATLAS CMS LHCb

- **Introduction & Overview**
- **Mass resonances: J/Ψ, Υ, Z**
- **Resolution Effects**
- **Degenerate Modes**
- **Monitoring**
- **Validation with MC**
- **Summary**

LHC Alignment Workshop – September 05 2006

Why Validate?

- The residual based alignment has limitations:

A 1-dimensional measure is used to determine 6 DoF per module (underconstrained) – this leads to more than one solution

→ Physics is biased

→ Validate to detect "wrong solutions"

Go one step further: Validation ⇒ Constraint

→ Use as alignment correction, make alignment more robust

however, then we cannot use it anymore to monitor

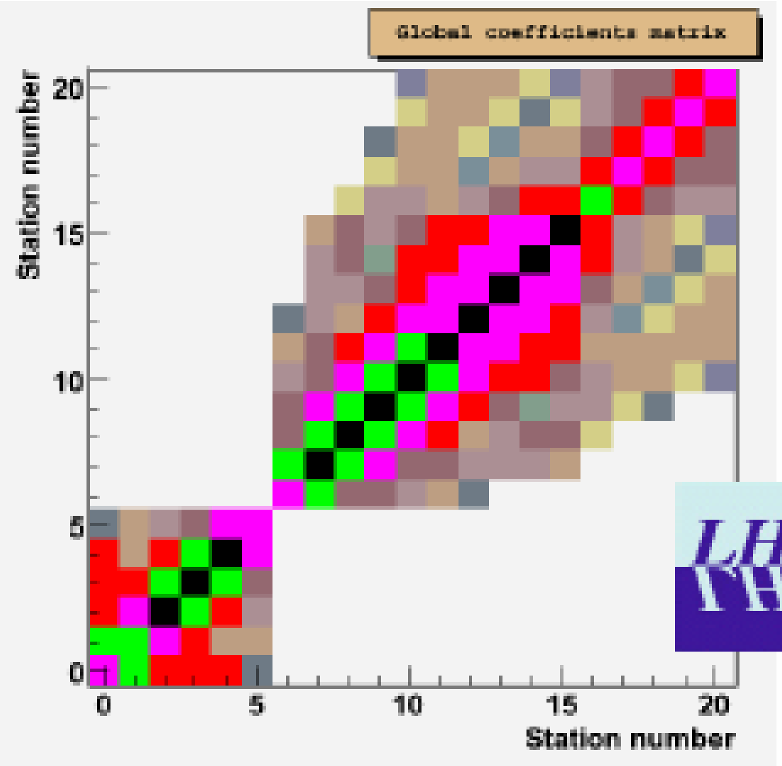
Rule of thumb:

- "Practical constraint" ⇒ feed back into alignment algorithm as additional constraint (straightforward in global algorithms)
- Else: use as monitor

Possible Handles

- Tracks correlating different modules, not from beamspot
  - Cosmics ⇒ Barrel, off-axis tracks (can reconstruct?), "two arms" muon trigger, ATLAS: ~40Hz through Inner Detector, ~1Hz through Pixel
    Caveats: Illumination not uniform / low statistics / low momentum
  - Halo muons ⇒ Endcap
  - Beam-gas, Caveat: low momentum (E_{CM}=113GeV)
  - Parasitic collisions at 0.9TeV

Rate, trigger? - ATLAS: Minbias scintillating trigger



Alignment algorithms more robust if parameter matrix well populated

Possible Handles cont'd

- Standard candles: J/Ψ, Υ, Z,...
  - Mass resolution probes pT resolution

  Caveat: Measure only convolution of material description, B-field uncertainty, misalignments ⇒ Disentangle!

  Rate, trigger?

- Overlap hits in the same layer: $\text{residual}_{\text{outer}} - \text{residual}_{\text{inner}}$
  - Not affected by misalignments elsewhere in the detector
  - Errors on $\text{residual}_{\text{outer/inner}}$ are highly correlated and subtract out
  - Less sensitive to MS, use lower pT and higher track density
  - Circumference constraint

  Caveats: Low statistics

  Usually used already in alignment algorithm

- Use redundancy of detectors: E/p, eta-phi match between tracking and calorimetry

- Alignment monitoring:
  - Lifetime, mass, residuals vs. eta, phi, pT, charge, module position,...

Possible Handles cont'd

- Biased track parameters can probe some degenerate modes
  e.g. IP distribution, charge asymmetries,...

- Vertex constraint: common vertex for a group of tracks

- Compare track-based alignment with survey and hardware alignment
  - Survey & hardware based alignment doesn't have the problem of "wrong solutions"

- Magnet-off data can eliminate some "wrong solutions"
  Caveat: turning B-field on and off changes the geometry,
  no pT measurement

Summary

- Central physics
- Cannot use E/p

- Forward physics
- No cosmics (acceptance)

- Soft physics, very little material
- Alignment mainly with magnet off data
- Reverse polarity
- Small magnetic field

- High pT physics, a lot of material
- Alignment mainly with magnet on data
- Do not reverse polarity
- Large magnetic field

Summary

Use all possible handles:

- Various topologies: cosmics, halo muons, beam gas, parasitics
- Overlap hits
- Use redundancy of different subdetectors: $\eta\phi$-match, E/p
- Vertex and mass constraints: J/Ψ, Υ, Z
- Resolutions: mass and IP
- Low level residual and alignment distributions
- Other external constraints: Survey, hardware alignment,...

If possible add handle as additional constraint in alignment algorithm

Else: Monitoring, quick turnaround, semi-automatic including human intervention

Test against expected misalignment scenarios in MC

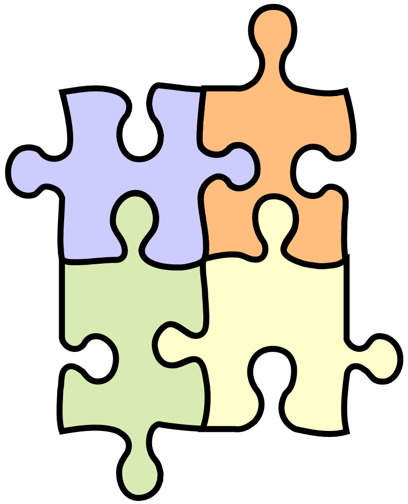
Be prepared for the unexpected!

