



**Universität
Heidelberg**

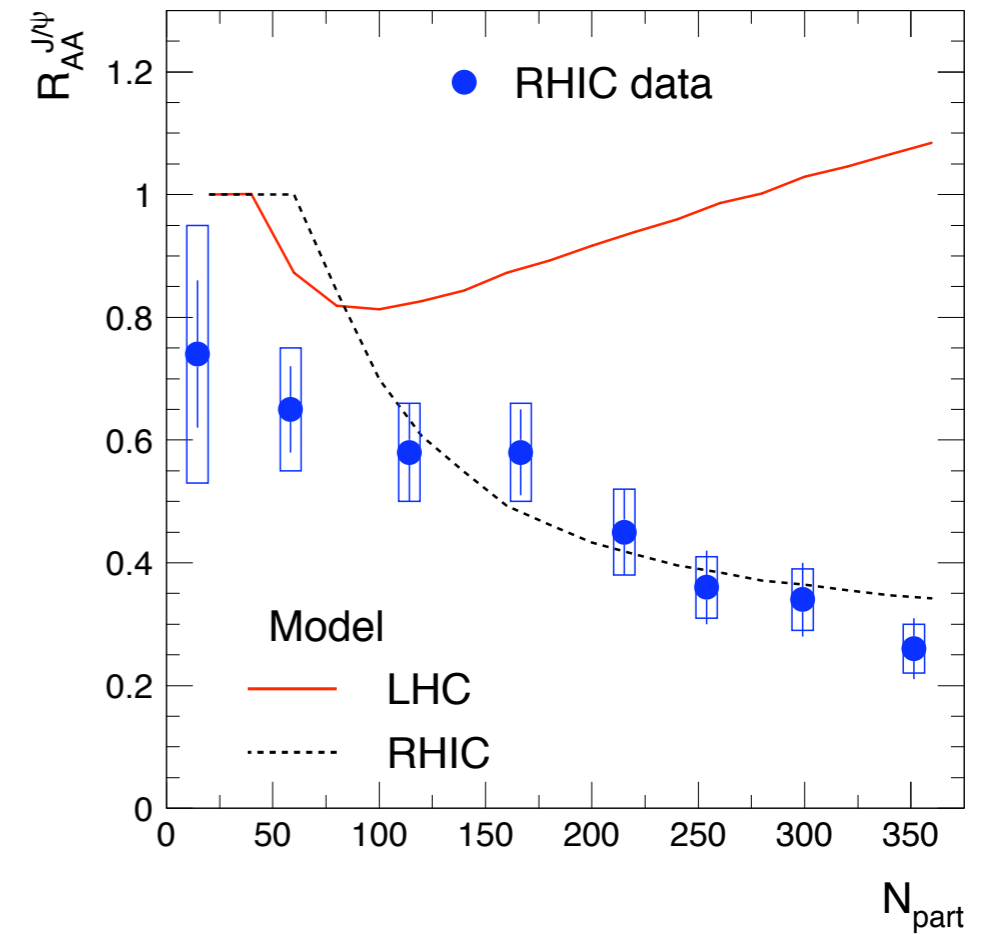
The Transition Radiation Detector for ALICE at LHC

MinJung Kweon
Physikalisches Institut, Universität Heidelberg
for the ALICE TRD Collaboration

- Physics motivation of ALICE Transition Radiation Detector (TRD)
- Detector
- Production
- Installation
- Commissioning
- Summary and Outlook

