Warsaw in LHCb experiment

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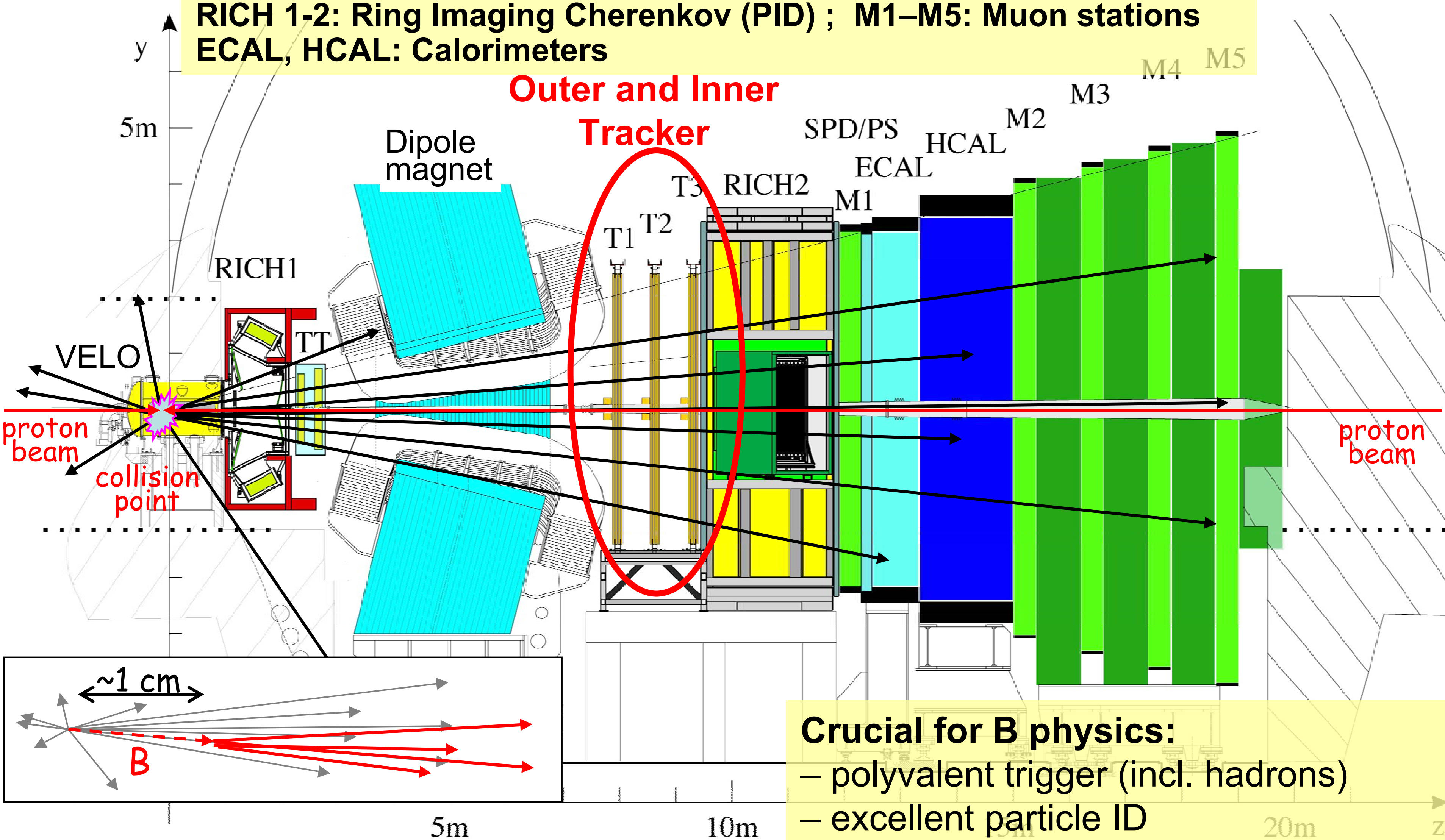
- Production of **130 + 1** modules of straw drift chambers for **Outer Tracker**
- Design, construction and tests of electronics boards for Time and Fast Control (TFC) part of **ONLINE** system :
  - **Readout Supervisor**
  - TFC Switch
  - TFC Throttle ….
- Beam Phase and Intensity Monitor (BPIM) readout
- LHCb upgrade : 40 MHz readout
- **High Level Trigger** (HLT2): selection for events of $B_s^0 \to J/\Psi(ee)\Phi$ decay (see Artur Ukleja talk)

Warsaw, 6.11.2009

LHCb Detector

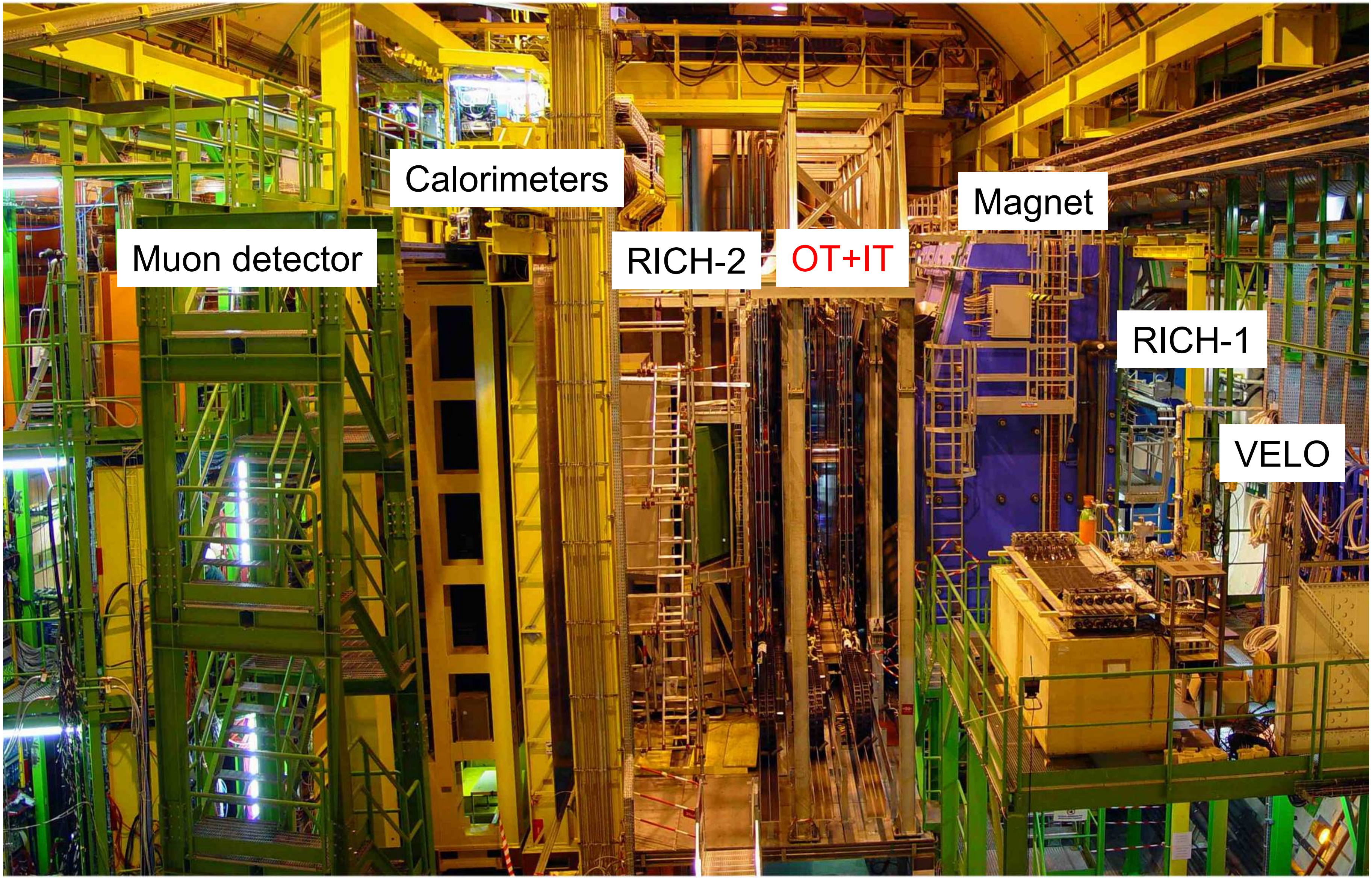
VELO: Vertex Locator (around IP) ; TT, T1, T2, T3: Tracking stations
RICH 1-2: Ring Imaging Cherenkov (PID) ; M1–M5: Muon stations
ECAL, HCAL: Calorimeters



Crucial for B physics:

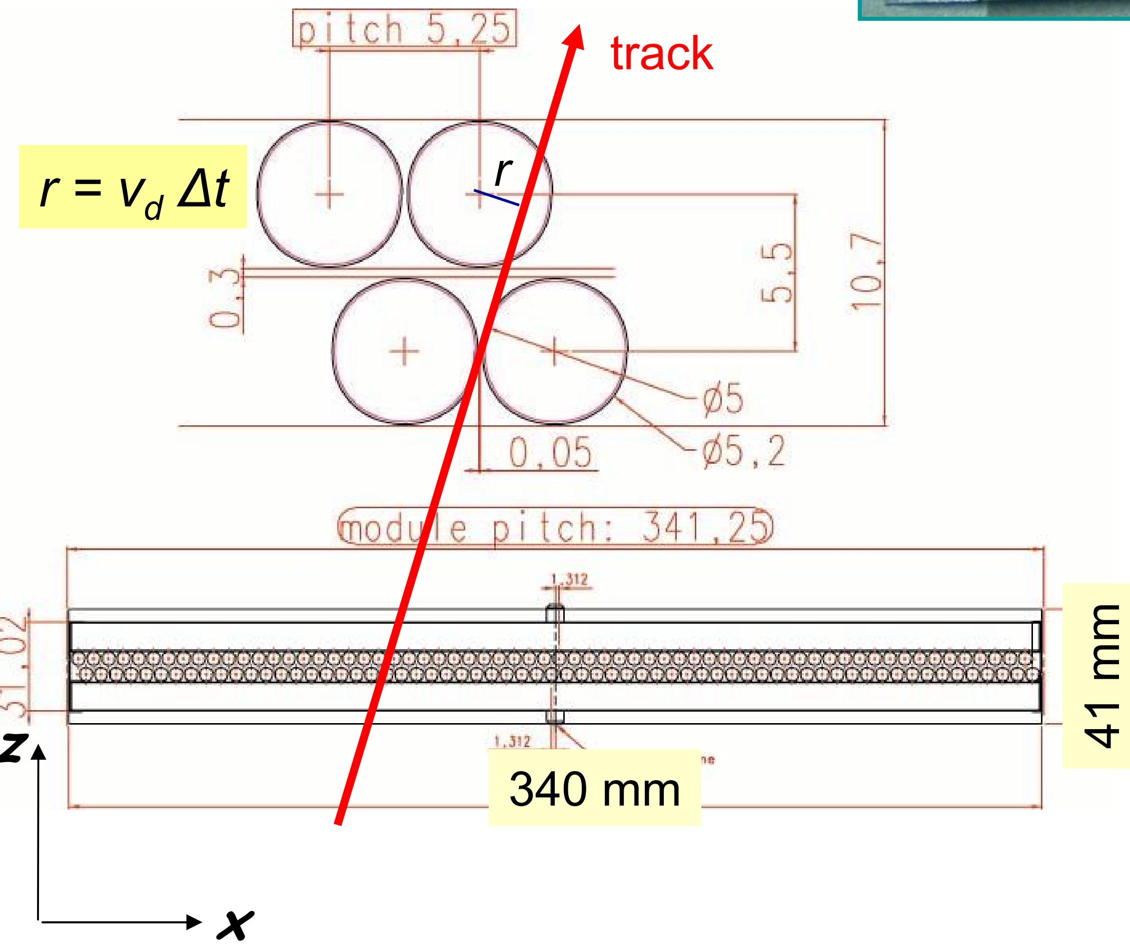
– polyvalent trigger (incl. hadrons)
– excellent particle ID
– excellent tracking/vertexing (σ_m , σ_τ)

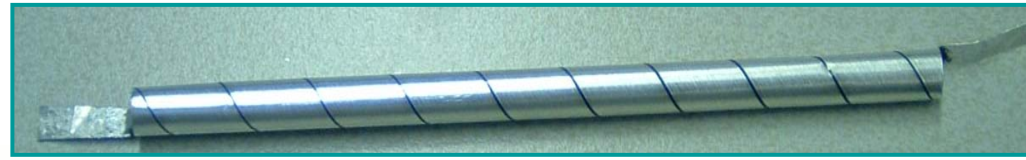
LHCb detector in UX85

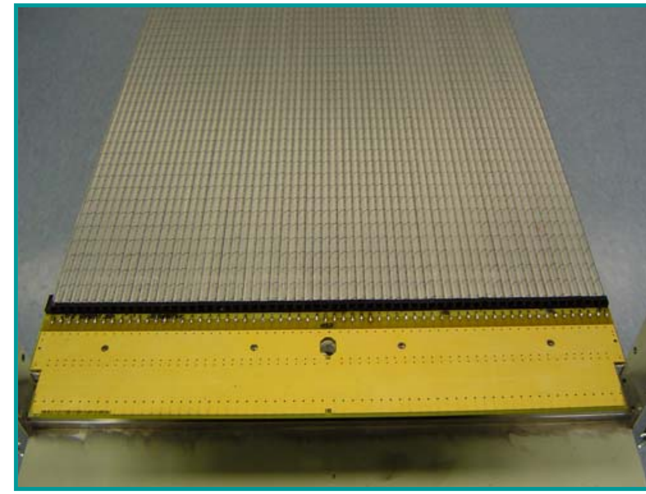


Straw Drift Tubes Modules

Straw Tubes packed in double-layered modules







25 µm tungsten (gold plated) wire

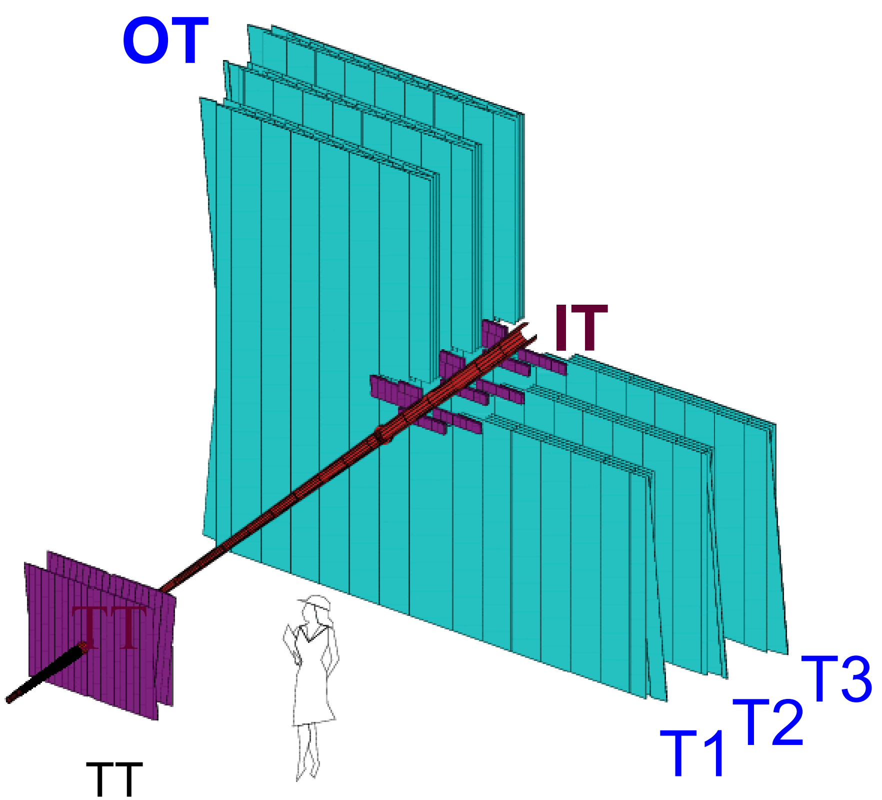
- modules 64-cells wide
- modules only ~0.37% X_0:
  - -"light" panel