Alignment strategy for the LHC detectors

- More detailed/technical contributions from all the 4 LHC experiments:
  - Hardware alignment systems
  - Software alignment tools
  - Alignment flow and Databases
  - Status and plans
  - MC misalignment studies
  - Infrastructure etc.

Typical Topics

More details later on



In the forthcoming ALICE contributions:

All LHC exp. → **Detector Description – C. Cheskov**

MUON Arm alignment – J. Castillo

ALICE misalignment framework – R. Grosso

Outer barrel alignment plans – M. Ivanov

Alignment Survey Data session

(C. Lasseur CERN TS-SU)

WE DO NOT WANT TO GIVE A CONCLUSION …

EVERY KNOWN AND IDENTIFIED STEP OF SURVEY IS FOLLOWED UP, UPDATED WHEN NECESSARY AND DOCUMENTED …

HAVE WE MISSED A DETECTOR ???

→ Question to the project leaders … to your community also

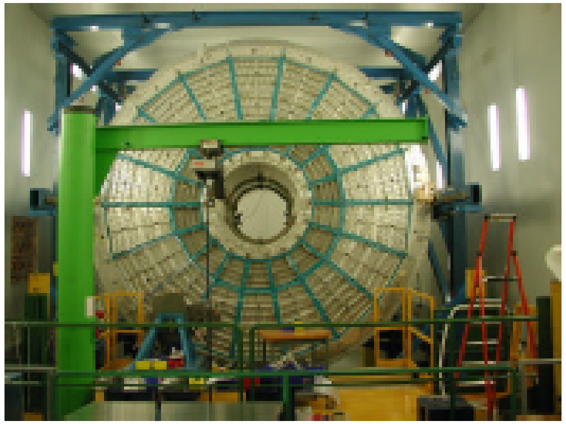
→ Still time to correct … maybe it is too late

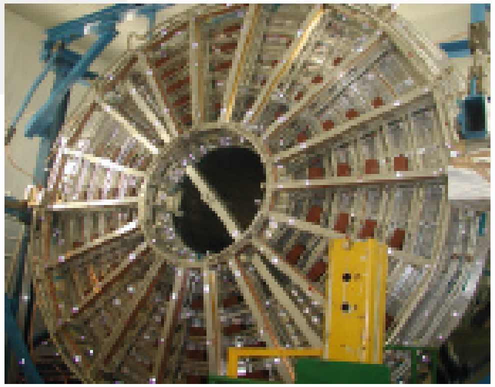
THE DISCUSSION IS OPEN

... IN ALICE - EDMS Id: ATI- 0000000407

- ALICE Engineering Baseline
  - Survey and Alignment
    - ALICE Survey Documents
      - L3 region
        - ACORD
        - ITS
        - TPC
        - TRD
        - TOF
        - HMPID
        - PHOS
        - FMD
        - ZDC
        - PMD
        - VO
        - TO
        - Structures
      - ALICE Cavern
      - Dimuon Arm
    - Alignment

TPC metrology during assembly : marks well defined in advance





... control after dummy load of the electronics

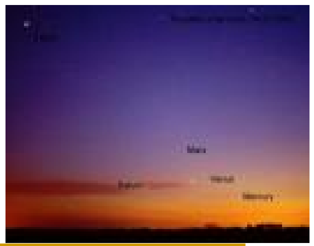
Workshop Summary by Dave Brown (LBNL , BaBar)

- Optimization algorithms usage

Iterative (residual chisq)
  BaBar, CDF, STAR, Atlas, CMS, ALICE(?)
Closed-form
  SLD (SVD)
  Zeus, H1, Atlas, CMS, LHCB, ALICE (Millepede)
  CMS (Kalman)

‘Iterative’ vs ‘closed form’ optimization

- **Also known as**
  - **Uncorrelated vs correlated**
  - **Global chisq vs local chisq**
  - **Biased vs unbiased**
- **Both algorithms are really iterative**
  - **Nonlinearities, outlier rejection, …**
- **Both algorithms can treat correlations**
  - **One explicitly, one implicitly**
- **Both algorithms are complex, elegant**
- **Both algorithms are only as accurate as the information that you feed them**
  - **There is no substitute for careful data preparation!**



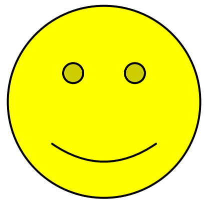
‘How I Would Align an LHC Detector’

- Assemble a complementary set of events
  - Muons, pairs, cosmics, survey, …
- Align the innermost (most sensitive) detector first
  - Align internal DOFs with complimentary data
    - Rigid body parameters plus non-planar distortions
    - Use sanitized outer-tracking constraint (on curvature, …)
- **Align the next detector outwards next**
  - Include (aligned) innermost detector in track fit
  - Align using standard techniques
    - Track self-consistency, survey, …
- Continue outwards
  - Include calorimeter, muon chambers
- Repeat (if necessary)

Good advice
For ALICE !

(Overall) Conclusions

- This workshop was a **success**
  - Lots of participation
  - Communication of new ideas
  - Sharing of techniques between LHC experiments
  - Comparison of existing (and former) experiments' methods against LHC experiments' plans



- With 1st data ~1 year away, LHC detector alignment preparation is in good shape
  - Alignment infrastructure incorporated into all experiments
  - (multiple) alignment techniques in place at all experiments
  - Realistic scenarios starting to be considered
  - Test beam and cosmic data being examined
- The scale of the problem is daunting
  - Time remaining must be spent wisely to insure success

Backup slides

In case of need…

4. Mathematical methods Overview

The introduction of overall equality constraints requires the solution of large systems of equations!

How to solve very large systems of equations?

