First Alignment Geometry of LHC*b* (Survey and First Data)

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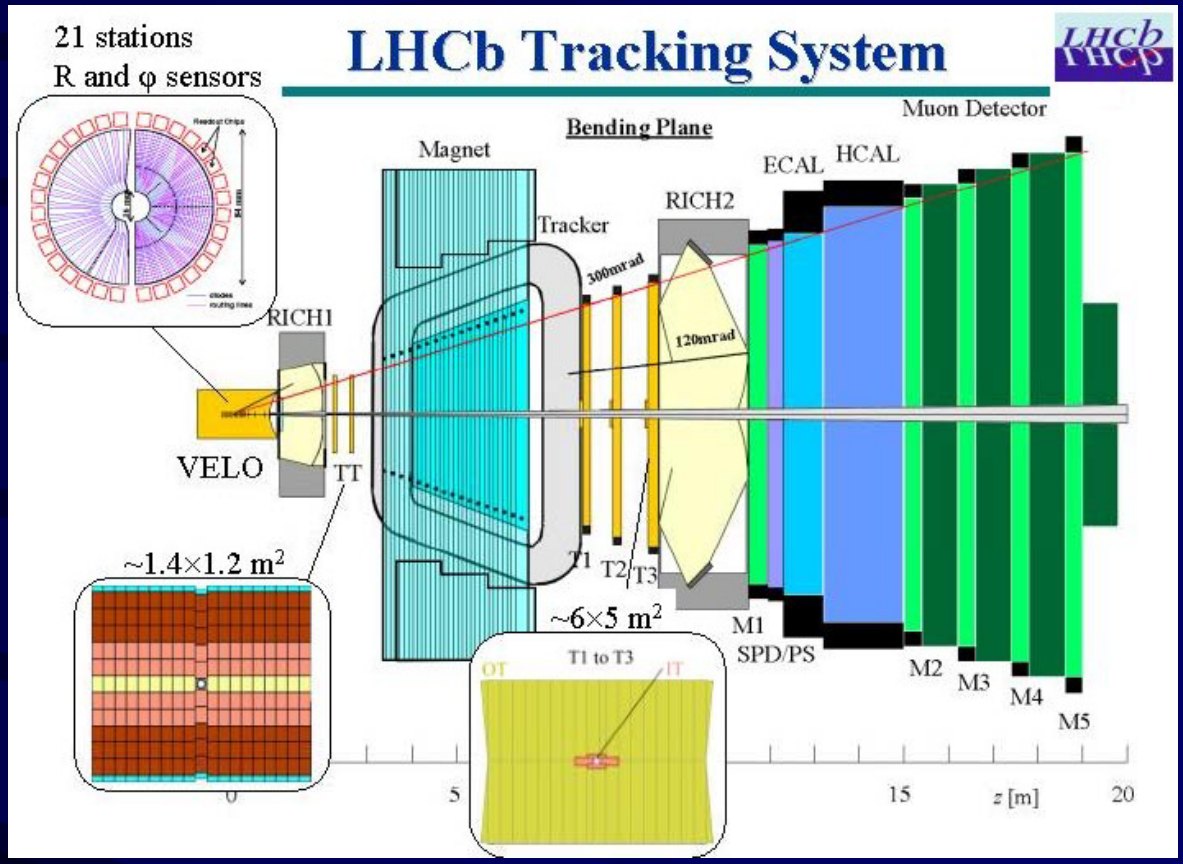
Syracuse University

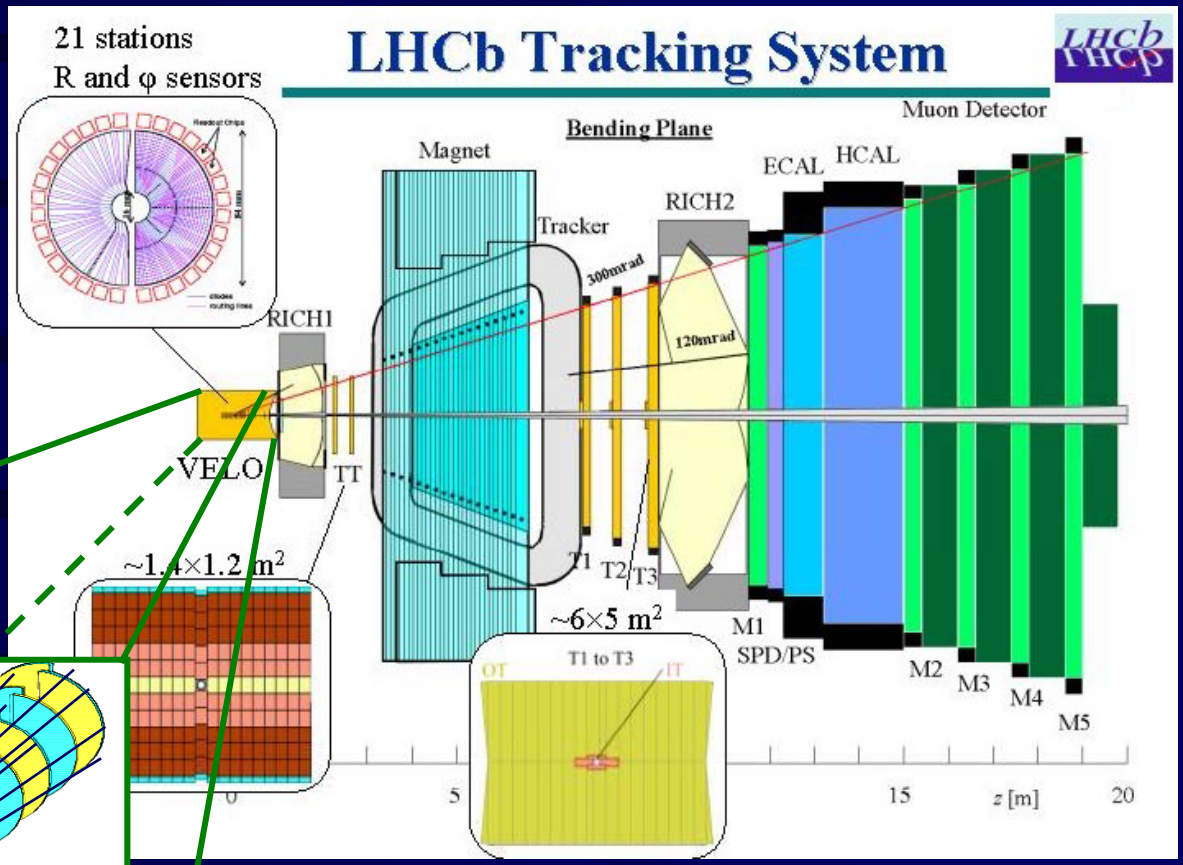
On behalf of the LHC*b* Collaboration

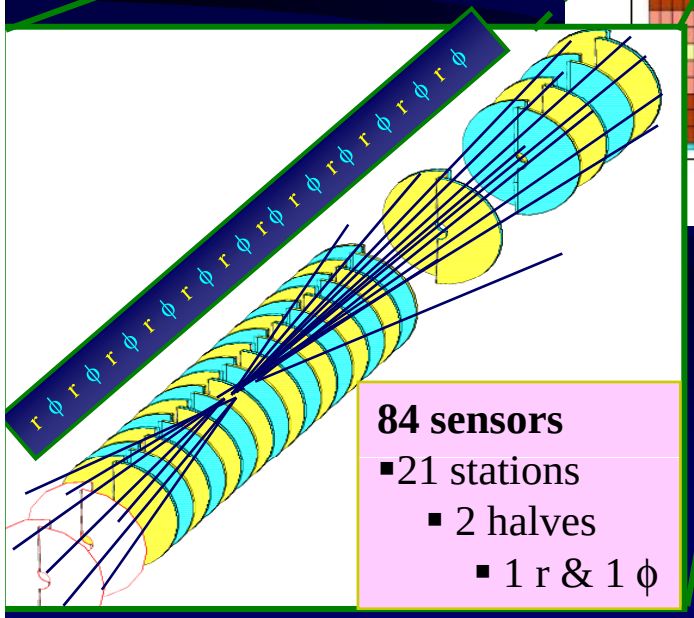
LHC Detector Alignment Workshop, June 25-26, 2007