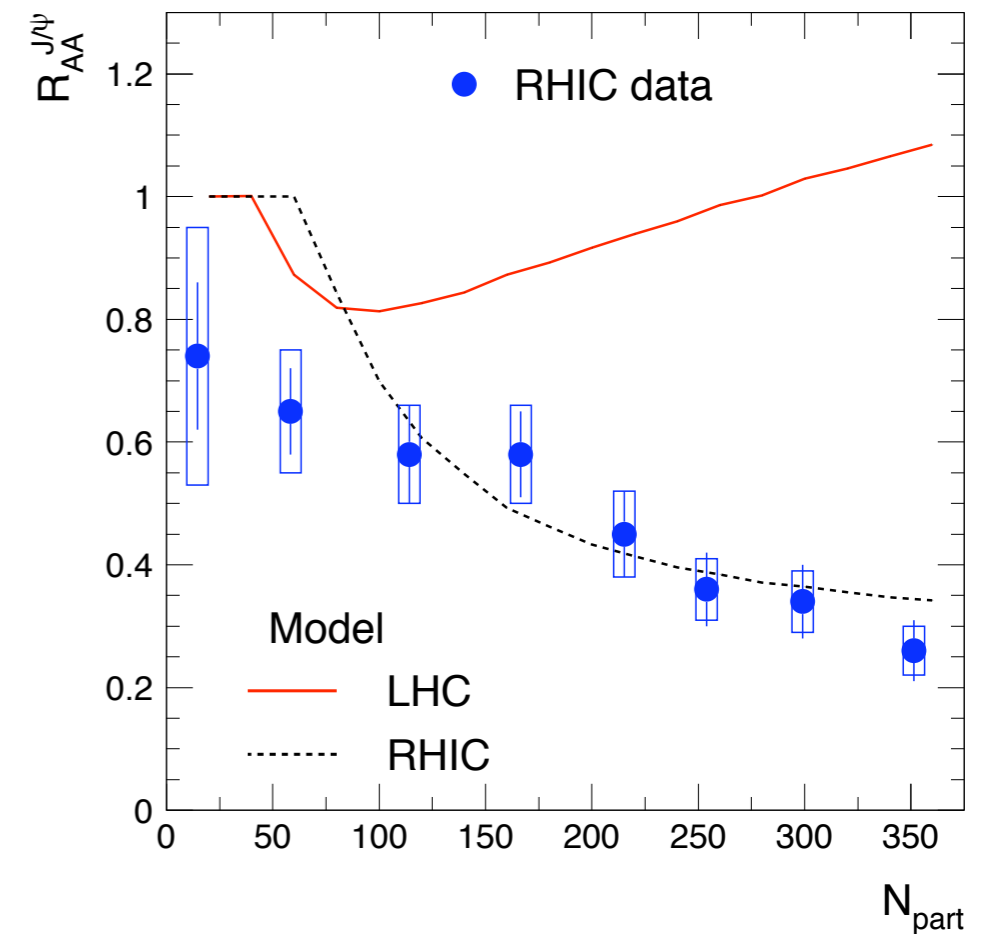
J/ψ Production: Suppression or Enhancement?