No single optimal method, different methods for different conditions (number of parameters, sparsity):

Matrix inversion: • e.g. routine in MP I, for up to 5 000 parameters, with time / n3;

Diagonalization: • slower than inversion, allows to recognize insignificant linear combinations (no
constraints necessary); possible for large n on special hardware;

Sparse matrix storage: • allows to store big sparse matrices

Generalized minimal residual method: • fast method for large sparse matrices, factor > 1 000 faster than inversion for n =12 000. Routines MINRES • (and SYMMLQ);

Preconditioning: allows to reduce number of iterations, possible in MINRES (and SYMMLQ);

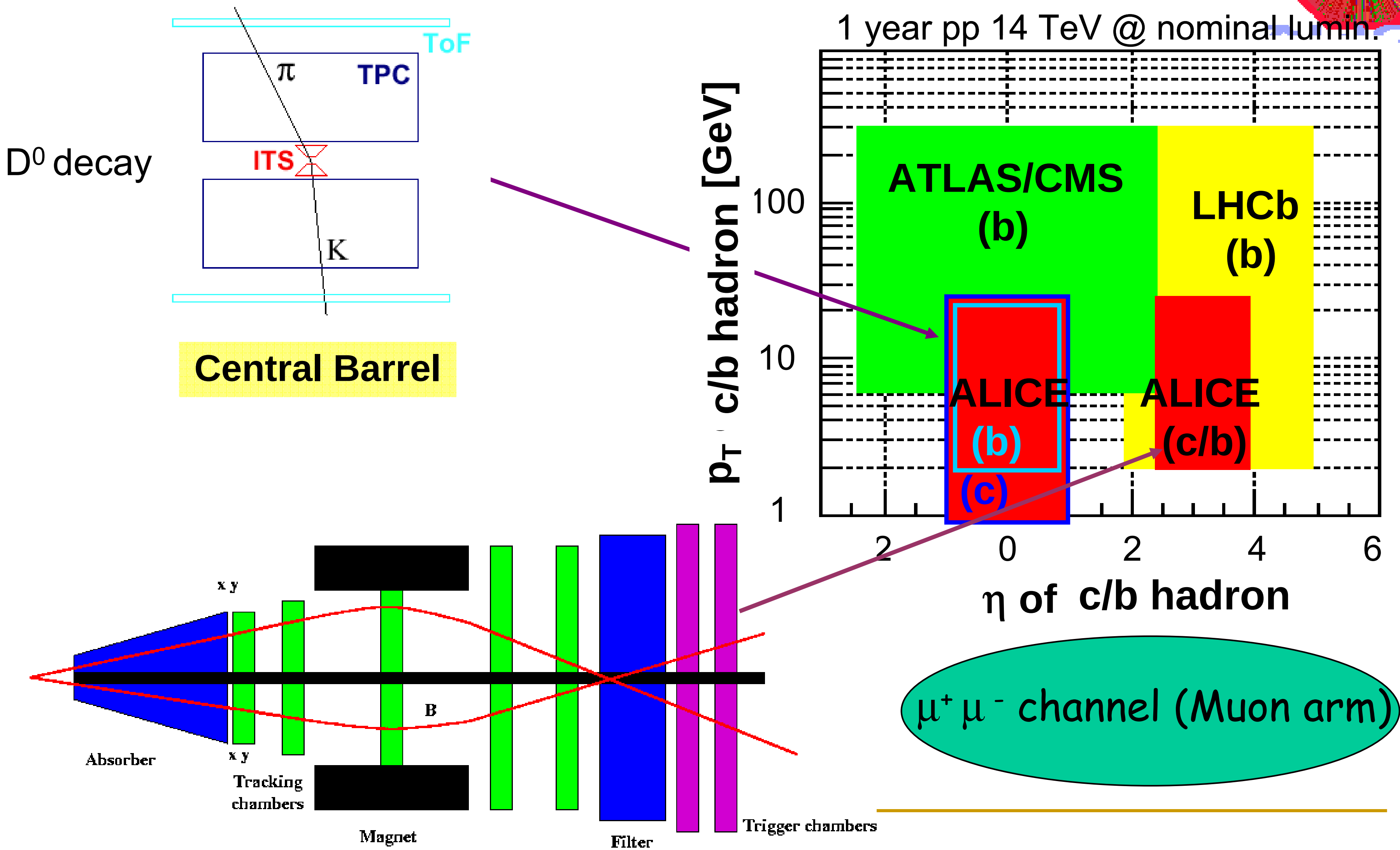
Limited memory BFGS: • uses only virtual matrix, low space requirement, but many iterations(?);

Millepede II Code: • =included, = not yet tried.

Method of M-estimates instead of cuts against outliers; square (of least squares) replaced by density
with larger tails for outliers.