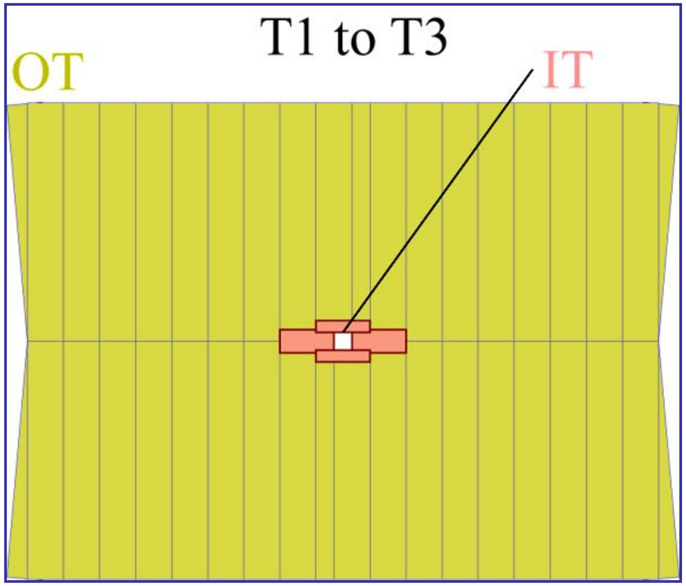
  (Rohacell core with carbon fiber skins)
  - -"light" straws:

    2 strips of thin KAPTON foil:
    - 40 µm kapton XC
    - 25 µm kapton +12.5 µm Al

Outer Tracker

- 3 stations T1,T2,T3
- Each station: 4 planes of modules **XUVX** (3*4*2 = 24 points on track)
- Vertical B field ⇒ measurement of x
- $\boldsymbol{\theta_{U,V} = \pm 5^o}$ enough to reduce combinatorics

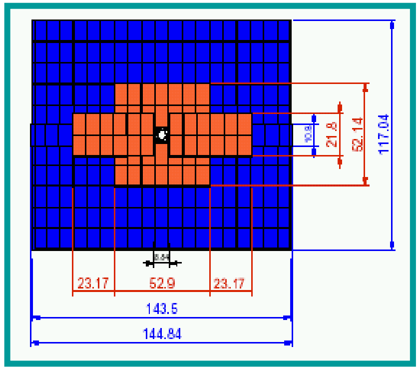


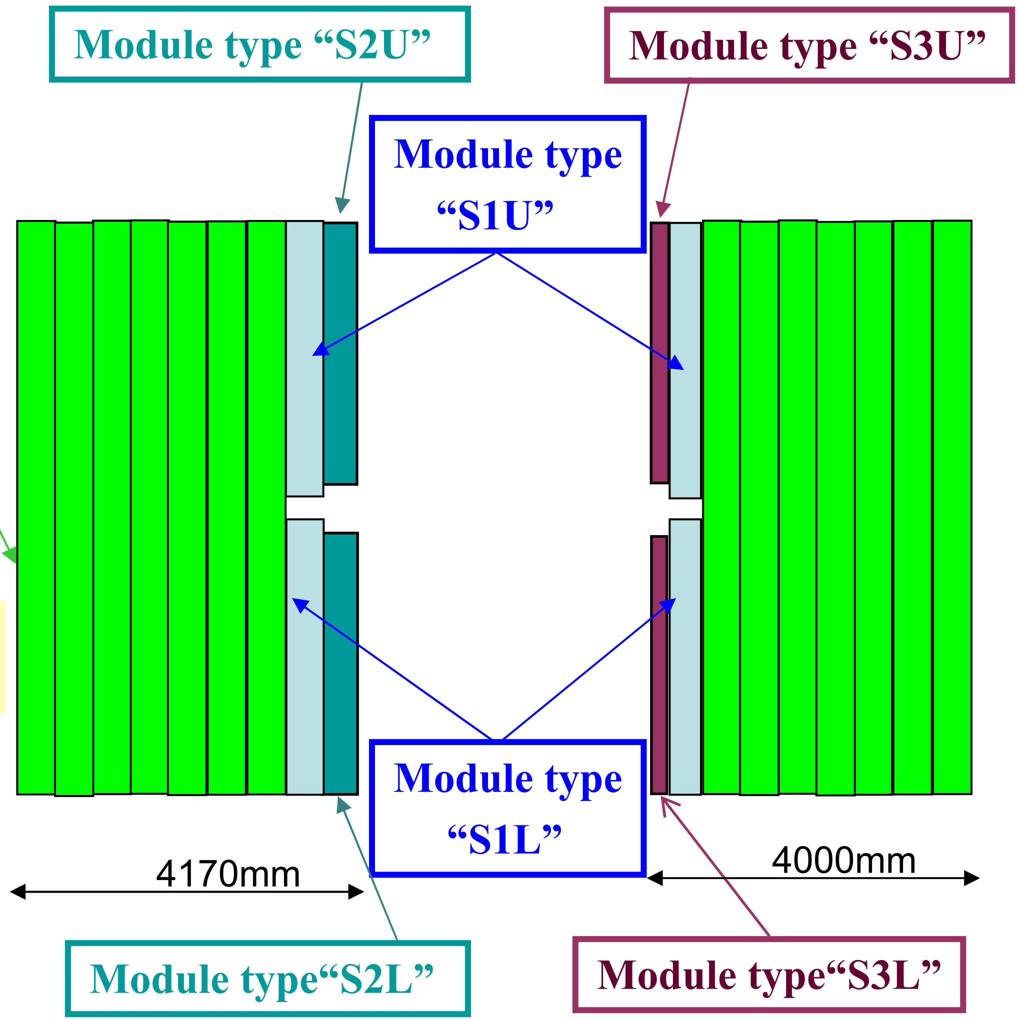


For each plane modules of standard heights and widths

Modules of Outer Tracker

Geometry of IT requires special modules of OT around IT





Short frames

- **F,S1U,S1L,S2U,S2L**: 64 straws
- **S3U,S3L**: 32 straws in layer

Scope of production

Type	Quantity	Spare	Total
F	168	17	185
S1U	24	6	30
S1L	24	6	30
S2U	12	4	16
S2L	12	4	16
S3U	12	4	16
S3L	12	4	16

Production division: Heidelberg 60 F modules
NIKHEF 125 F modules
Warsaw all 124 S modules (96+28) + 6 + 1 (TRA-BOND glue)

309 modules ⇒ **~ 63 000 straws** ⇒ **~ 190 000 soldering points**

Steps of module production

Straw preparation:
length, tongue, wire locators, end pieces

Panel flatness adjusting on template

Adjustment of straws on template, soldering tongues to PCB

Gluing panel to straws
(wait one day for glue hardening)

Wiring 64 straws

H.V. and wire tension tests

PANEL **A** and **B**

Gluing spacers, gas blocks, gas pipes in panel A
(wait one day for glue hardening)

Module assembly: gluing side walls and spacers (panel B)
(wait one day for glue hardening)

Soldering Faraday cage points,
Gluing Al foil for F. cage
(wait one day for glue hardening)

Gas leak test
H.V.test in Ar/CO_2
Fe^{55} test

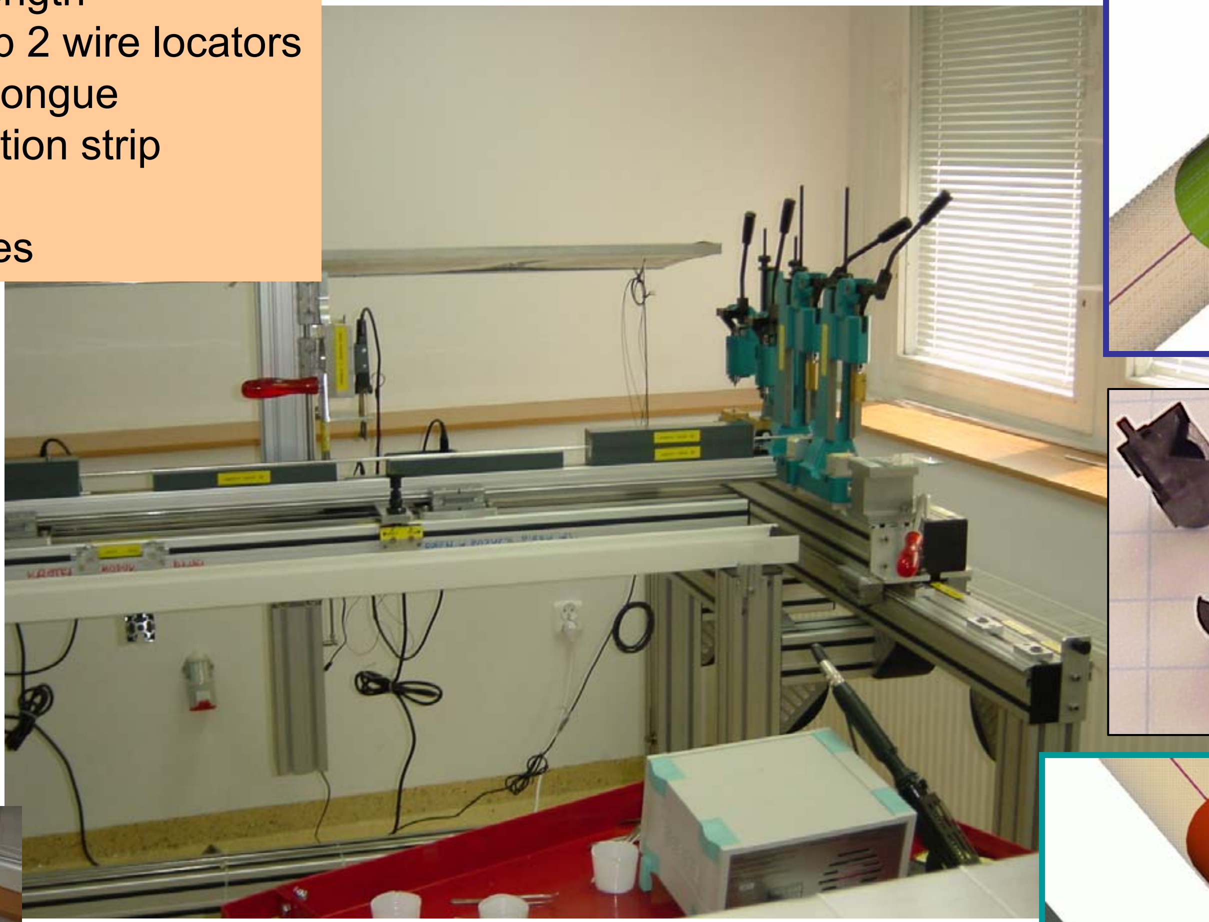
Repair
(wait one day for glue hardening)

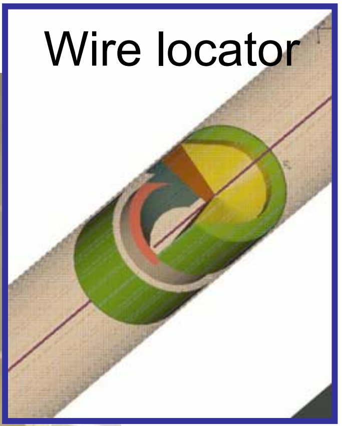
Packing and storage

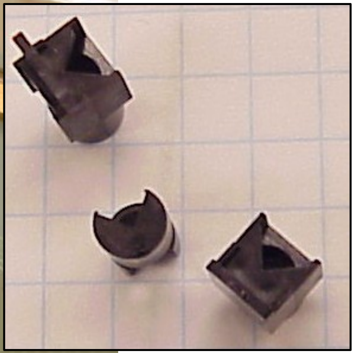
The crew

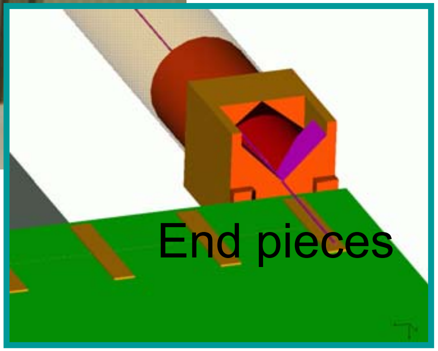
Straw preparation

1. Cut to proper length
2. Insert and crimp 2 wire locators
3. Cut grounding tongue
4. Crimp prolongation strip to the tongue
5. Insert end pieces







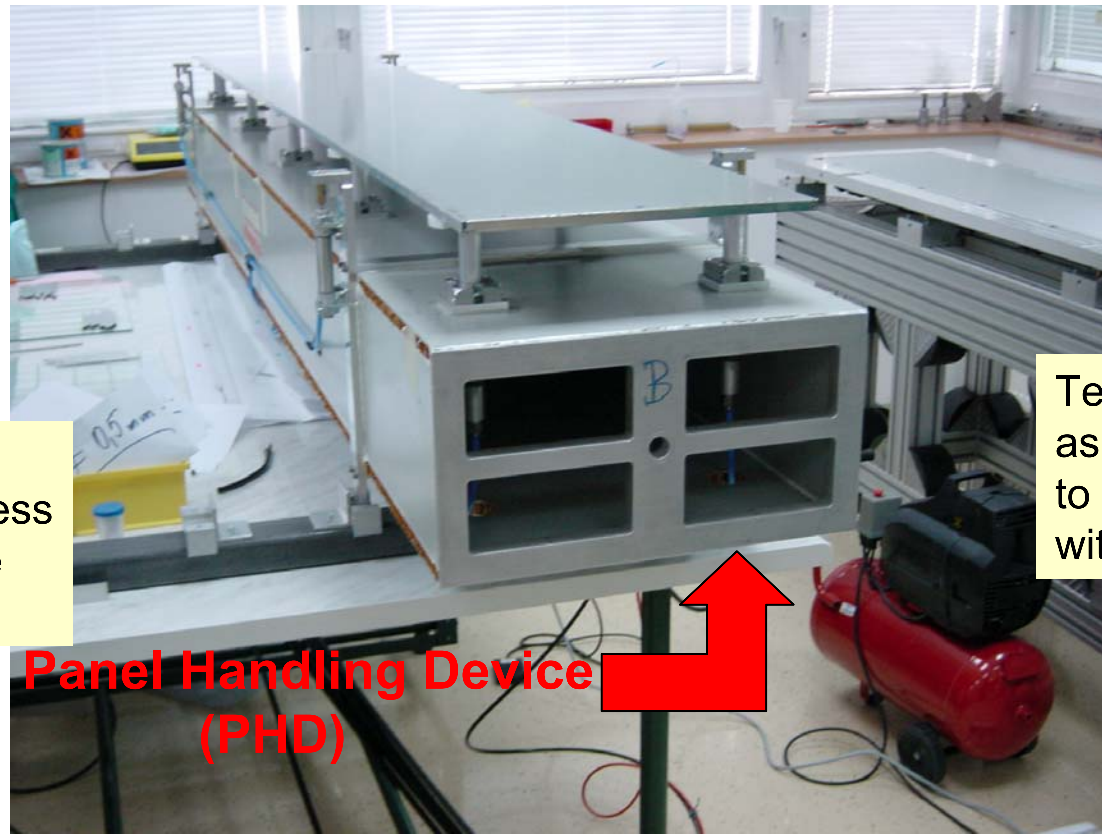


Substantial increase of production speed with crimping tool

Special tool designed by Frans Mul (Vr.Uni.)