- screening of color charges
→ “melting” of $c\bar{c}$ bound state



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

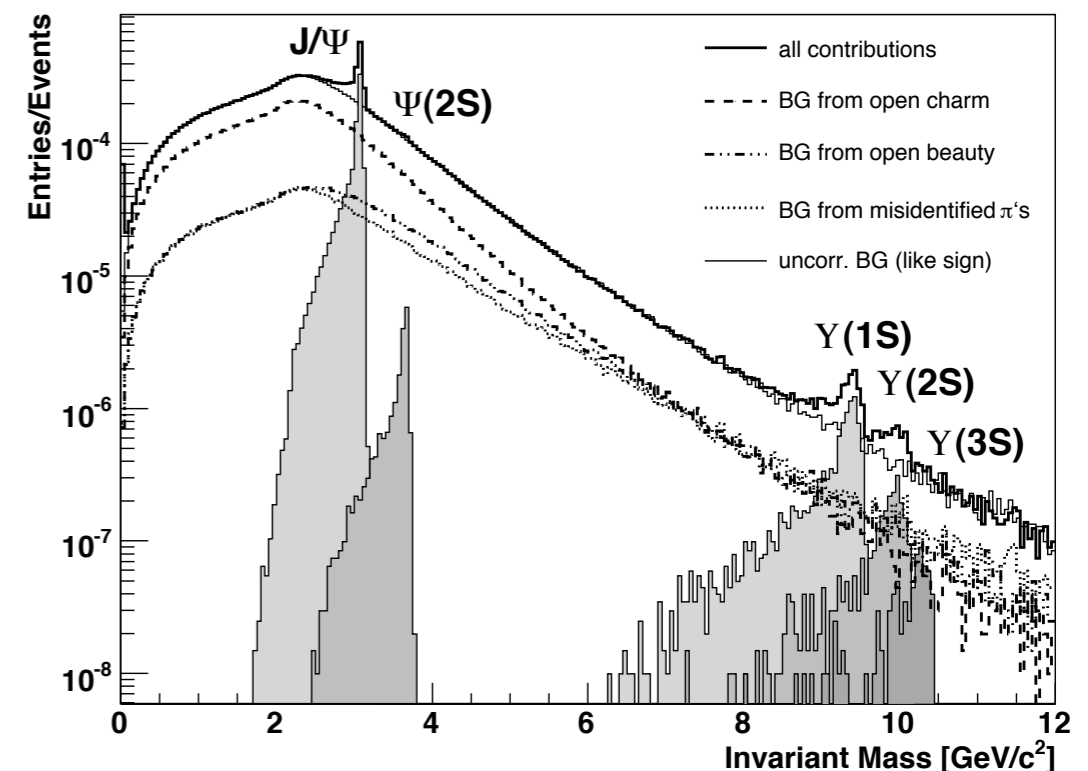
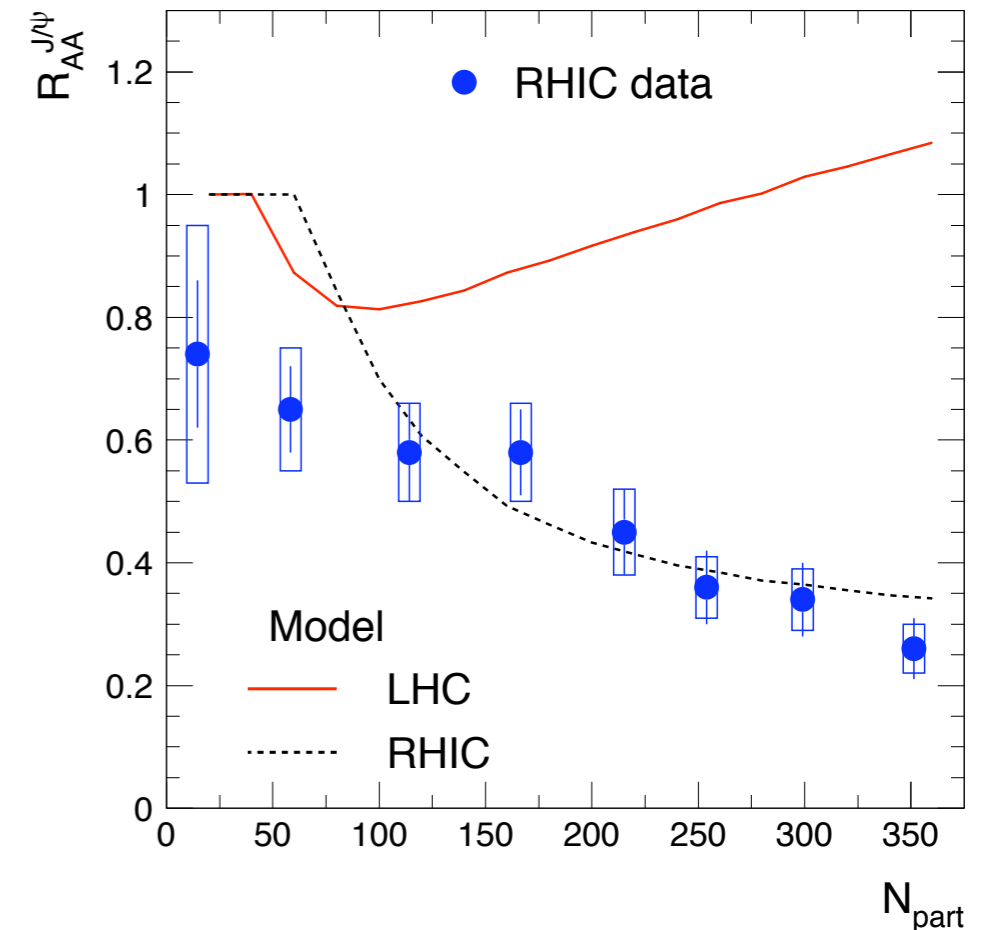


Physics Observables Accessible with the TRD

J/ψ Production: Suppression or Enhancement?

