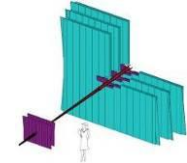


A High-Efficiency and High-Resolution **Straw Tube Tracker** for the LHCb Experiment

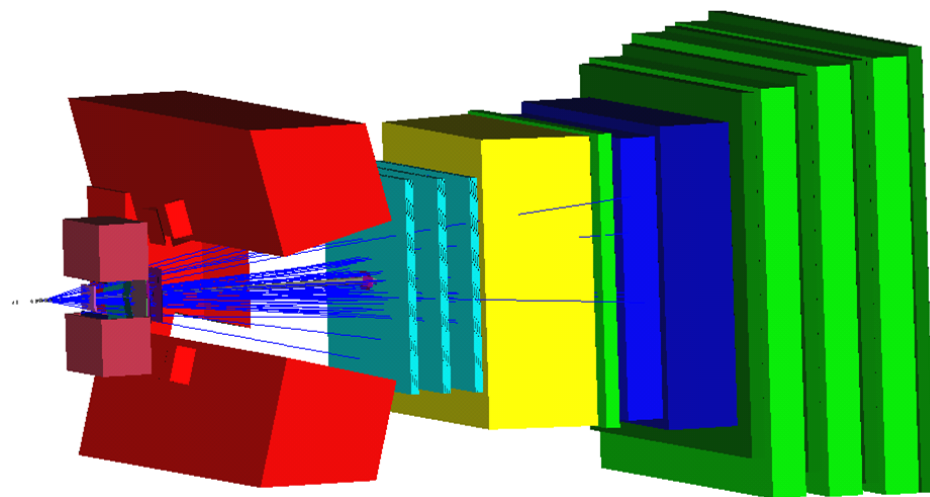
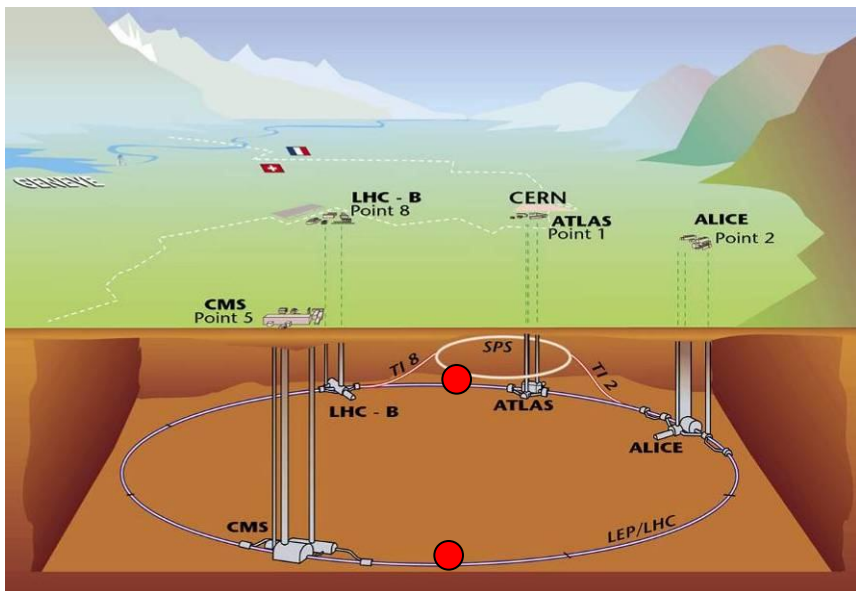


Niels Tuning

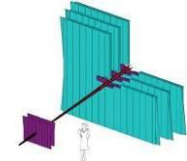
NIKHEF Amsterdam, The Netherlands

On behalf of the LHCb Outer Tracker Collaboration

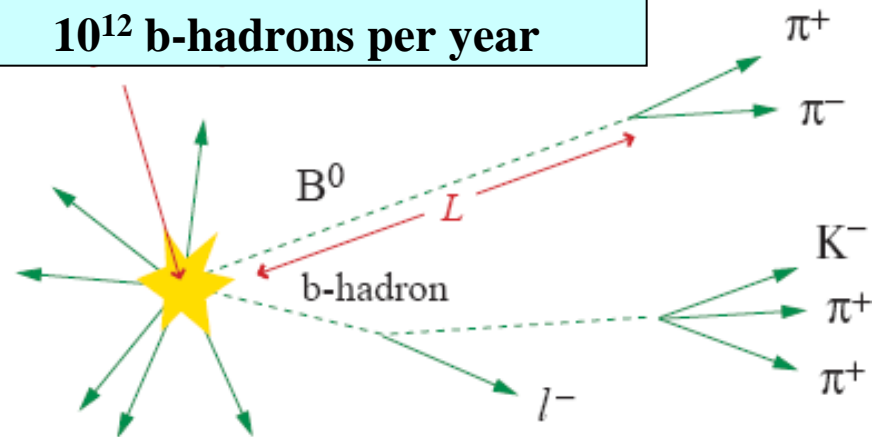
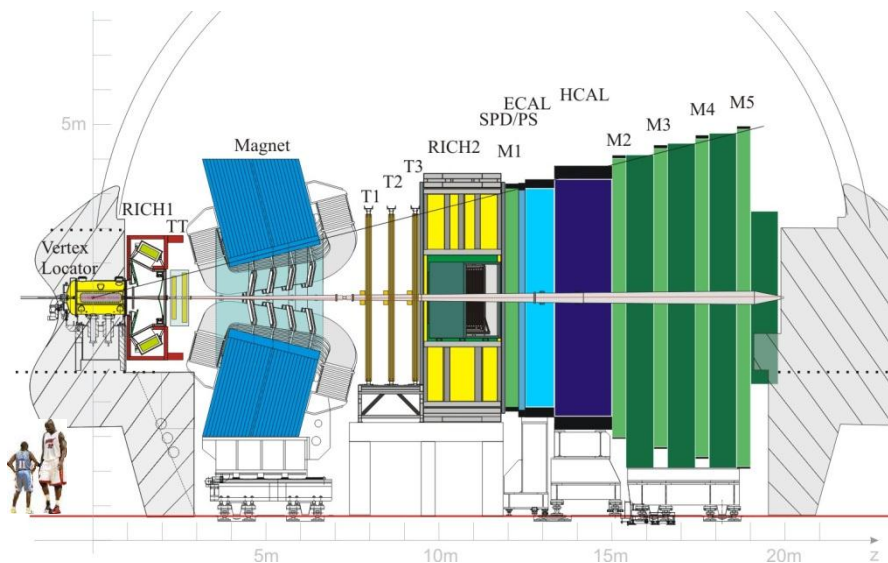
- 1) Detector Construction
- 2) Beam Test Results



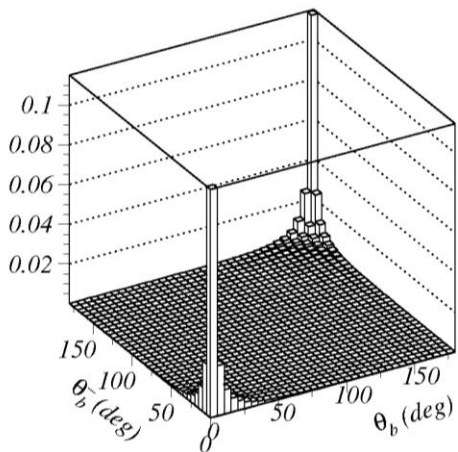
LHCb in a nutshell



- pp with $\sqrt{s} = 14$ TeV
- $\mathcal{L} = 2 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
- 10^{12} b-hadrons per year



Both b's are produced forward:

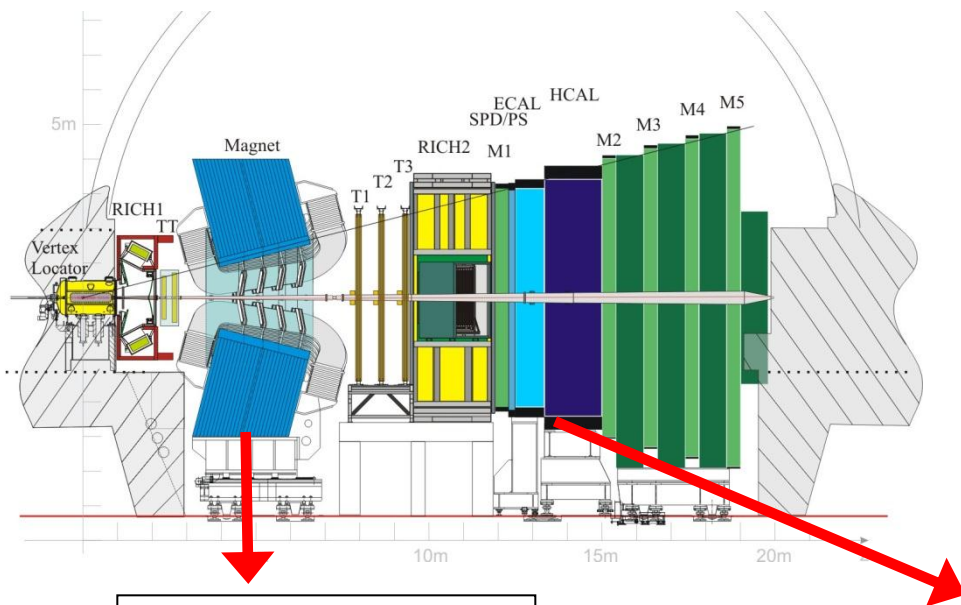
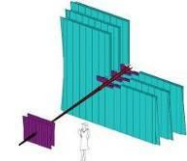


Aim: measure CP violation and rare decays

- B_s mixing
- CKM angle γ
- Small branching fractions
- ...

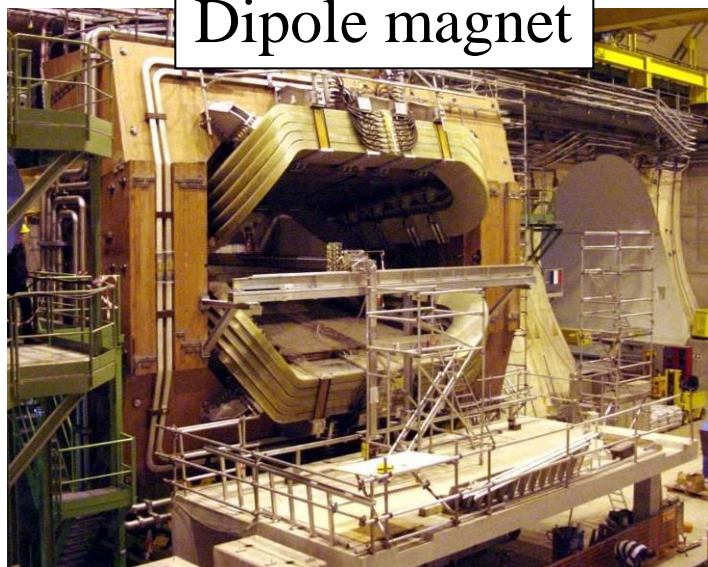
} All affected by new particles inside loops!

The LHCb experiment

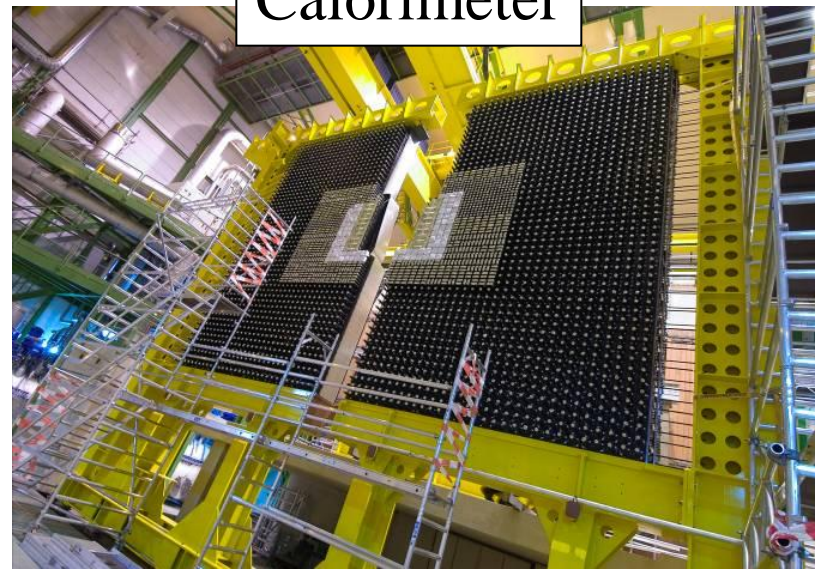


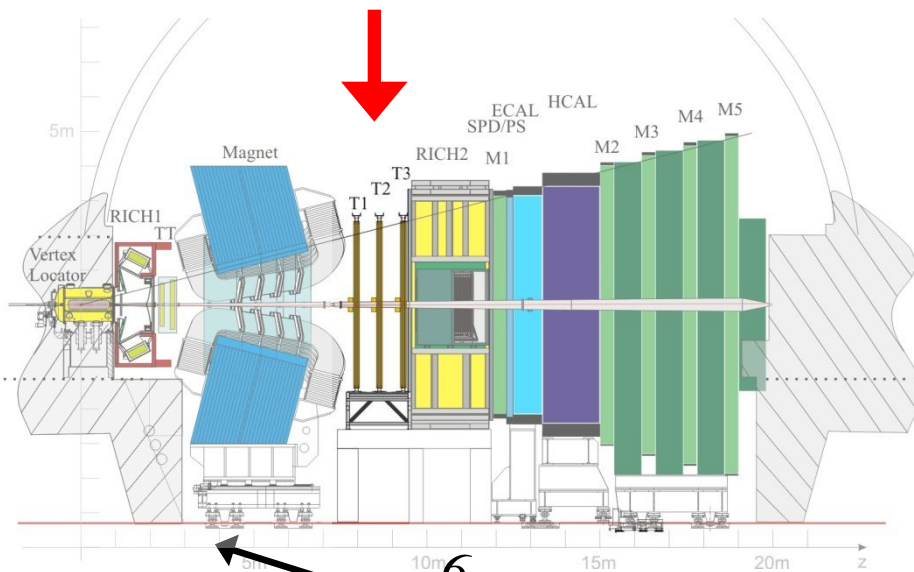
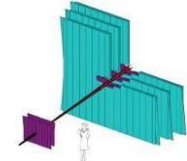
Status down in the pit:
LHCb is real!