LHC*b* Detector/Tracking



LHC*b* Detector/Tracking



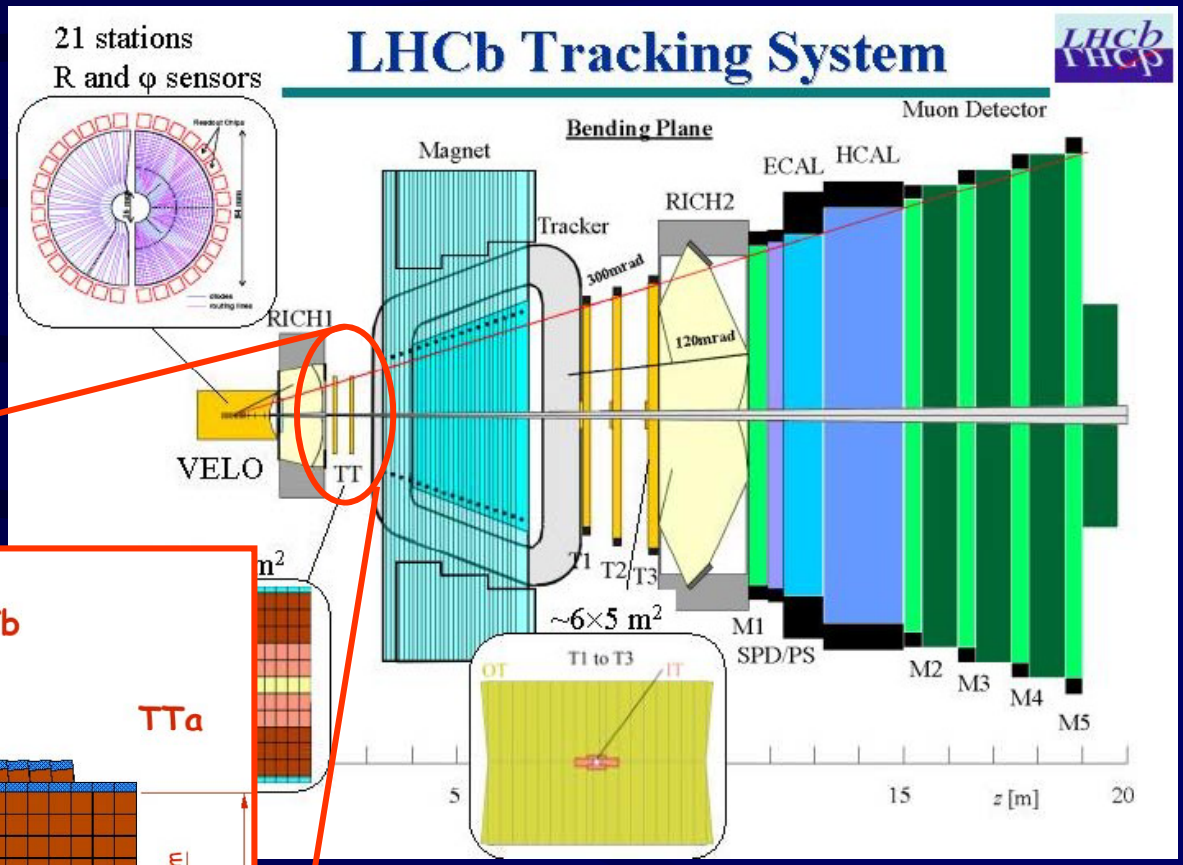


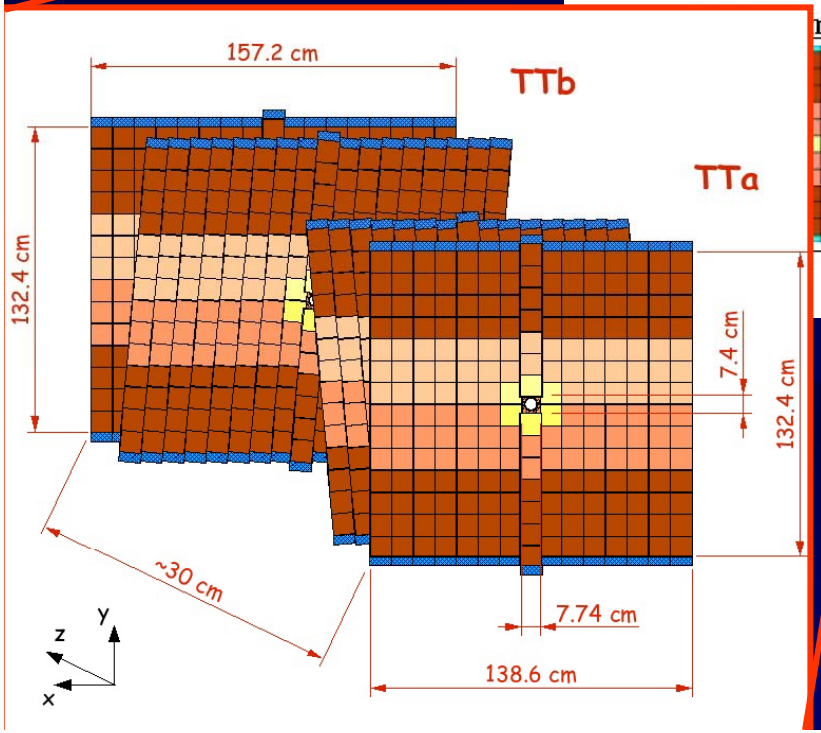
84 sensors

- 21 stations
  - 2 halves
    - 1 r & 1 ϕ

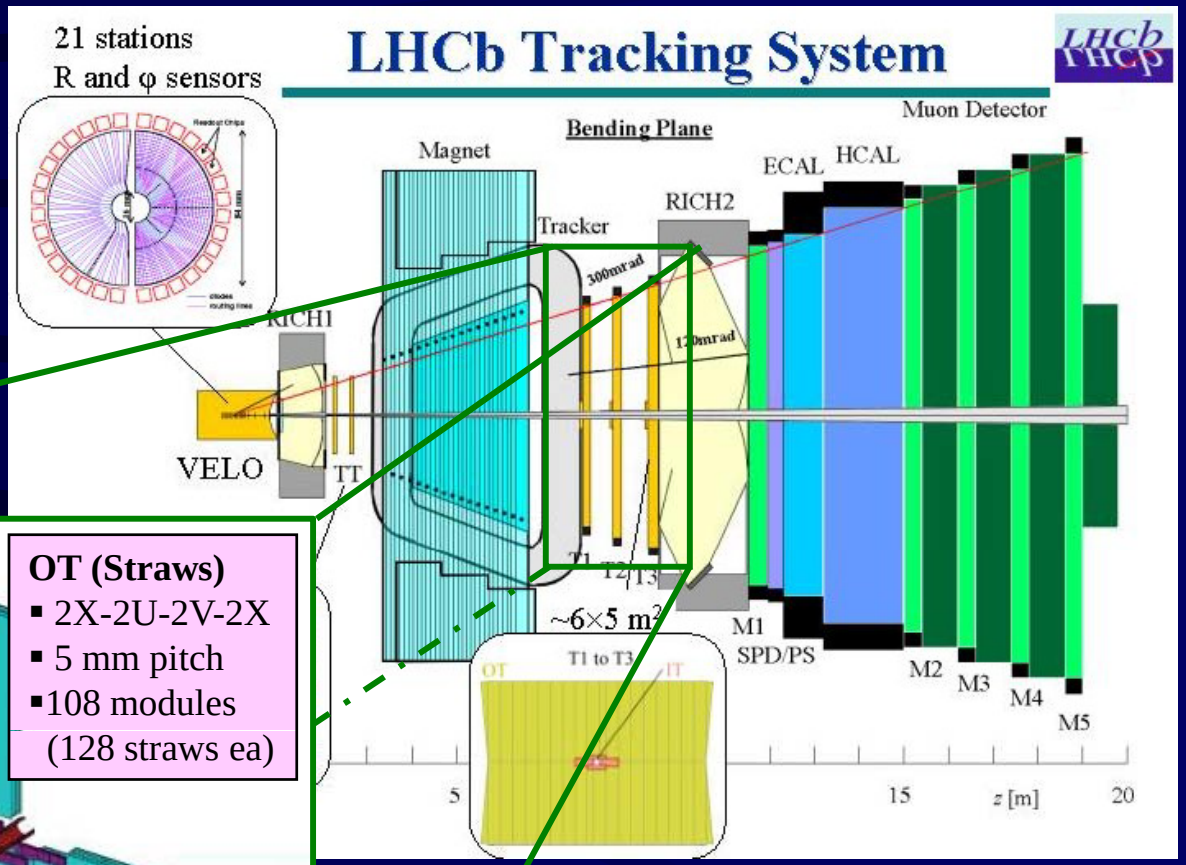
LHC*b* Detector/Tracking

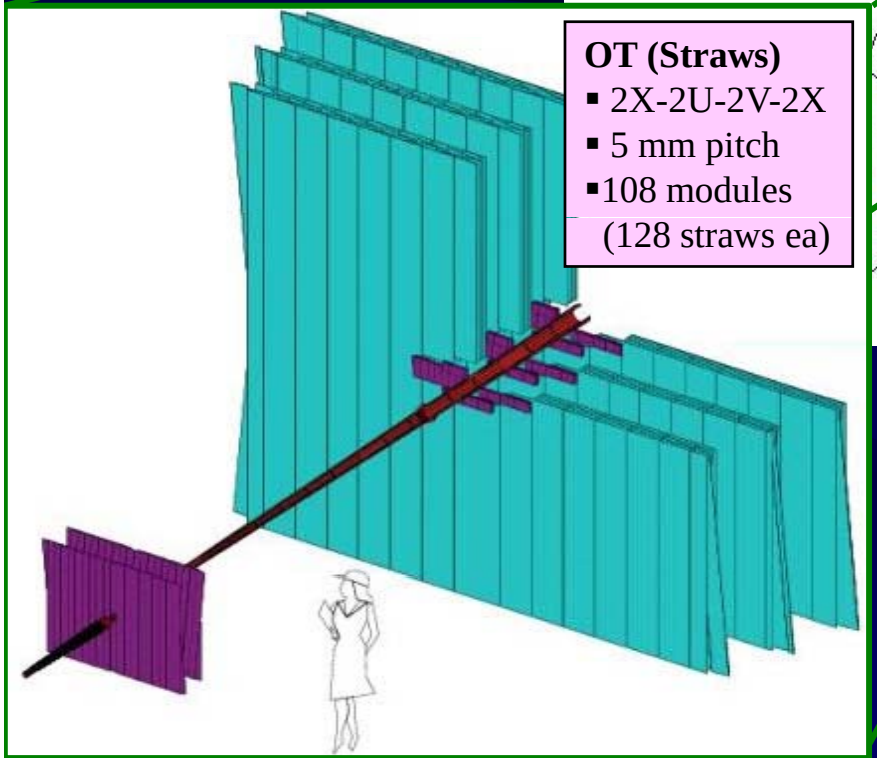
TT: Silicon Strips
- 183 μm pitch
- 128 seven-sensor ladders
- 4 layers: X,U(5°),V(-5°),X





LHC*b* Detector/Tracking

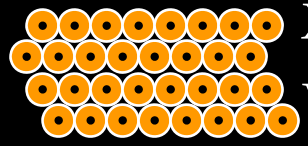


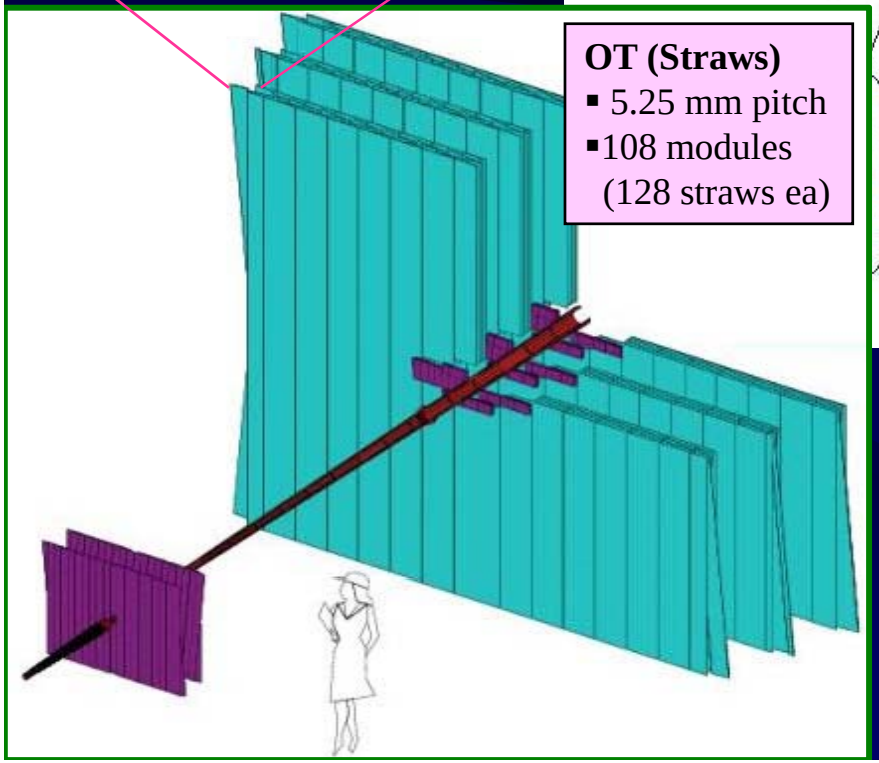


OT (Straws)
- 2X-2U-2V-2X
- 5 mm pitch
- 108 modules (128 straws ea)

LHC*b* Detector/Tracking

Straw geometry





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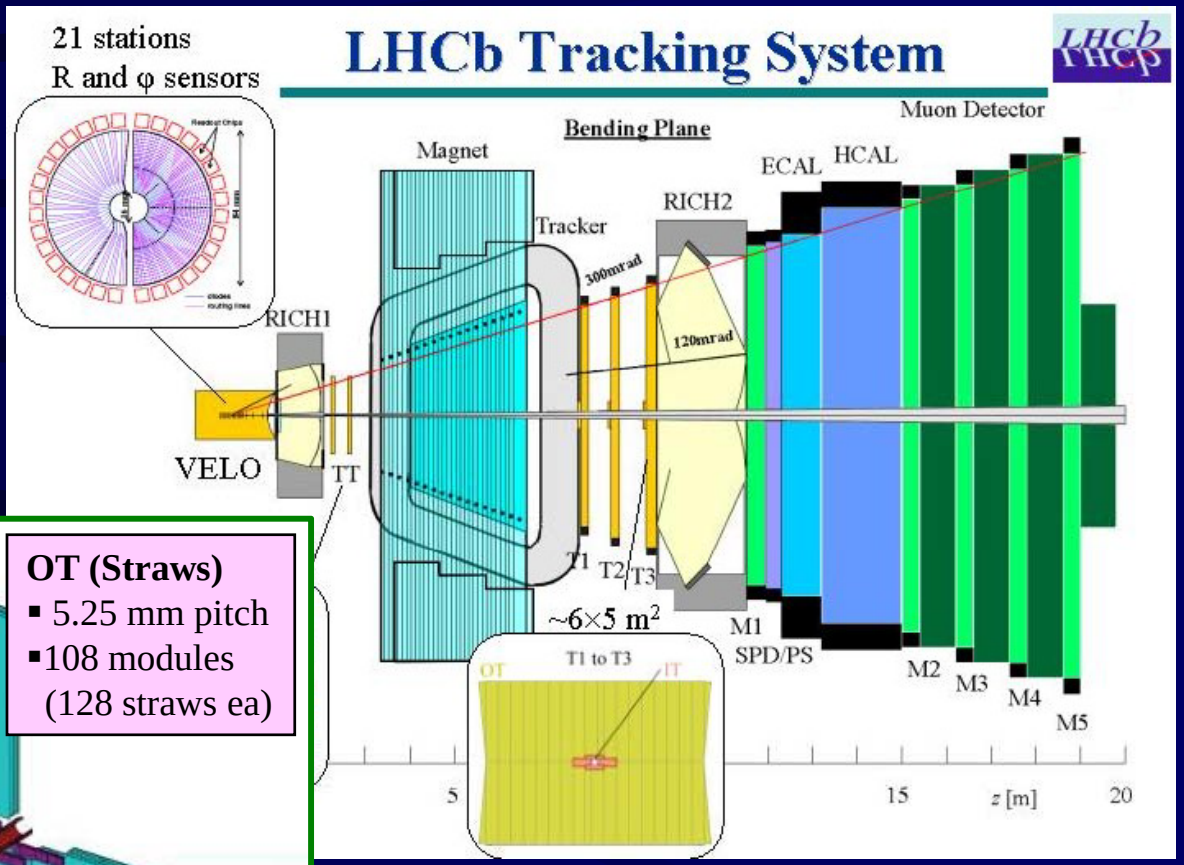
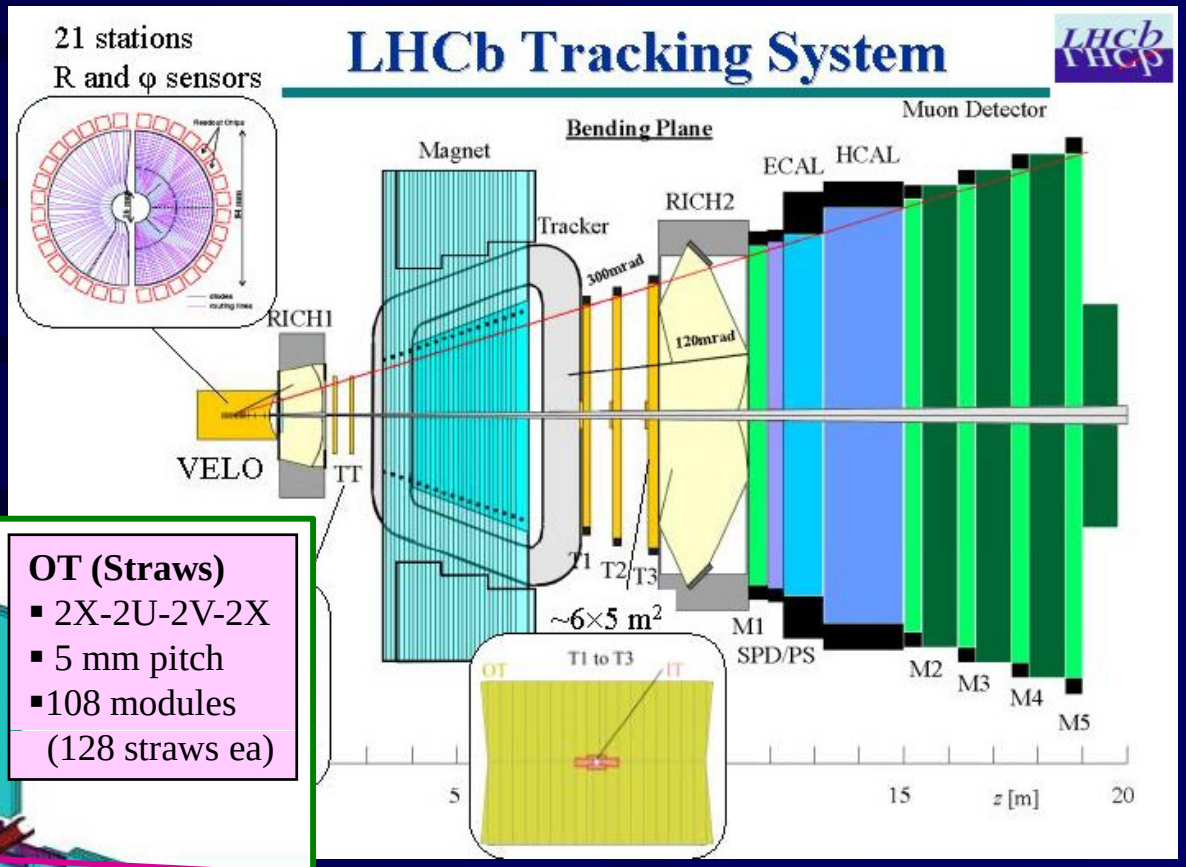
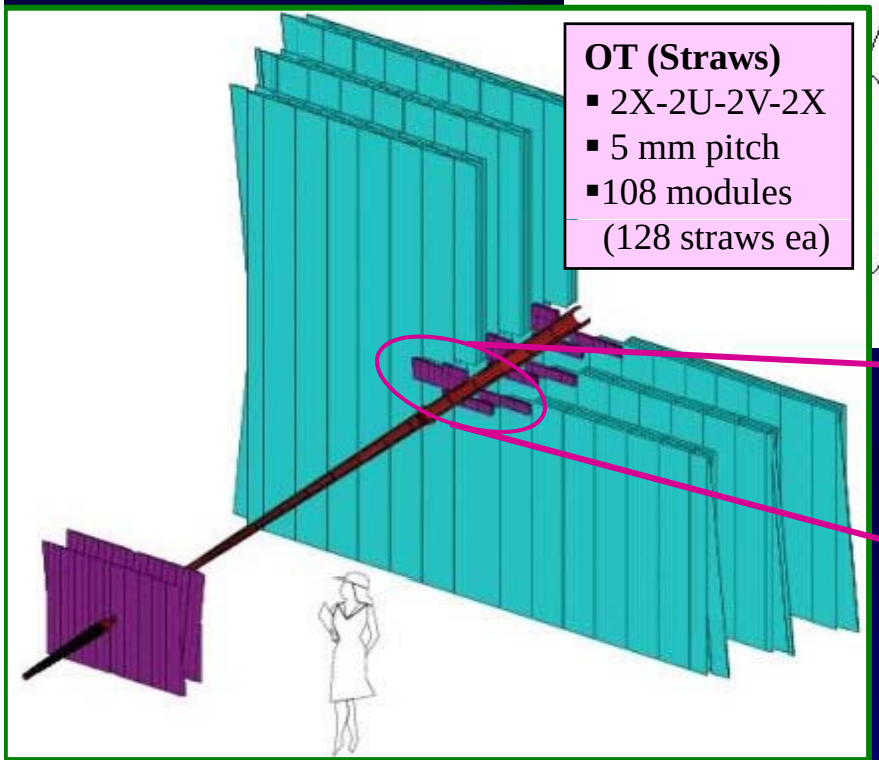