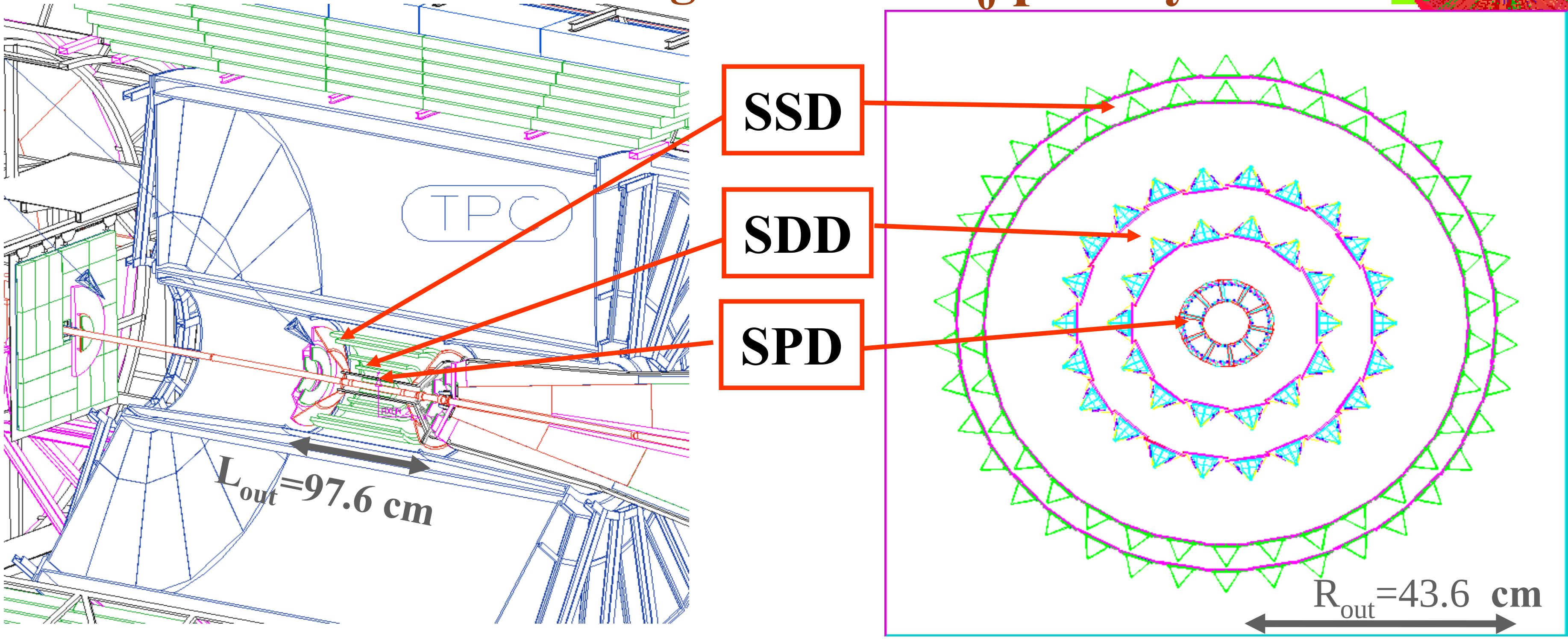
V. Blobel – University of Hamburg Alignment Algorithms page 28

ALICE acceptance



ITS – Inner Tracker System

Material Budget: ≤ 1% X_0 per layer !



- 6 layers, three technologies (keep occupancy at a few % for max multiplicity)
  - SPD: silicon **pixels** (0.2 m^2, two layers, 9.8 M channels, **240 modules**)
  - SDD: silicon **drift** (1.3 m^2, two layers, 133 k channels, **260 modules**)
  - SSD: double-sided silicon **strips** (4.9 m^2, two layers, 2.6 M channels, **1698 modules**)

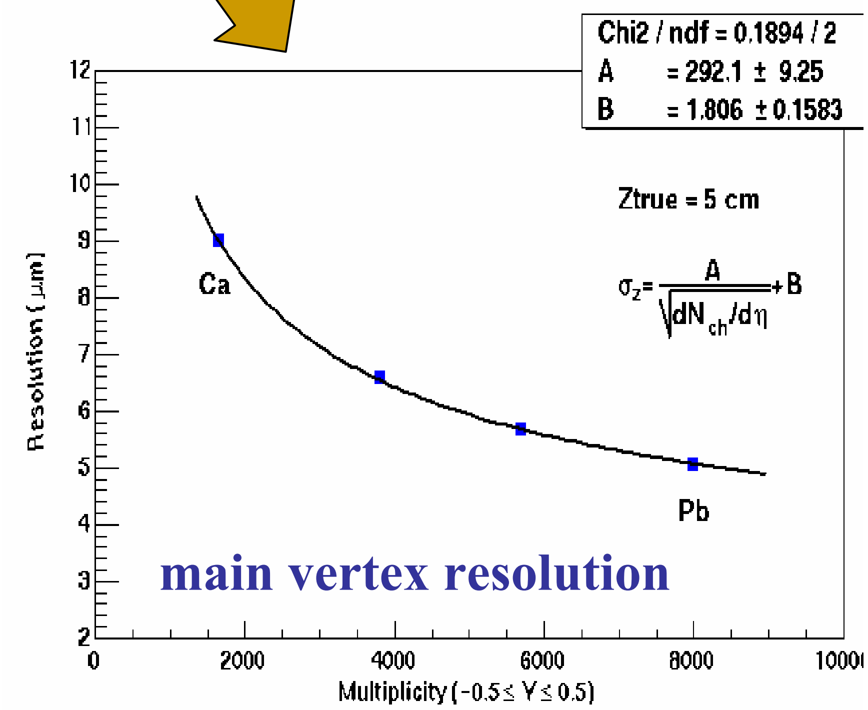
Detector/Reconstruction performance

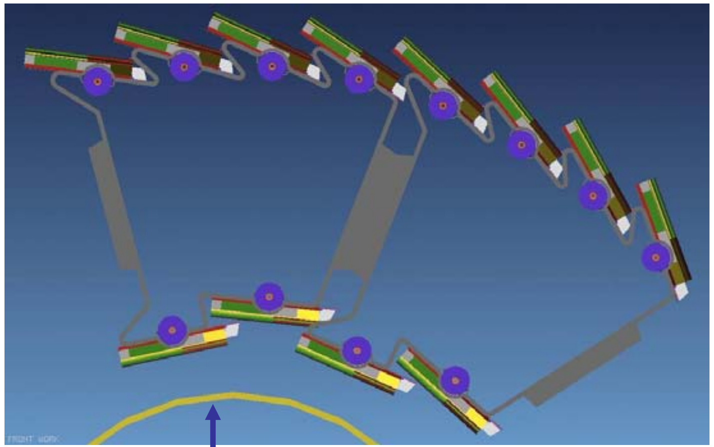
Tracks and Vertices

Main Vertex Resolution

Correlation of two innermost pixel layers (tracklets !)