Panel flatness adjusting

PHD with vacuum system assures flatness of panel during whole production process

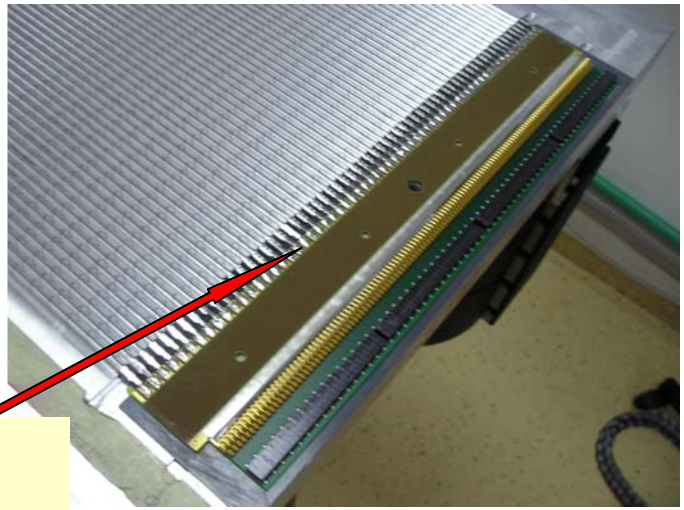


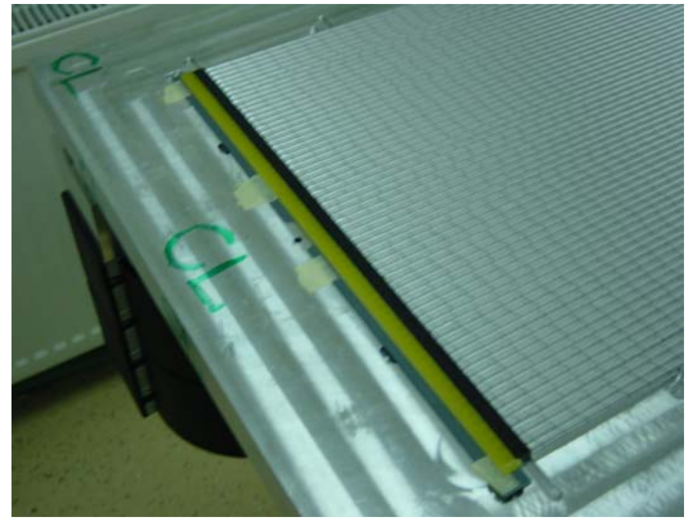
Template used as reference plane to obtain flat surface within ± 0.1 mm

PHD designed in Heidelberg

Adjustment of straws on template

Wide PCB side





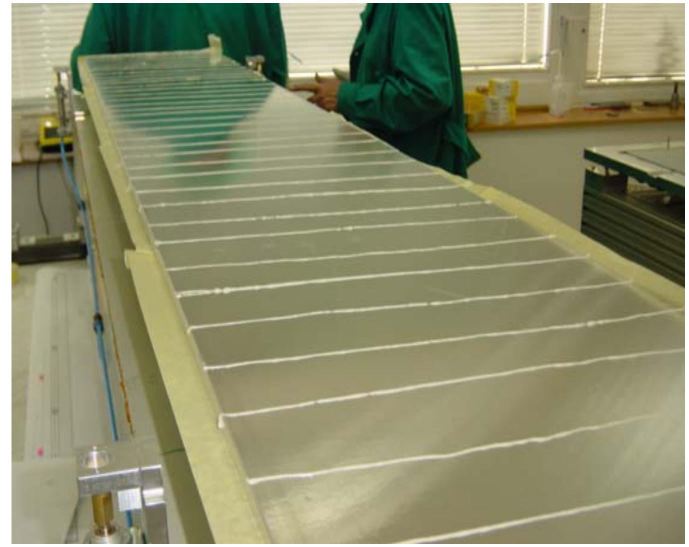
Narrow PCB side

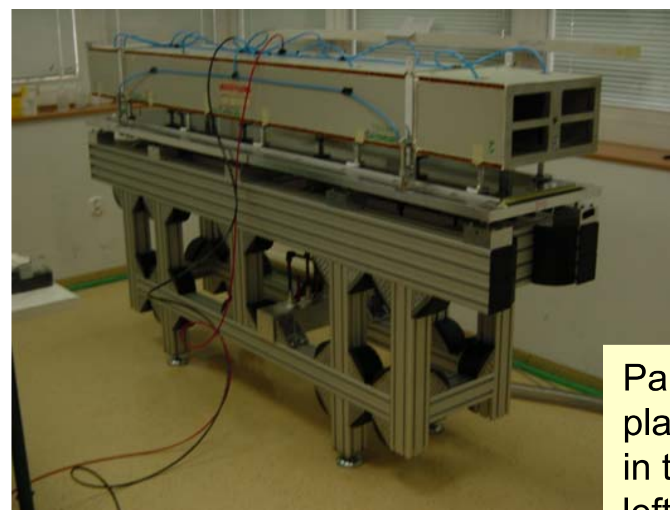
Soldering tongues to wide PCB pads for proper grounding

Straws sucked to template grooves with vacuum system

Gluing panel to straws

Glue:
50% Araldite AY 103
+ 50% (vol.) colloidal silica

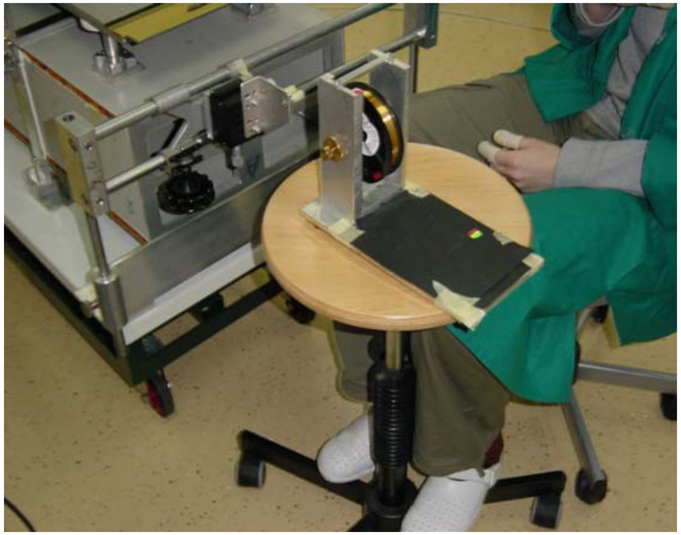




Panel with glue placed on straws in template and left for one night

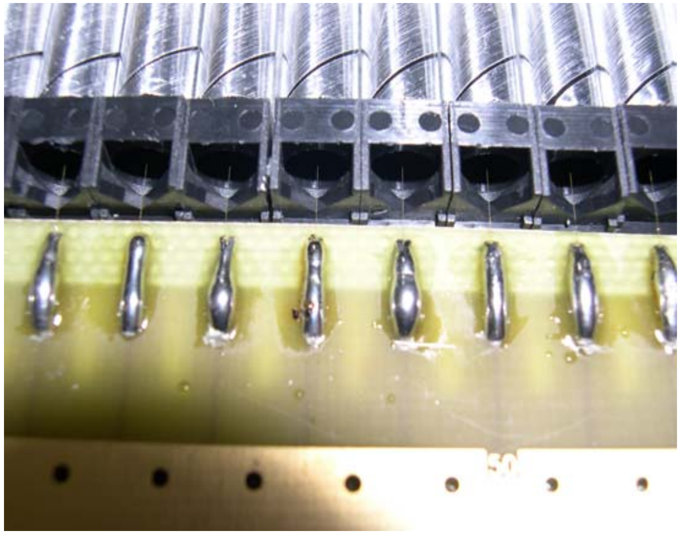
Wiring 64 straws on panel

Low table
for wiring



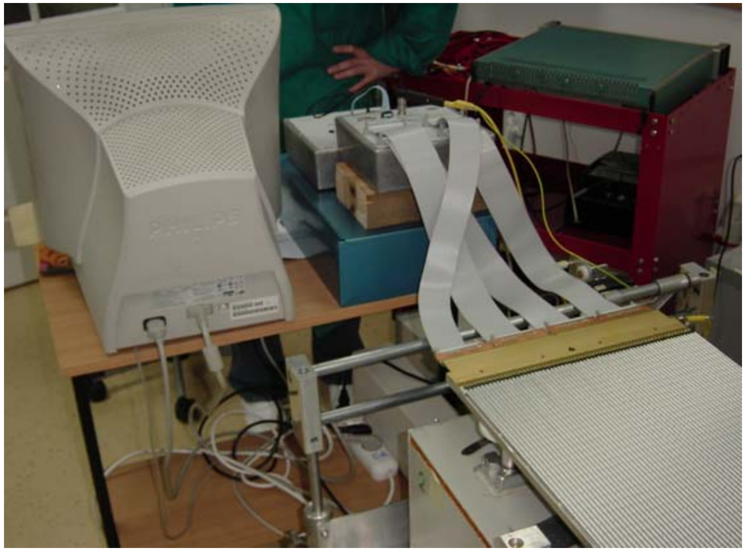
Wire:
tungsten
gold plated
25 micron
diameter

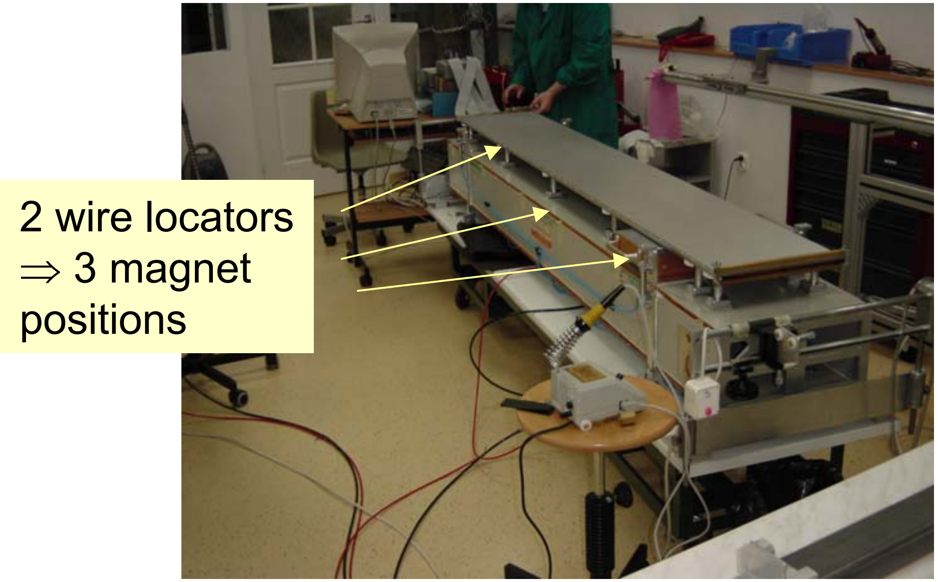
Vacuum used
to suck wires
through straws