LHC*b* Detector/Tracking





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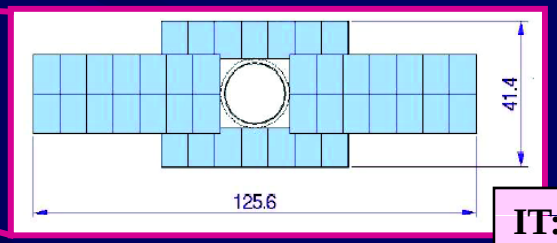
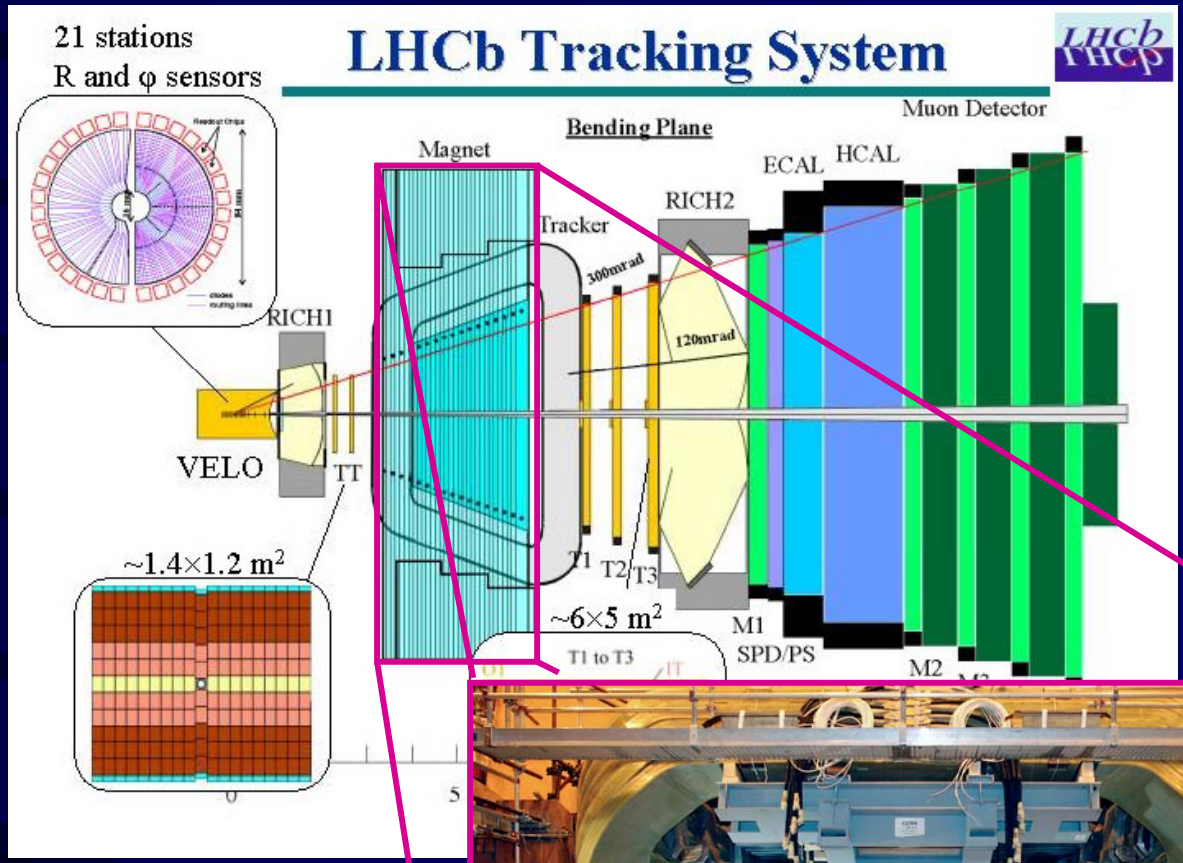
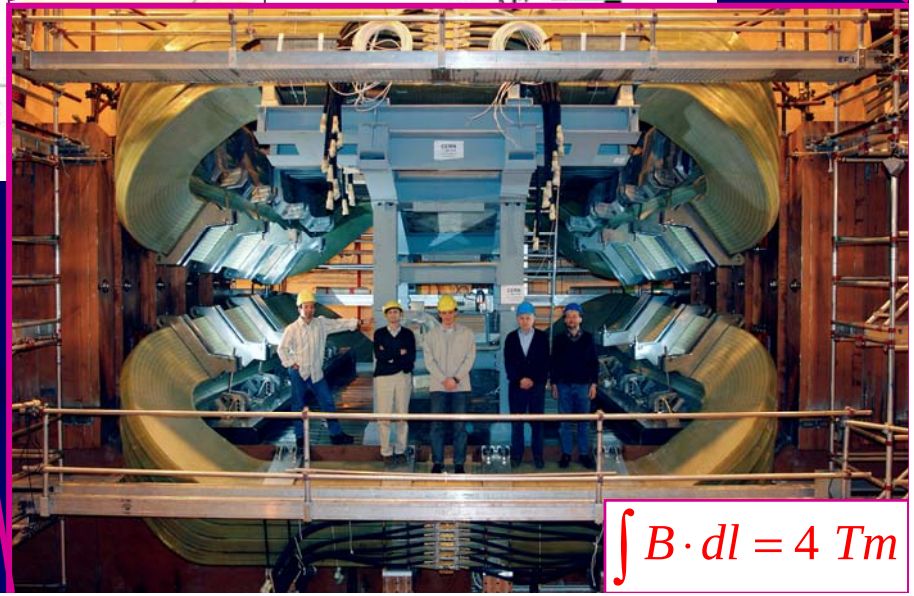


