The Transition Radiation Detector for ALICE at LHC

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Physics Observables Accessible with the TRD

Quarkonia Production in the QCD matter:

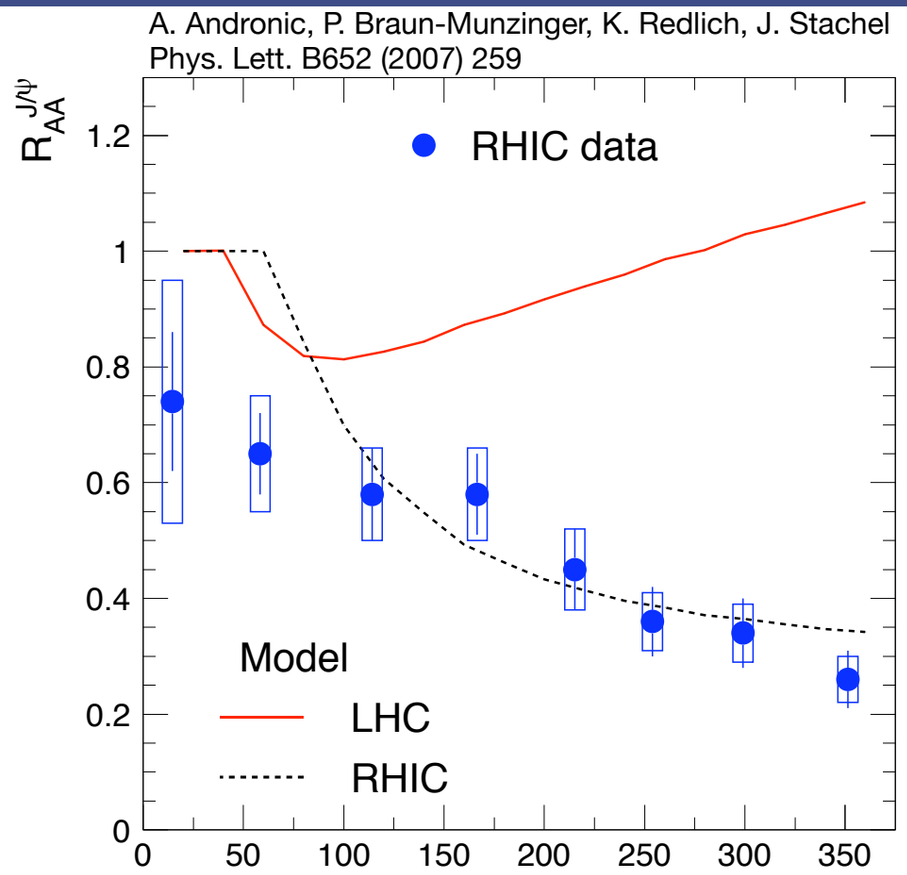
Suppression or Enhancement?

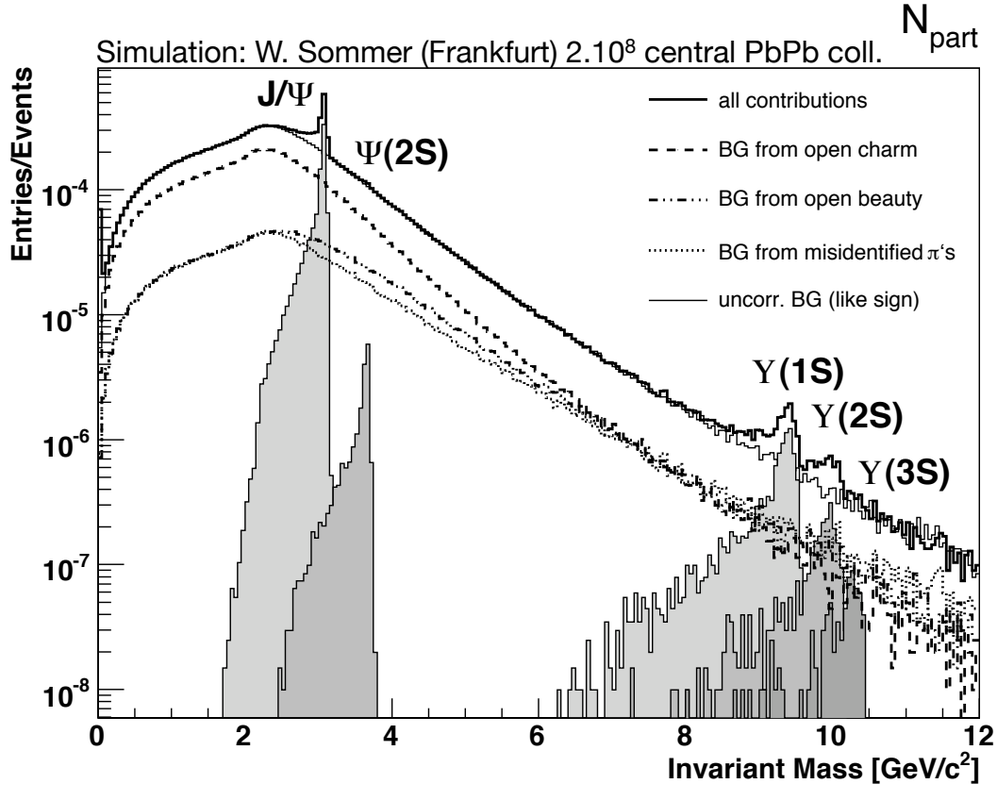
- screening of color charges
  → "melting" of $c\bar{c}$, $b\bar{b}$ bound state

- large abundance of $c\bar{c}$, $b\bar{b}$ quarks at LHC
  → statistical combination to J/ψ, Υ

Golden Channel: J/ψ, $\Upsilon \rightarrow e^+e^-$

⇨ Requires good electron PID



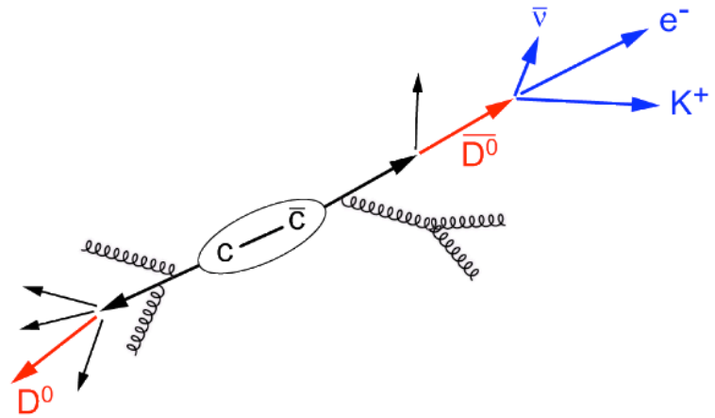


Physics Observables Accessible with the TRD II

Open Heavy Flavor Electrons

- open charm, beauty from semi-electronic decays

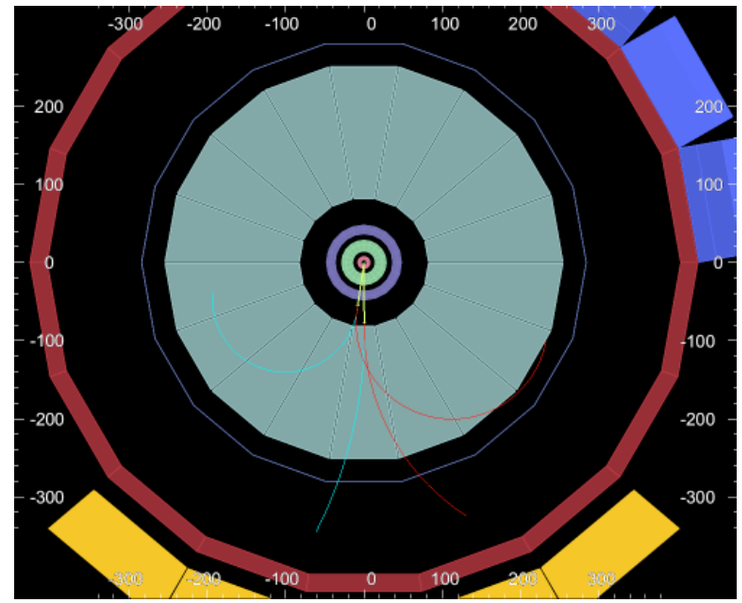
  → charm, beauty cross-section



Photon Conversions

- $\gamma_{\,in\ matter} \rightarrow e^+e^-$

  → direct γ, π^0, η

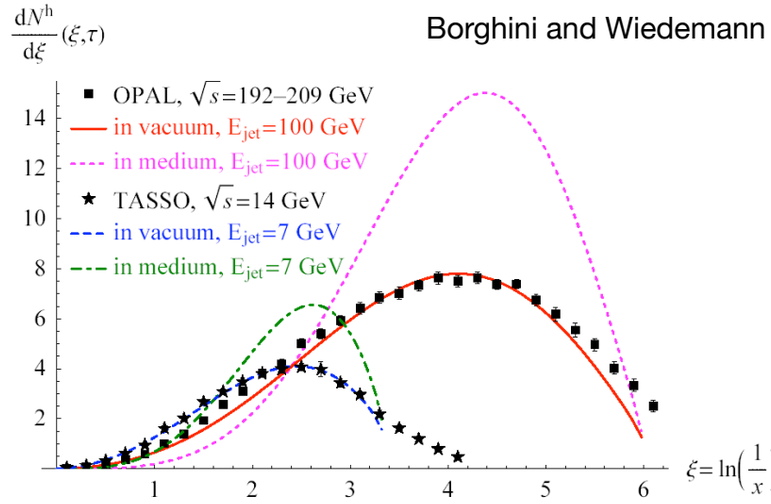


Jets and High-p_T Hadrons

- trigger on high-p_T tracks

  → energy loss in QGP

  → medium-modified fragmentation functions



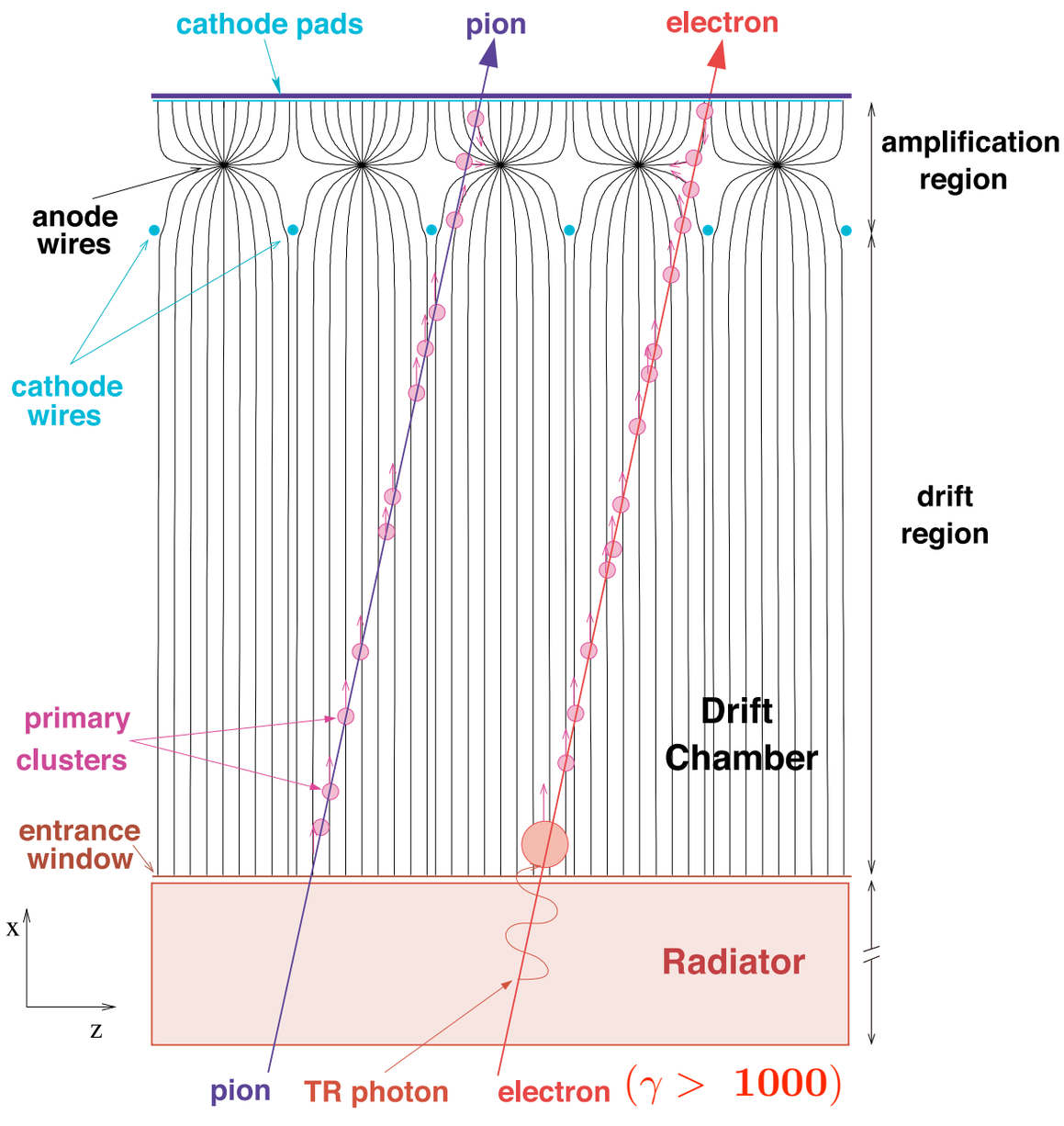
☞ Essential probe for QGP

⇨ Requires:

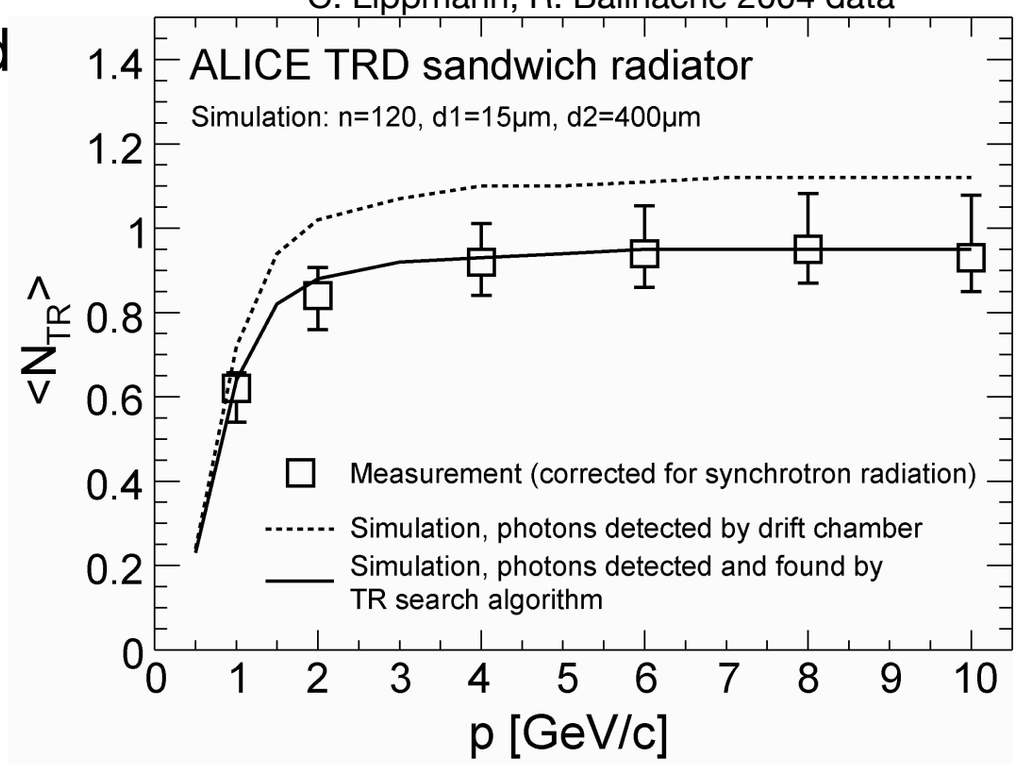
- pion rejection by factor 100 for p > 1 GeV/c
- tracking capability
- trigger on single/pairs of electrons or cluster of high p_t tracks

Working Principle of TRD

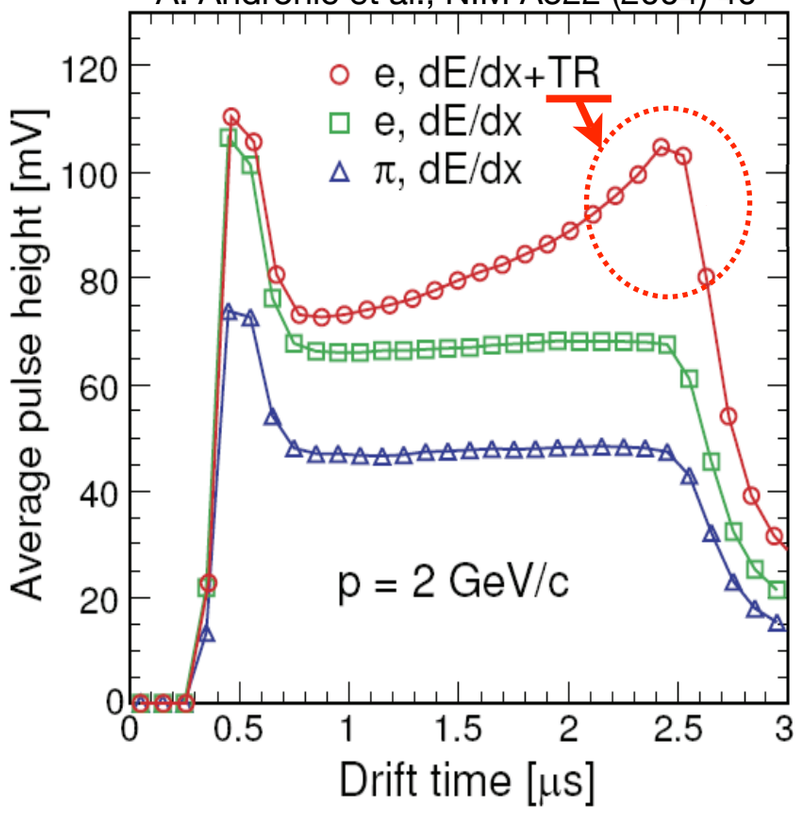
- Drift chambers with cathode pad readout combined with a fiber/foam sandwich radiator in front
- Transition Radiation (TR) photons are absorbed by high-*Z* gas mixture (Xe + CO_2)