At beam axis	1cm off beam axis
σx = 15 μm	σx = 25 μm
σy = 15 μm	σy = 25 μm
σz = 5 μm	σz = 5 μm

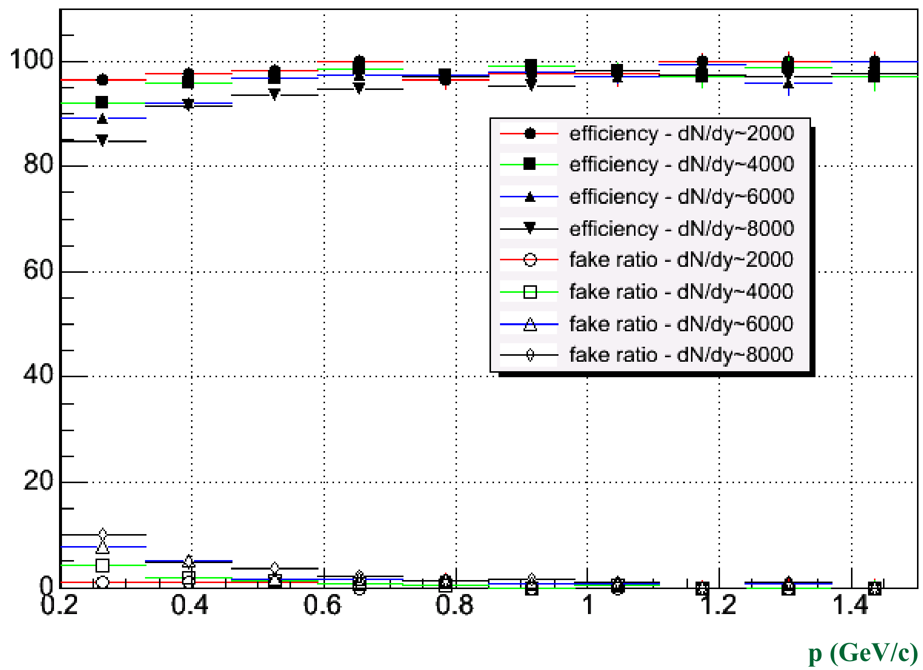




2 pixel sectors (out of 10 total)

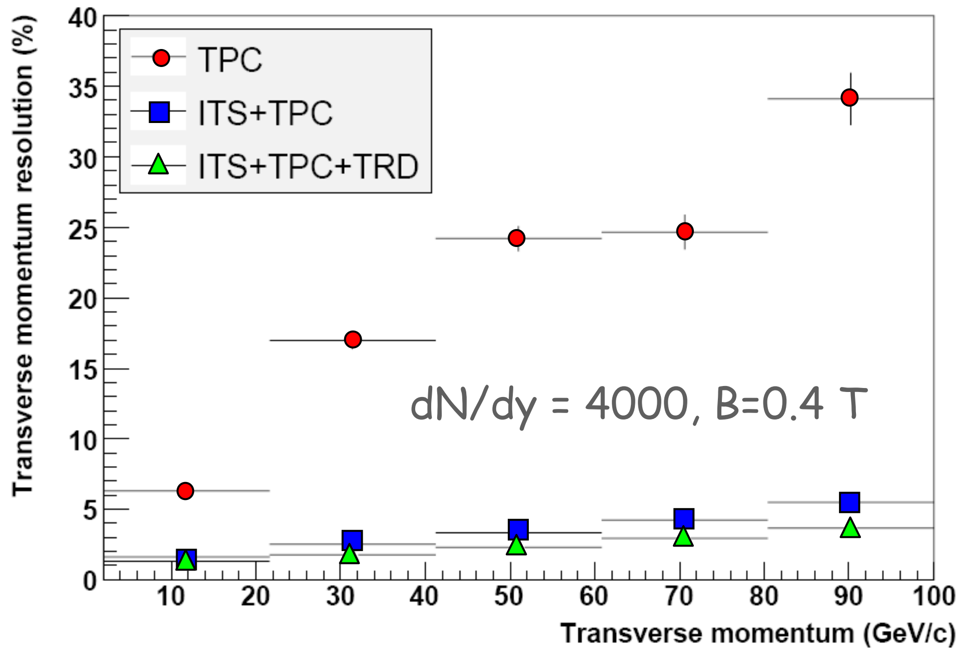
beam pipe

Tracking Performance



For track densities dN/dy = 2000 - 8000, combined tracking efficiency above 90% with <5% fake track probability

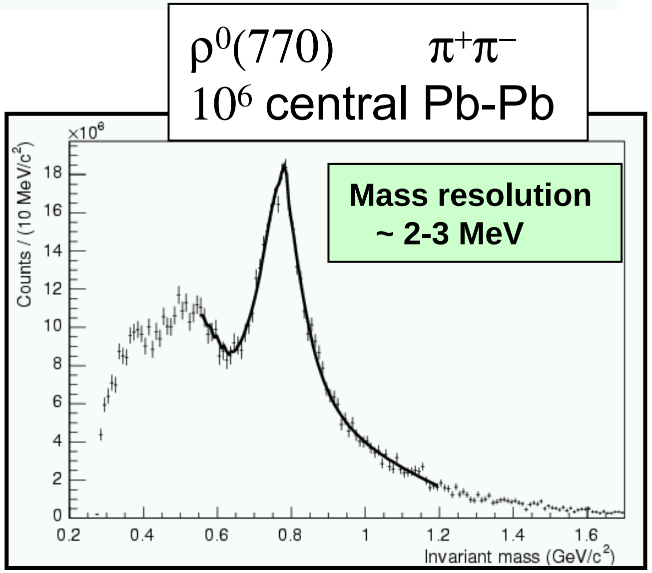
resolution ~ 5% at 100 GeV/c excellent performance in hard region!



PHYSICS PERFORMANCE

few examples:

1. Particle correlations, resonances



Two pion momentum correlation (HBT) analysis

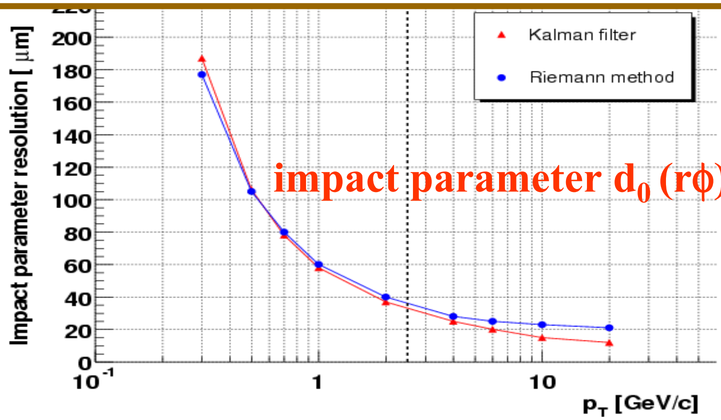
Studies on event mixing and two track resolutions.
Investigated track splitting/merging and pair purity.
Calculated momentum resolution corrections and PID corrections