IT: Silicon
- 198 μm pitch
- 336 ladders

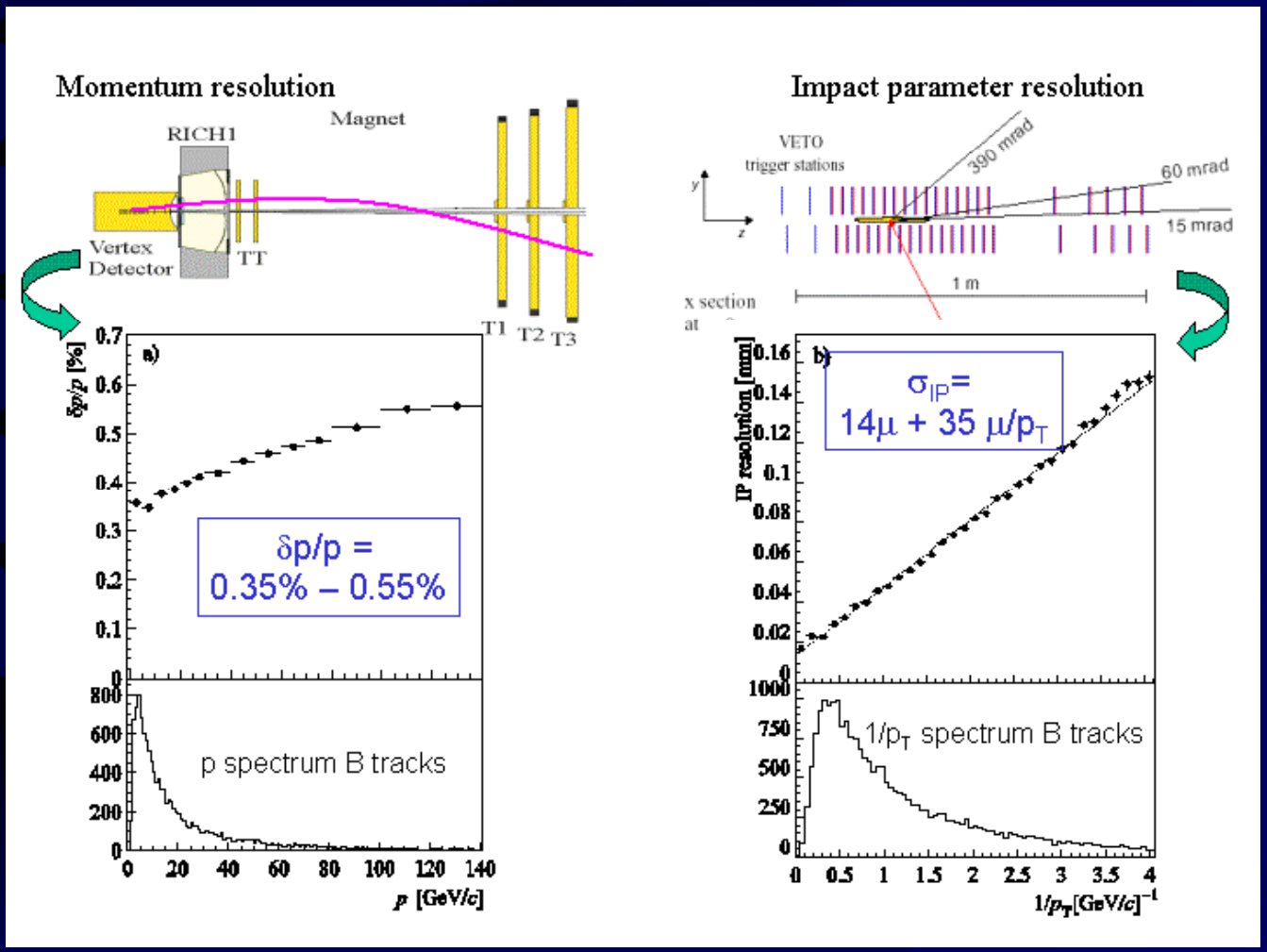
LHC*b* Detector/Tracking





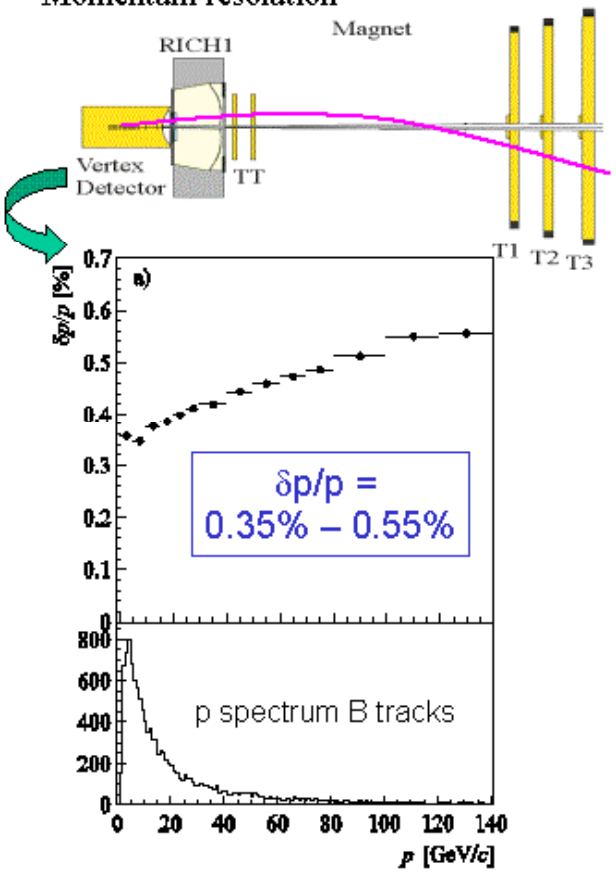
$$\int B \cdot dl = 4\ Tm$$

Expected Performance

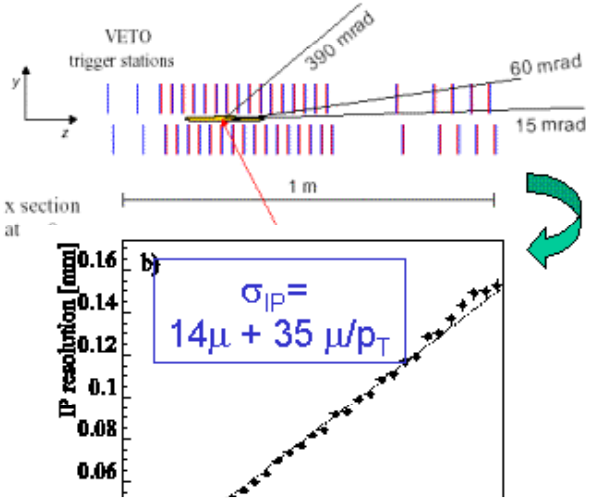


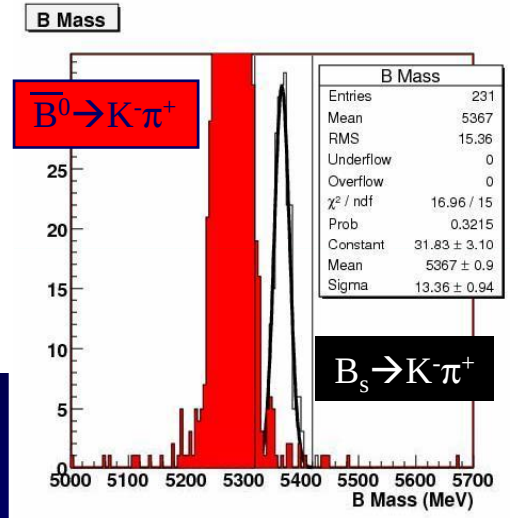
Impact of Misalignments

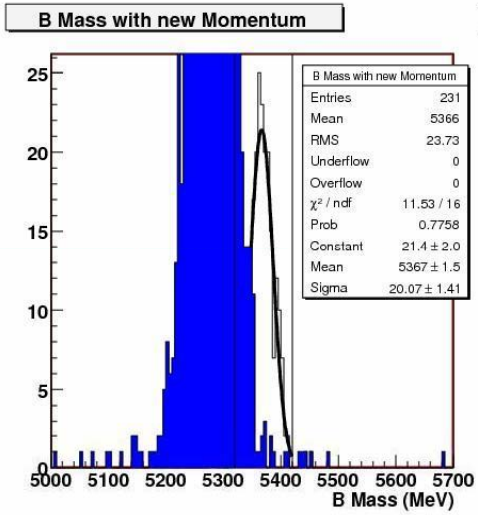
Momentum resolution



Impact parameter resolution





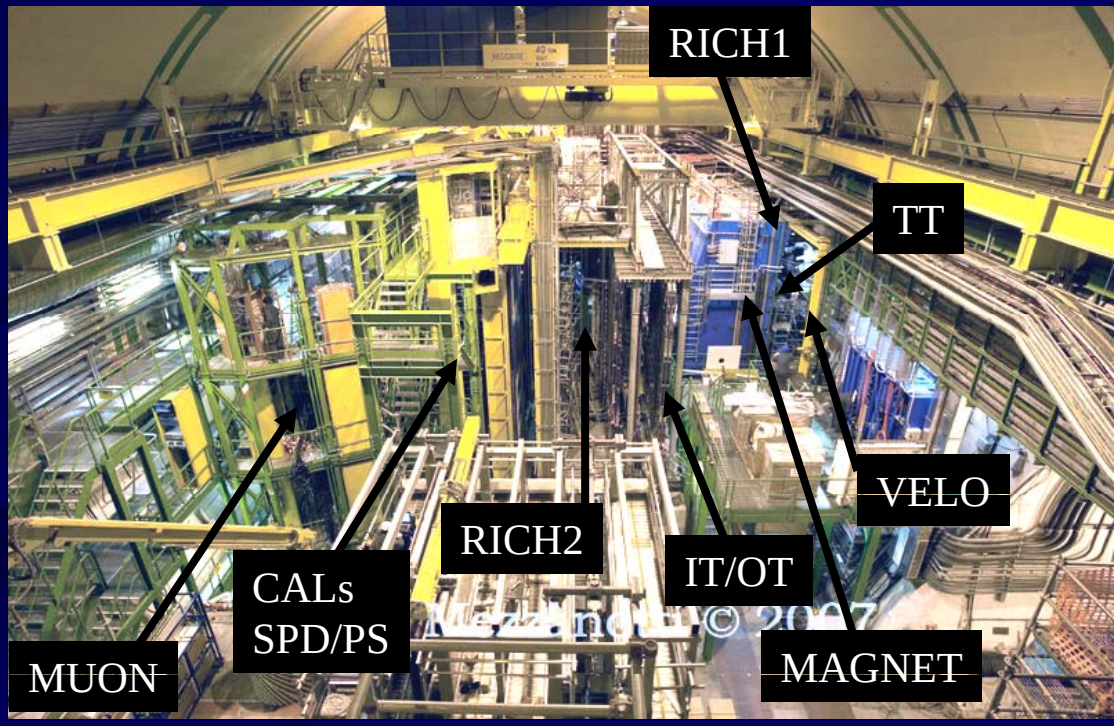


$\sigma_p/p = 0.004$ ⟶ $\sigma_p/p = 0.005$

Alignment Project Goals

- Precision of final detector alignment should lead to negligible impact on physical measurements.
  - Momentum resolution, e.g., kinematic separation of $B \rightarrow K\pi$, $B_S \rightarrow K\pi$
  - Impact parameter / proper time resolution.

- Number of alignable objects in LHC*b* < ALICE << CMS, ATLAS
  - VELO: 84 sensors
  - IT: 336 ladders
  - OT: 108 modules
  - RICH: Internal alignment and alignment to tracking system critical for PID.
  - MUON, CAL more course granularity



- LHC*b* an "open" detector
  - Has some benefits for in situ survey, although its getting very tight!
  - Little/no deflection of chambers when B turned ON

LHC*b* Survey Task Force

- Survey Task Force Charge: To analyze survey data from the CERN Survey group, CMM surveys from the Institutes and CERN, and determine a first set of alignment constants for LHCb.

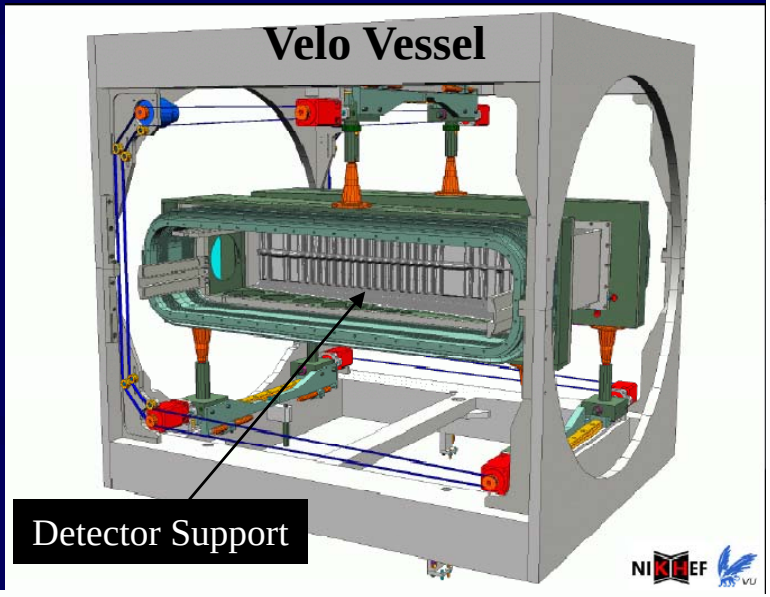
That is: Where is each detector as compared to where we “wanted it to be”.

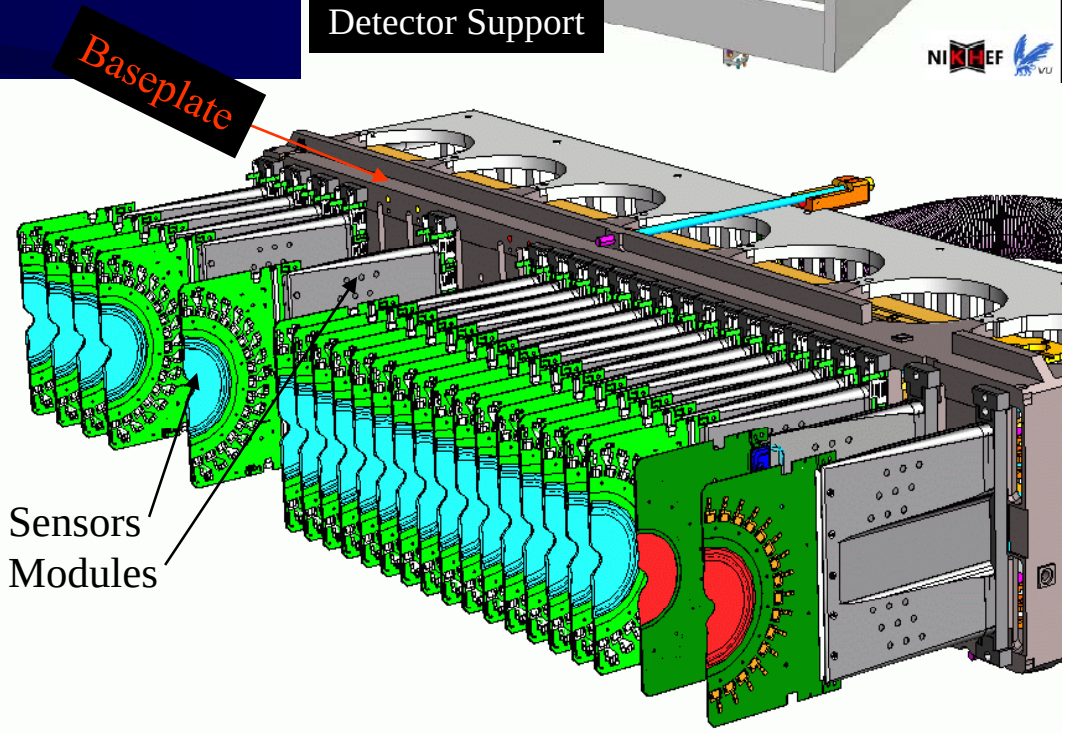
- Geometry DB will be updated once analysis is complete. Expect final analysis ~Sept.

- Team of sub-detector experts are:
  - VELO: Sebastien Viret, Malcolm John
  - IT: Geraldine Conti
  - TT: Jeroen Van Tilburg
  - OT: Antonio Pellegrino
  - RICH1: Fabio Metlica
  - RICH2: Antonis Pananestis, Christopher Frei
  - Muon: Katherine Mair
  - SPD, ECAL, HCAL: Olivier Deschamps
  - Beam Pipe: Gloria Corti
  - Magnet: Rolf Lindner
  - Coordinator: S.B.

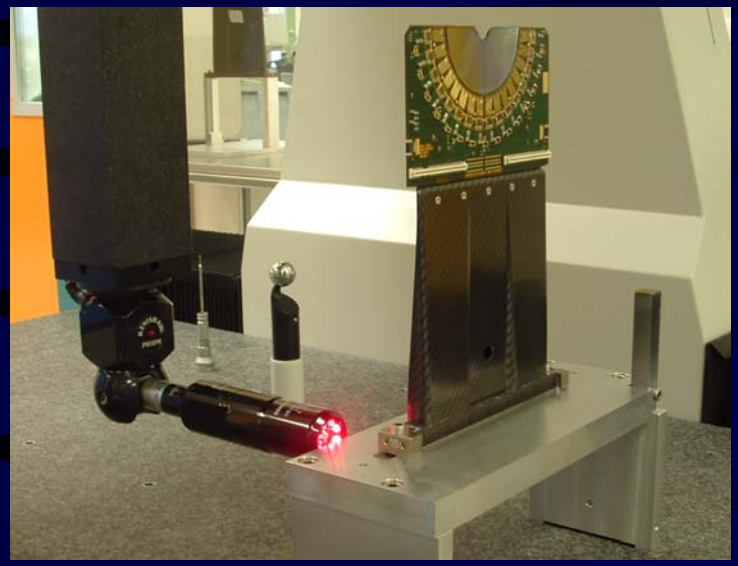
VErtex LOcator

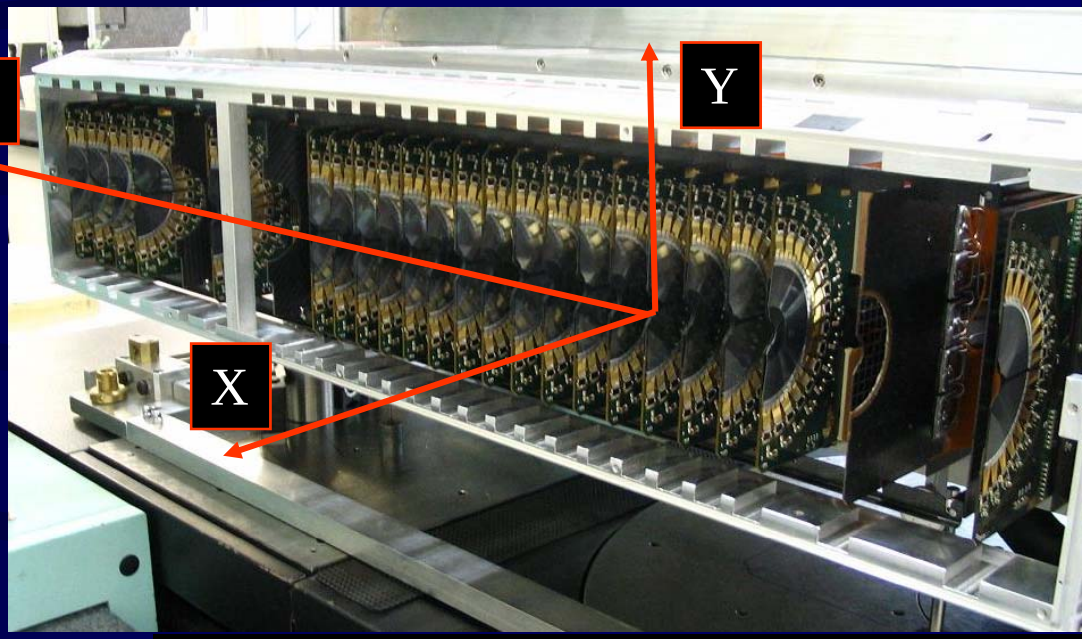
- ~10μm hit resolution (depends on radius)
  - ➔ Requires precise alignment
- Locating the VELO in LHC*b*
  - Sensors on Modules
  - Modules on baseplate
  - Baseplate on detector support
  - Detector support in VELO vessel
- Surveys, every step of the way!
  - Often, several times using different techniques
- 2D tracks in R-view used in trigger to detect large IP tracks
  - ➔ Sensor rel. alignment to within ~50 μm (3D tracks fully exploit alignment)
- VELO retracted and re-insterted between fills (3 cm ←→ ~7 mm).
  - ~10 μm repeatability