Dipole magnet



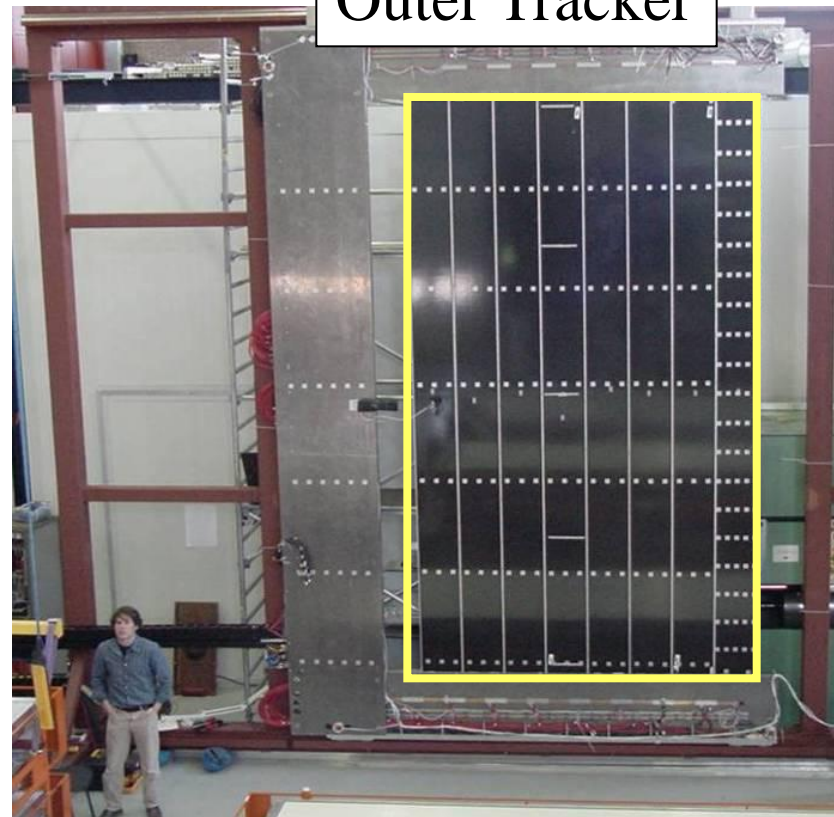
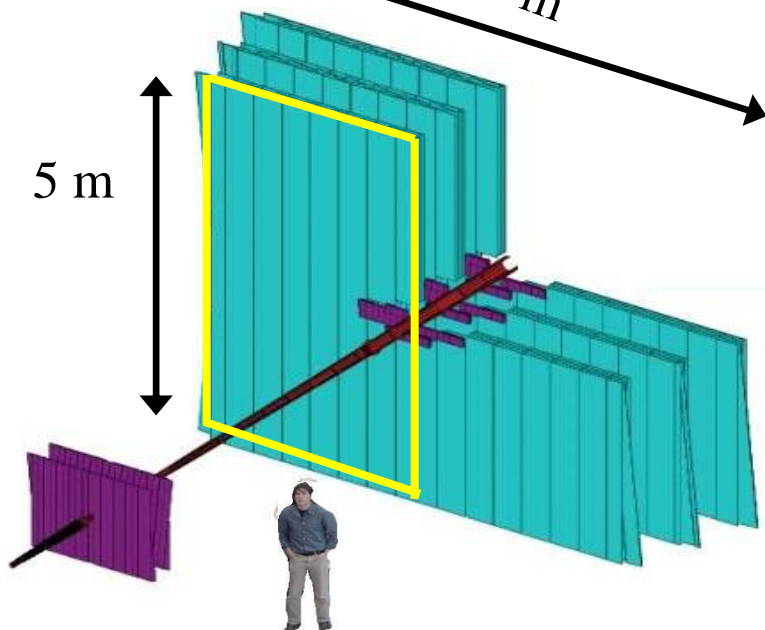
Calorimeter



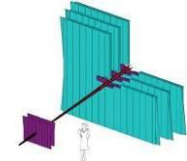


1/4 station prototype:

Outer Tracker

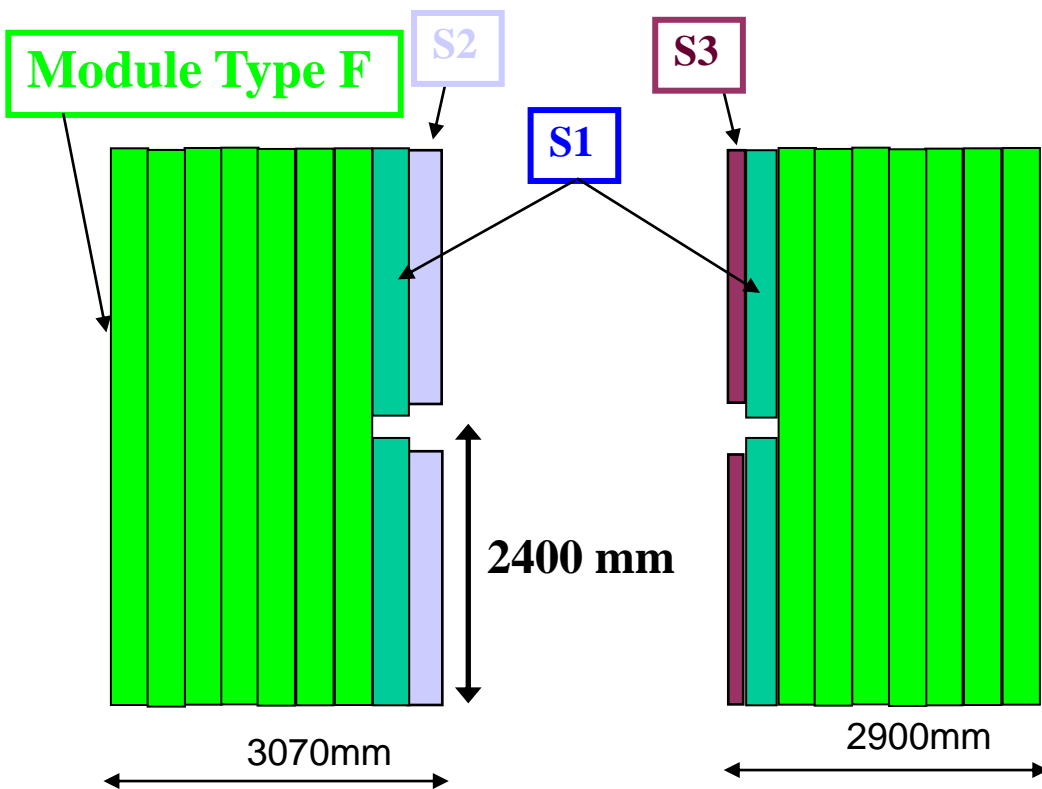


The Outer Tracker



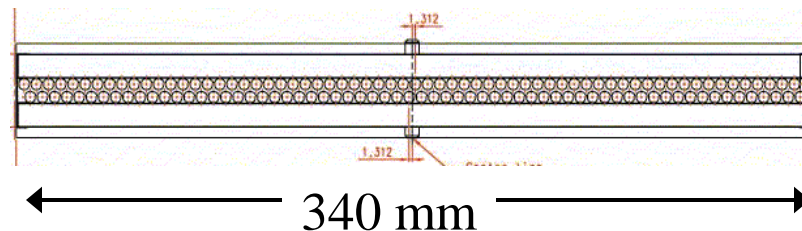
- **Cracow:** all straw-support panels
- **Warsaw:** 124 *short* modules (6 types)
- **Heidelberg:** 62 *long* modules
- **NIKHEF:** 130 *long* modules

Two Halves:



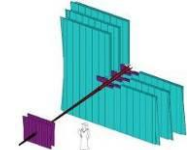
One large module:

- 34 x 490 cm²
- 4 x 64 = 256 channels



Total nr of channels:

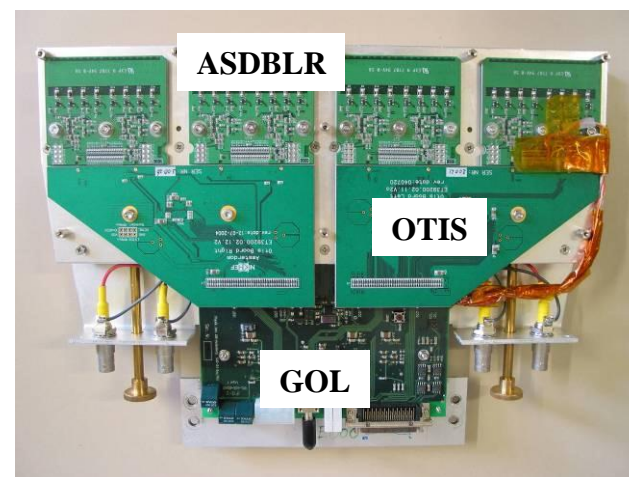
- 53.760

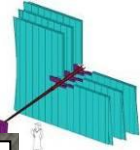


- Straw:
 - Radius: 2.5 mm
 - Length: 2.5 m
- Gas:
 - Ar/CO₂ 70/30, flush at 1 volume/2 hr
 - Drift time: ~45 ns for 2.5 mm