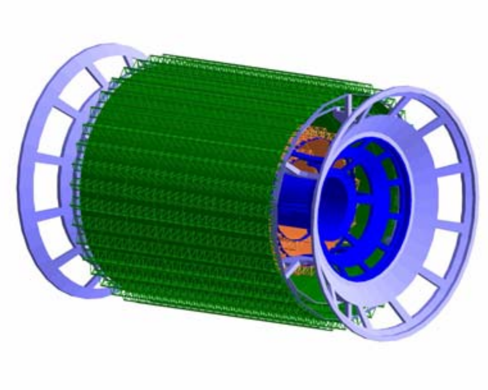
Radii can be recontructed up to 15 fm

In medium modifications of mass, width, hadronic and leptonic channels; partial chiral symmetry restoration

2. Impact Parameter resolution

Impact parameter resolution is crucial for the detection of short-lived particles: charm and beauty mesons and baryons.
Determined by pixel detectors:
at least one component has to be better than 100 μm (cτ for D^0 meson is 123 μm)

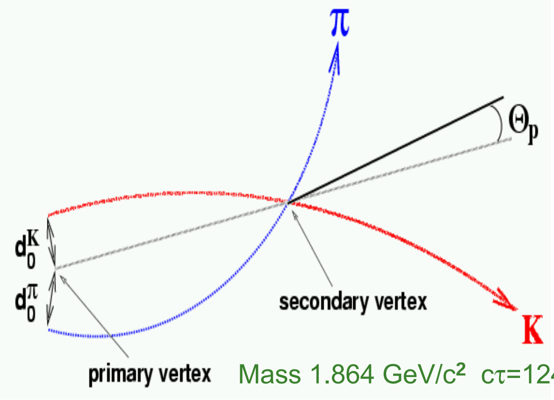




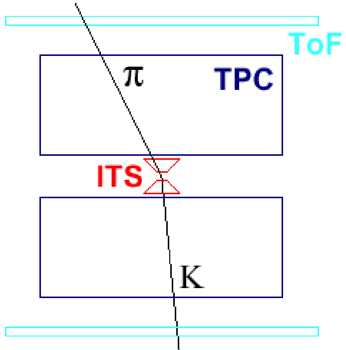
better than 40 μm for p_T > 2.3 GeV/*c*
~20 μm at high p_T

	Position resolution	Mass resolution	Momentum resolution	Efficiency
K^0_s	200÷300 μm	6÷8 MeV	1.5÷1.8%	21÷25%
Λ	~500 μm	3÷4 MeV	1.3%	15%

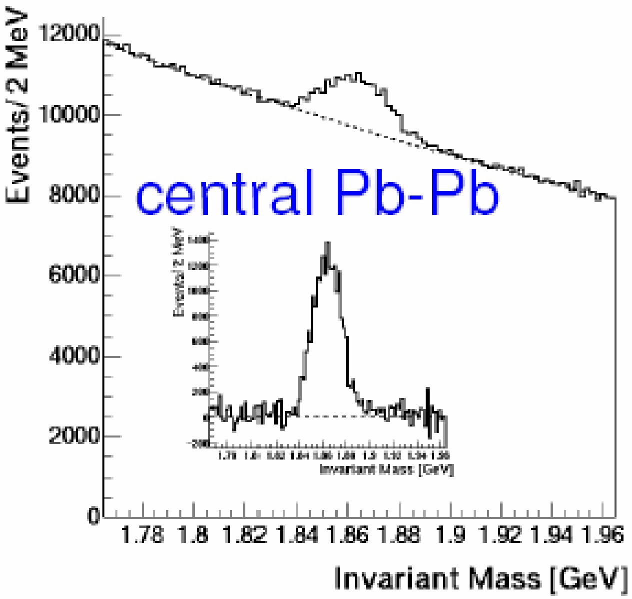
3.Open Charm Detection in Hadronic Decays



Mass 1.864 GeV/c² cτ=124 µm



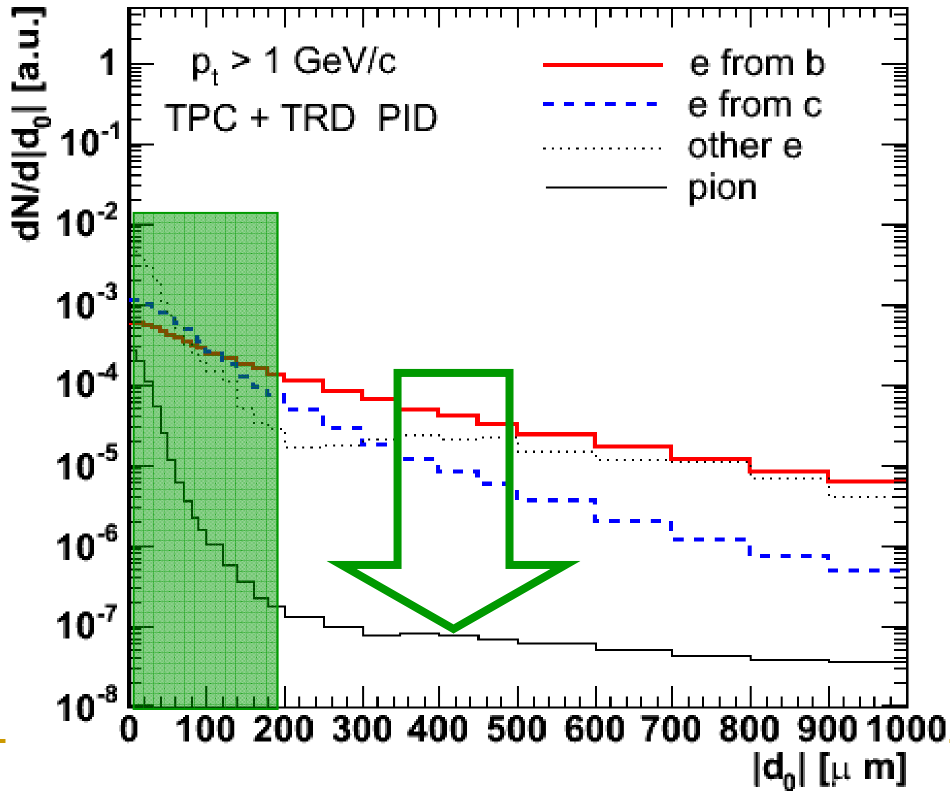
~0.55 $D^0 \rightarrow K^- \pi^+$ accepted/event
important also for J/ψ normalization