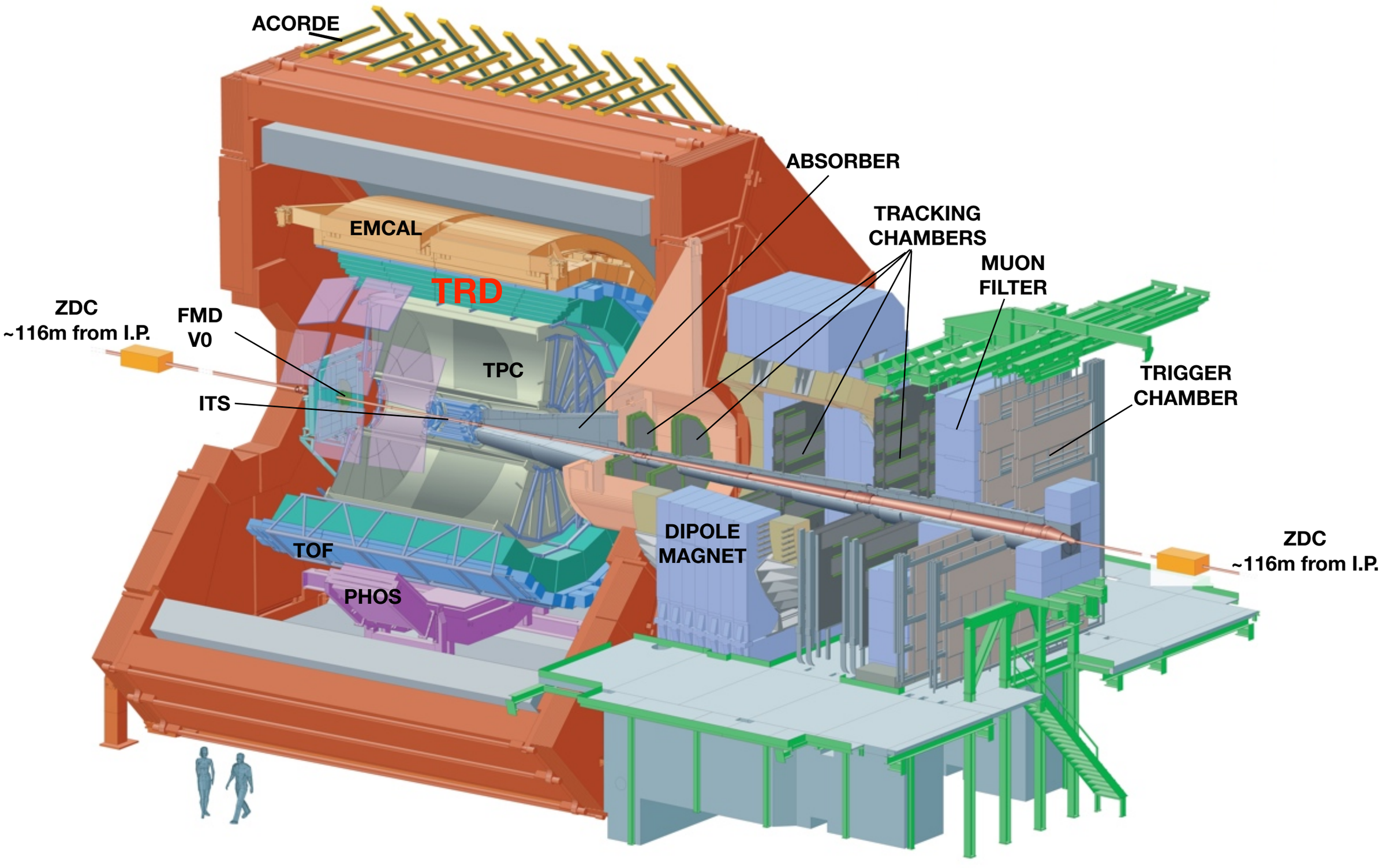
C. Lippmann, R. Bailhache 2004 data



A. Andronic et al., NIM A522 (2004) 40



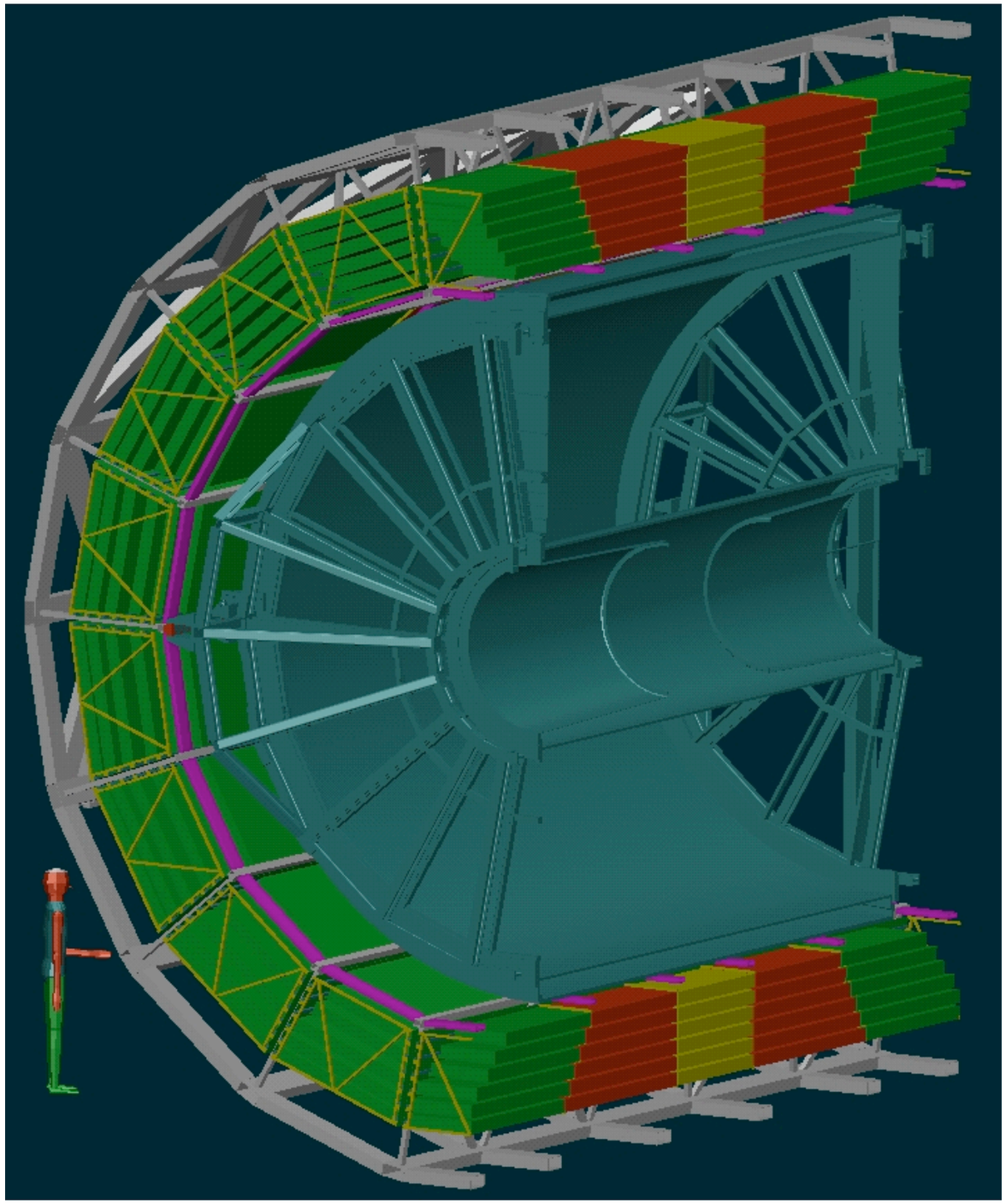
A Large Ion Collider Experiment



Collaboration: 31 countries, 109 institutes, > 1000 people

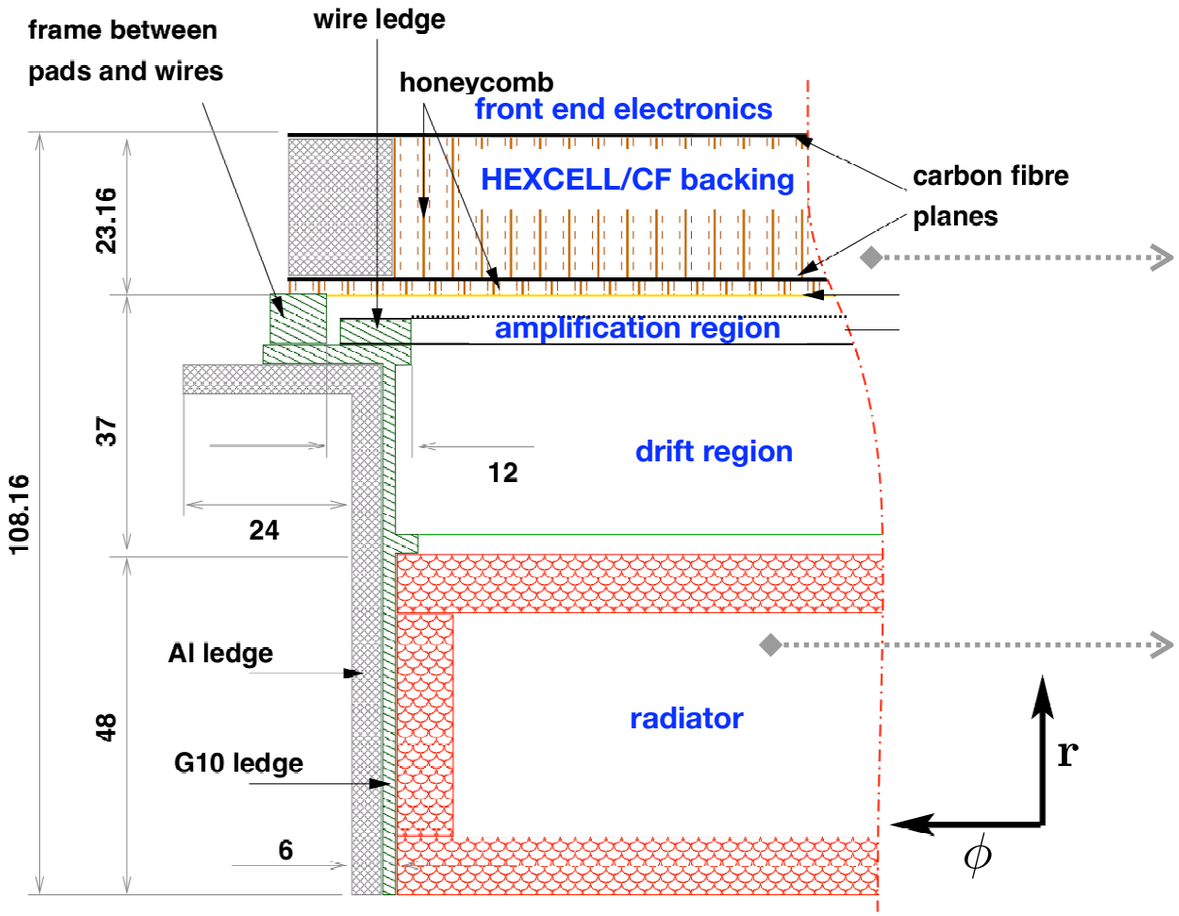
The ALICE TRD

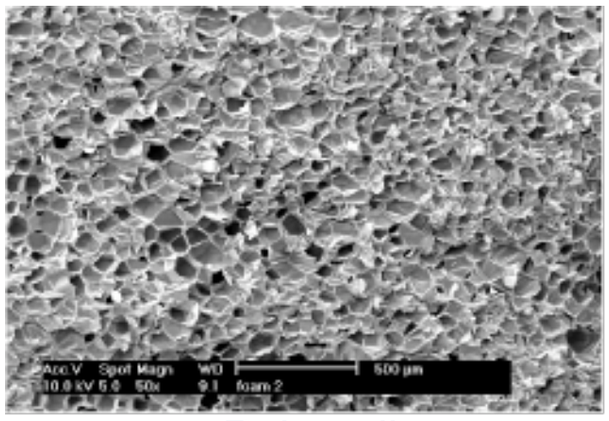
- Surrounds ALICE TPC
  - radial position 2.9 < *r* < 3.7 m
  - maximal length 7 m
  - full azimuthal coverage
  - $|\eta| < 0.9$
- 540 detector modules arranged in:
  - ϕ: 18 super modules
  - *r*: 6 layers
  - *z*: 5 stacks
- 694 m^2 active area
- 28 m^3 detector gas of Xe/CO_2
- $X/X_0 \sim 24$ %
- 30 tons
- 10 M Euro and 250 person years

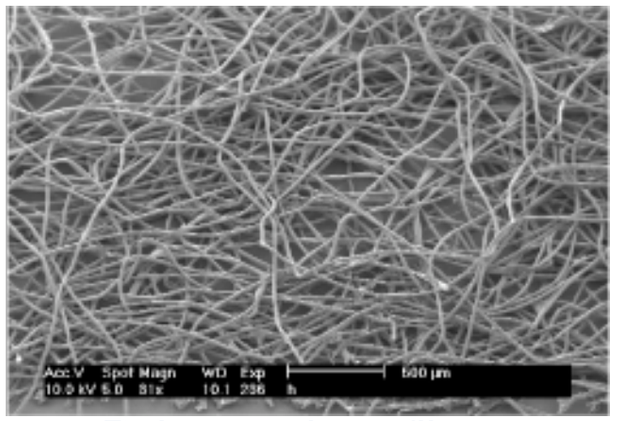


Collaboration for TRD: TU Darmstadt, U Frankfurt, U Heidelberg, U Münster, U Tokyo, U Tsukuba, Bucharest, FH Cologne, Dubna, GSI, Worms

TRD Readout Chamber

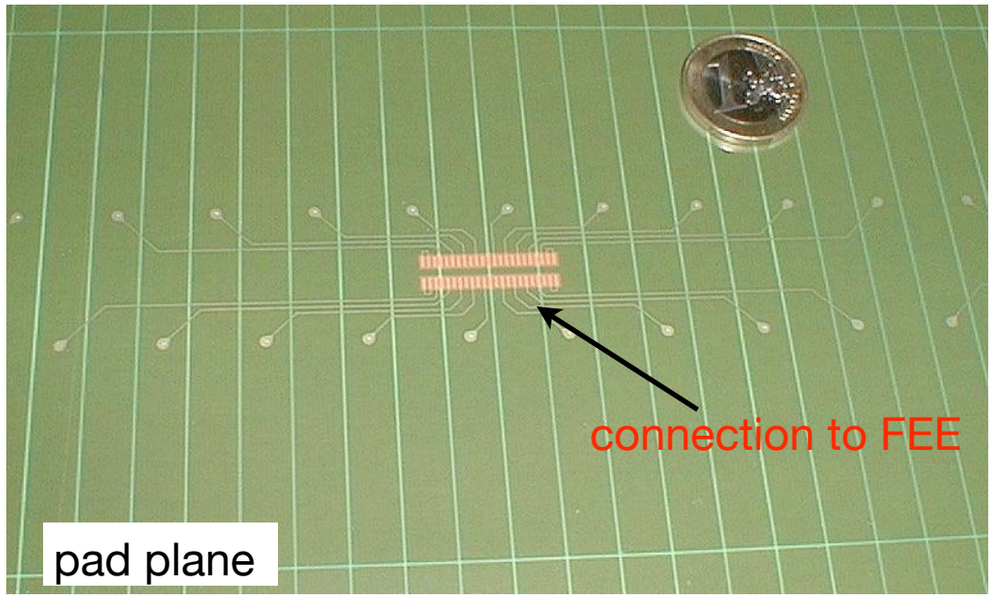






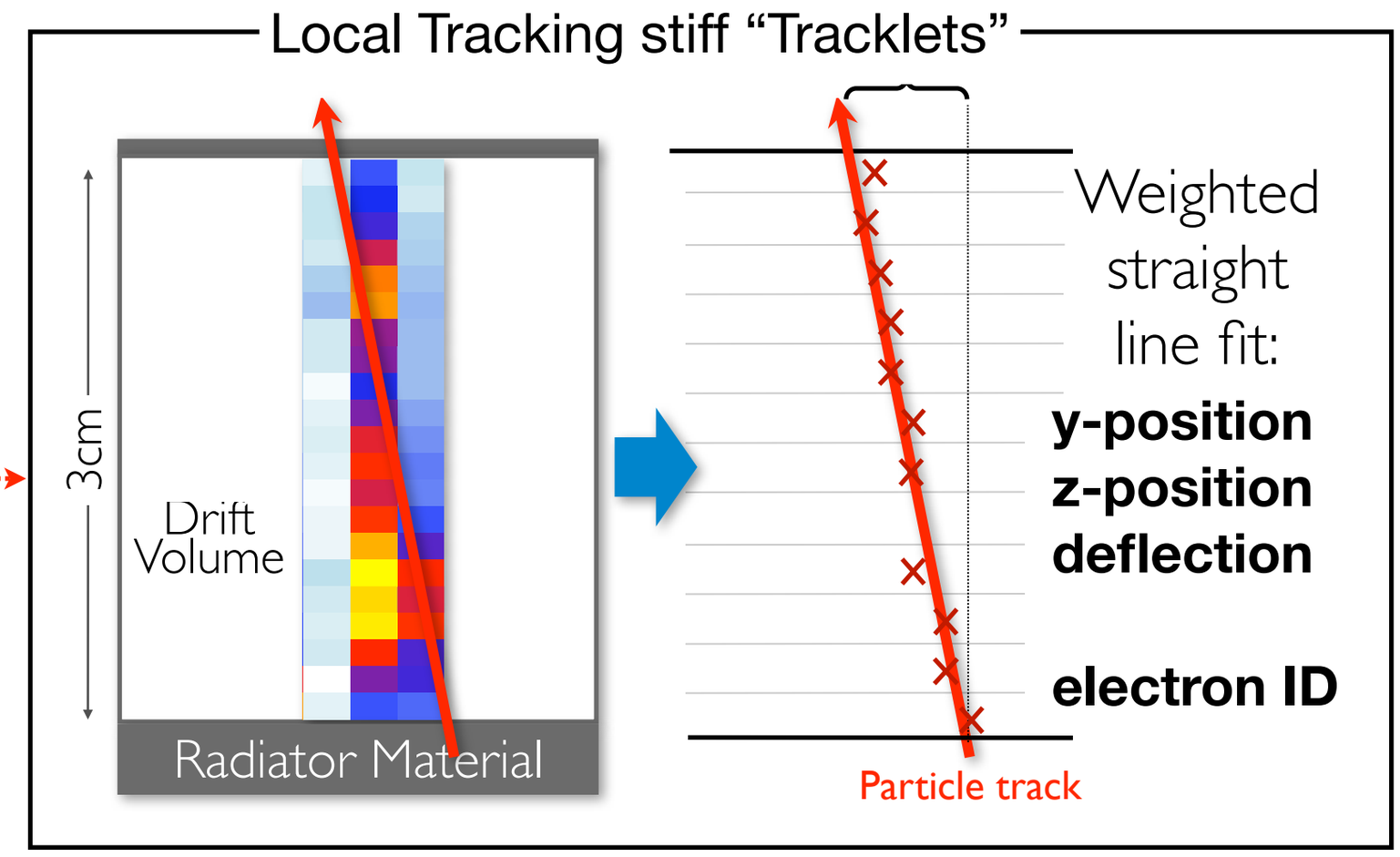
- Electronics directly on detector
- Detector needs to be very thin in radiation lengths, but at the same time very rigid (keep gain uniformity better than 20%)