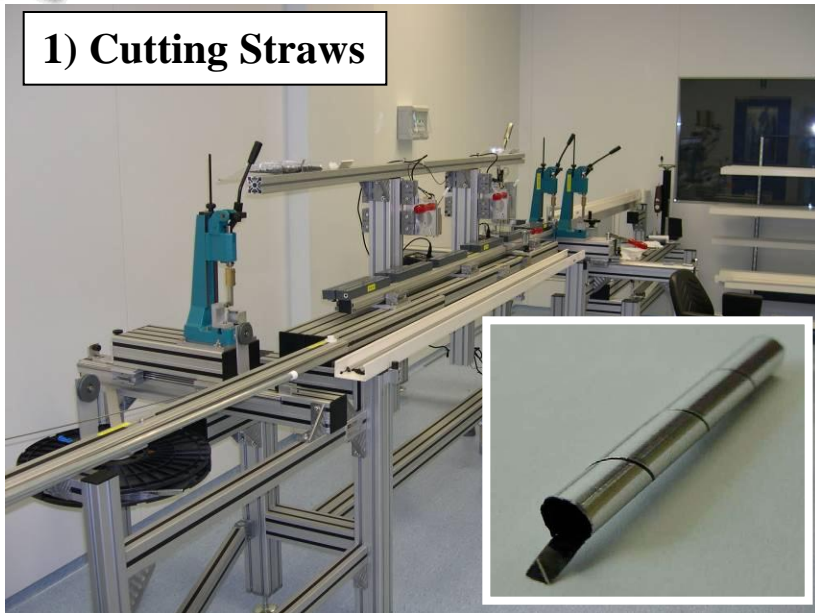


- Electronics:
 - ASDBLR chip:
 - Amplifies, shapes and **discriminates**
 - Profit from ATLAS TRT
 - OTIS chip:
 - Measure time with accuracy < 1ns
 - Gigabit Optical Link (GOL)
 - Serializes and ships data at 1 MHz

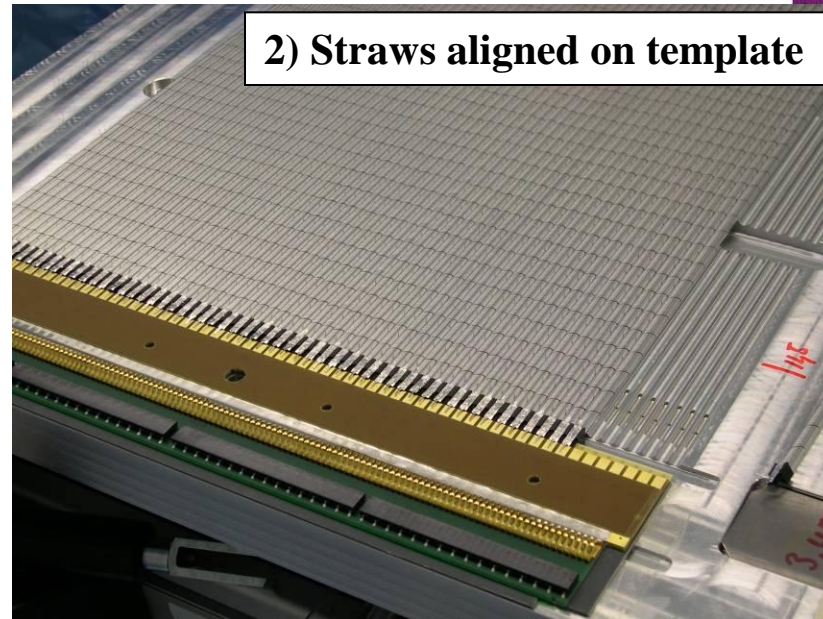




1) Cutting Straws



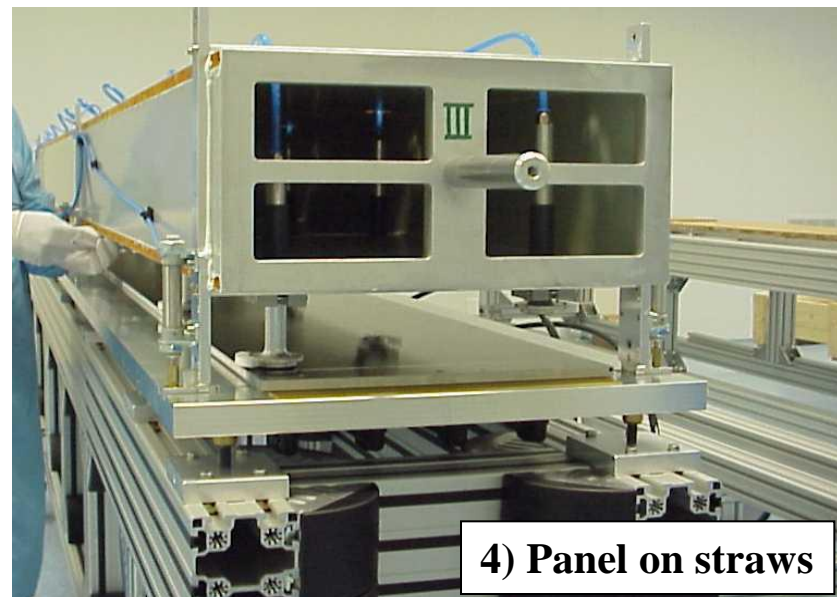
2) Straws aligned on template

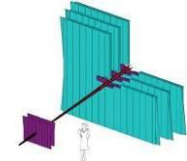


3) Glue on panel

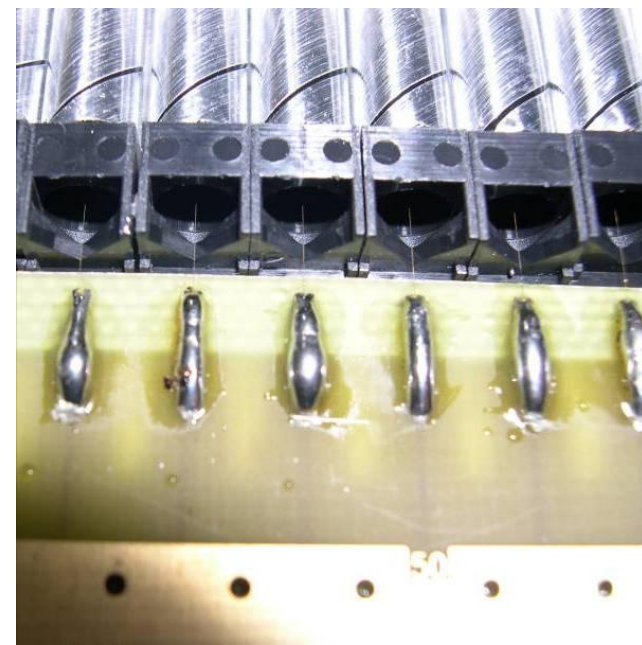
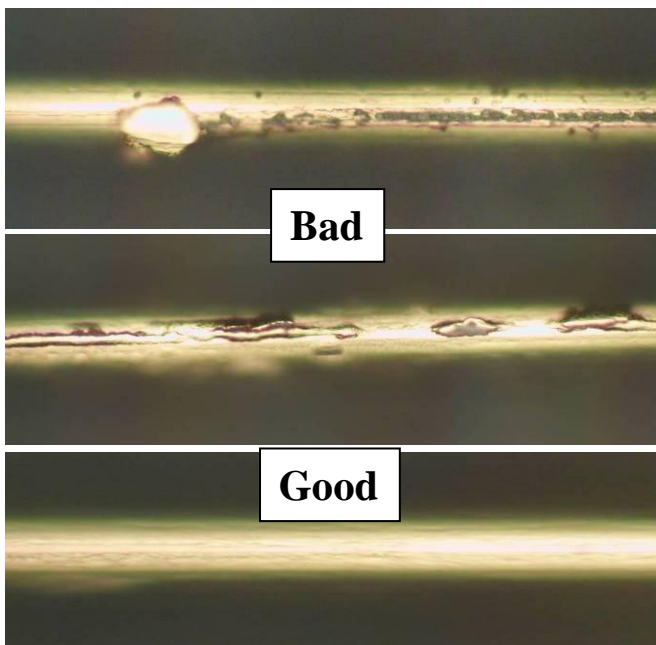