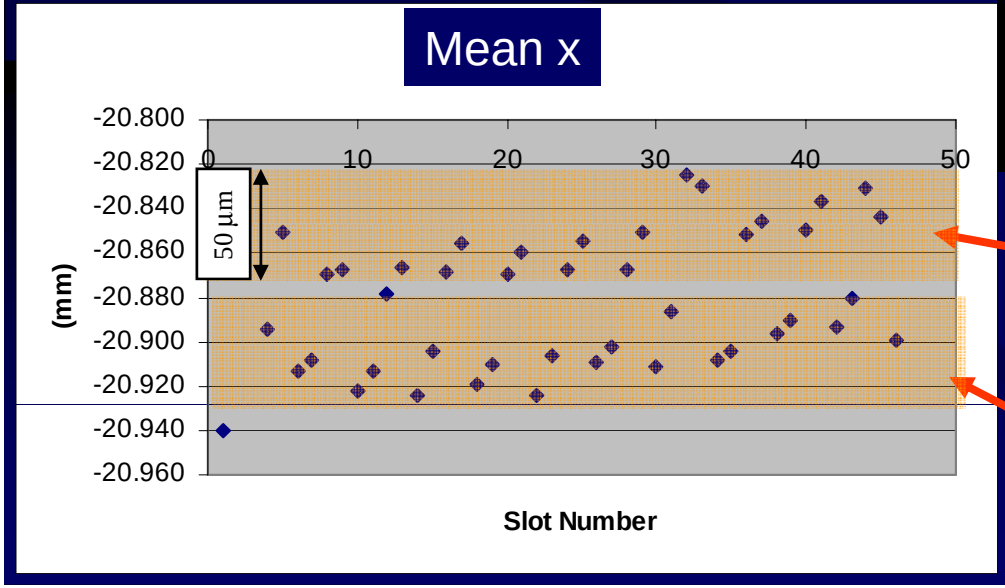


VELO Sensors Survey





❑ Metrology of modules before (left, at Liverpool) and after (right, at CERN) installation in the detector half.



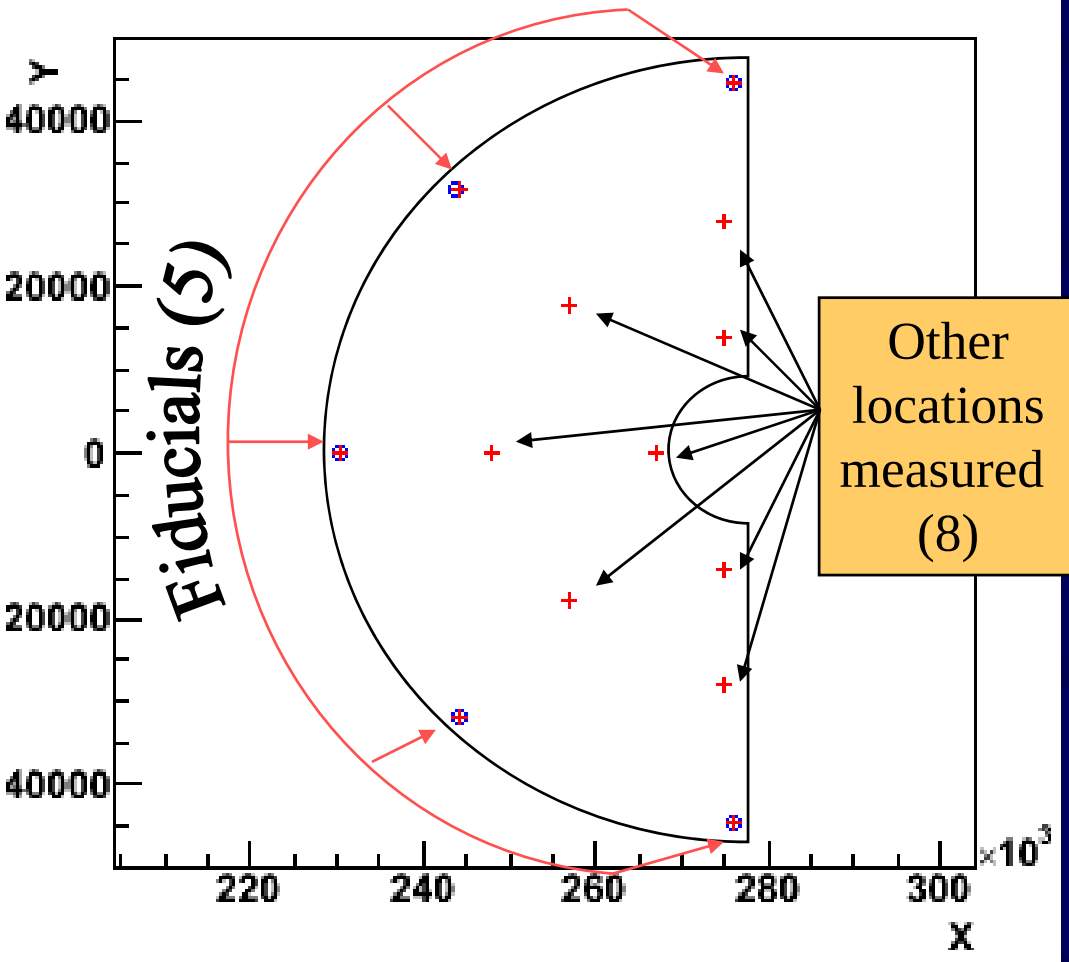
<Phi sensor>: -20.854 mm
Deviation 4 ± 15 µm

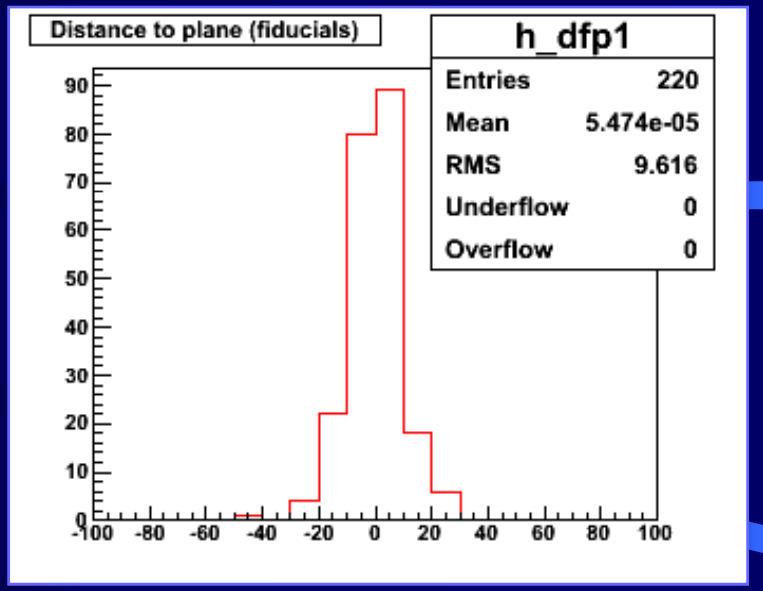
Expect:
-20.850 mm

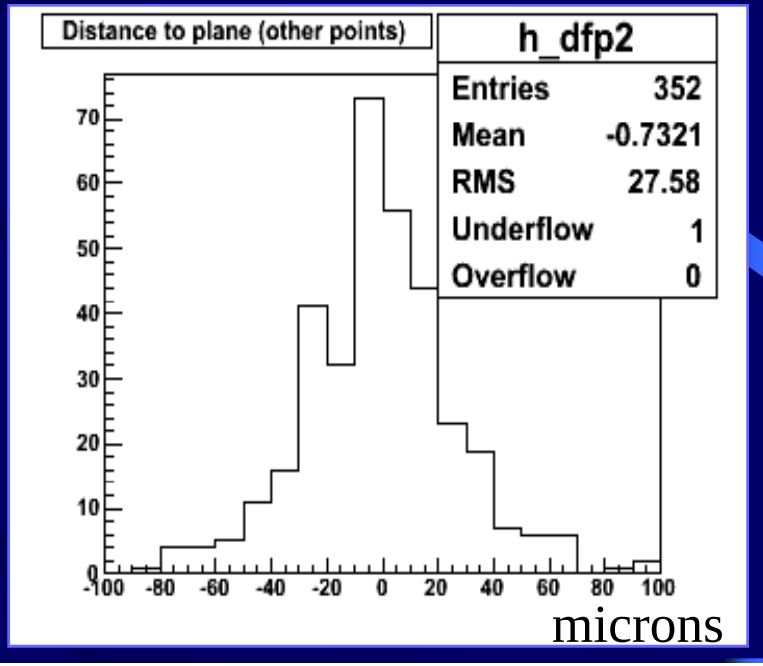
<R sensor>: -20.908 mm
Deviation 8 ± 13 µm

Expect:
-20.900 mm

Planarity of sensors



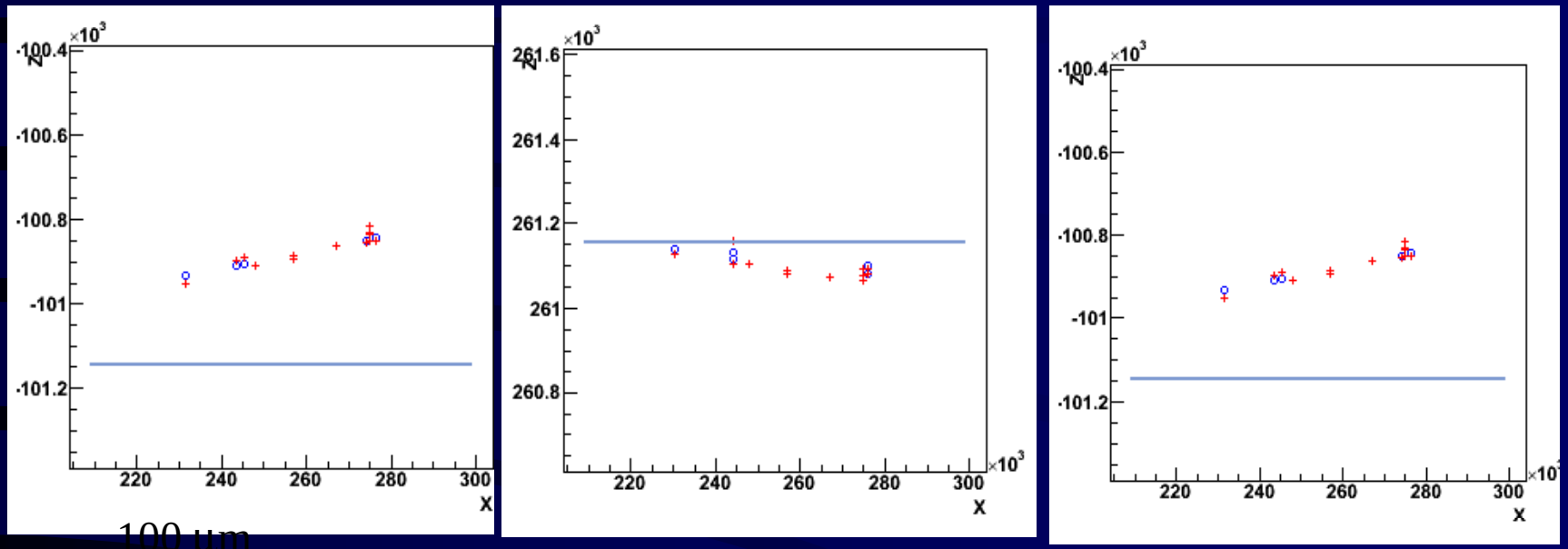




Detectors quite flat, as expected

Planar and Vertical?

3 of the 42 modules



100 μm

- Constraint system added to keep modules' positions stable along beam axis
- Slightly tilted by the constraint system
  - Well measured by survey, to be included in Geom DB

Placement of VELO Vessel

•VELO vessel installed in pit & surveyed

Deviations from nominal
1σ error = 0.3 mm

Point	DX (mm)	DY (mm)	DZ (mm)
LOTU	0.4	-0.3	-0.5
LOTD	0.5	-0.2	-0.4
LOBD	0.4	-0.1	-0.2
LOBU	0.3	-0.3	-0.2
LOTM	0.3	-0.2	-0.4
ROTU	-0.4	0.0	-0.2
ROTD	-0.3	0.2	-0.4
ROBD	-0.6	0.3	-0.5
ROBU	-0.4	0.3	-0.1
ROTM	-0.2	0.2	-0.3

- ❑ VELO well positioned.
- ❑ Z-axis known to ~0.3 mrad.

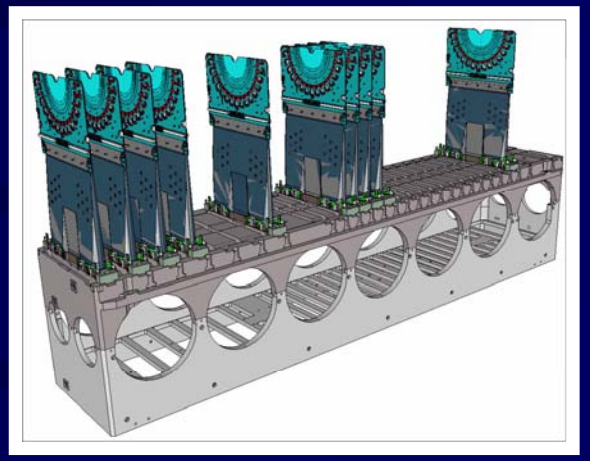
Once we have collisions, we can adjust if necessary.

Photogrammetric measurements of VELO vessel

VELO Alignment @ Work

November ‘06 test-beam of VELO half (6 modules read out).