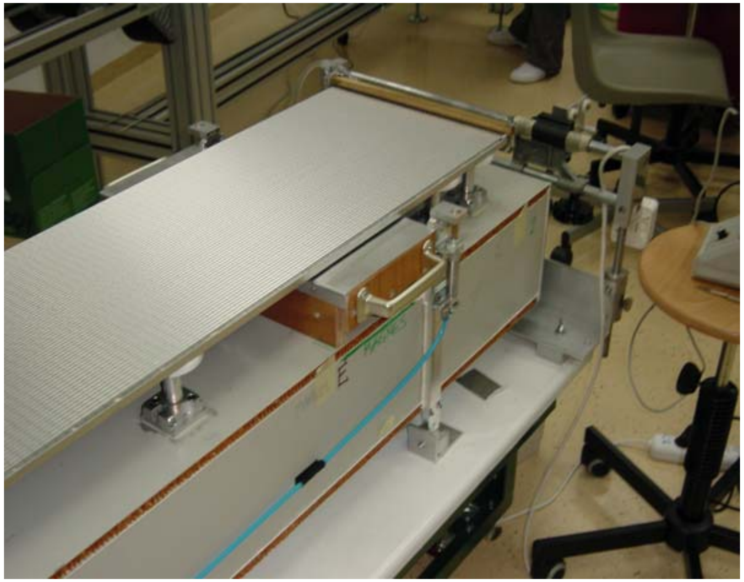


Wire streched to 70 G

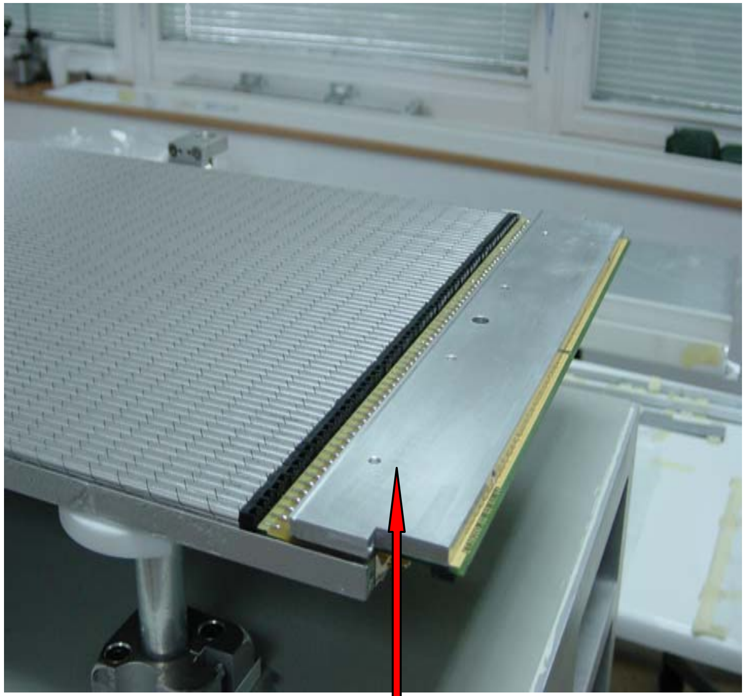
H.V. and wire tension tests





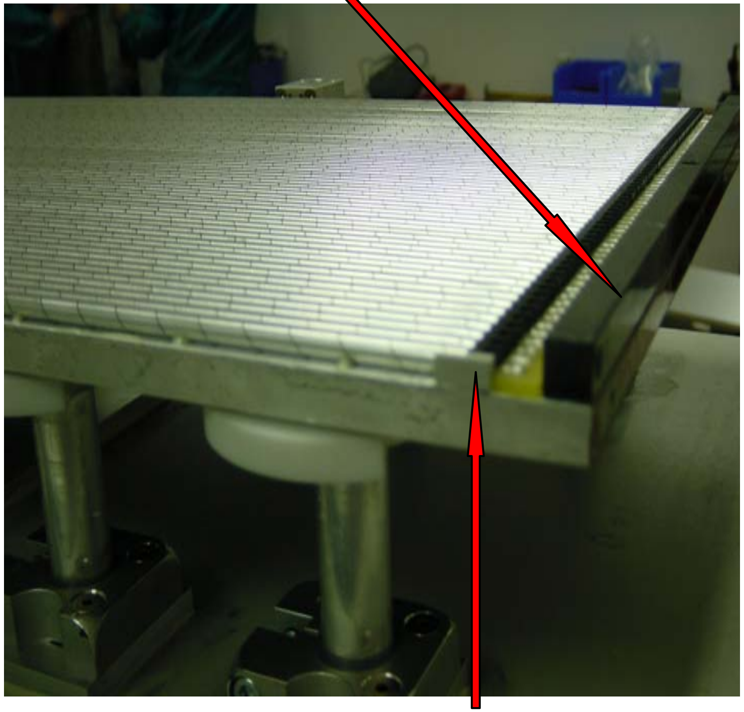


Gluing spacers and gas blocks (panel A)



Aluminium spacer

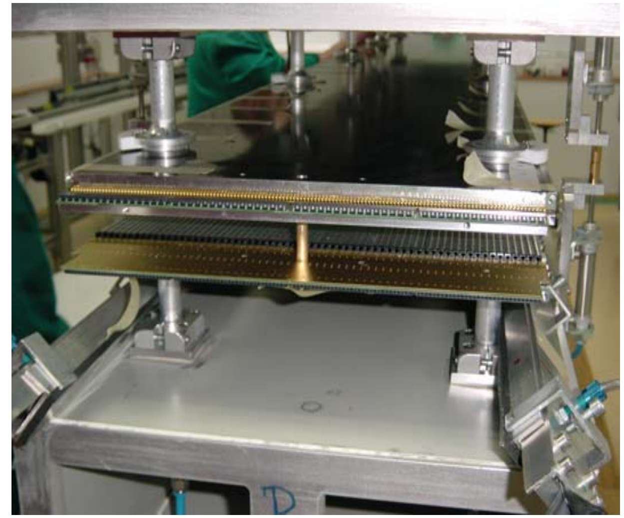
Plastic spacer (beam side)



Gas block

Module assembly (1)

Two panels placed
on top of each other



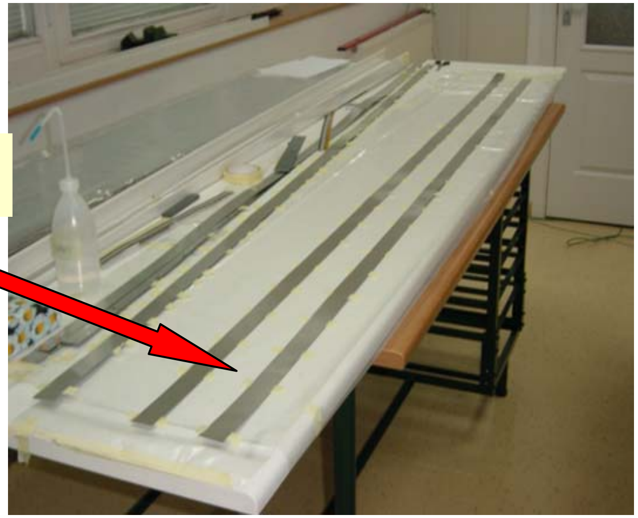
Lowered to
the proper positions

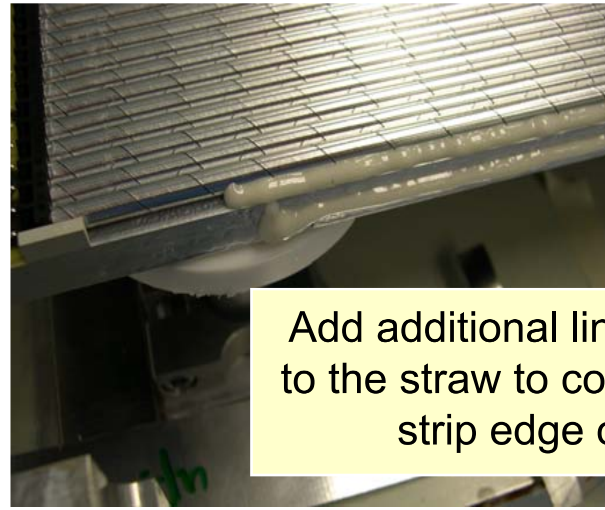
Beam side
(plastic spacer)

Outer side
(Al spacer,FTB with connectors)

Module assembly (2)

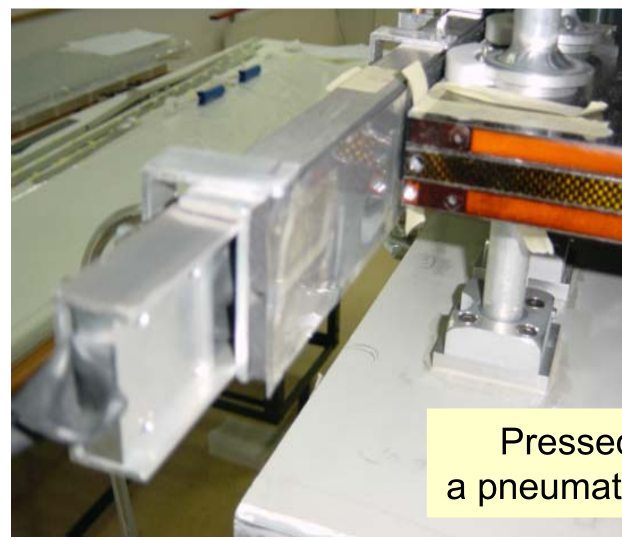
Side walls





Add additional line of glue next to the straw to cover the Al side strip edge on panel

Side walls gluing



Pressed with
a pneumatic system

Module assembly (3)

Assembled module is left for one night for glue hardening

Module finishing

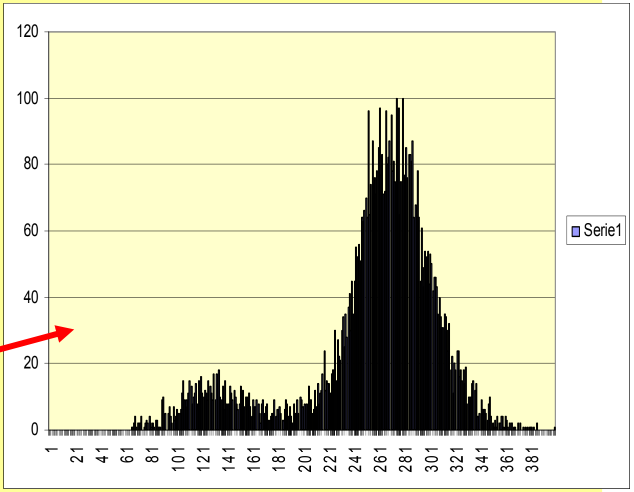
- Soldering strips of Faraday cage
- Gluing Al foil (beam side) for Faraday cage
- Gluing gas pipes

Quality Assurance

Quality Assurance during production:

- wire tension
- dark current

5.9 keV γ from ^{55}Fe $\rightarrow$ 226 e^-



Quality Assurance after production:

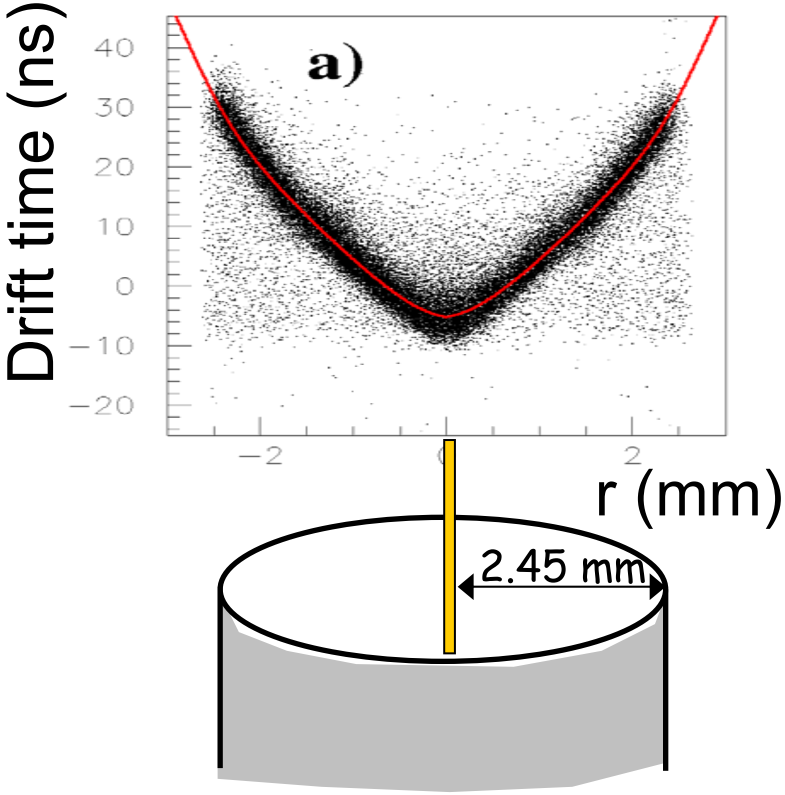
- gas tightness, dark current
- **^{55}Fe** uniform gain test
- detector response to **^{90}Sr** β-source.

Full scan (every cm^2) of all OT modules at NIKHEF

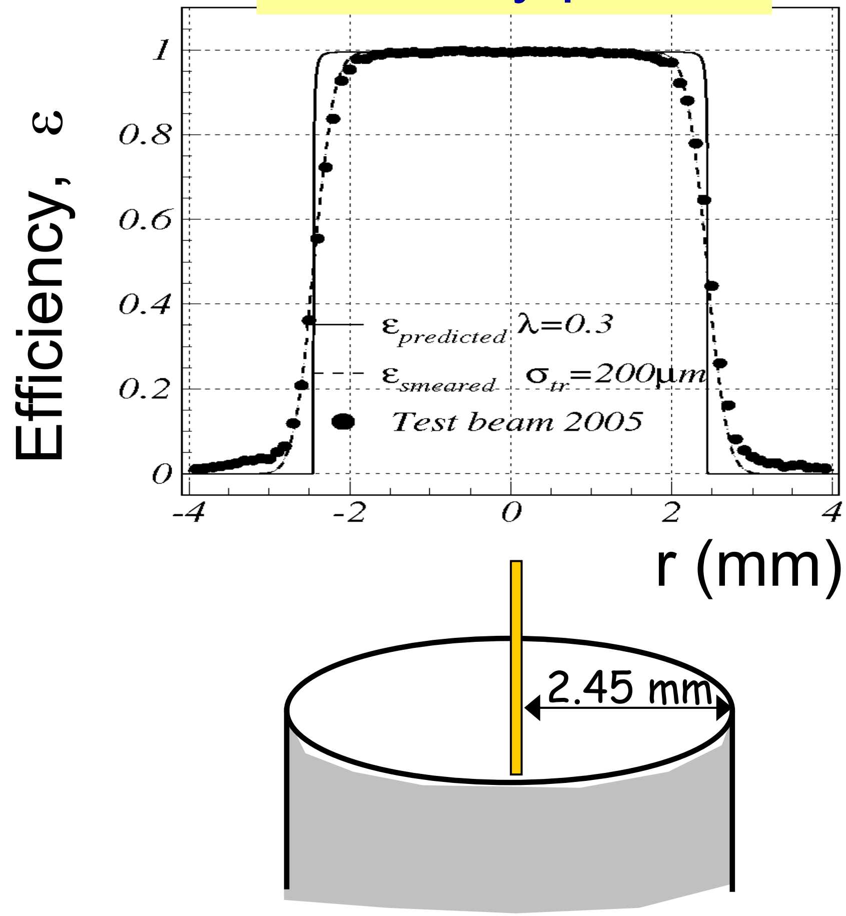
~ 0.1 % of "bad" channels

Test Beam Results

r - t relation:



efficiency profile:



Test Beam Results (cont'd)