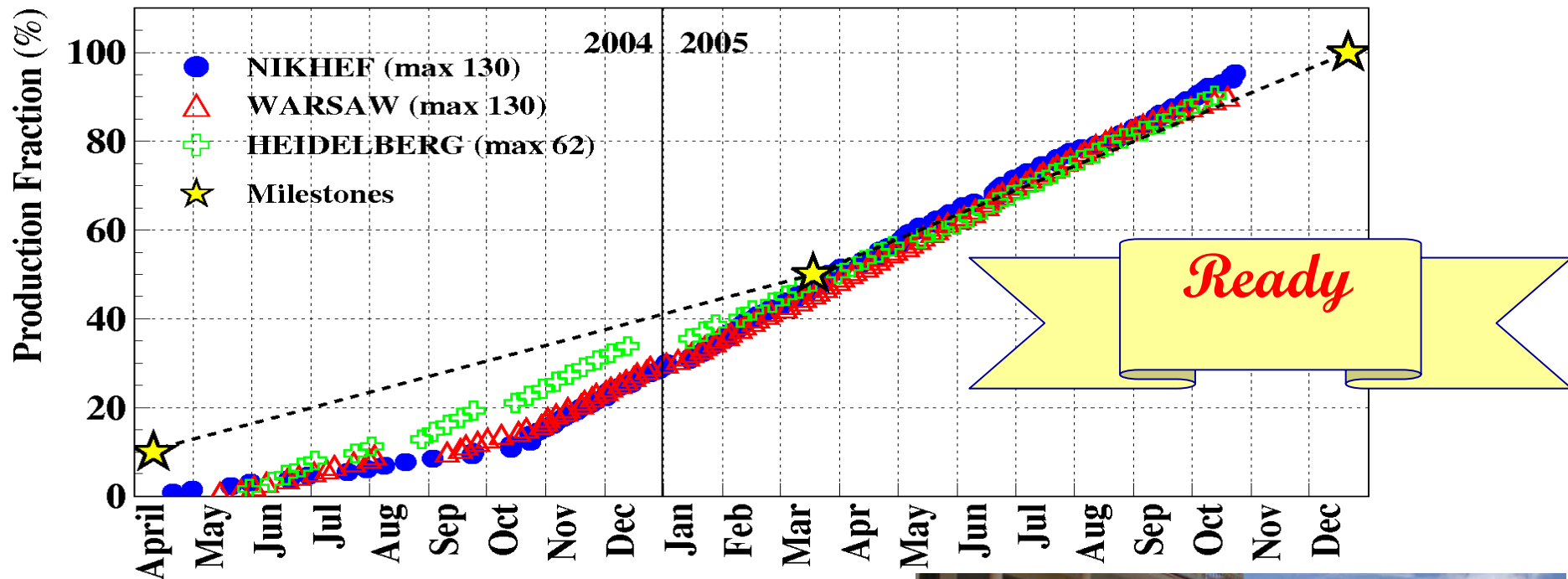
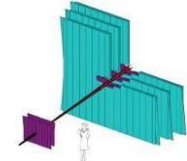
4) Panel on straws





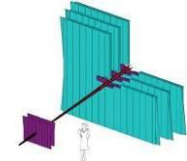
- Wire quality was problem
 - Wire: W/Au
 - Curliness: difficult for the wiring
 - Gold layer: high currents
 - Rejection caused tight delivery schedule, but **good wire quality eventually for all modules**





- We will produce last module **next Monday** !
- Ship to CERN in January 2006





Per Wire:

- Wire Tension: **70 g**
- Dark Current: **<2 nA**

Per Module:

- Gas Tightness: **<10⁻⁴ l/s**
- Response to source: **±10 %**



Findings:

- **Bad wire quality**
- **Leaky gluing procedure**
- **Bad gas flow in outer straws**
- **Bad soldering of connectors**
- **Missing wire locators**
- ...

Spotted timely

→ **Adapted Procedure**

→ **All solved!**

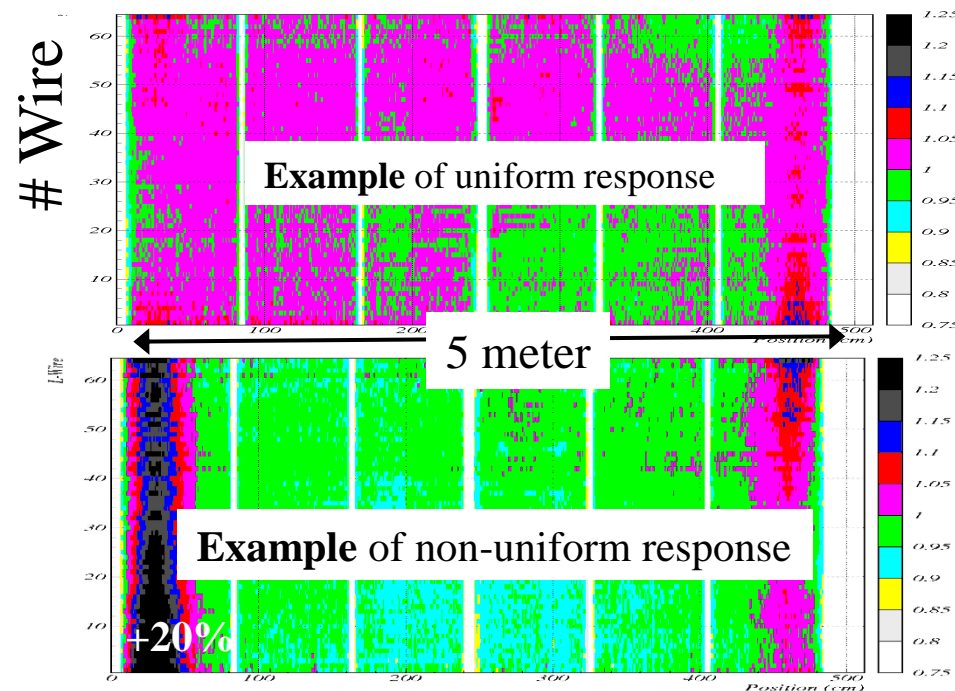
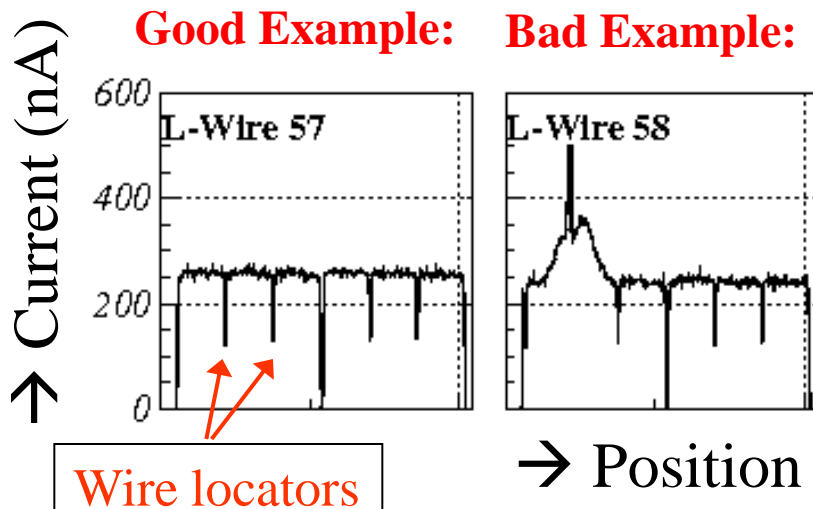
Total number of bad channels:

- **Dead, tripping or noisy**
- **< 1 ‰**

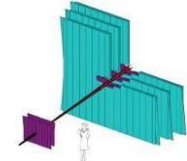
Final module check: radio-active sources

Check detector response:

- Current from ^{90}Sr β -source
- Pulse height from monochromatic ^{55}Fe γ -source
- Full scan of the entire module
 - Every cm^2 of the OT is checked



Beam Test



First, get the cables sorted...