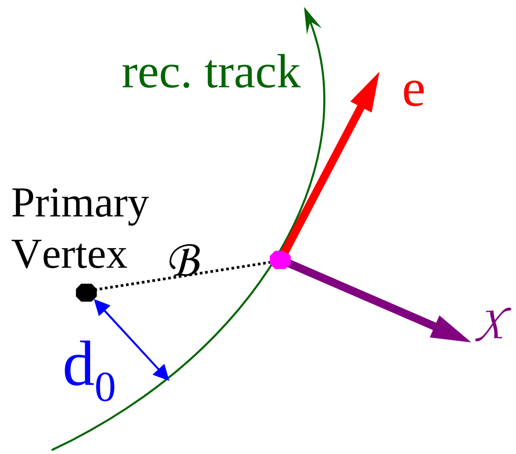


	S/B initial (M±3σ)	S/B final (M±1σ)	Significance S/√S+B (M±1σ)
Pb-Pb Central (dN_{ch}/dy = 6000)	$5 \cdot 10^{-6}$	10%	~35 (for 10^7 evts, ~1 month)
pPb min. bias	$2 \cdot 10^{-3}$	5%	~30 (for 10^8 evts, ~1 month)
pp	$2 \cdot 10^{-3}$	10%	~40 (for 10^9 evts, ~7 months)

4.Beauty via displaced electrons

- ALICE has excellent electron identification capabilities (TRD)
- Displaced electrons from B decays can be tagged by an **impact parameter cut**

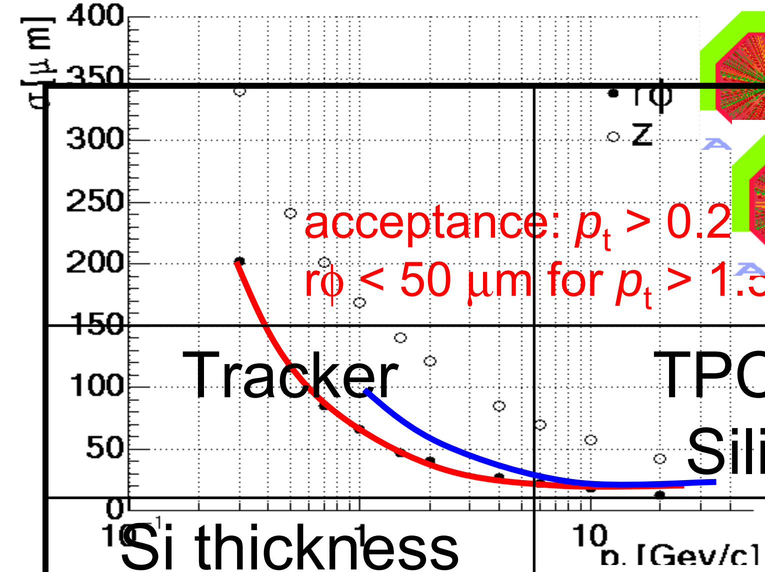


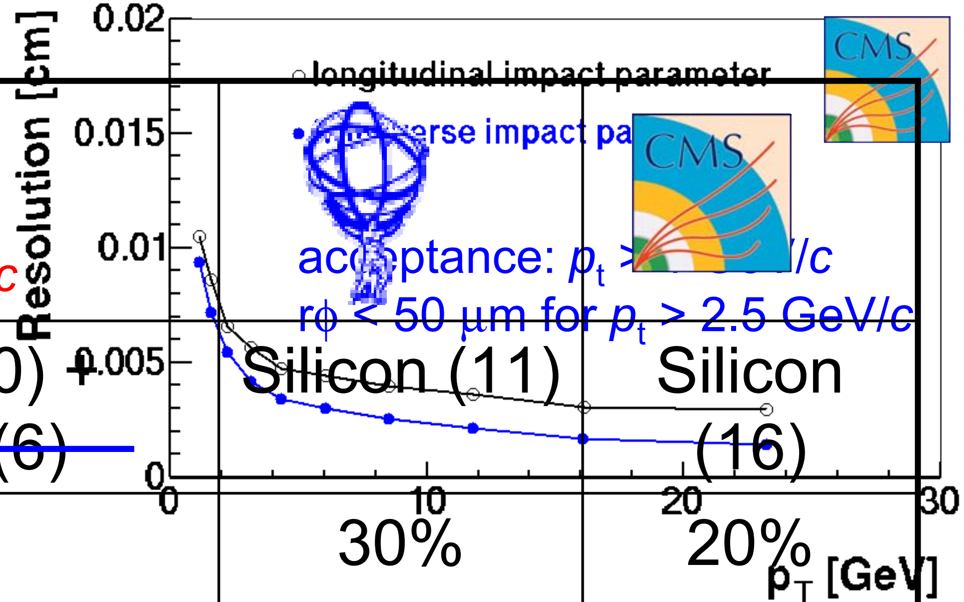


5. Open Charm: ALICE vs CMS

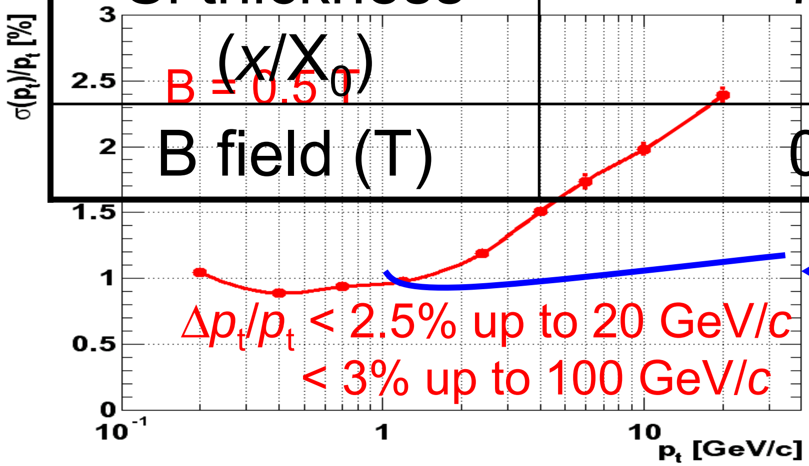
(A. Dainese @ Hard Probes)