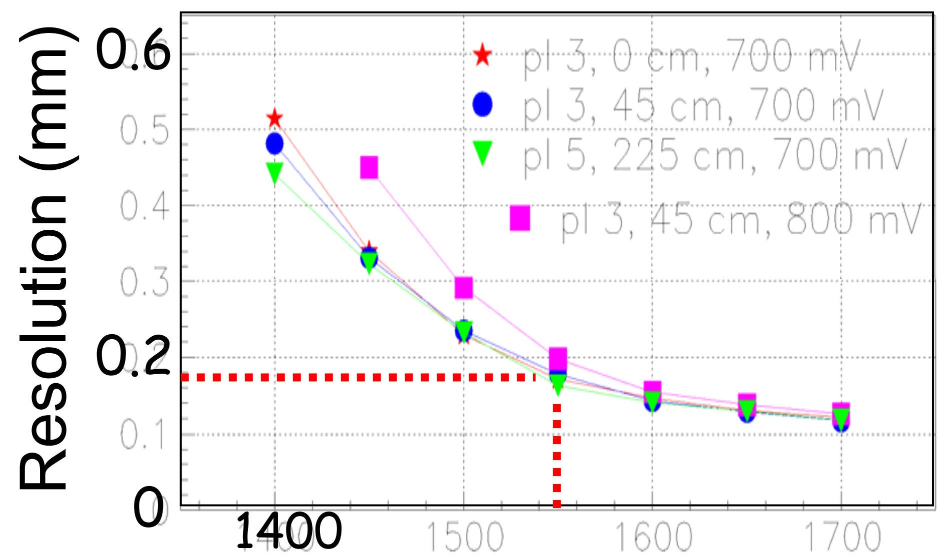
Good efficiency and resolution for

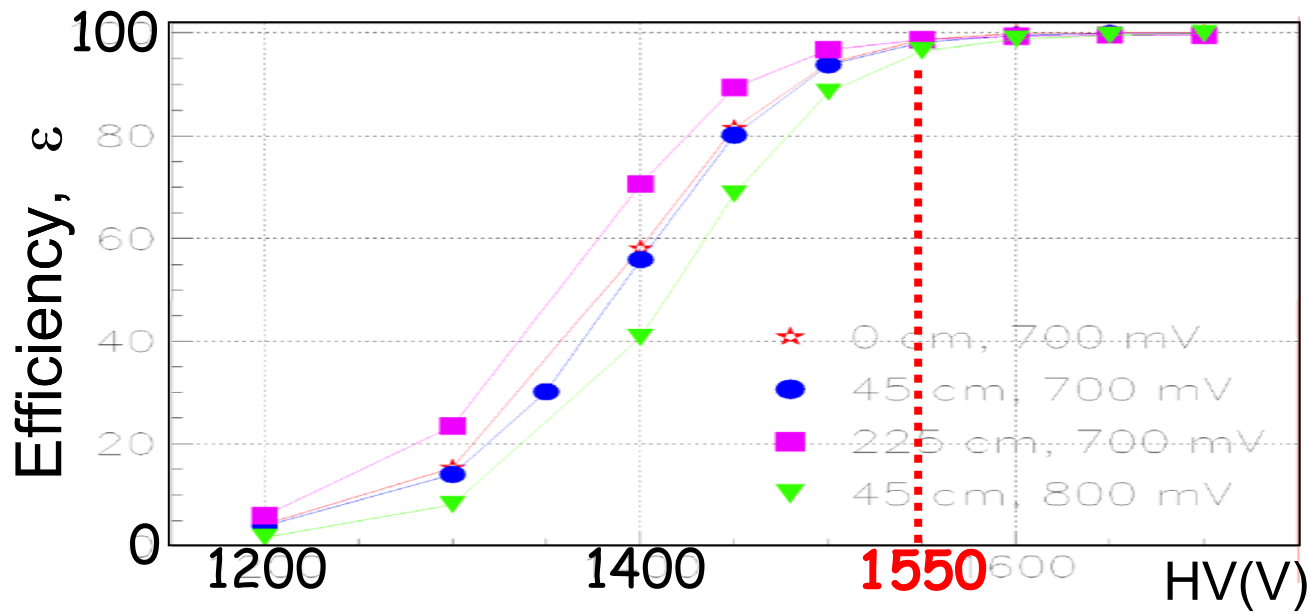
HV > 1520 V

$\varepsilon \approx 98\%$

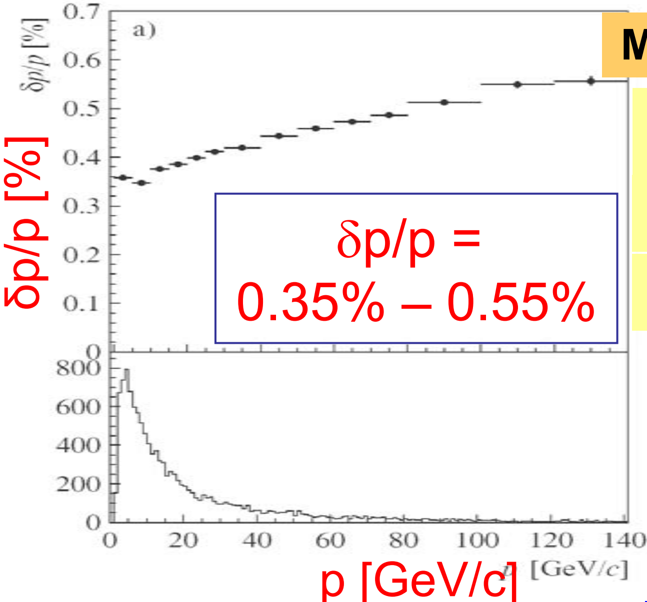
$\sigma \approx 200$ µm

corresponds to gain > 50,000





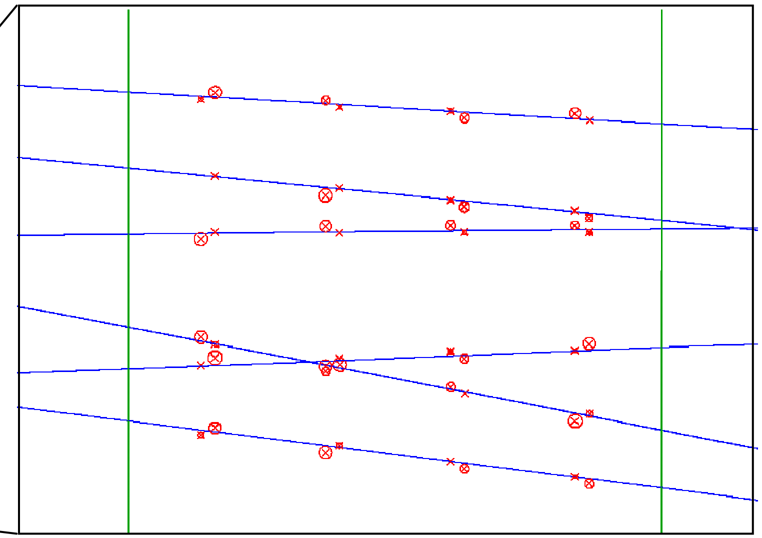
Tracking Performance

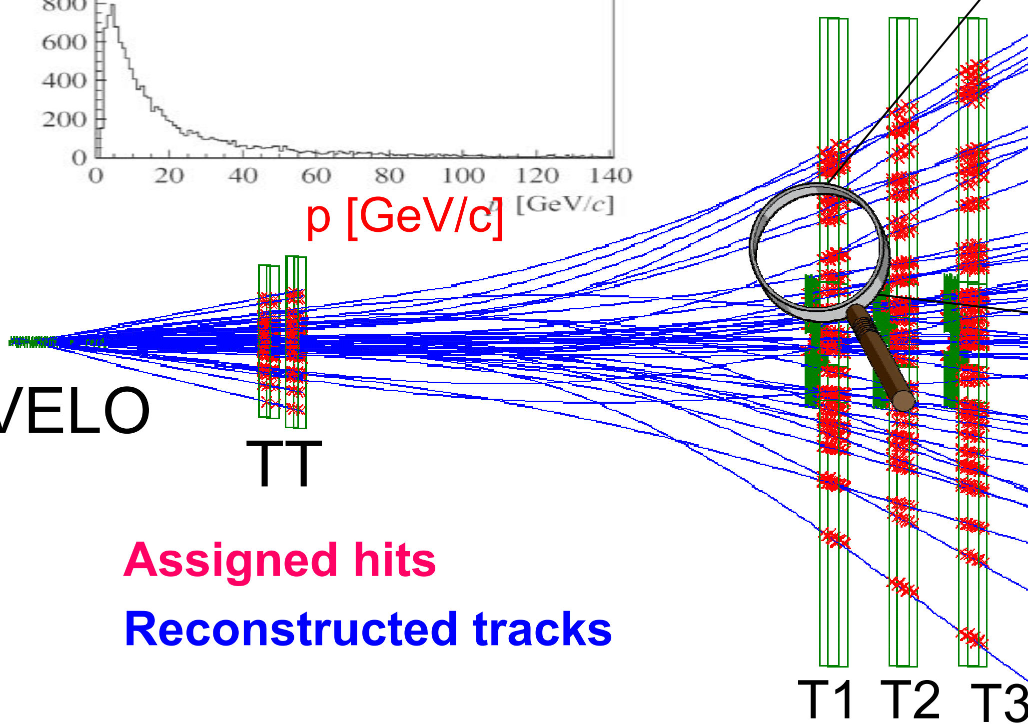


Mass resolution (MeV)

$B_s \to \mu\mu$	18
$B_s \to D_s \pi$	14
$B_s \to J/\psi\, \phi$	16

Outer Tracker station





Assigned hits

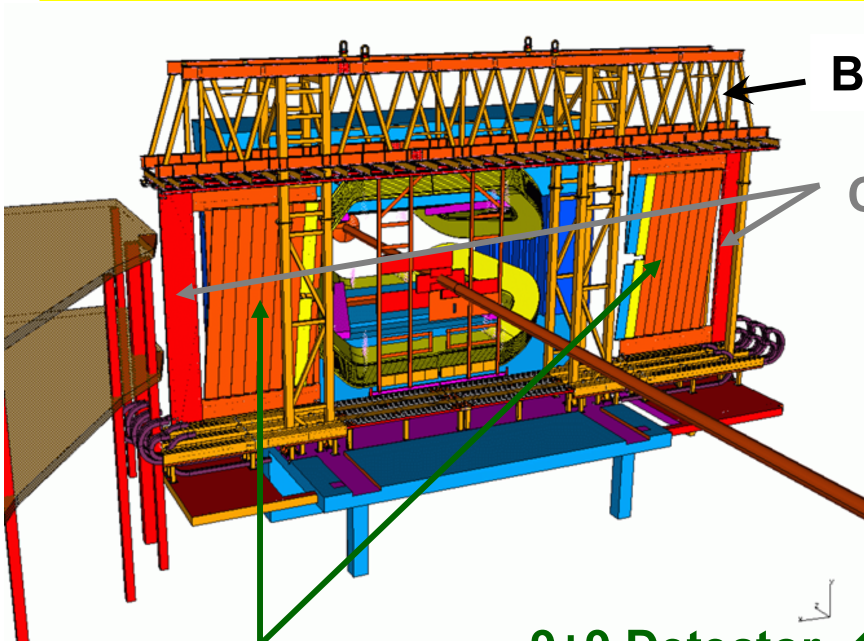
Reconstructed tracks

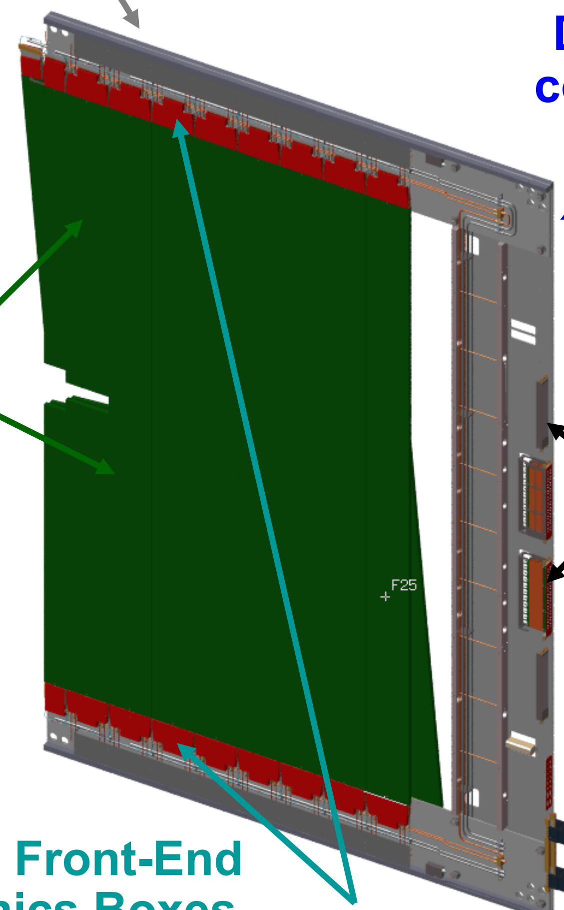
Long tracks:

- ~38 measurements per track
- Efficiency >95% (p>12 Gev)
- Ghost rate <7% (p>12 GeV)

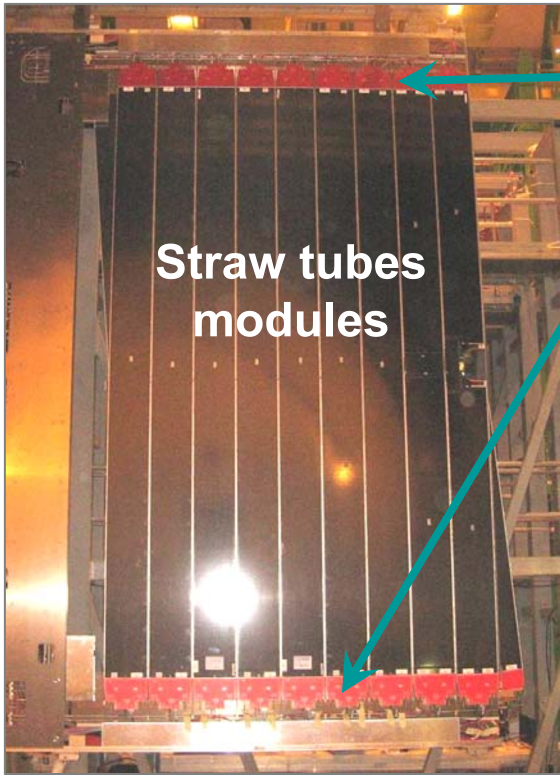
in $b\,\bar{b}$ events: $\langle n_{ch,reconstructed} \rangle \approx 72$

OT Installation (1)

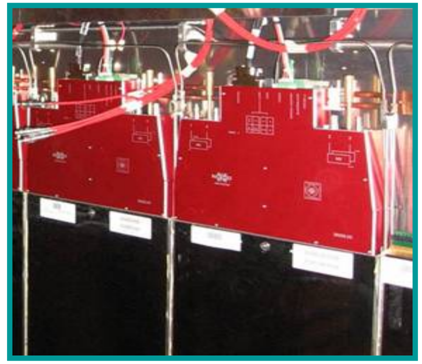


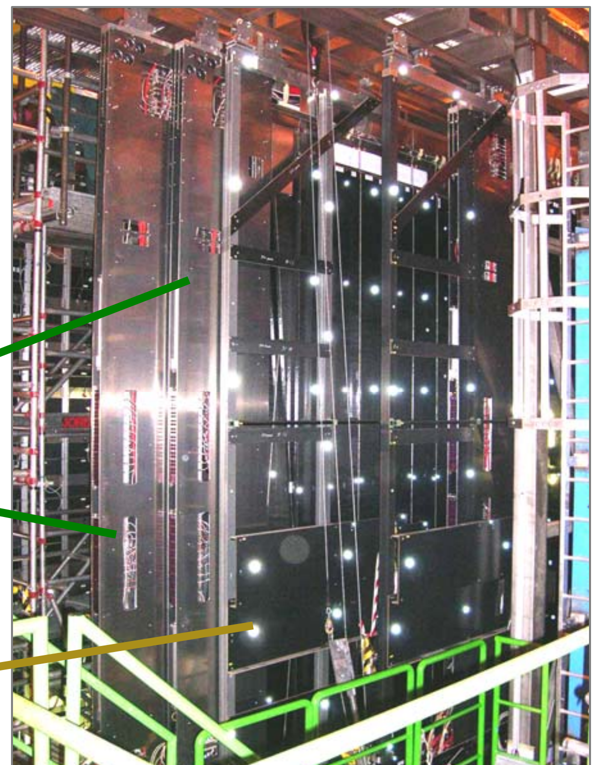


OT Installation (2)