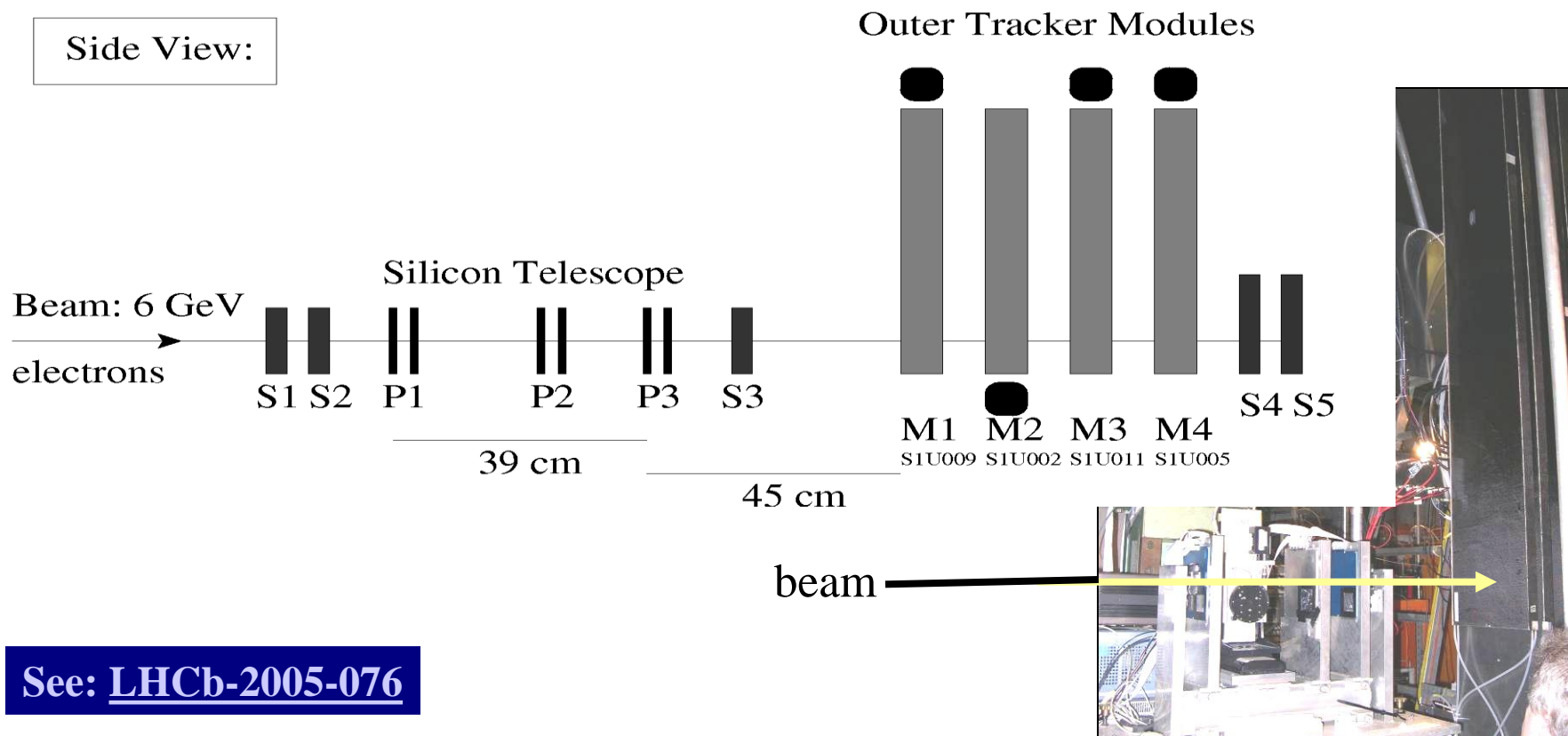
- Final detector modules
- Final prototype electronics
- 6 GeV electrons at DESY

- Efficiency
- Resolution
- Noise
- Cross talk

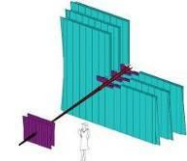
vs

- HV
- Amplifier threshold
- Position along straw

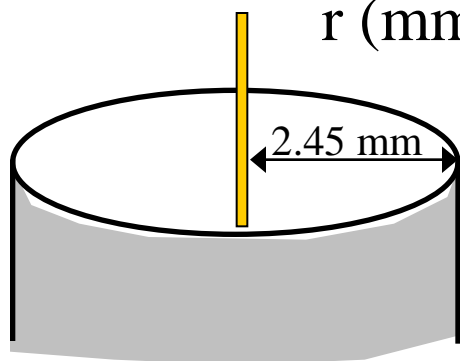
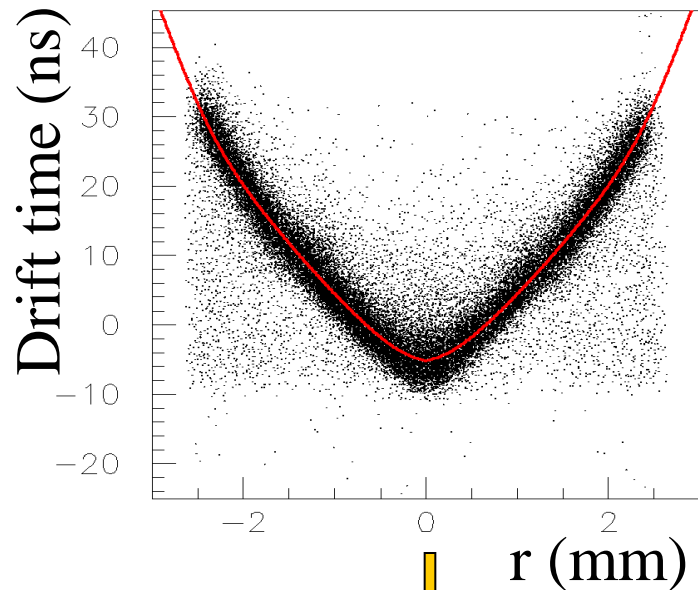
Side View:



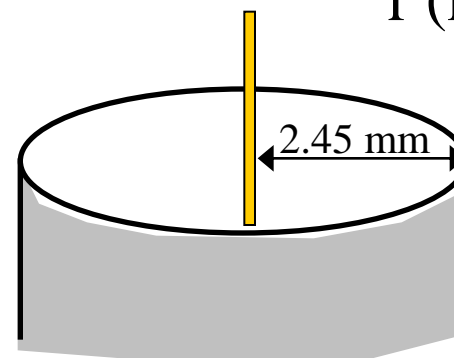
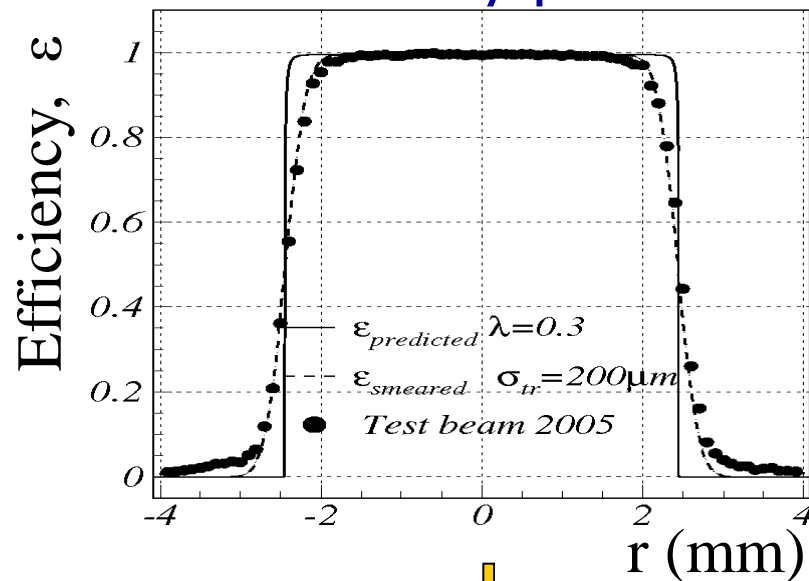
See: [LHCb-2005-076](#)