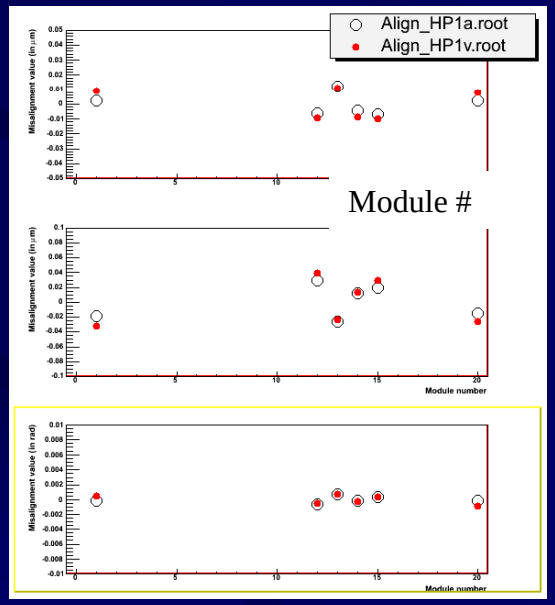
- Usage of survey data in detector description as seed for track-based alignment.
- Millepede-1 algorithm deployed, worked as expected (kudos to Seb!)
- Usage of r-ϕ relative sensor alignment survey data greatly improved resolution.
- MC invariant bugs in geometry uncovered; only uncovered by having data!
- Alignment unchanged as VELO pressure reduced from ATM to ~few*10^{-5} mbar.
- Small changes in alignment in going from RT to -20C



X

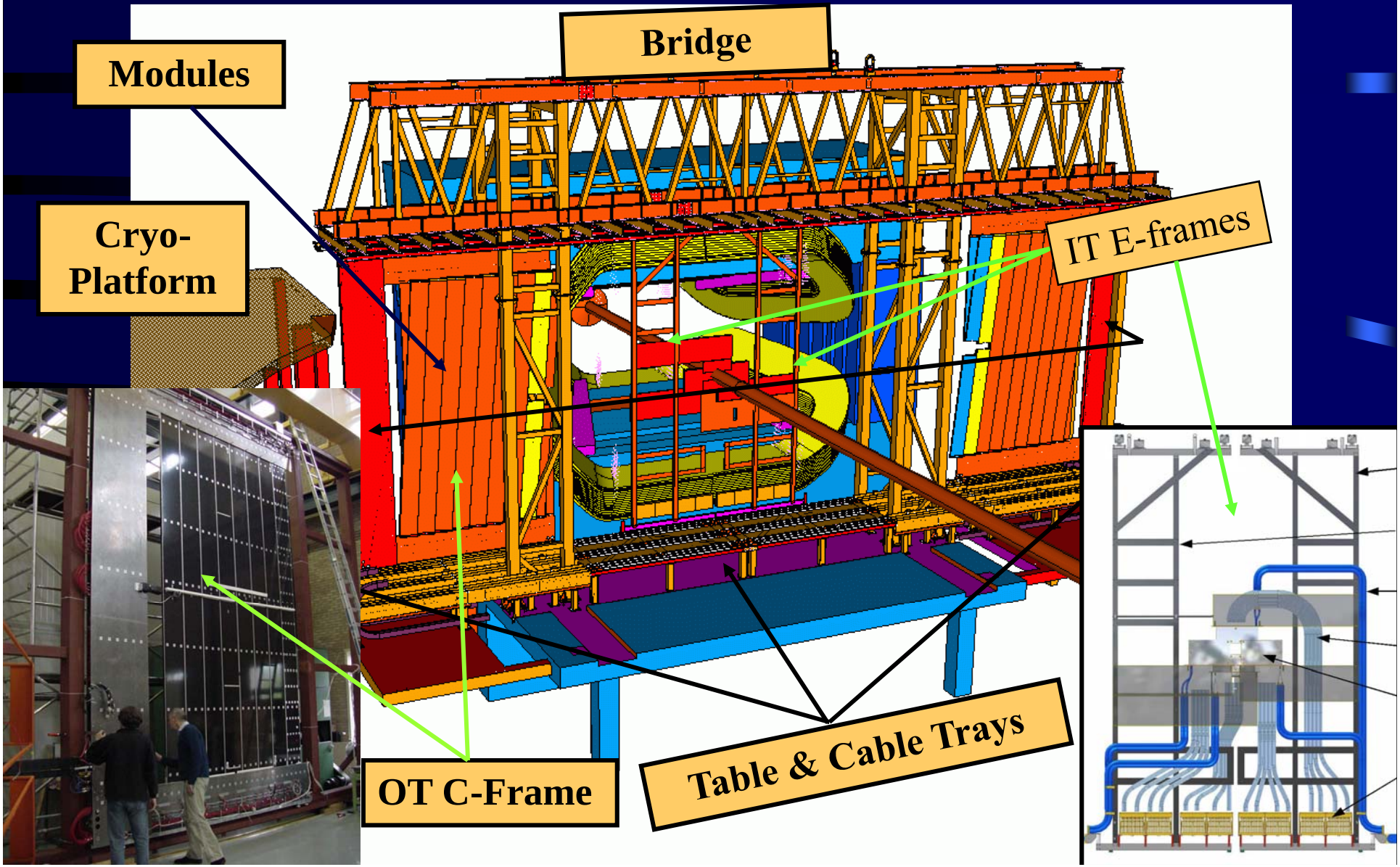
Y

γ



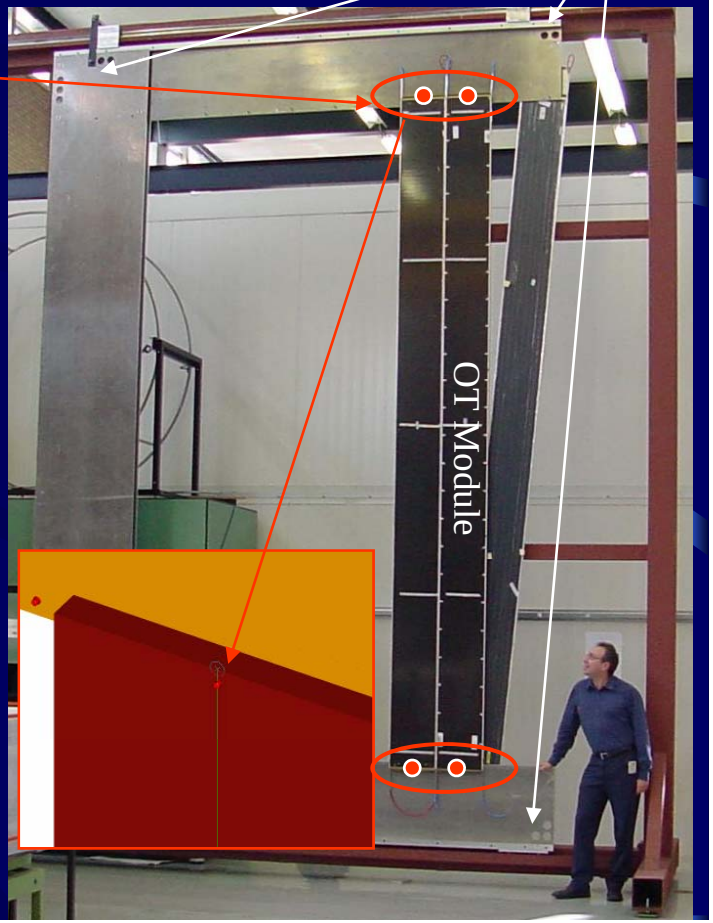
Alignment before(open) after (red) pumping down

Tracking Stations Global View



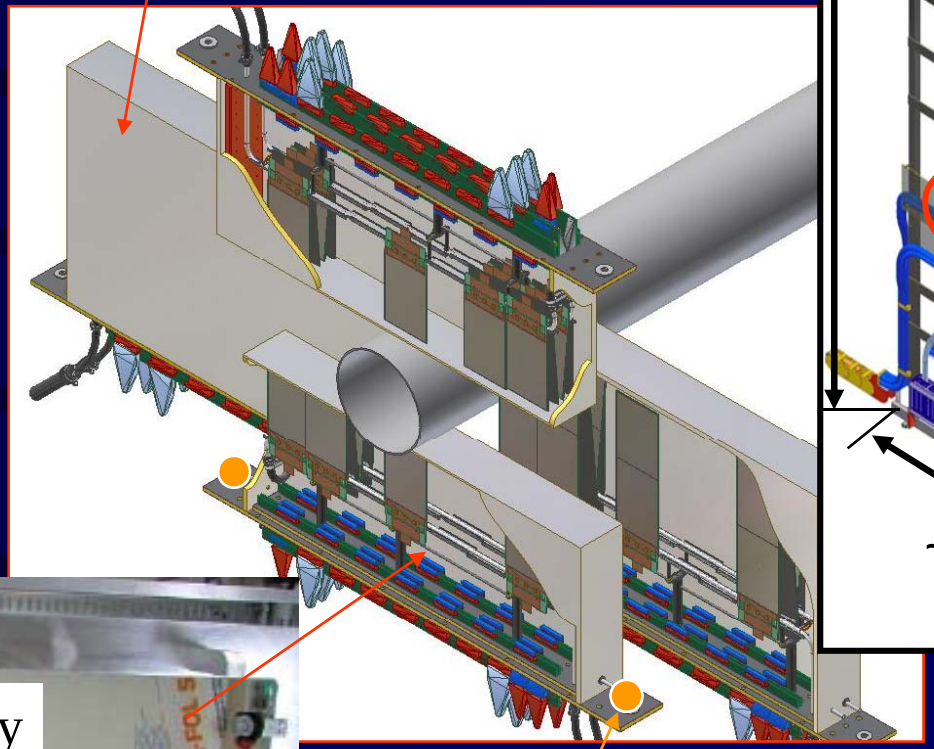
Outer Tracker

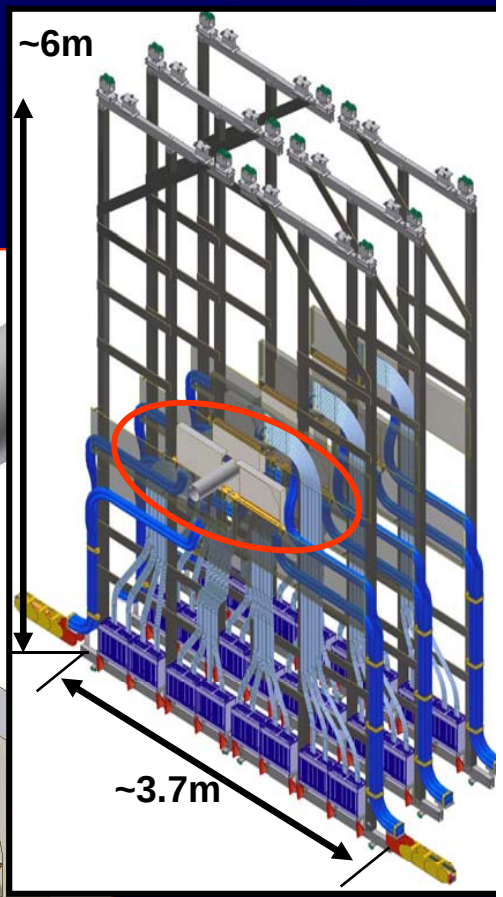
- Pitch of 5.25 mm tightly controlled by mechanical jigs
  - Tolerance 20 μm maximum deviation of wire from center of tube
- Module mechanics tightly controlled by precision jigs
- Straw modules are located on C-frame using precise dowel pin alignment
  - Dowel pins will be surveyed with OT in its nominal closed position
- C-frame attached to *bridge*;
  - Position adjustable both vertically and along beam direction
- Bridge (upper), table (lower) and rails (top&bottom) surveyed, adjusted and within tolerances
- Monitoring of C-frame with RASNIKs
- Status: All modules installed. Final survey with OT in closed position needs to be done (beam pipe protection prohibits closing).

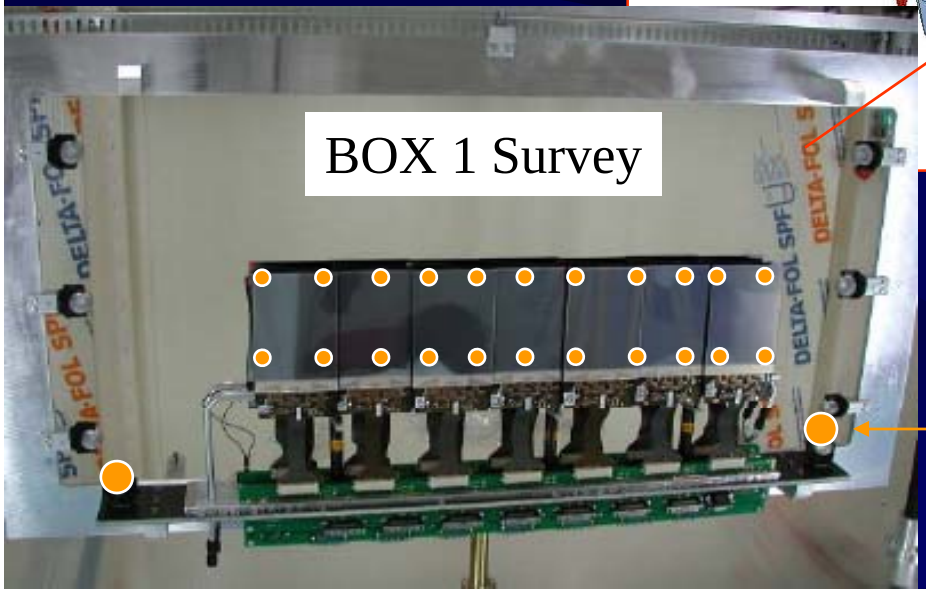


Inner Tracker (IT)

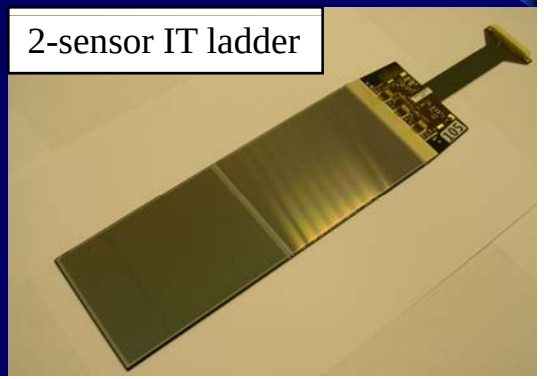
- Relative alignment of two-sensor ladders done and well within tolerance (see next slide)
- Survey of sensor with respect to fiducials exterior to the box underway
- Survey of boxes in detector hall on E-frame still to come