  → supporting structures



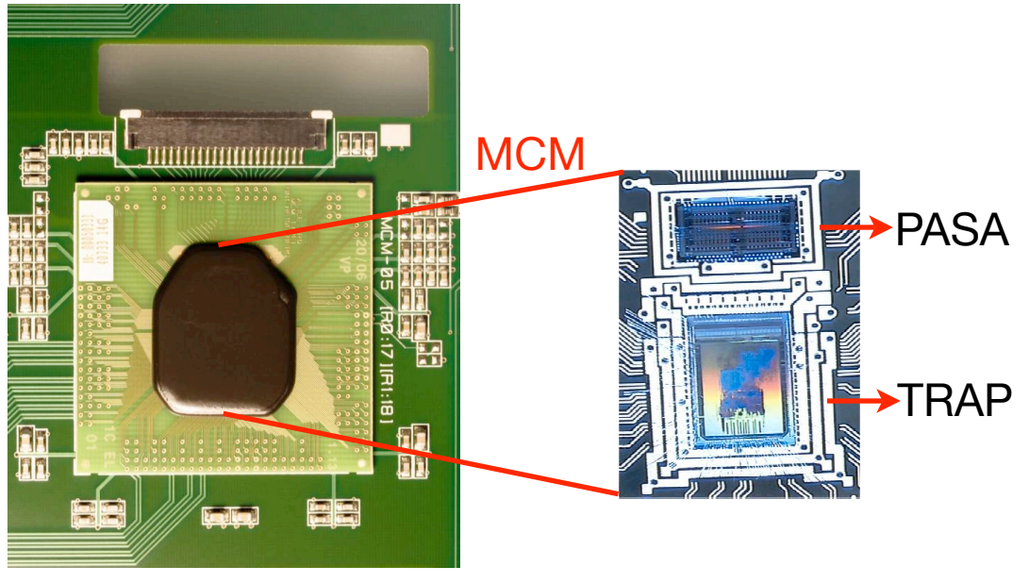
Front-End Electronics

FEE on detector:
Amplifying/Shaping
AD Conversion
Digital filtering
Local Tracking
Raw data readout



Multi Chip Module (MCM)

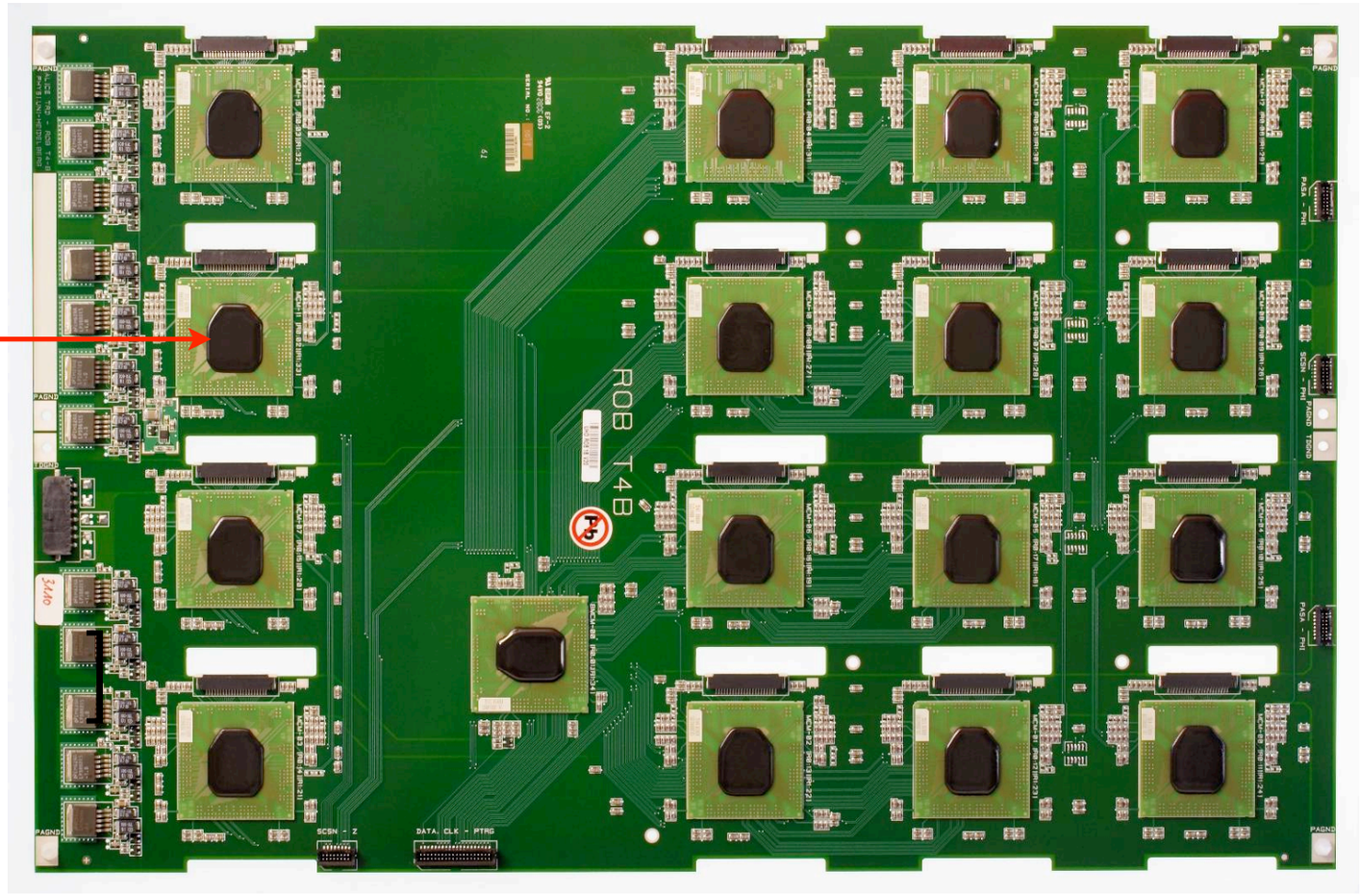
- PASA: PreAmplfier/ShAper (for 18 channels)
- TRAP: TRAcklet Processor
  - 21 ADCs (10 MHz)
  - Digital Filters
  - Event Buffer, Preprocessor
  - 4 CPUs (120 MHz RISC)
  - Readout Network Interface



Readout Chamber Electronics

Read Out Board (ROB)

- MCMs equipped on ROB



6/8 ROBs

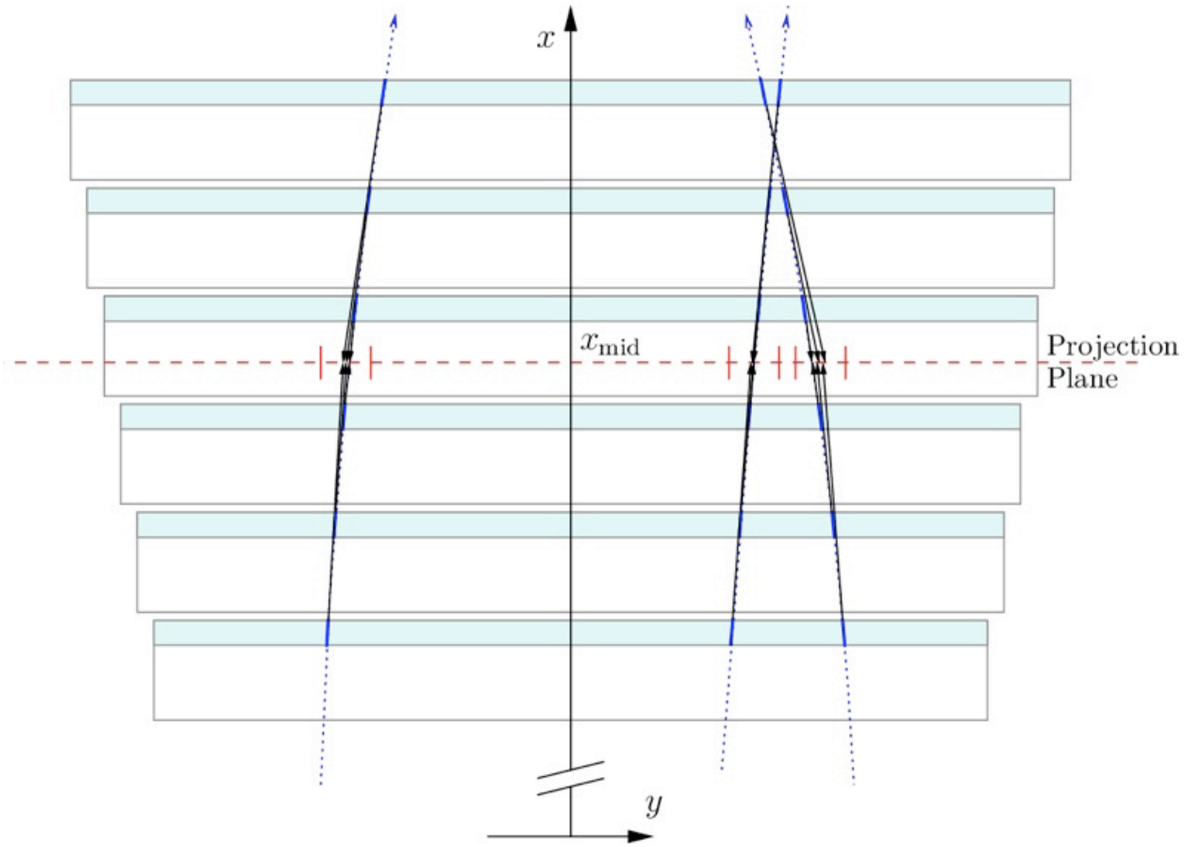
+ 1 linux based Detector Control System (DCS) board
+ 2 Optical Readout Interfaces (ORI) for data shipping

} equipped on one read out chamber

Global Tracking Unit

Trigger

- merge tracklets from MCMs
- reconstruct tracks, calculate momentum
- find high-p_t tracks
- apply various trigger schemes:
  di-lepton decays, jets, cosmics,...
- level-1 trigger decision, done within 6.5 μs from collision