FE Boxes

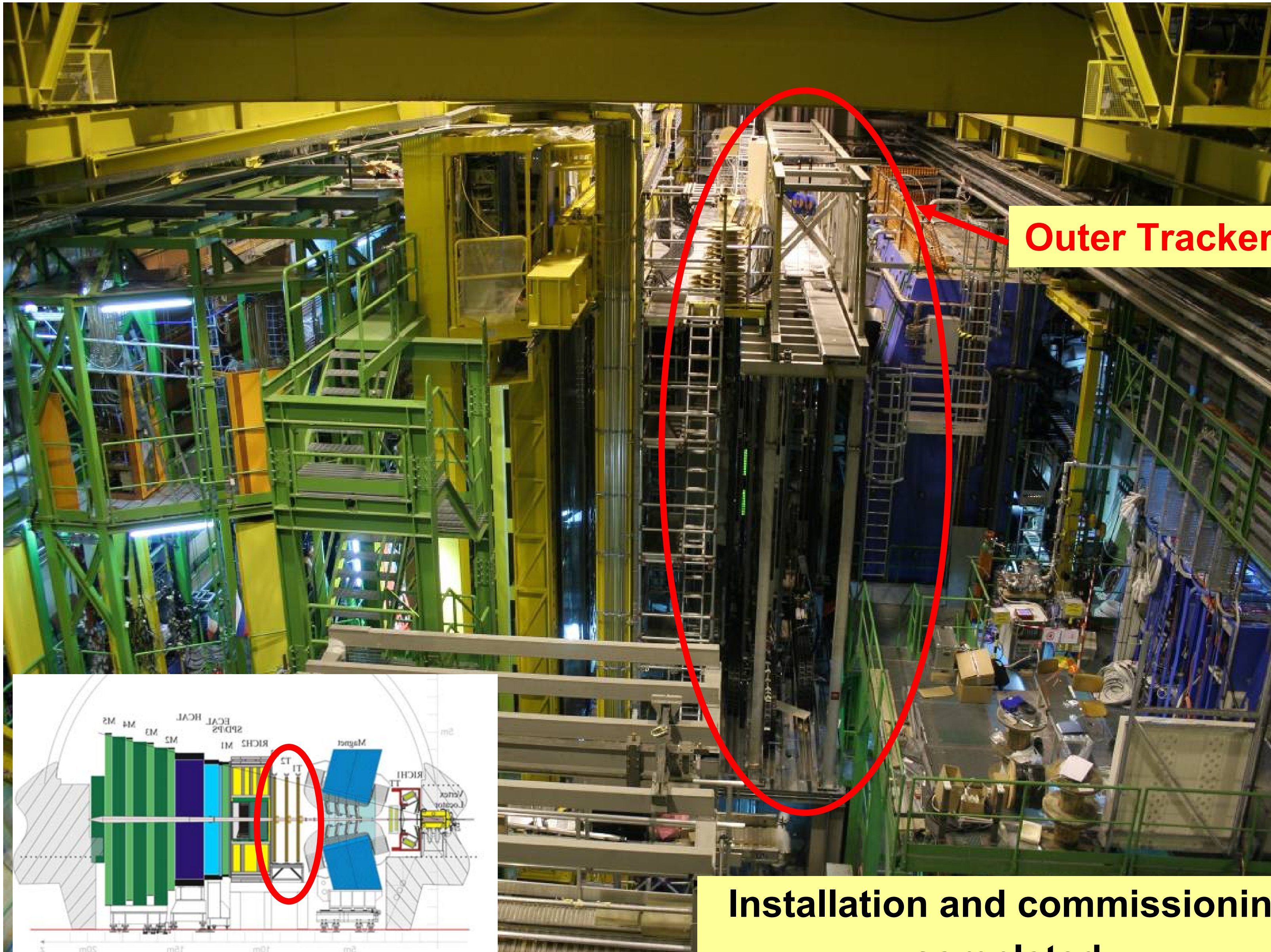




OT C-frames

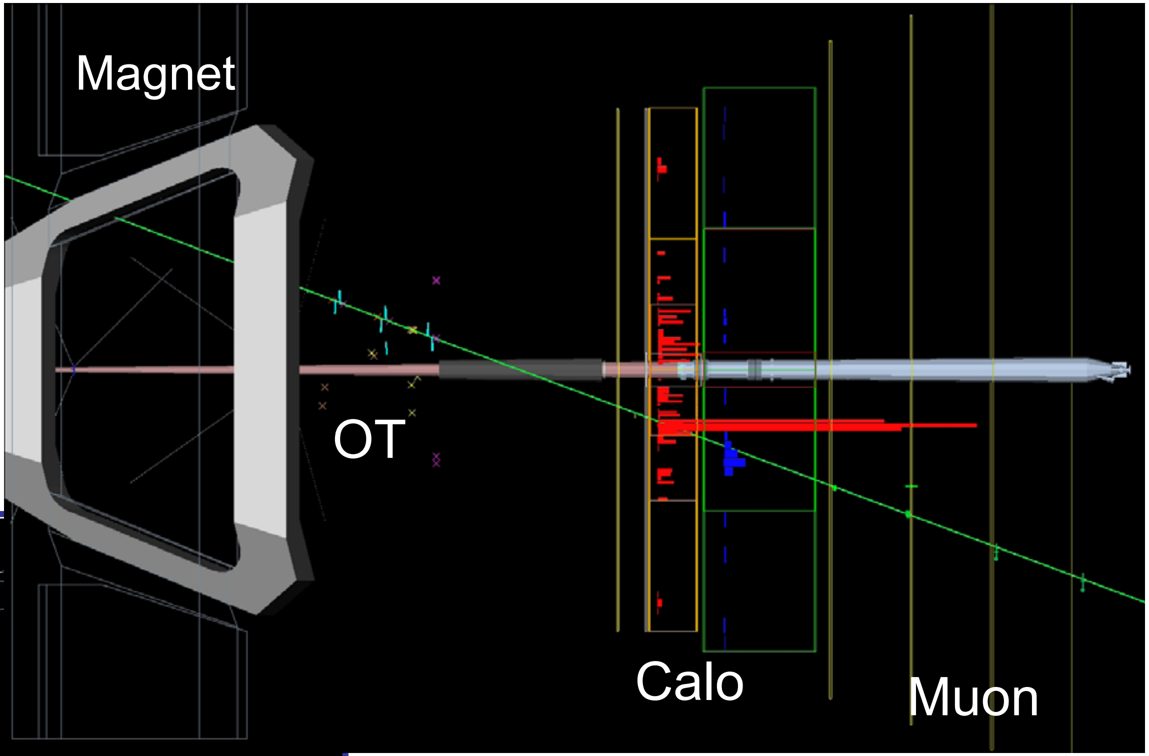
survey targets (photogrammetry)