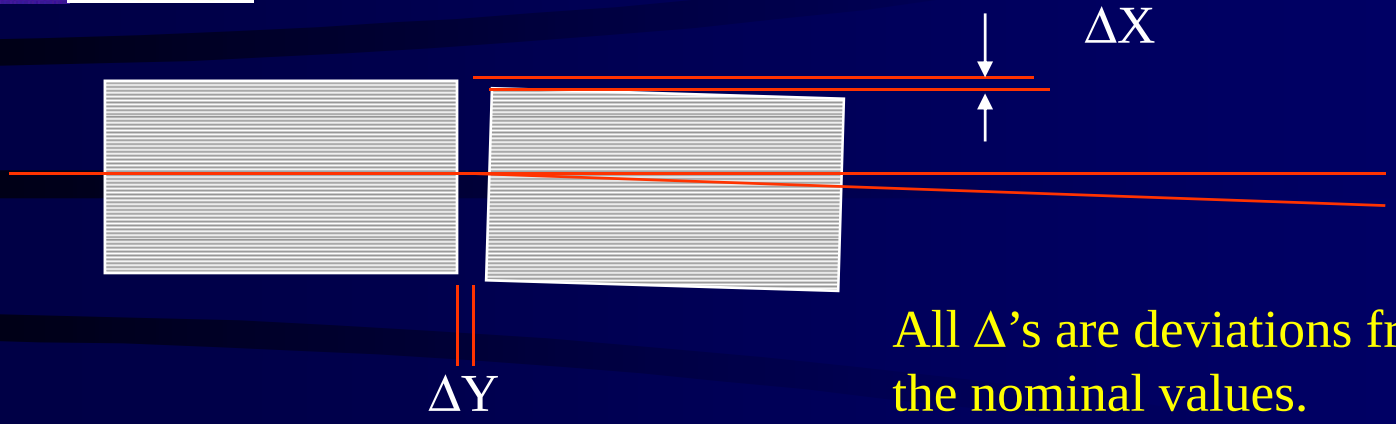




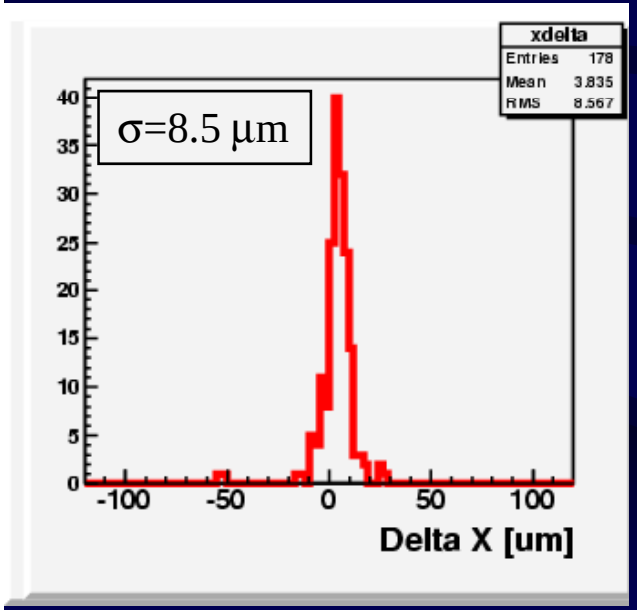
Location for Survey Balls (in lab and in pit)

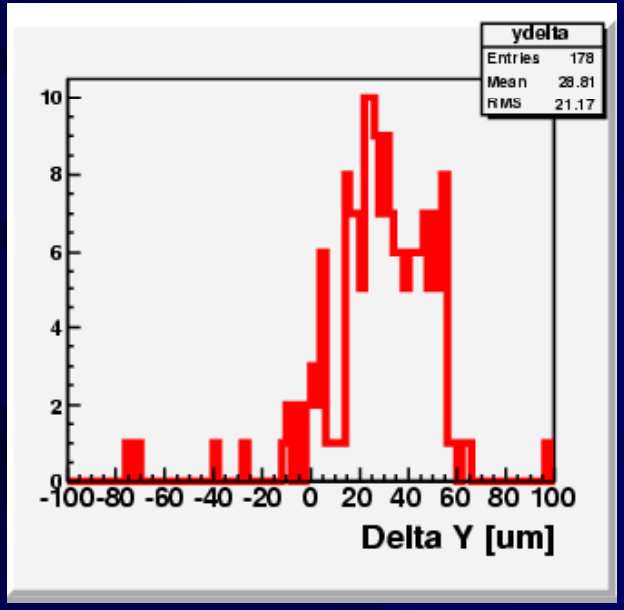


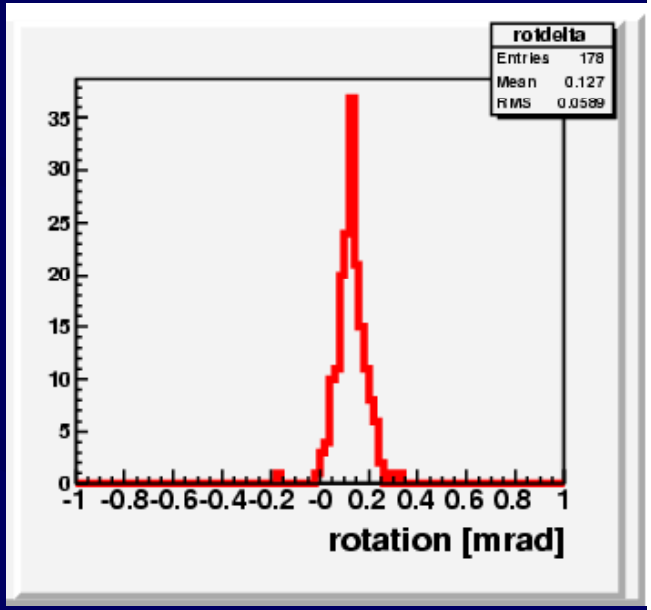
IT 2-sensor ladder metrology



All Δ's are deviations from the nominal values.







➔All misalignments small compared to intrinsic resolution (198μm pitch)

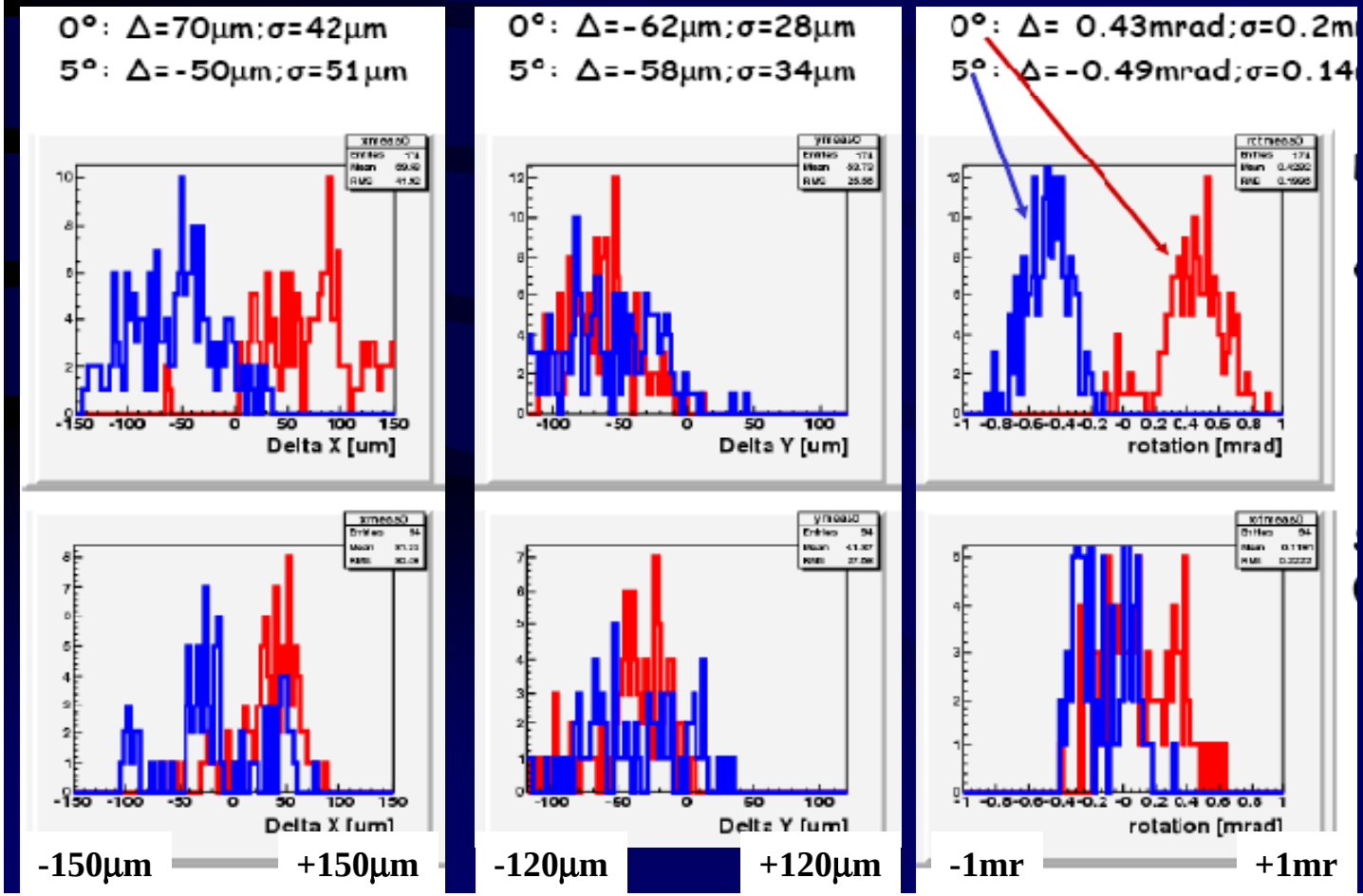
➔1-strip 57 μm, 2-strip ~20μm.

➔Only need to align ladders, not the individual sensors (at least at t=0)

IT Ladder Survey

Survey with respect to precision alignment pins on ladder.
Systematic shifts from nominal values
Small, will be corrected in software alignment

X_{meas}-$X_{nominal}$ | Y_{meas}-$Y_{nominal}$ | R_{Zmeas}-$R_{Znominal}$

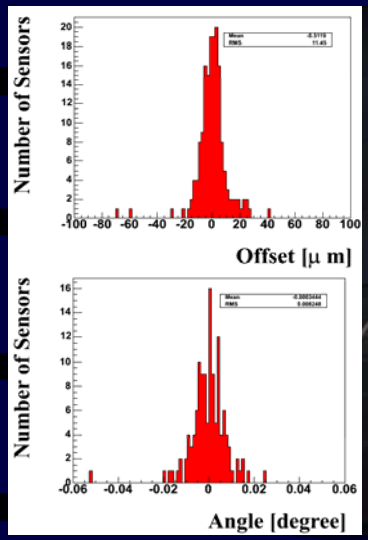


Two-sensor ladders

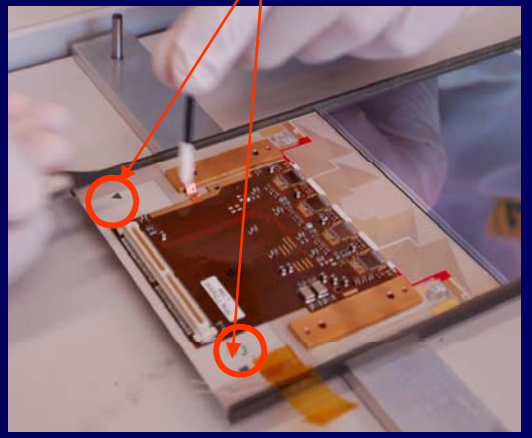
One-sensor ladders

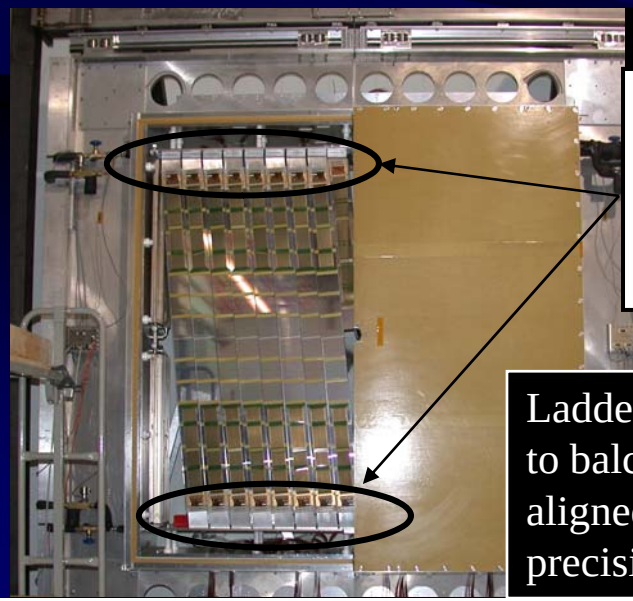
Trigger Tracker (TT) Alignment

Survey of all ladders

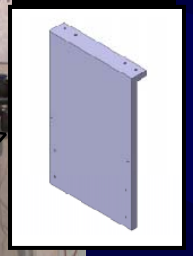


Precision alignment holes on AlN ceramic substrate





Balcony



Ladders attach to balconies; aligned with precision pins

TT rails, boxes installed and surveyed. Well within tolerances!

Excellent repeatability wrt open/close

Next up: Survey of balconies, install service boxes, install ladders & test…

Muon Alignment

- Modest alignment requirements for muon system in LHCb.
  - Hardware alignment to within ~1 mm is expected to be achieved through various survey measurements
  - Mainly used in L0 trigger and for identifying muons reconstructed in T-Stations.
    - Momentum measurement comes from T Stations.