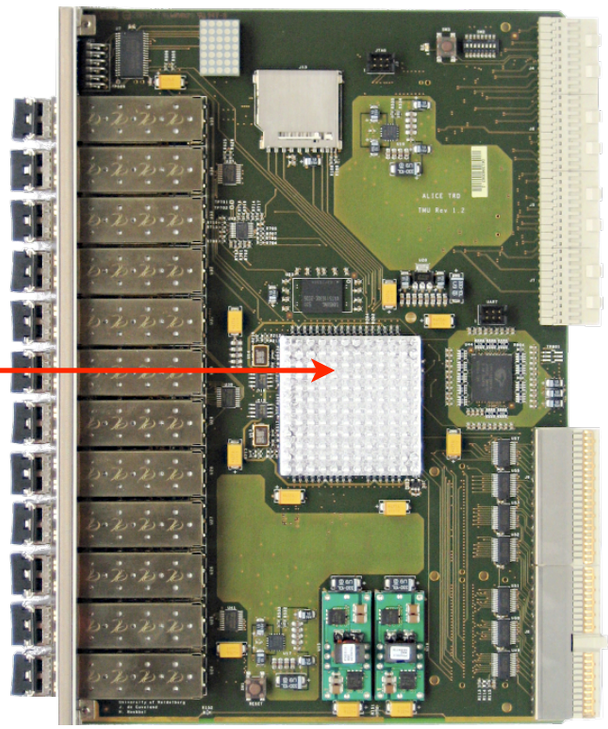


⇨ processed in a short time with lots of data

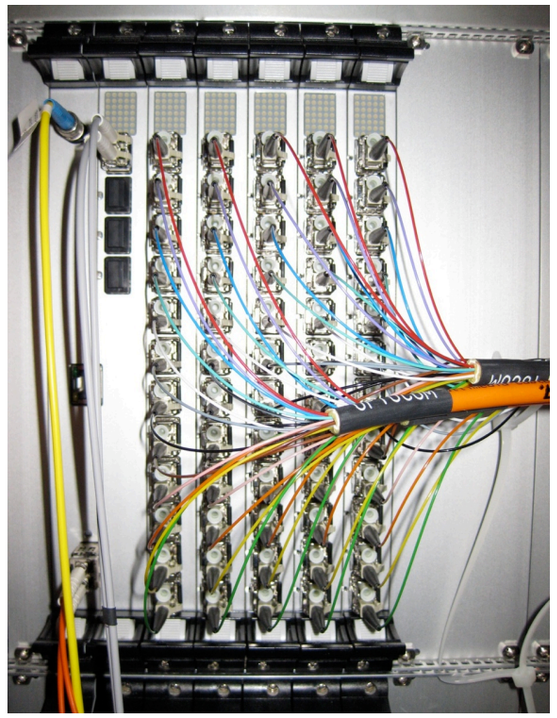
(Virtex-4 FX100 FPGA: 95k LCs, 768 I/Os, 20 Internal Multi-Gigabit Serializer/ Deserializer Units, 2 PowerPC cores)

Raw Data Readout

- collect data from ROCs
- forward to DAQ



GTU processing node (TMU)



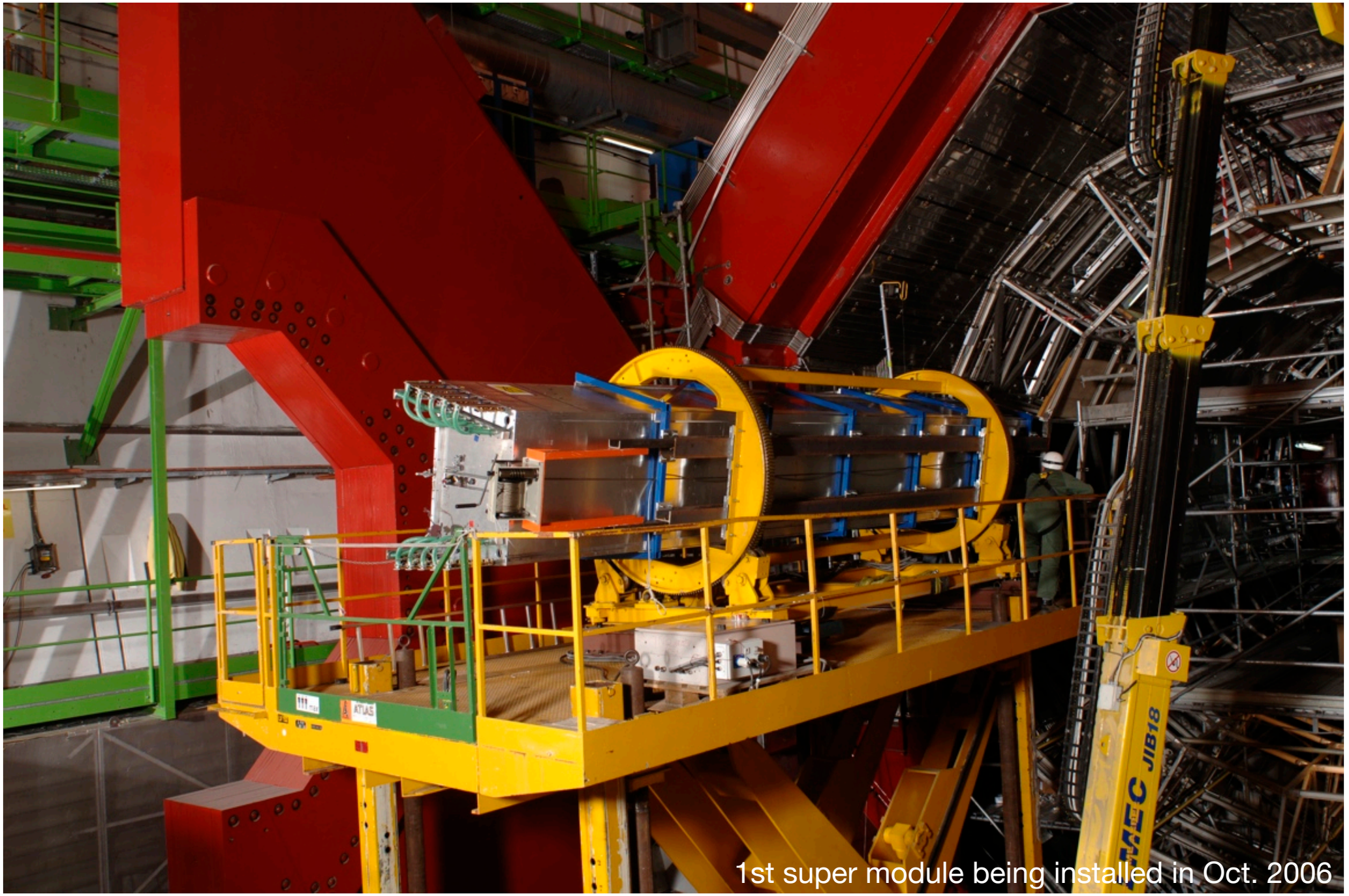
GTU segment for one TRD SM

Electronics and Super module Integration

Install electronics, assembles into one super module

2nd layer being tested in the super module

Installation at ALICE

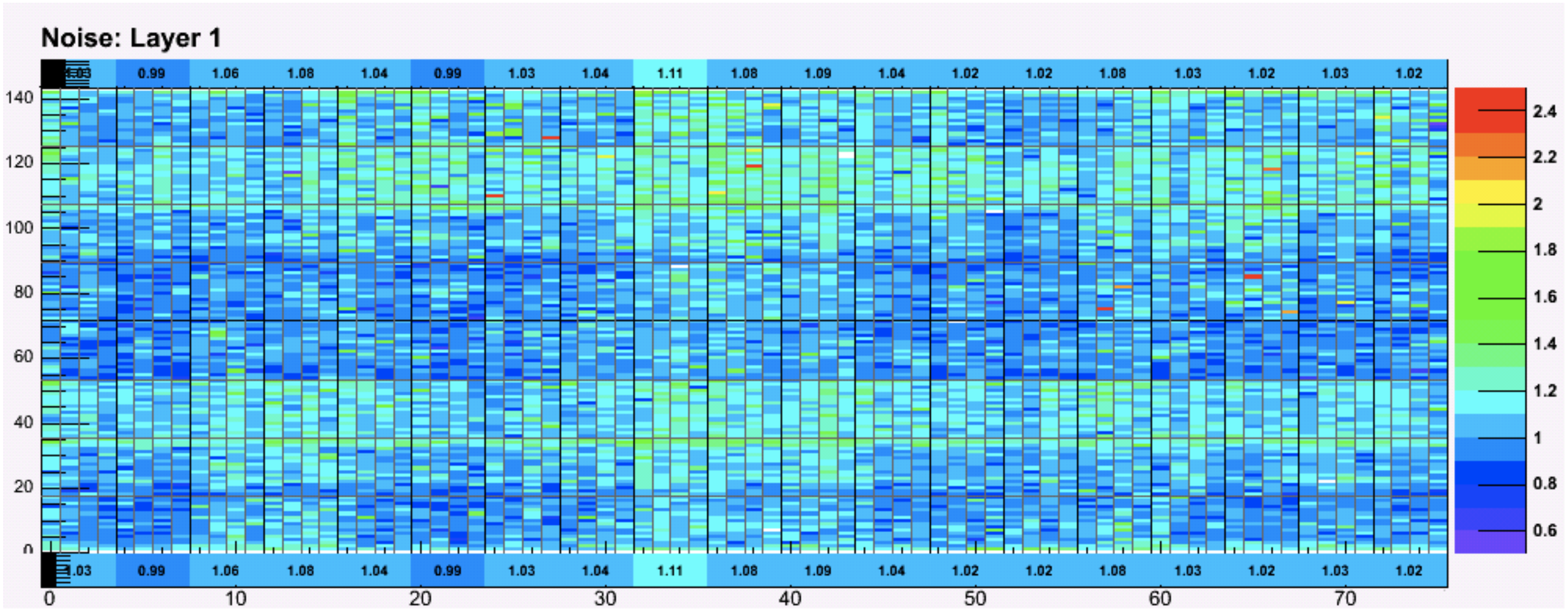


1st super module being installed in Oct. 2006

- 1st TRD super module installed in October 2006
- 6th super module installed January 2009

Electronics Noise

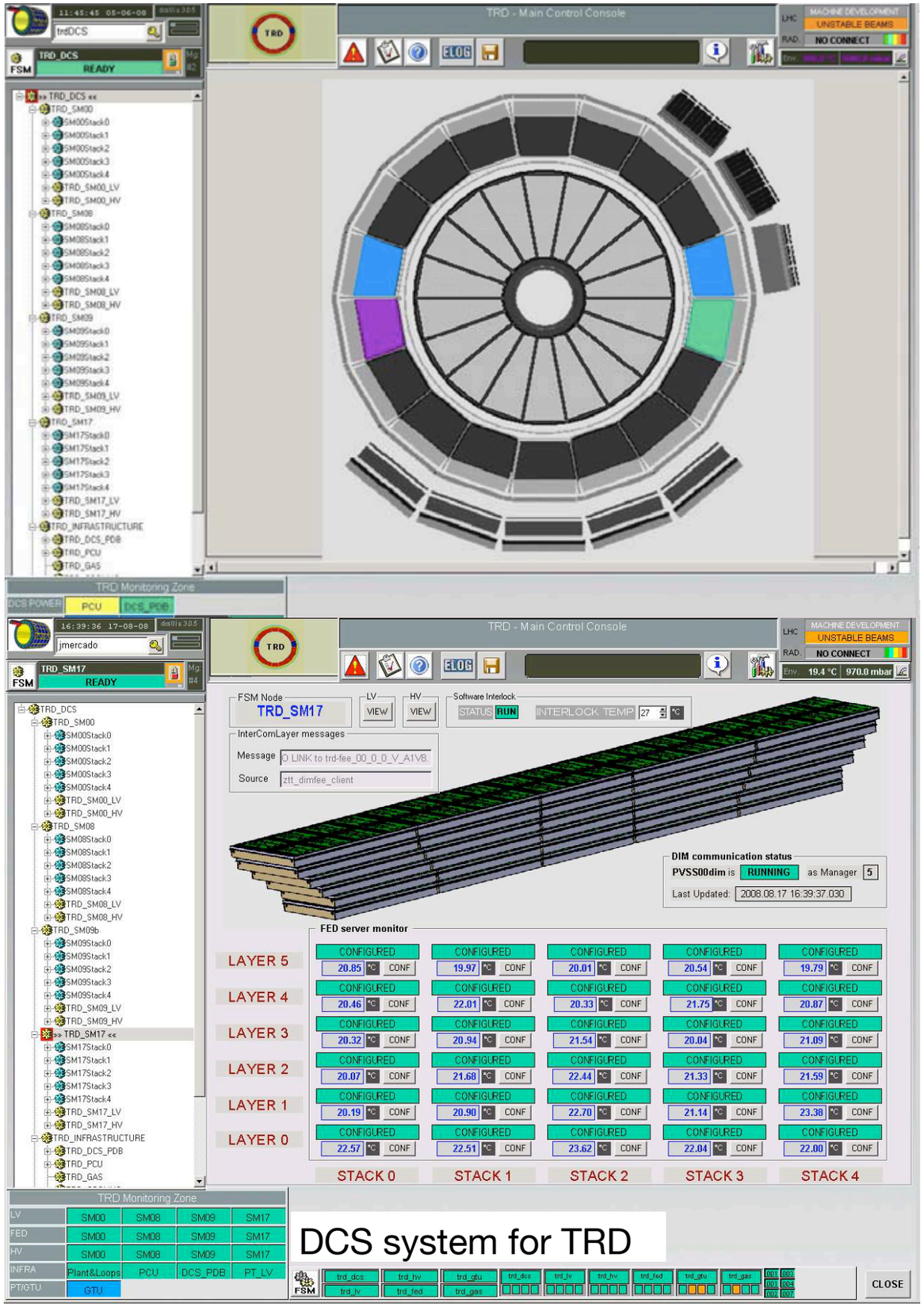
RMS noise map of one layer of a super module