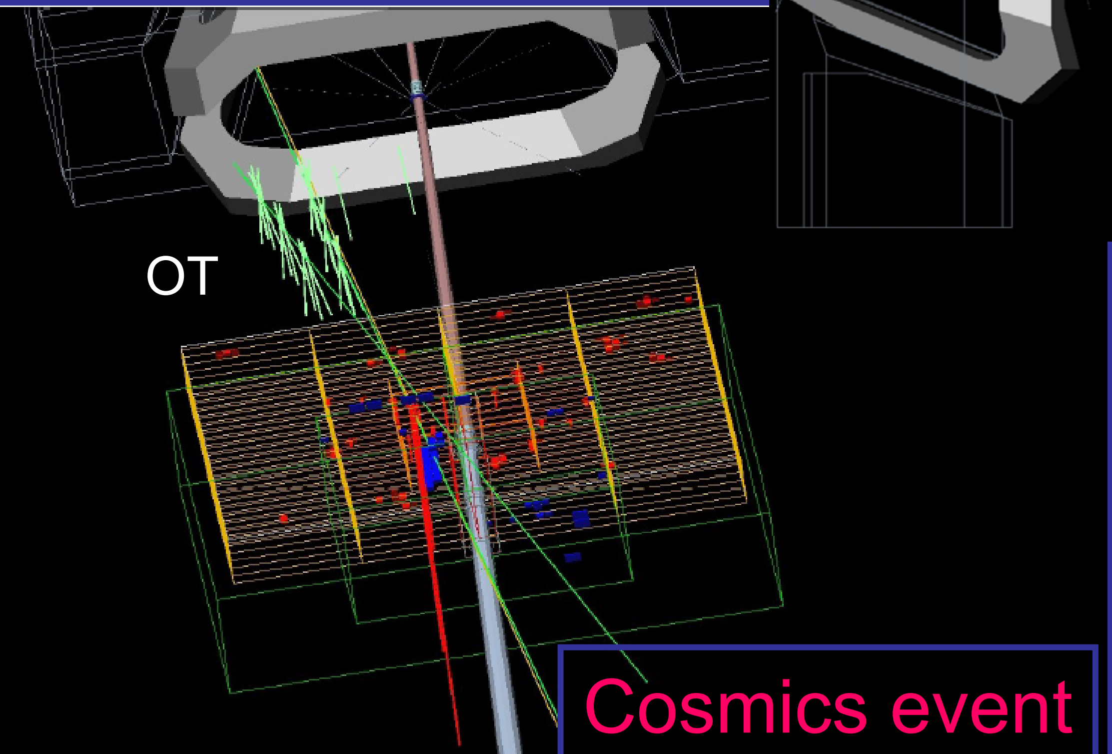
LHCb Experiment Status



Installation and commissioning completed

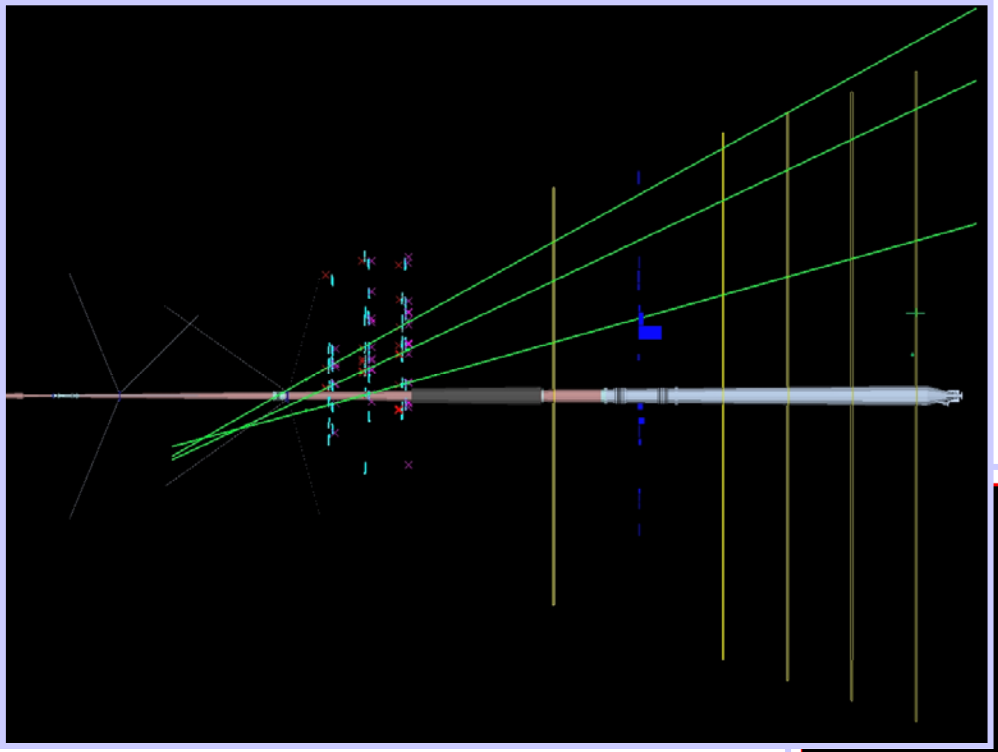
Data taking with cosmics



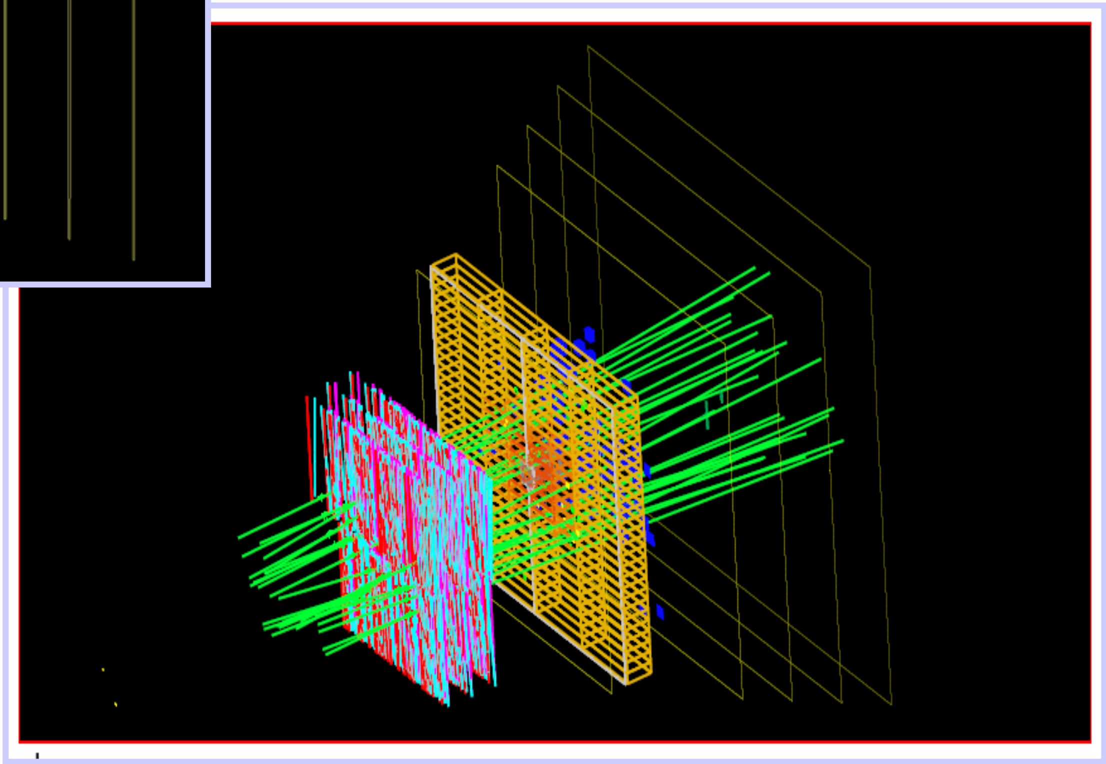


Cosmics event

Some Events…



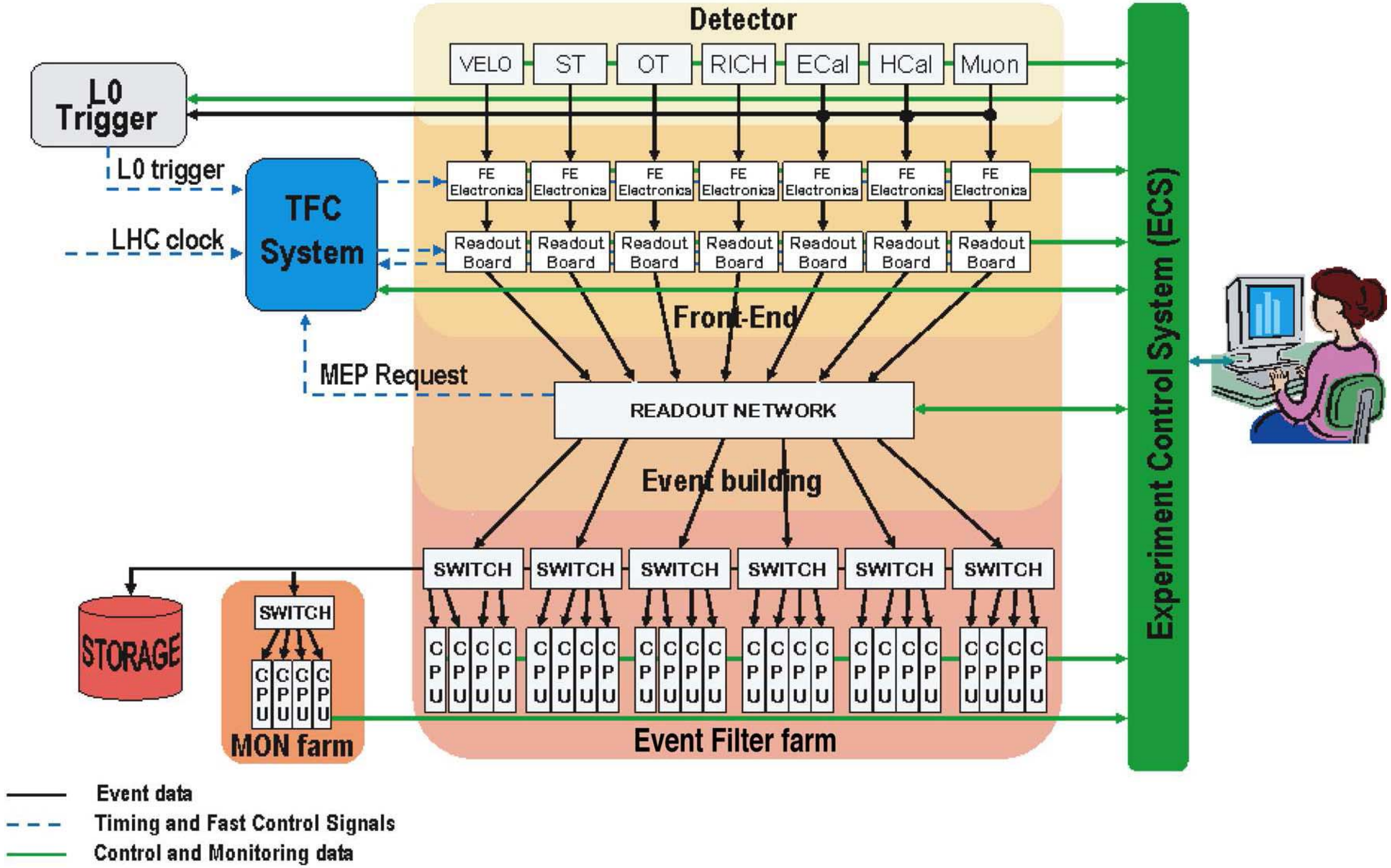
Clean event



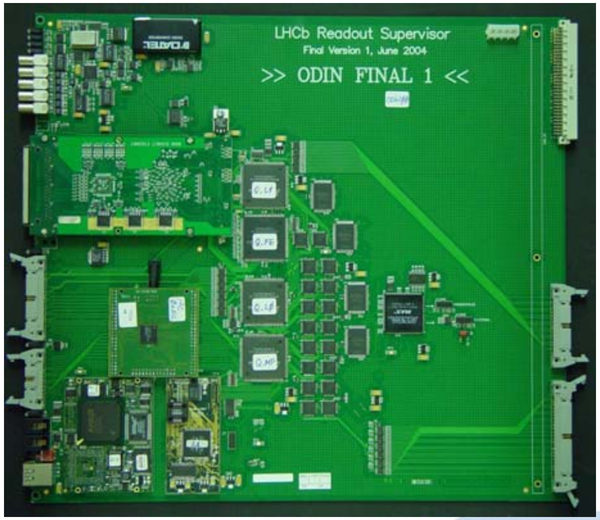
Splashy event
(not all tracks reconstructed...)

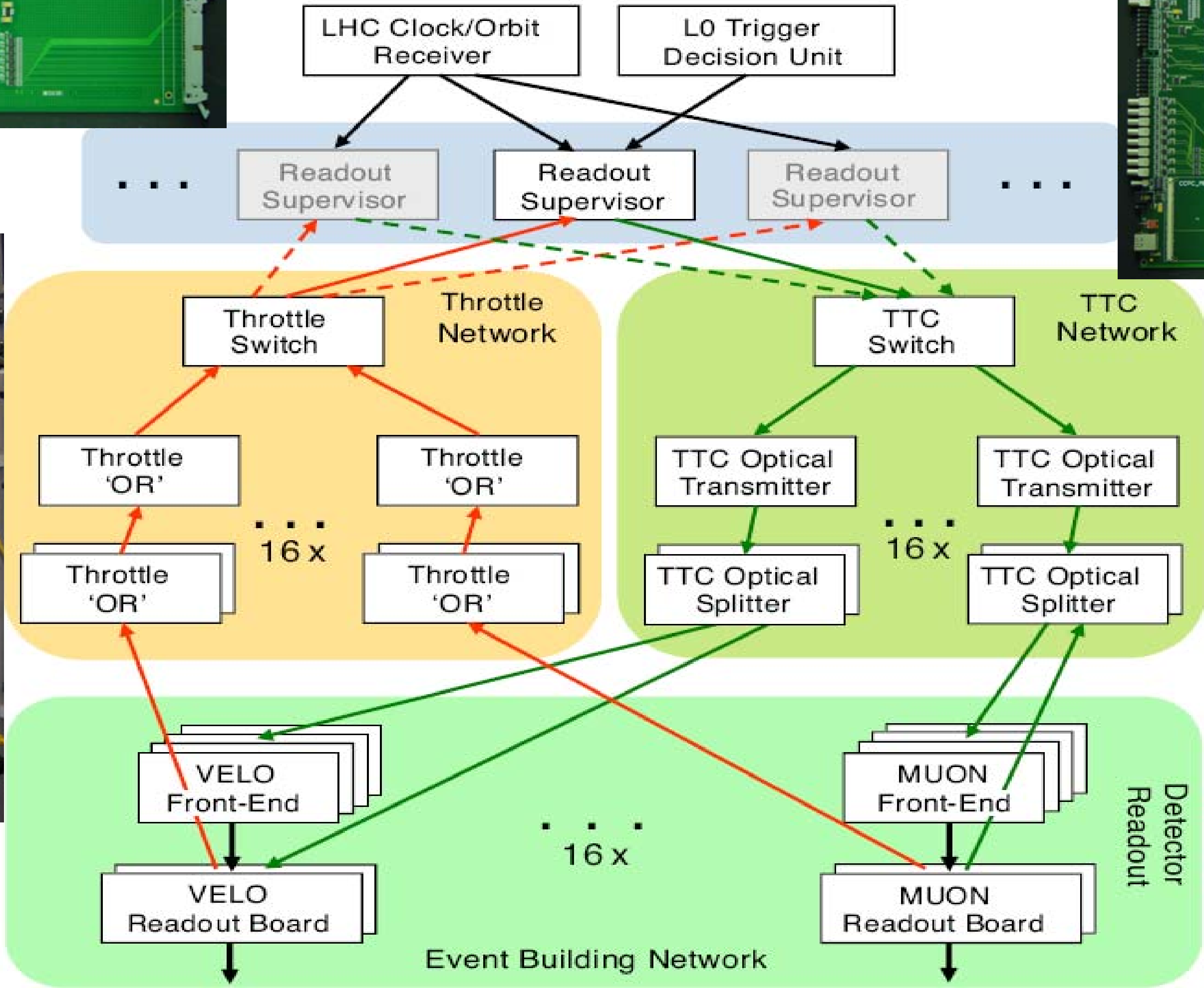
LHCb ONLINE system

Three components:
- **Time and Fast Control (TFC)**
- Data Acquisition (DAQ)
- Experiment Control System (ECS)



LHCb TFC system

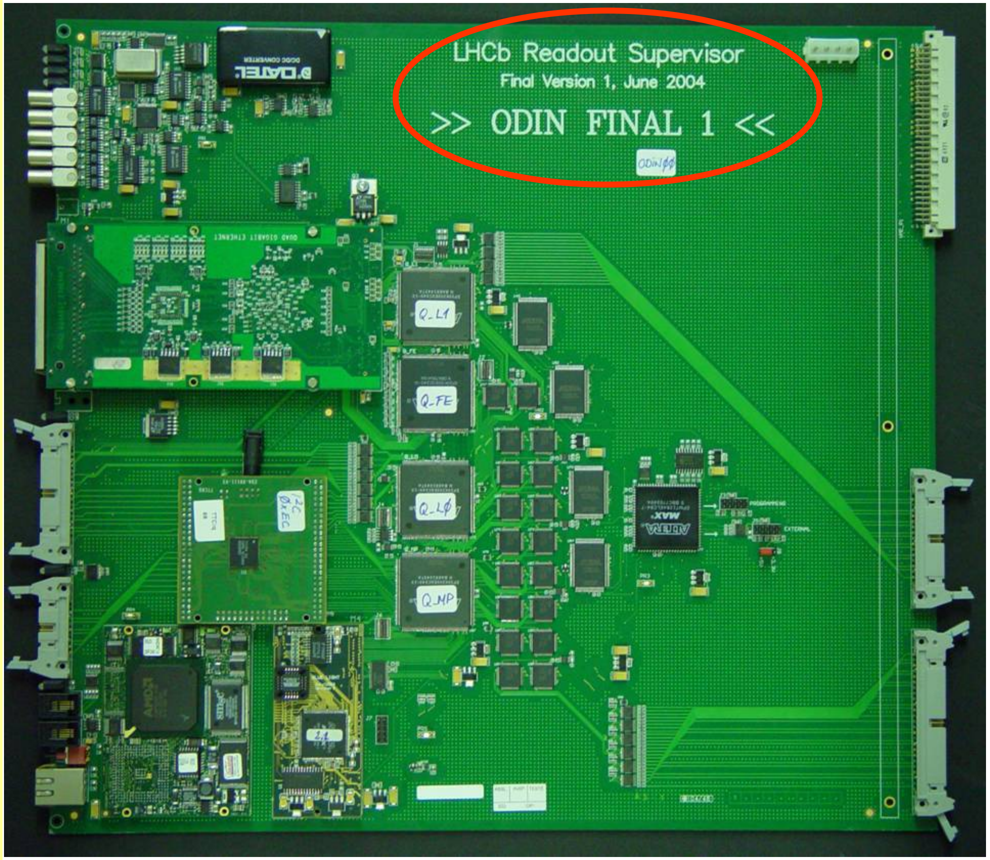




Readout Supervisor

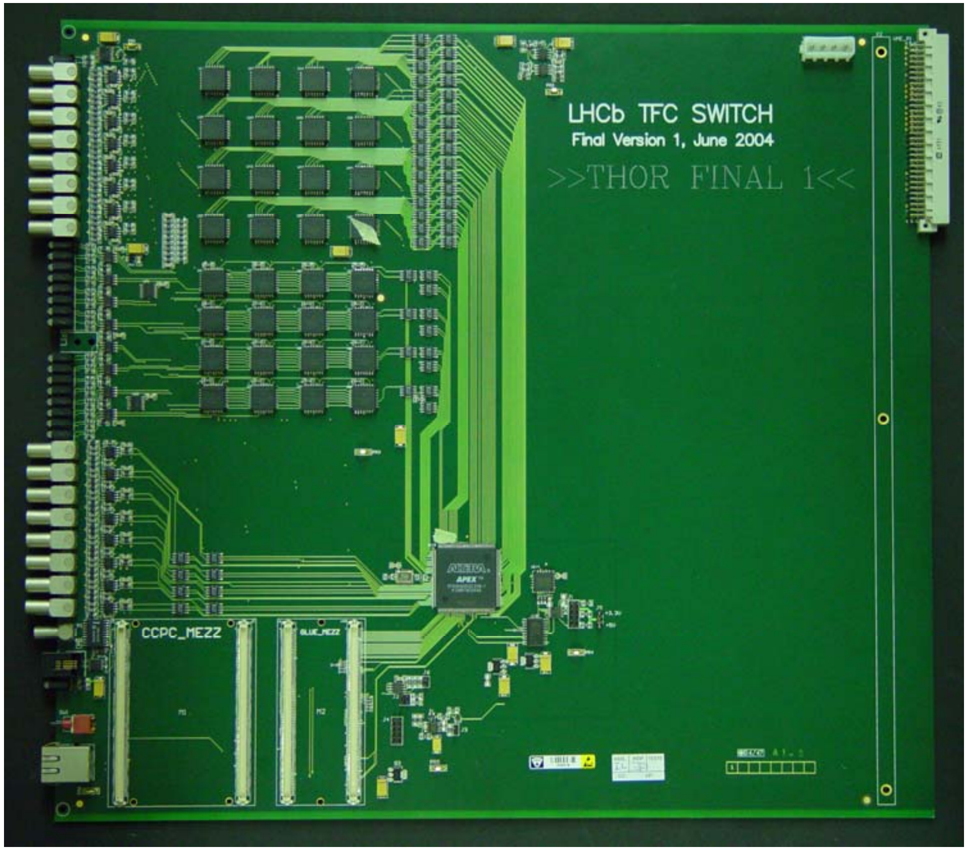
The heart of the TFC system is the Readout Supervisor