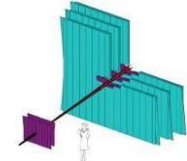
rt-relation:



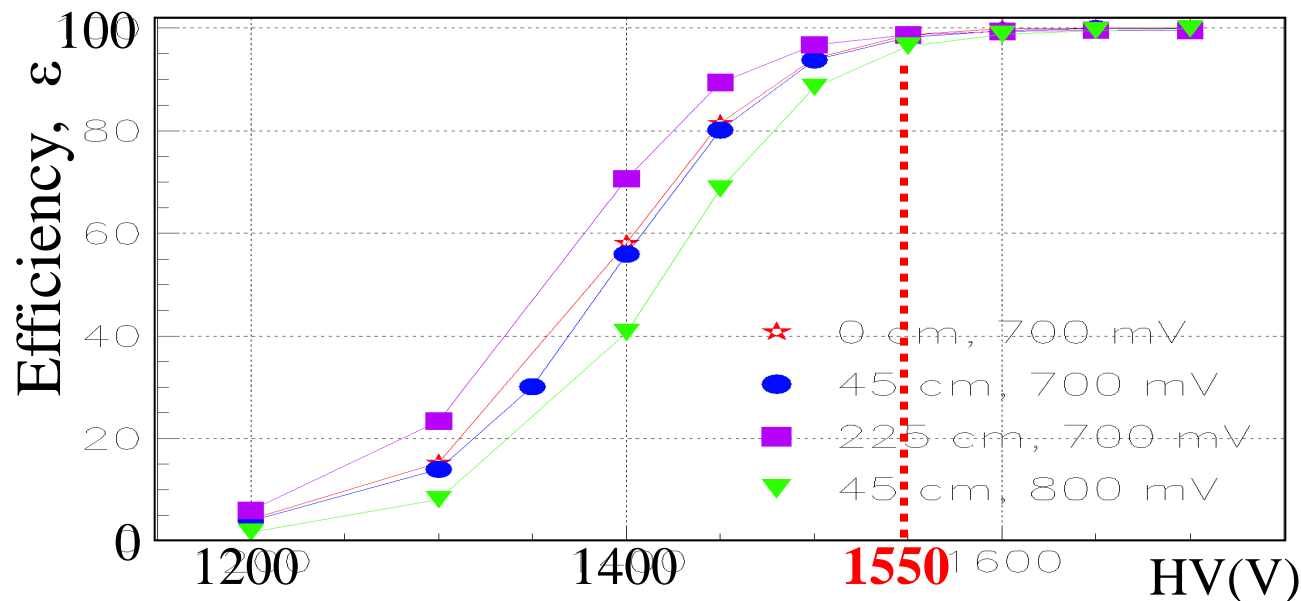
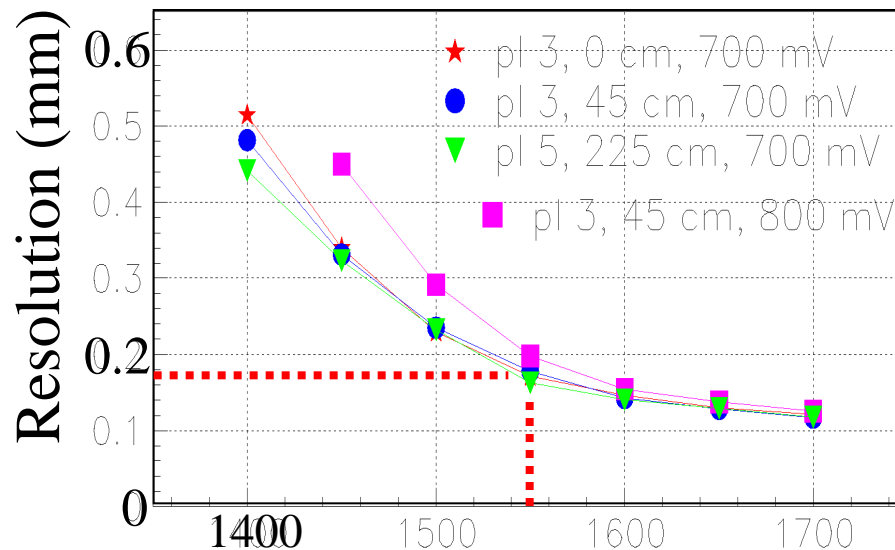
efficiency profile:

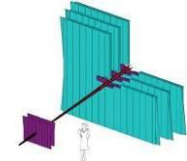


→ Resolution and efficiency for different HV and amplifier threshold

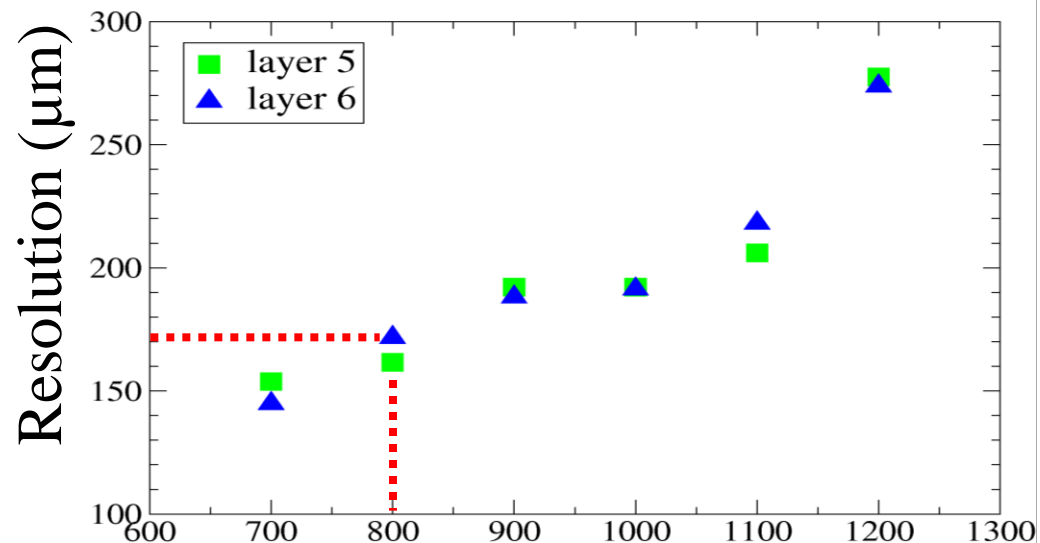


- Good efficiency and resolution for **HV > 1520 V**
 - $\epsilon \approx 98\%$
 - $\sigma \approx 200 \mu\text{m}$
- Corresponds to Gain > 50,000