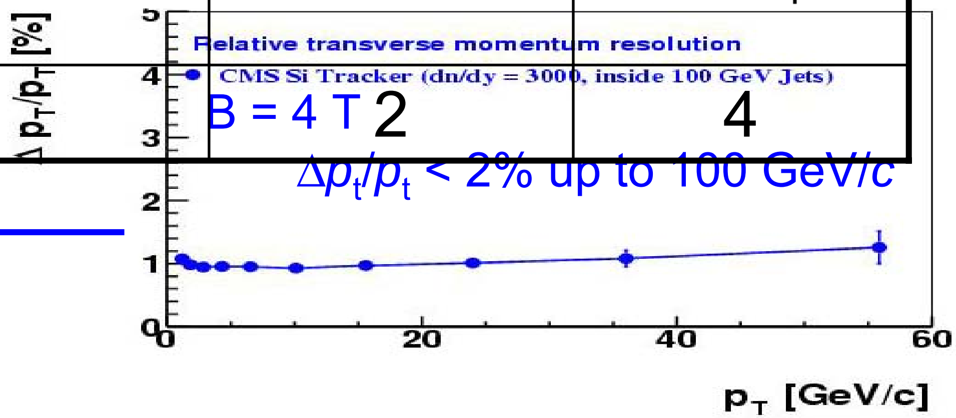
- D mesons $c\tau \sim$ 100–300 μm, B mesons $c\tau \sim$ 500 μm
- Secondary vertex capabilities! → **Impact param. resolution!**





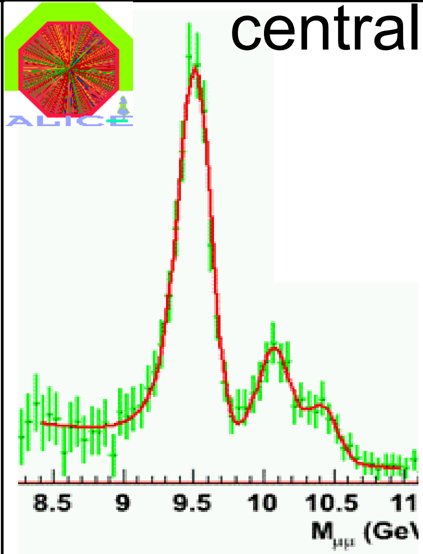
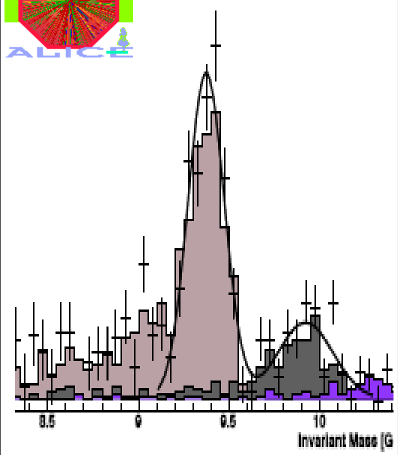
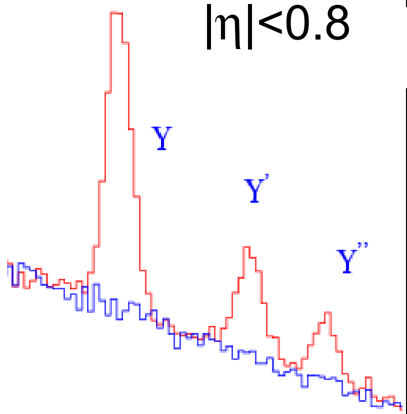
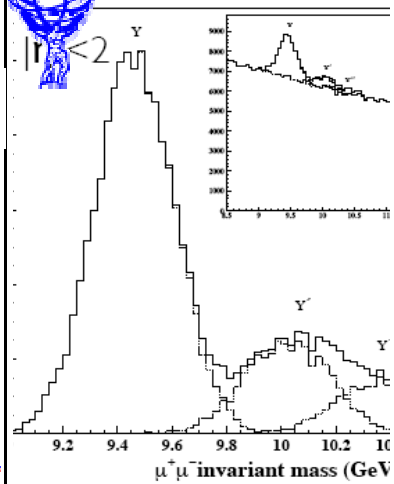
Tracker	TPC (100) + Silicon (6)	Silicon (11)	Silicon (16)
Si thickness (x/X_0)	7%	30%	20%
B field (T)	0.5	2	4





5. Bottonia: Alice vs CMS & Atlas

Bkg input: dN_{ch}/dy~2500-4000 in central Pb-Pb. $S/\sqrt{S+B}$ for 1 month

	ALICE $\mu^+\mu^-$	ALICE e^+e^-	CMS $\mu^+\mu^-$	ATLAS $\mu^+\mu^-$
	central 	central 	min. bias 	central 
acc. η	-4 < η < -2.5	|η| < 0.9	|η| < 0.8(2.4)	|η| < 2
M res.	90 MeV	90 MeV	54(85) MeV	145 MeV
$S/\sqrt{S+B}$ ϒ,ϒ',ϒ''	**30, 12, 8**	**21, 8, --**	**50, 17, 12** |η|<2.4	**45, --, --**
perf.	ϒ, ϒ', ?ϒ''	ϒ, ?ϒ', no ϒ''	ϒ, ϒ', ϒ''	ϒ, ?ϒ', no ϒ''
p_t ϒ	0-8 GeV	--	few-10 GeV	--