- Distributes **the LHC clock** to the entire FE electronics and the trigger systems.
- Distributes **the L0 trigger decision** to the L0 FE electronics.
- Generates and time-in **all types of self-triggers** (random triggers, calibrations, etc.).
- **Controls the trigger rate** by taking into account the status of the different components in the system in order to prevent buffer overflows and to enable/disable the triggers at appropriate times during resets, etc.
- Generates and time-in resets (counters- and electronics-) and the other asynchronous commands.
- Records **detector status information** and information related to timing, triggering and fast control in a special data block and transmits them to the event building
- Incorporates an **ECS interface** for configuring, controlling and monitoring the Readout Supervisor



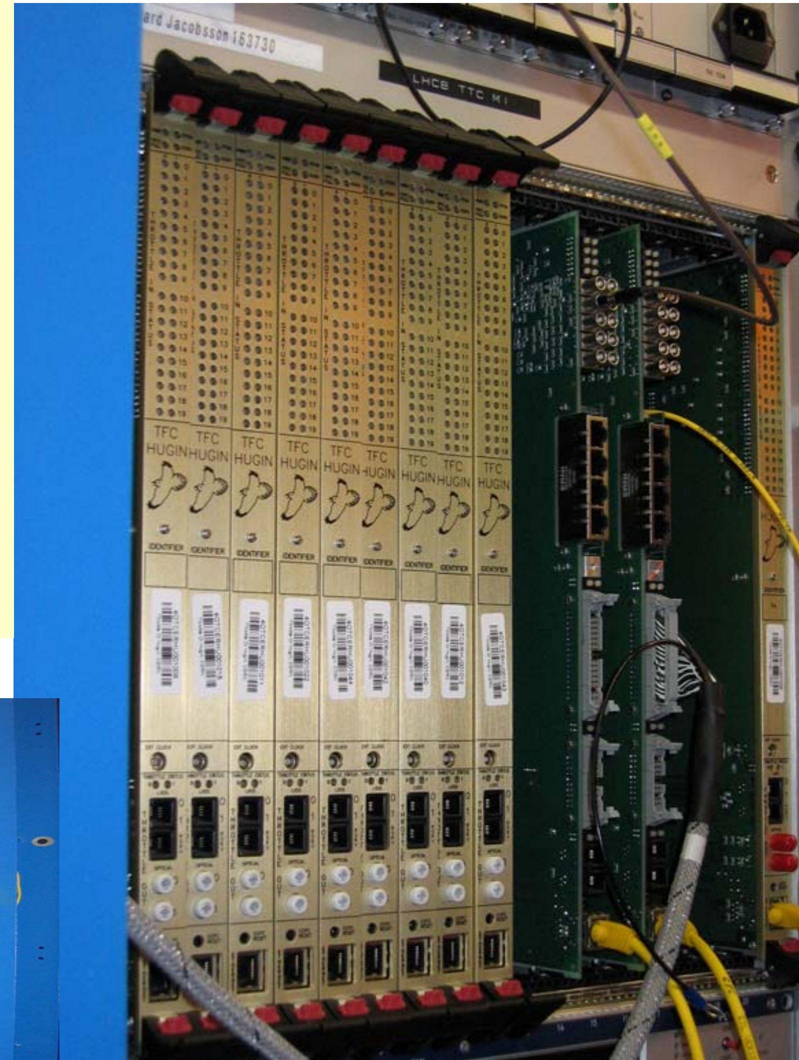
TFC Switch

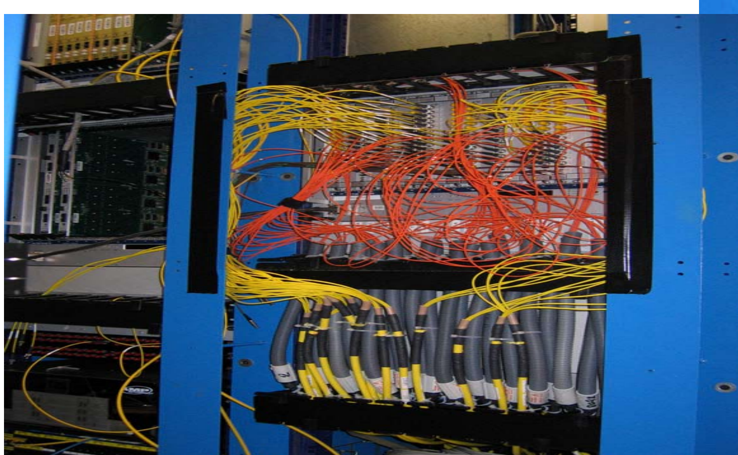
A TFC switch allows a dynamic partitioning of the LHCb detector to support independent and concurrent sub-detector activities such as commissioning, calibration and testing



Throttle Switch and throttle „OR”

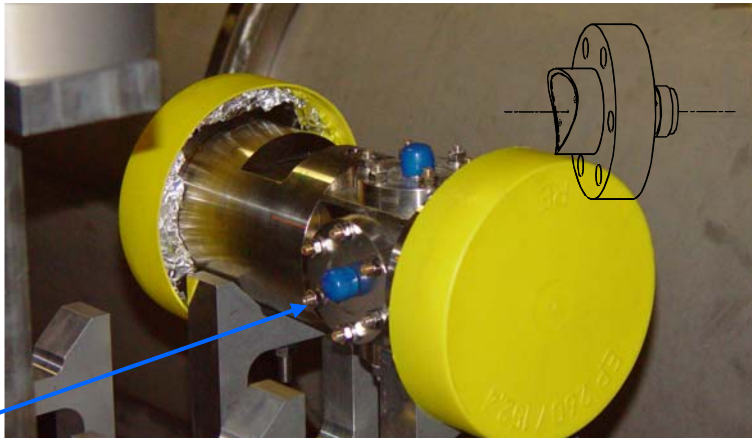
The optical throttle network is used to transmit trigger inhibit from the asynchronous parts of the readout system to RS in case of congestion of data path. It incorporates a Throttle Switch to allow partitioning of the readout system and modules which perform locally an OR of the throttle signals of each subsystem.

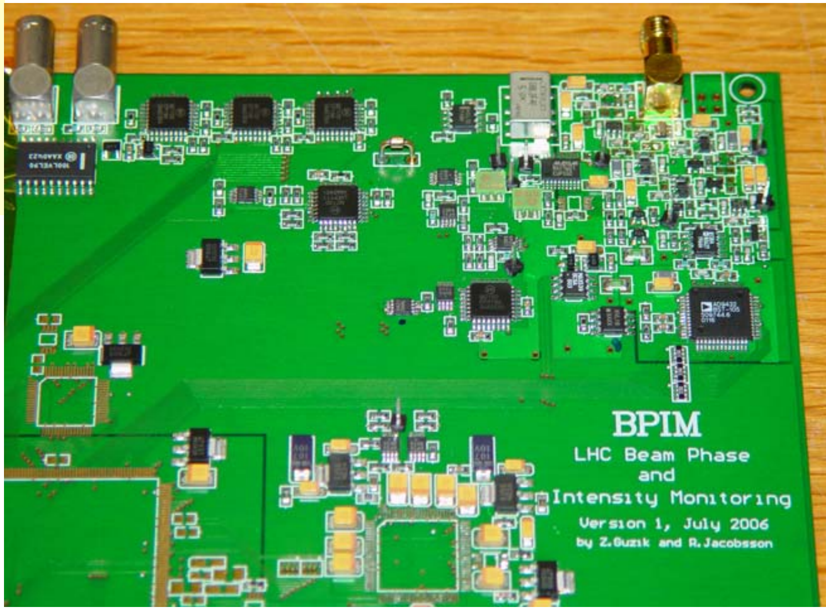


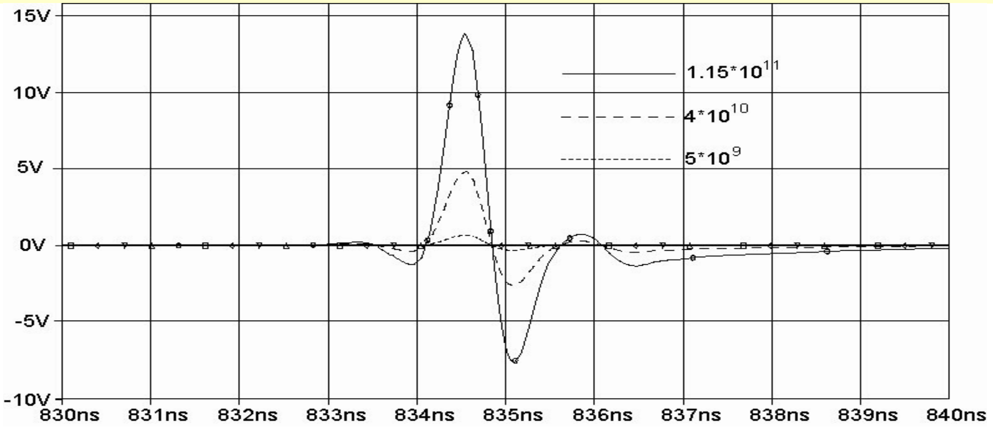


Beam Phase and Intensity Monitor

- Global clock stability:
  - LHCb: 14 km of fibre between SR4 and PA8 at a depth of ~1m
  - Estimated max. diurnal drift 200 ps
  - Estimated max. seasonal drift 8ns
- Local beam monitoring:
  - Measure bunch phase bunch-by-bunch
  - Bunch intensity bunch-by-bunch
- **Beam pick-ups are installed on both beams**

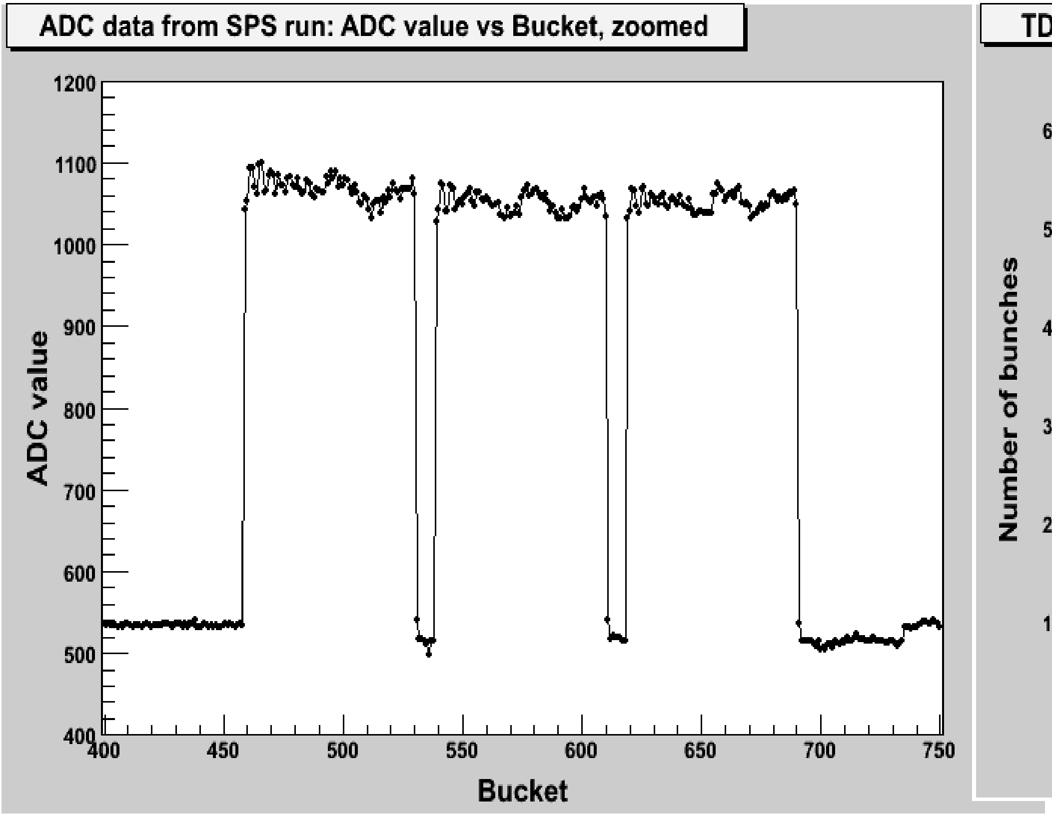

4 plate pick-up electrodes

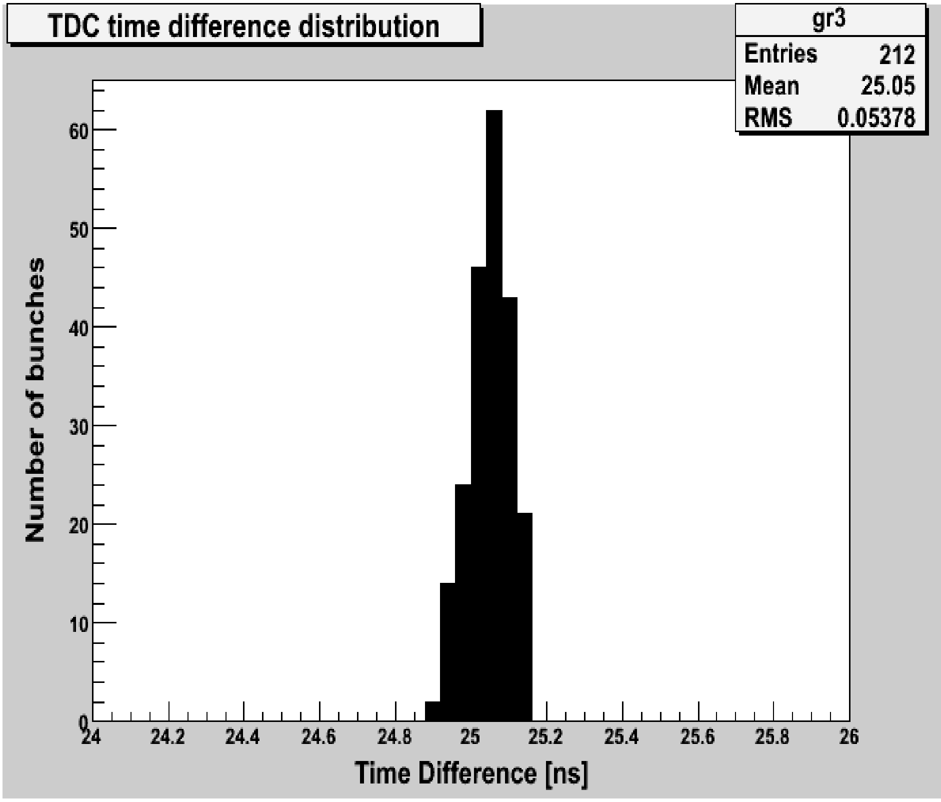




Beam Phase and Intensity Monitor readout

Test results





Measured intensity of SPS beam (three groups of 72 bunches)

Measured time intervals between bunches: mean = 25.05 ns, r.m.s. = 54 ps

The end