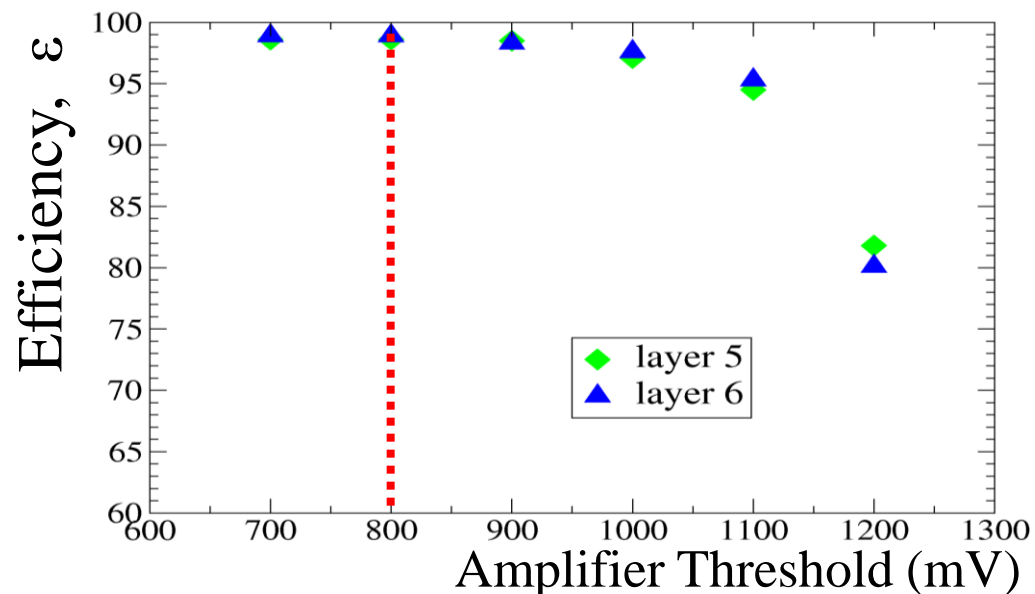




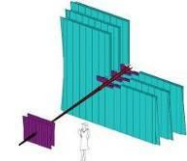
- Good efficiency and resolution for **$700 < \text{thr} < 900 \text{ mV}$**
 - $\epsilon \approx 98\%$
 - $\sigma \approx 200 \mu\text{m}$
- Corresponds to 3 – 5.5 fC



- Electronic noise at 750 mV (= 3.5 fC):
 - $\approx 5 \text{ kHz / straw}$
 - $\approx 0.03\%$ occupancy
 - **Acceptable**

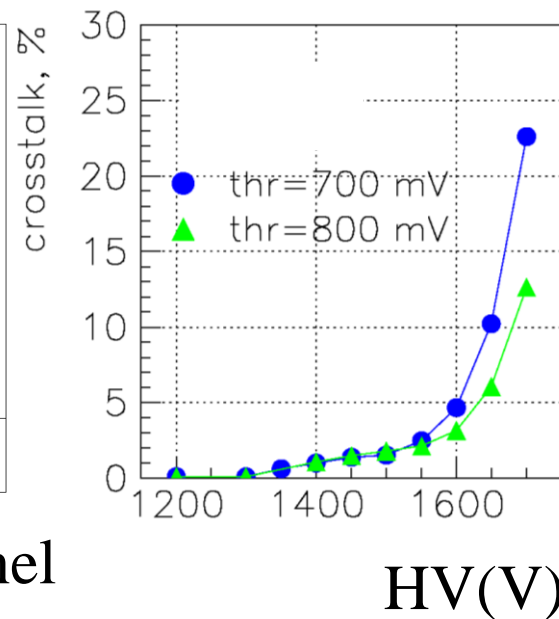
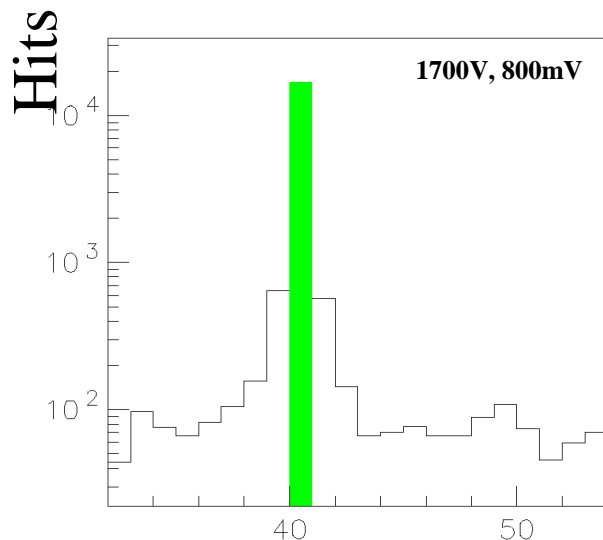


Not everything is perfect...



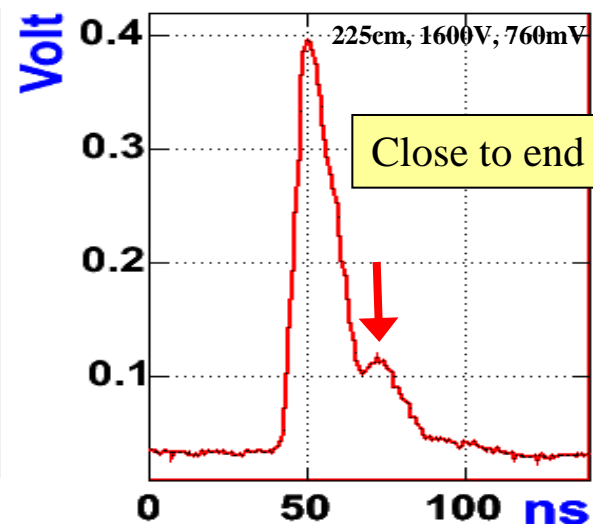
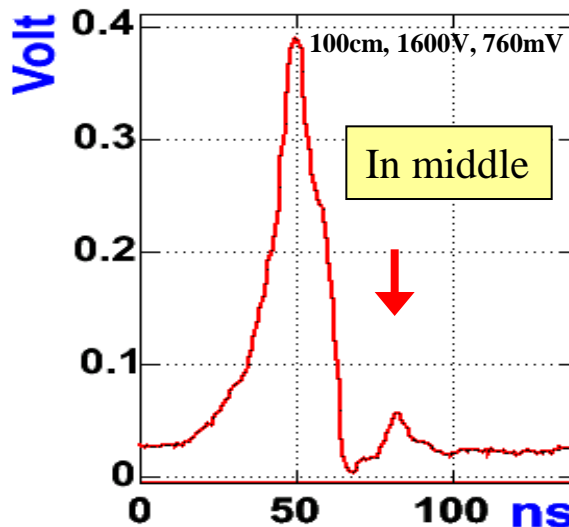
- Cross talk:

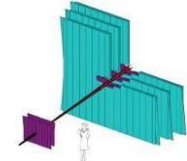
- Probability that neighbours fire
- $\approx 5\%$: acceptable



- Reflections:

- Straw not terminated
- New version of ASDBLR faster shaping
- $\rightarrow \approx 20\%$ have additional after-pulse
- Effect much reduced depending on readout mode





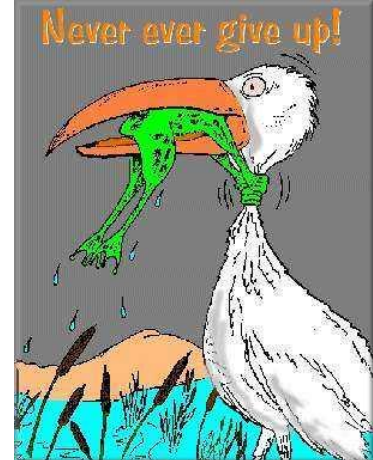
- Module production **finished** this week!
- Beam Test: detector characteristics determined:
 - Good efficiency ($>98\%$)
 - Good resolution ($<200\ \mu\text{m}$)
 - Noise level acceptable ($\sim 5\ \text{kHz}$)
 - With some flexibility
 - 1520 – 1600 V
 - 3-5 fC threshold

To do:

- Mechanical support
- Services
 - HV, LV
 - Gas
 - Cooling

→ Install and commission in 2006

Backup: ageing studies



- No news since report last year in the **IEEE 2004 NSS-MIC conference** (Oct 2004, Rome) by Sebastian Bachmann
 - Session N39: Radiation Damage Effects II - Aging of Gaseous Detectors
 - Title: *Ageing Studies for the Straw Tube Detectors for the LHCb Outer Tracking System*

**No ageing observed
Studies continue**