1 ADC ≙ 1000 *e*

- average 1.1 ADC → achieved design goal
- dead channels < 0.1 %

Detector Control System



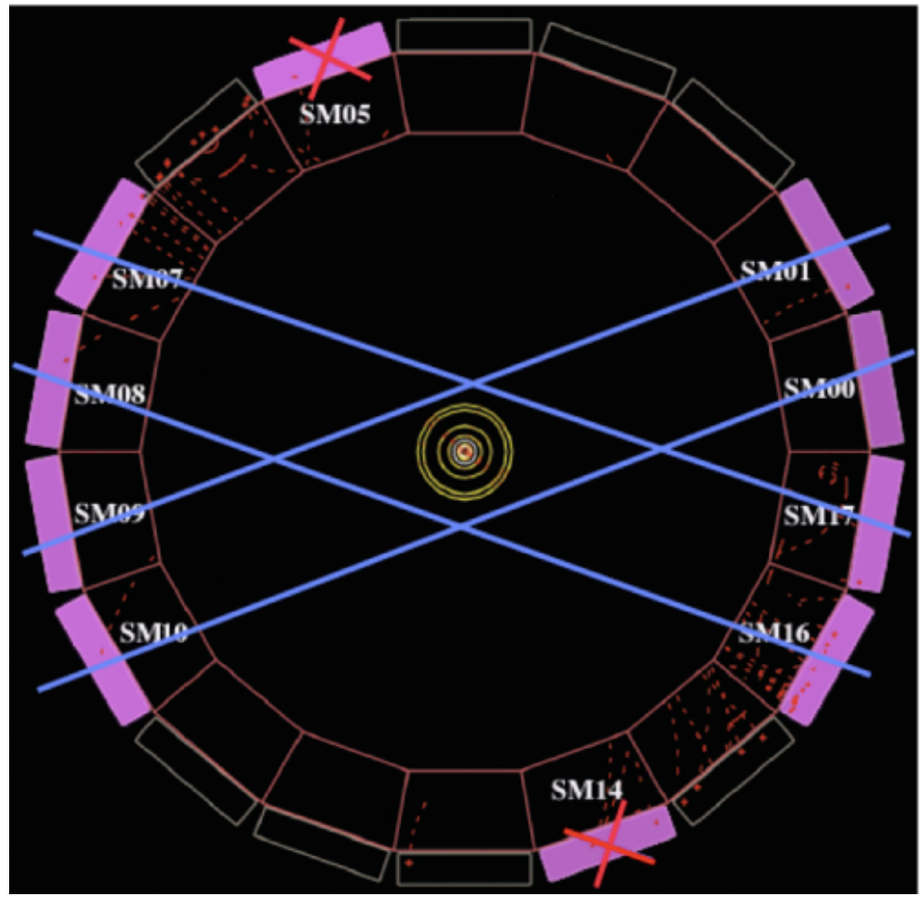
- User friendly detector control system based on PVSS-II
- Ensure safe/stable detector operation and monitoring:
  - 90 low voltage power supplies
  - 1080 HV channels
  - 540 linux clusters
  - 280 k on-detector CPUs
  - 1.2 M channels of preamplifiers and ADCs and digital filters
  - gas systems
  - cooling systems (for 63 kW power consumption)
  - trigger systems
- Based on tree structure of distributed Finite State Machines
- TRD can be operated by half a shift person (combined shift with other detectors)

Commissioning

ALICE cosmic runs (Dec. 2007, Jul.~Oct. 2008)

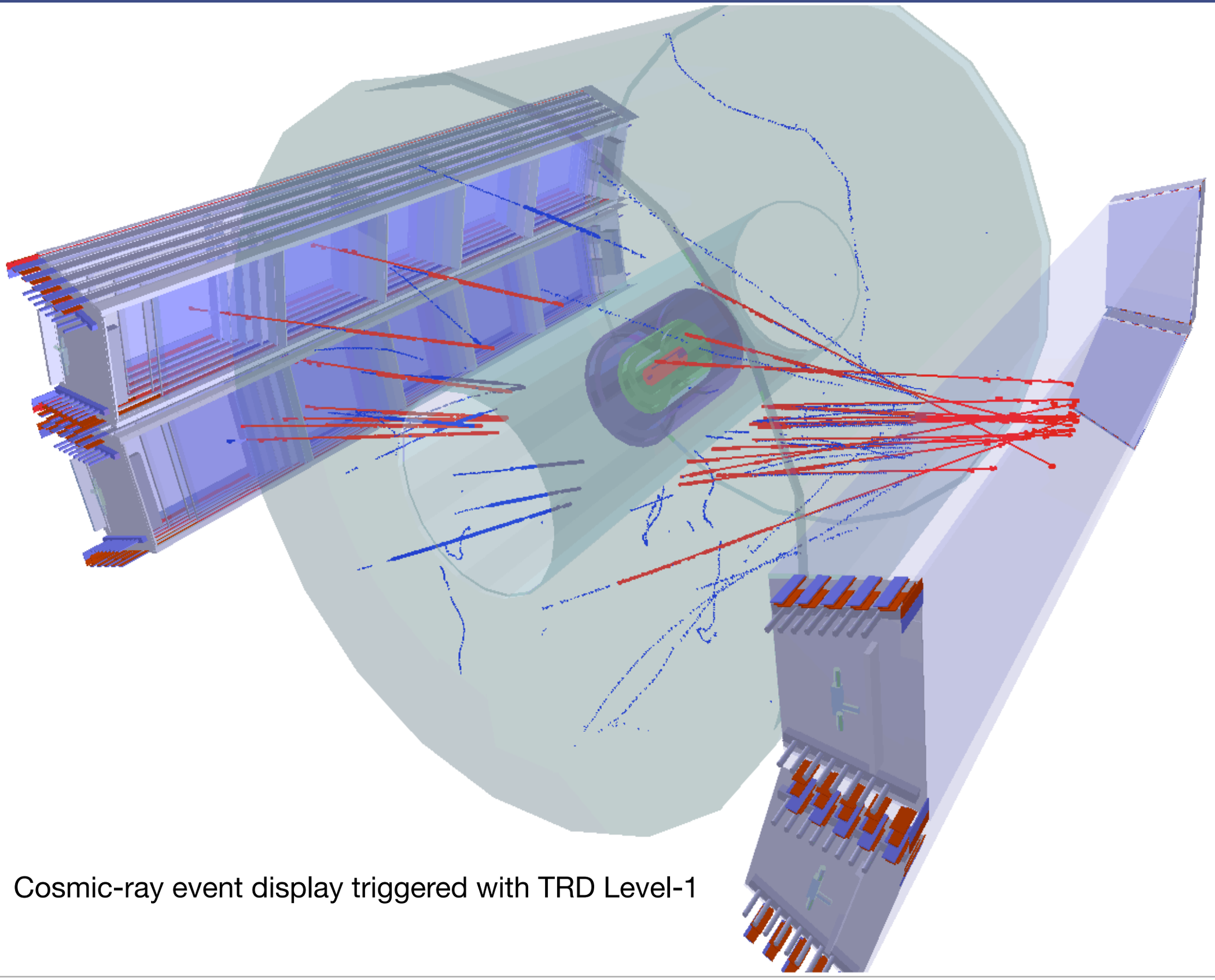
- 4-TRD super modules participated
  (total $\Delta\phi = 80^{\circ}$)
- combined running with other detectors
- TOF pretrigger
  - coincidence of two opposite modules
- GTU L1 trigger
  - 1st running L1 trigger in ALICE
  - L1/L0 ~ 1/20, L1 rate 0.05 Hz
  - purity > 85 %
- 55 k tracks under extreme condition:
  - 60m below the surface
  - require cosmic flux close to horizontal