Alignment Strategy First Collisions

- Magnet OFF data
  - Straight track segments
  - Magnetic field effects decoupled from geometry
  - Use calorimeter for rough momentum estimate (if necessary)
  - ~1M min-bias events should be sufficient to obtain reasonably good alignment for ~entire detector
    - At 2 kHz, this is 10 minutes of data.
  - Halo tracks to reduce systematics, improve precision
  - Clean event/track selection, isolation requirements(?) hit ambiguity(?), avoid LR ambiguity in straw for first pass, usage of overlap regions in IT/OT; being implemented, considered.
  - All relevant DOF's determined
- Magnet ON data
  - Cross-check magnet off alignments.
  - Internal DOF should not change; perhaps (albeit unlikely) small global shifts (magnet tests later this summer)
  - Mass & Vertex constraints; see talk by Wouter Hulsbergen.

- Misalignment challenge: Misalign all relevant DOF's and perform alignment. Include correlations. Aligners blind to input misalignments (will assume rigid body elements for now). Try both random and systematic misalignments. Hierarchial, ala ATLAS study Timescale: Fall 07.

- Expect to employ both Millepede style approach and Iterative χ^2 technique.

Summary

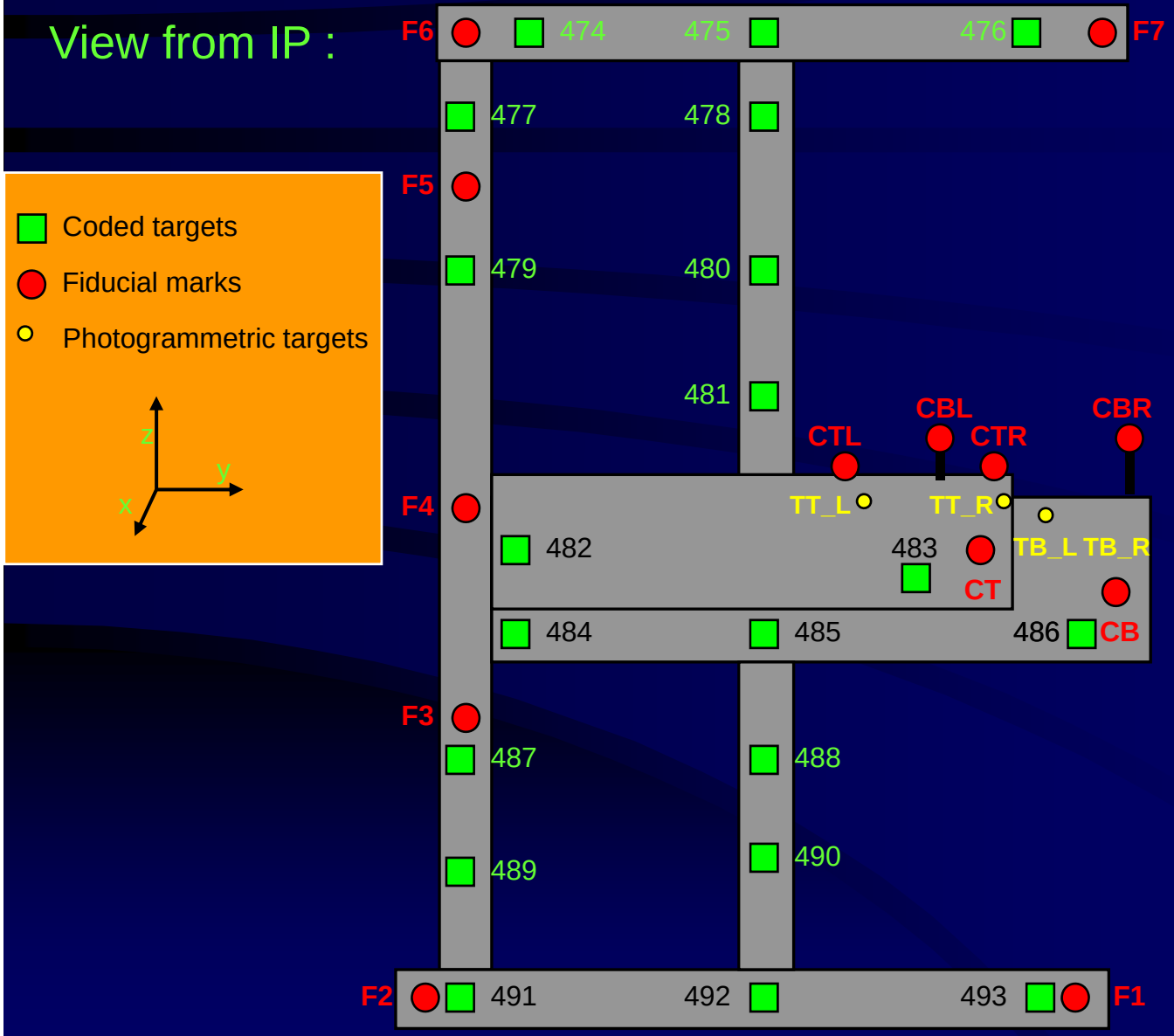
- LHC*b* surveys well underway
  - Generally excellent control over mechanical alignment during construction.
- In the final stages:
  - VELO: Just finished survey of second detector-half
  - IT: Finishing up sensor-to-box surveys; Install IT boxes
  - After beampipe protection removed, need to survey IT boxes and OT modules in the rolled in position.
  - Survey of TT balconies. Install TT, etc.
- Can collect reasonable size data samples for alignment “quickly”
  - Magnet off data critical, done first, then magnet on data
  - #Alignable elements ~10^3, not 10^5! 
- Integrated alignment framework still in development to allow for either a Millepede or Iterative style alignment
  - Velo alignment, already in action; well tested
  - T-Station framework rapidly developing
  - Eventually have a fully integrated tracking alignment package.
- Looking forward to misalignment challenge in Fall.

BACKUPS

Almost closed position, IT2A

https://edms.cern.ch/document/839426

View from IP :



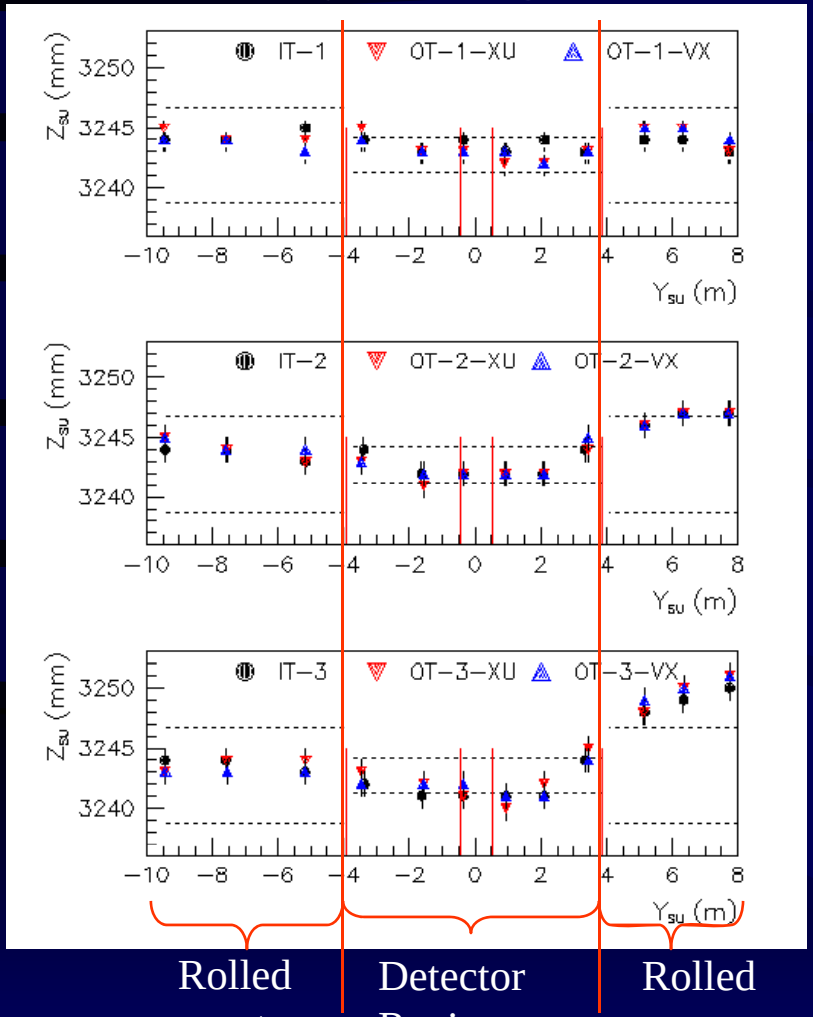
Calculated - Nominal		
DX (mm)	DY (mm)	DZ (mm)
1.5	-73.8	-3.4
2.1	-71.0	-1.1
1.3	-73.1	-0.7
0.8	-74.1	-1.0
0.8	-75.1	-1.0
2.8	-75.3	4.0
2.1	-74.4	3.8
-1.6	-73.3	0.6
-0.6	-74.0	0.9
2.7	-74.7	1.0
0.3	-75.0	1.9
1.6	-74.8	0.8
-0.9	-75.5	1.6
-0.7	-74.8	1.7

Z_{LHCb} X_{LHCb} Y_{LHCb}

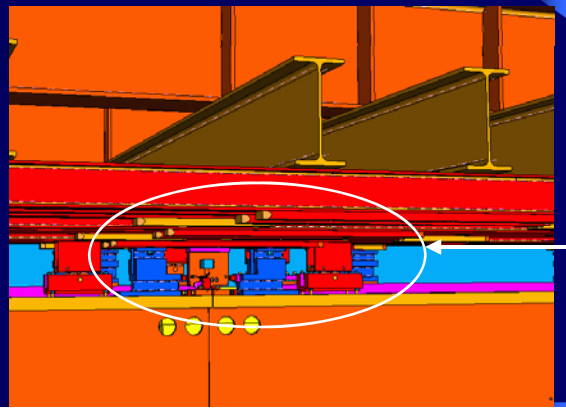
70 mm offset due to “almost closed” position

Status of OT Survey (A. Pellegrino)

Survey of Bridge Rails



- Bridge & Table surveyed in pit.
- C-frame attached to bridge rails at 2 points via adjustable trolley wheels
  - Flexibility to adjust OT C-frame along Y_{LHCb}, Z_{LHCb}.
- Nominal Z_{SU} ~3225 (2 cm too high)
  - C-frame lowered.

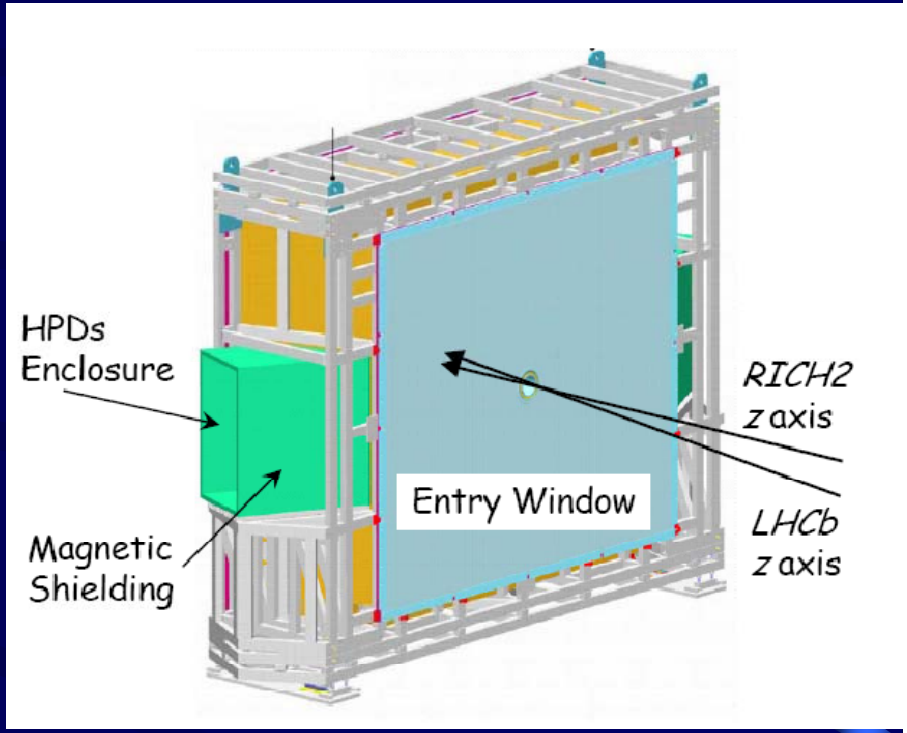


RICH-2

(Christoph Frei, A. Papenestis)

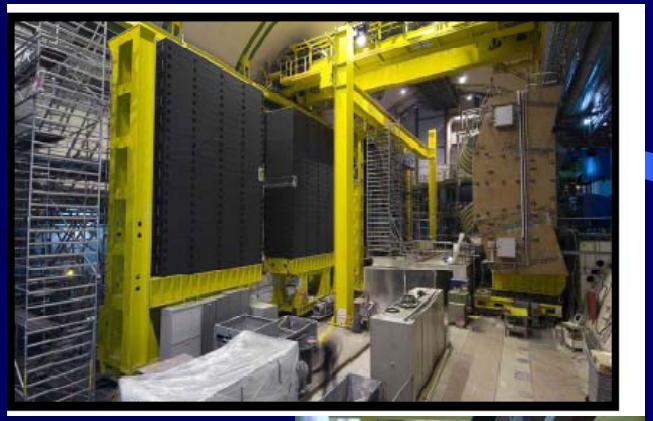
- RICH-2 built outside the cavern and installed as a unit in the cavern.

- Overall alignment of RICH2 with respect to nominal values
  - X axis rotated by ~-0.65 mrad
  - Y axis rotated by 0.1 mrad
  - ΔY = 1.2 mm
  - ΔX~0
  - ΔZ=-2.2 mm



ECAL/HCAL

- ECAL Survey Summary
  - Wall size is within measurement error to design value
  - x,y-positions of module are known to ±0.5 mm
  - z-position: all modules within ±2 mm



- HCAL Survey Summary
  - Lateral tolerance within +/- 1.5 mm
  - Front side vertical within +/- 0.5 mm
  - Height at four edges within +/- 0.2 mm

- PRS Survey Summary
  - Measurements of the vertical position of the super-module have been made
  - Has moved (~cm) after beam has been weighted (cable trays)
  - Re-positioning and measurement do be done

- Some offsets need to be included in geometry DB.
  - No conditions as of this point