Coincidence condition for pretrigger



TRD ready for beam in September 2008

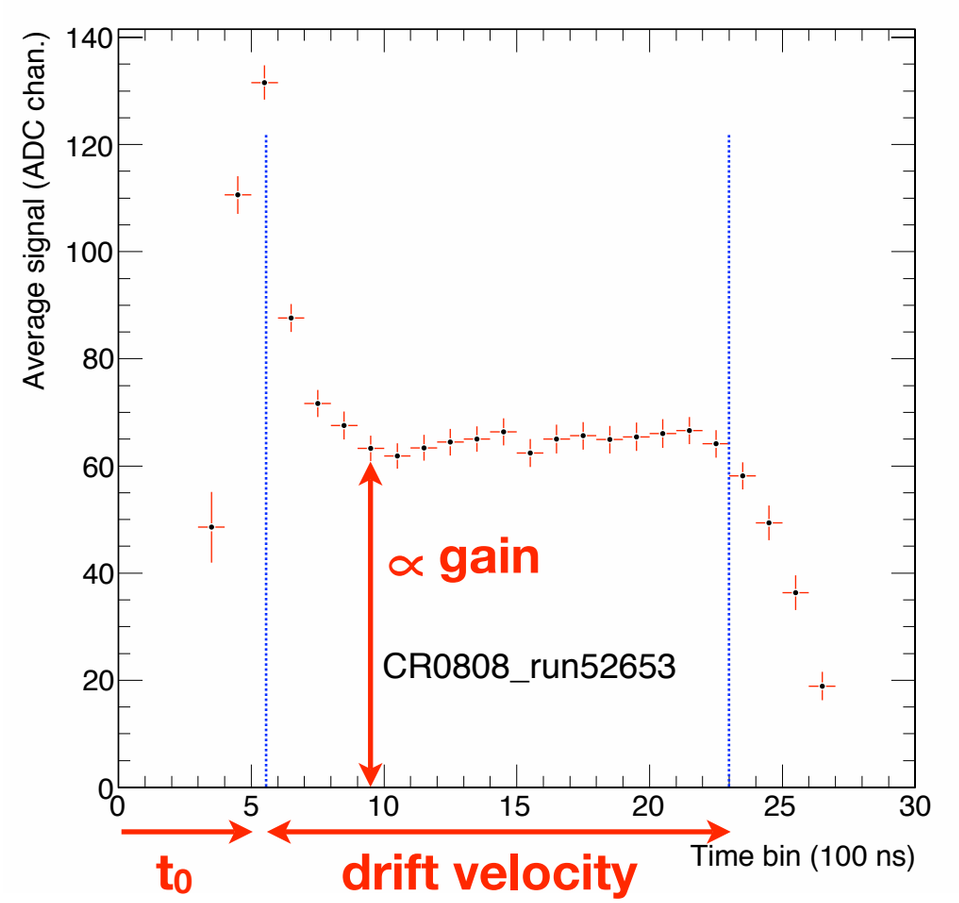
Cosmic Event Triggered

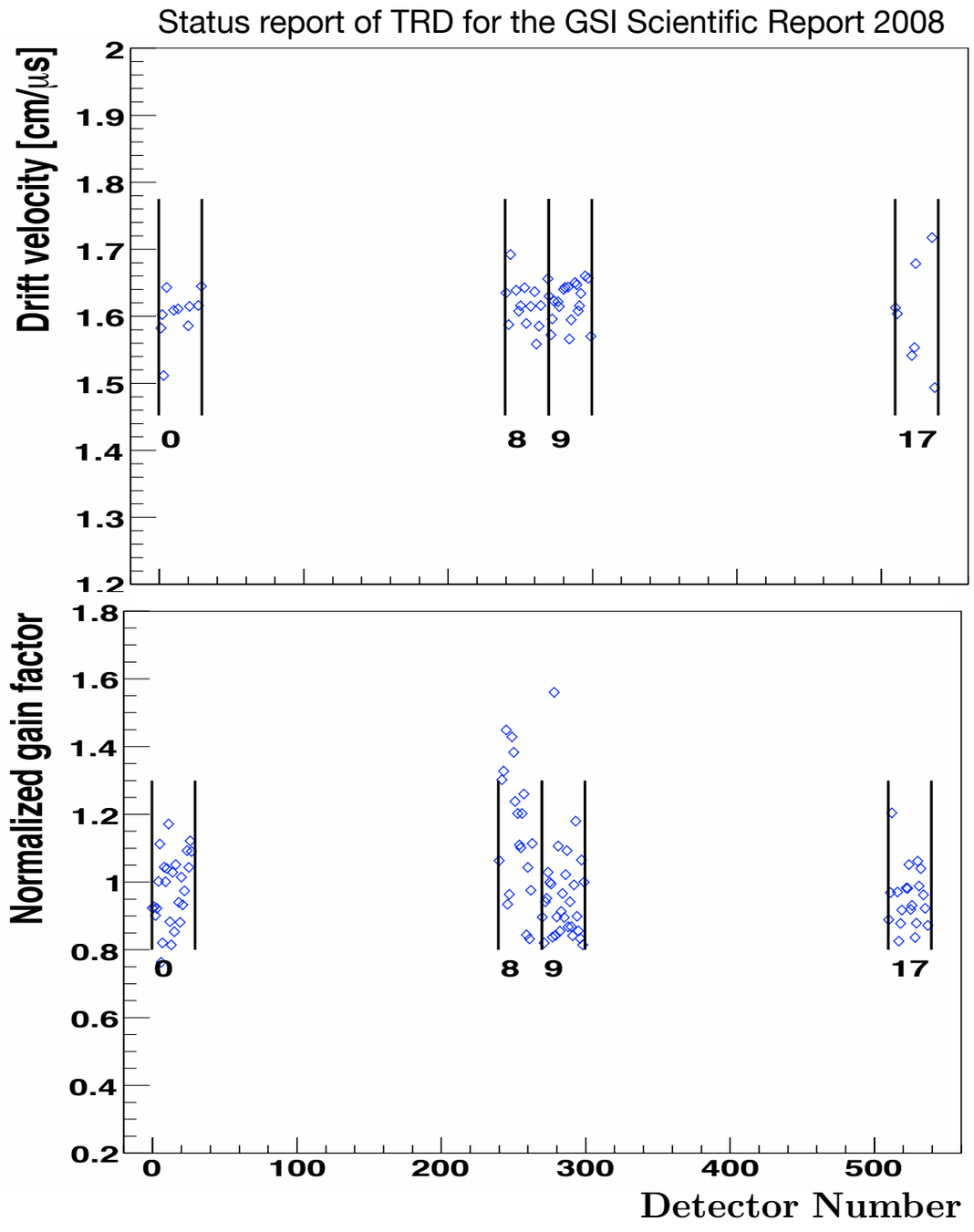


Cosmic-ray event display triggered with TRD Level-1

Calibration

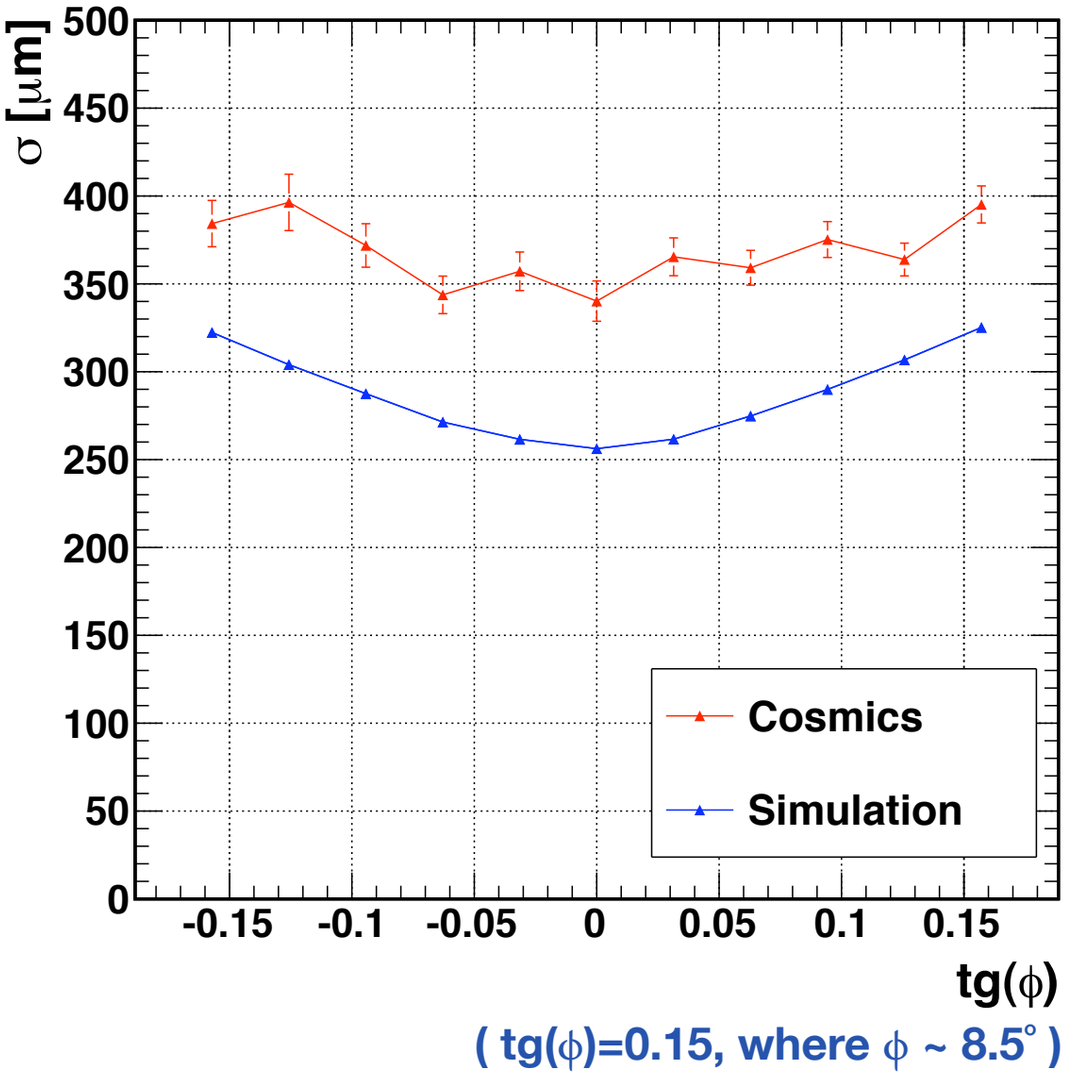
	nominal conditions	cosmic run
gas	Xe, CO_2 (15%)	Ar, CO_2 (18%)
U_a (V)	1550	1450
U_d (V)	-2100	-1200
v_d (cm/μs)	1.5	1.61





- Drift velocity ≈ 1.62 cm/μs, in the expected range from simulation and variation ≈ 3.3 %
- Gain variation ≈ 16 %, better than the design specification 20 % → important for trigger

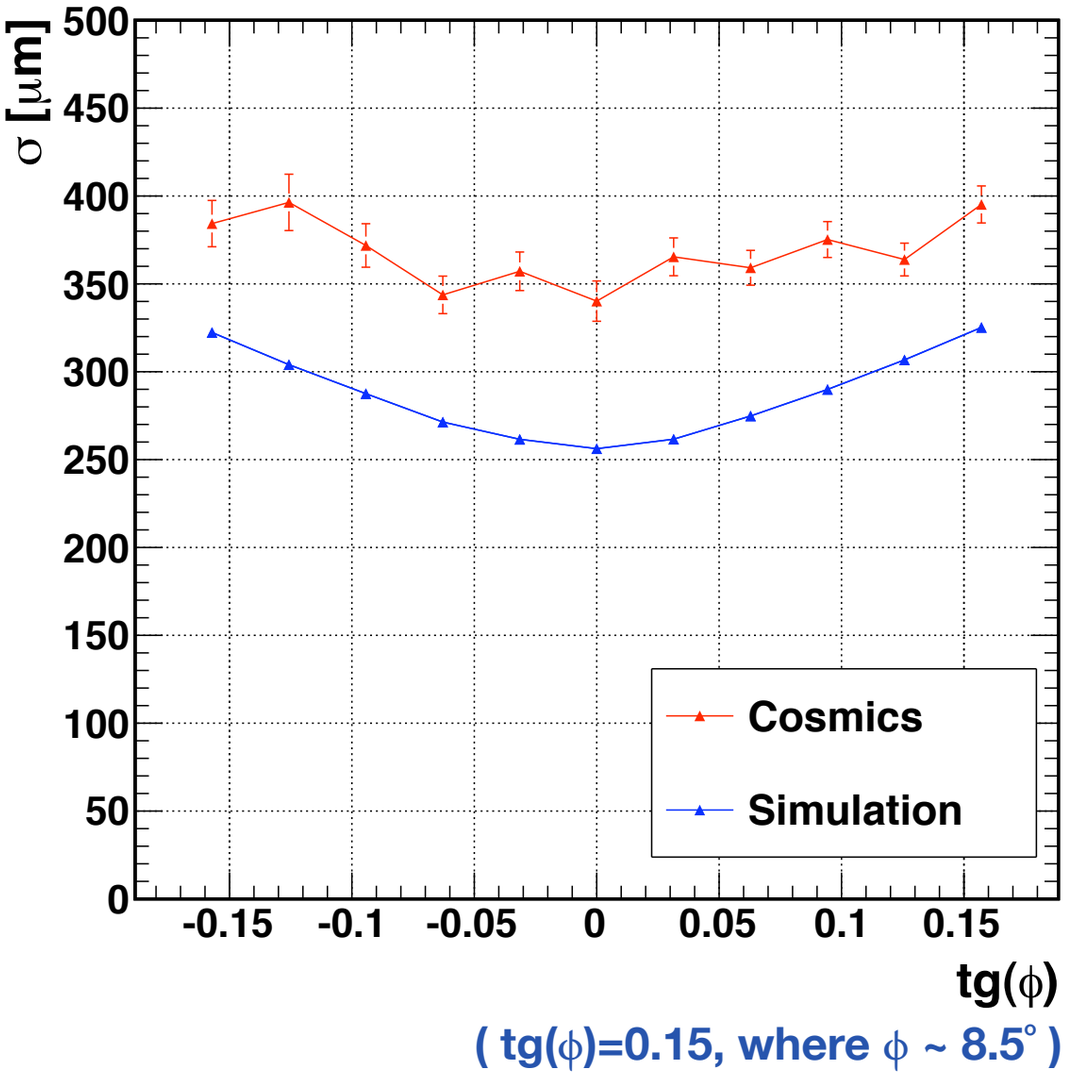
Tracking Performance



$r\phi$ directional position resolution:

- ≈ 350 μm at 0° incident angle
- close to design goal

Tracking Performance



(tg(ϕ)=0.15, where ϕ ~ 8.5°)

$r\phi$ directional position resolution:

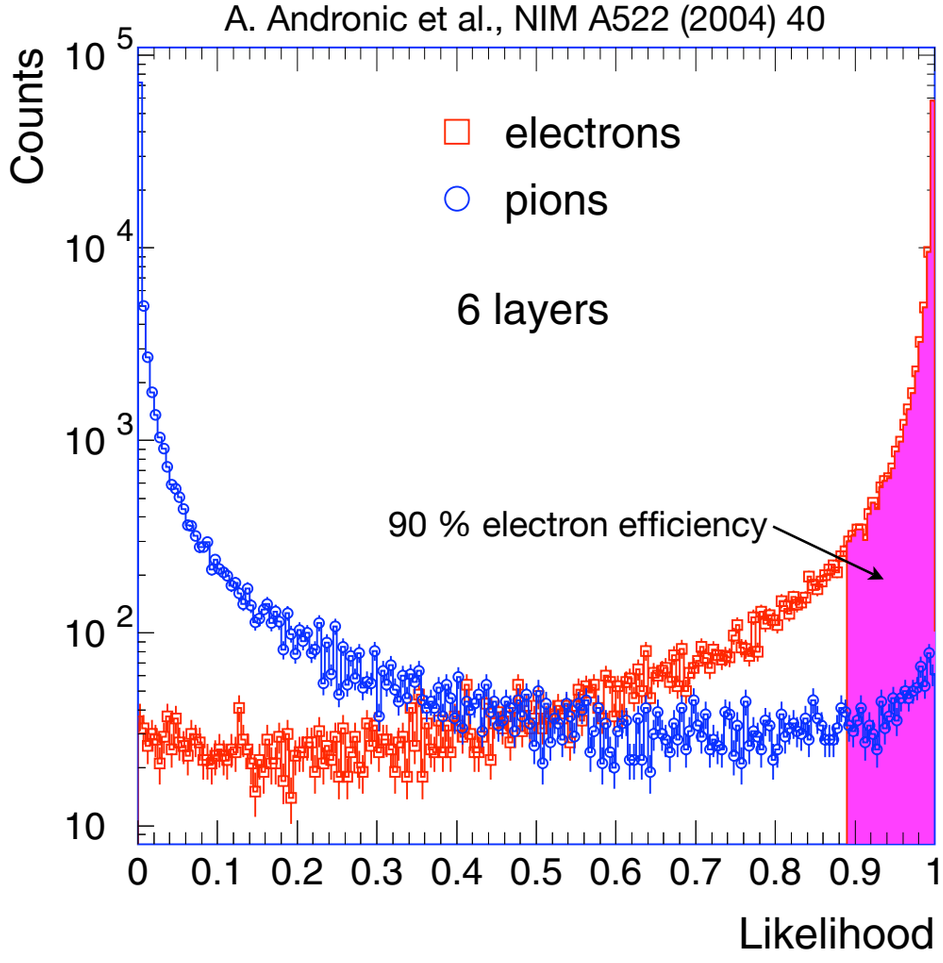
- ≈ 350 μm at 0° incident angle
- close to design goal

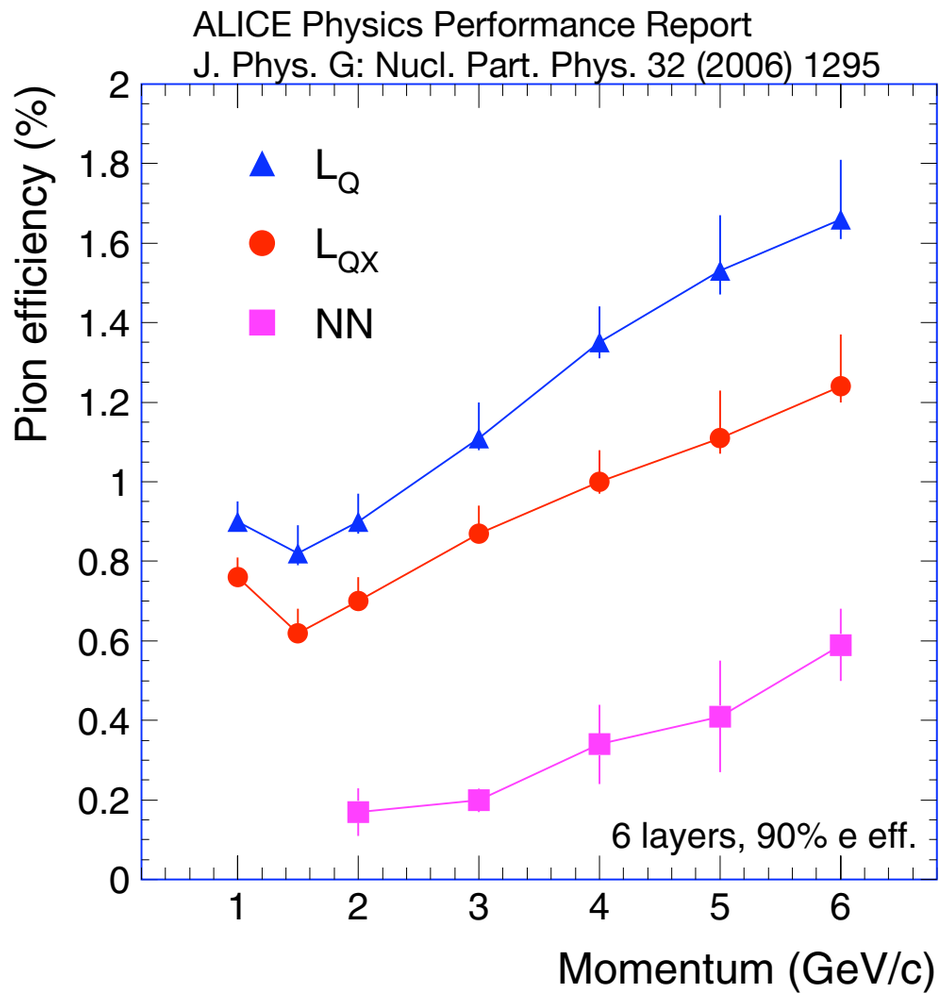
Various analyses ongoing:

- TPC-TRD track matching resolution
- geometrical alignment

Electron Identification and Pion Rejection

Test beam measurement at CERN PS with electron and pion beam





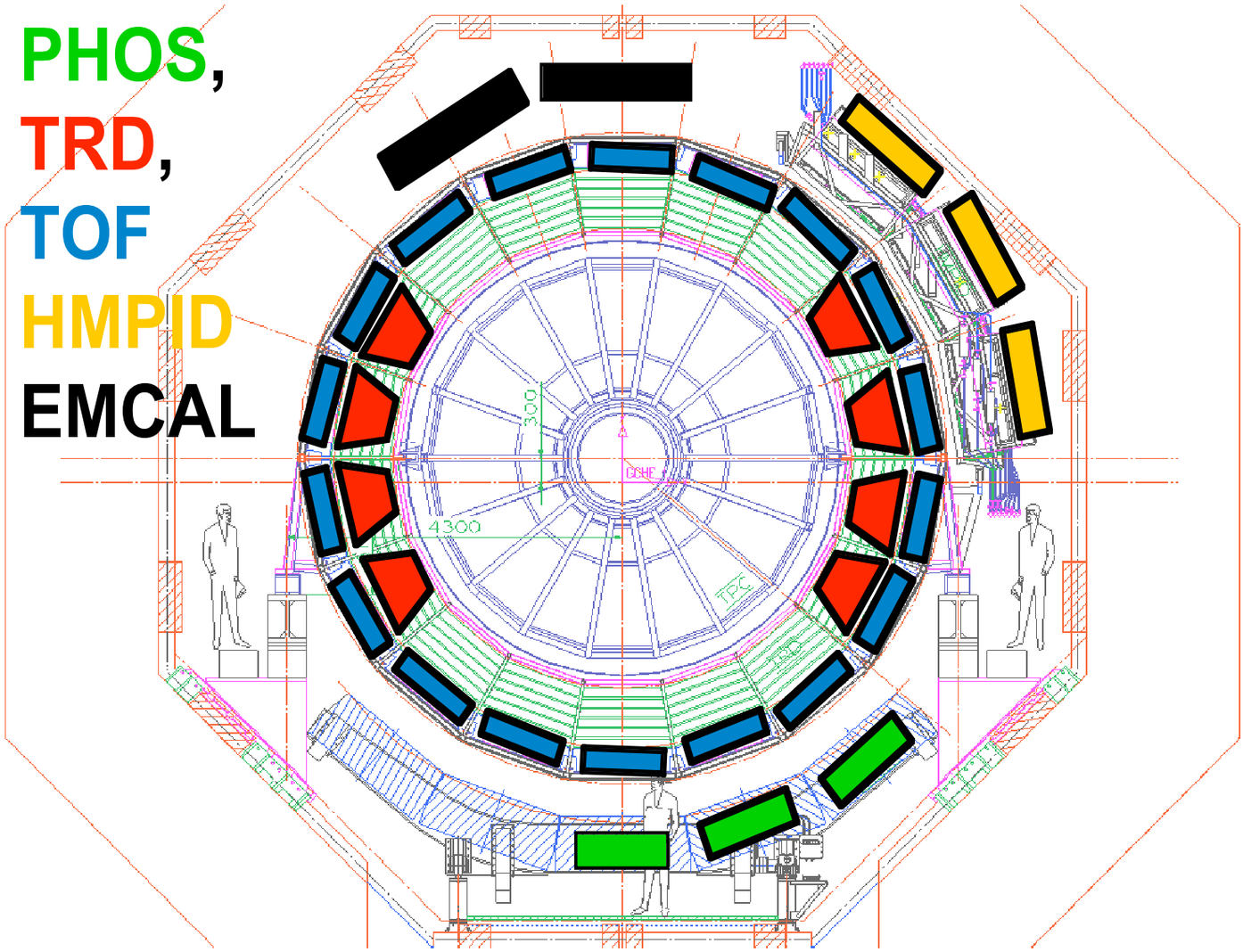
- Likelihood can be based on:
  - total deposited charge (LQ)
  - deposited charge/position (LQX)
- Performance close to desired 1 % at 1-3 GeV even with LQ method

Summary and Outlook

- TRD provides excellent electron identification and fast trigger capability
- 4-TRD super modules were commissioned successfully in 2008

- Continuos cosmic run will be from August until real collisions

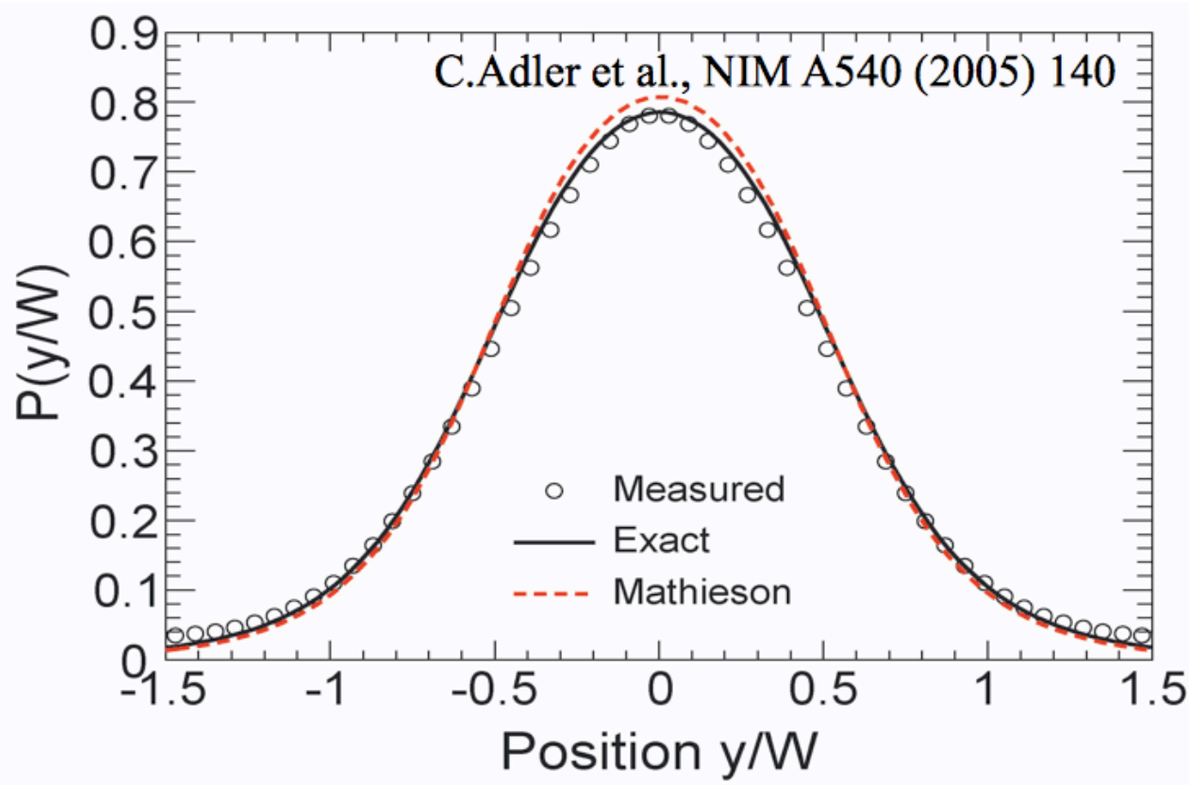
- For 2009 LHC run, 8 super modules will be ready
- Full TRD will be ready for 2011 run



TRD is ready and waiting for real collisions!

TRD Chambers

induced image charge on cathode pads of typically 0.75 × 8 cm^2
(pad - ground capacitance 20 – 25 pF)
pads tilted by 2^o to obtain z-resolution



typical signal size (3 GeV/c):
dE/dx = 5.5 keV/cm
≙ 243 electrons/cm
sampled every 2 mm
× gas gain 4000
× 0.2 (image fraction × shaping fraction)
⇨ **40 000 electrons**
☛ aim for total electronics noise of 1000 electrons

typical width: 0.5 pad units ≙ 3.8 mm