- screening of color charges
→ “melting” of $c\bar{c}$ bound state
- large abundance of $c\bar{c}$ quarks at LHC
→ statistical combination to J/ψ

➔ Requires good electron PID



Open Heavy Flavor Electrons

- open charm, beauty from semi-electronic decays
→ charm, beauty cross-section

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→ direct γ , π^0 , η

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Jets and High- p_T Hadrons

- trigger on high- p_T tracks
→ energy loss in QGP
→ medium-modified fragmentation functions

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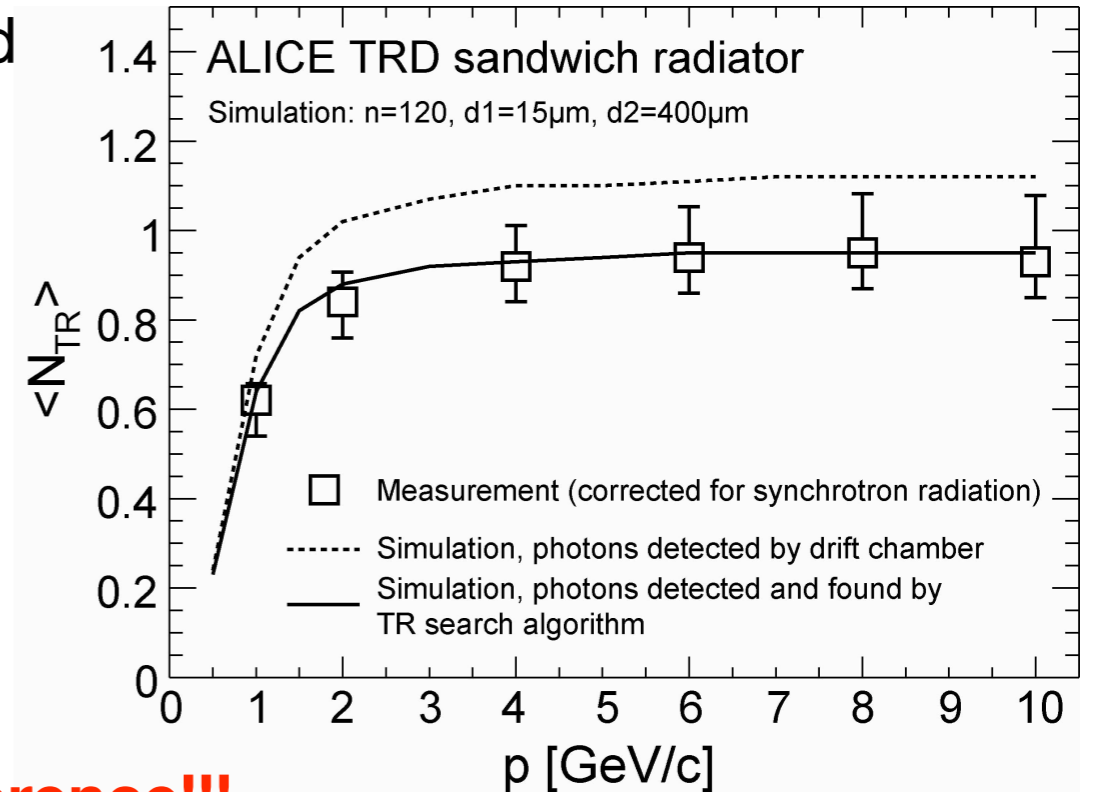
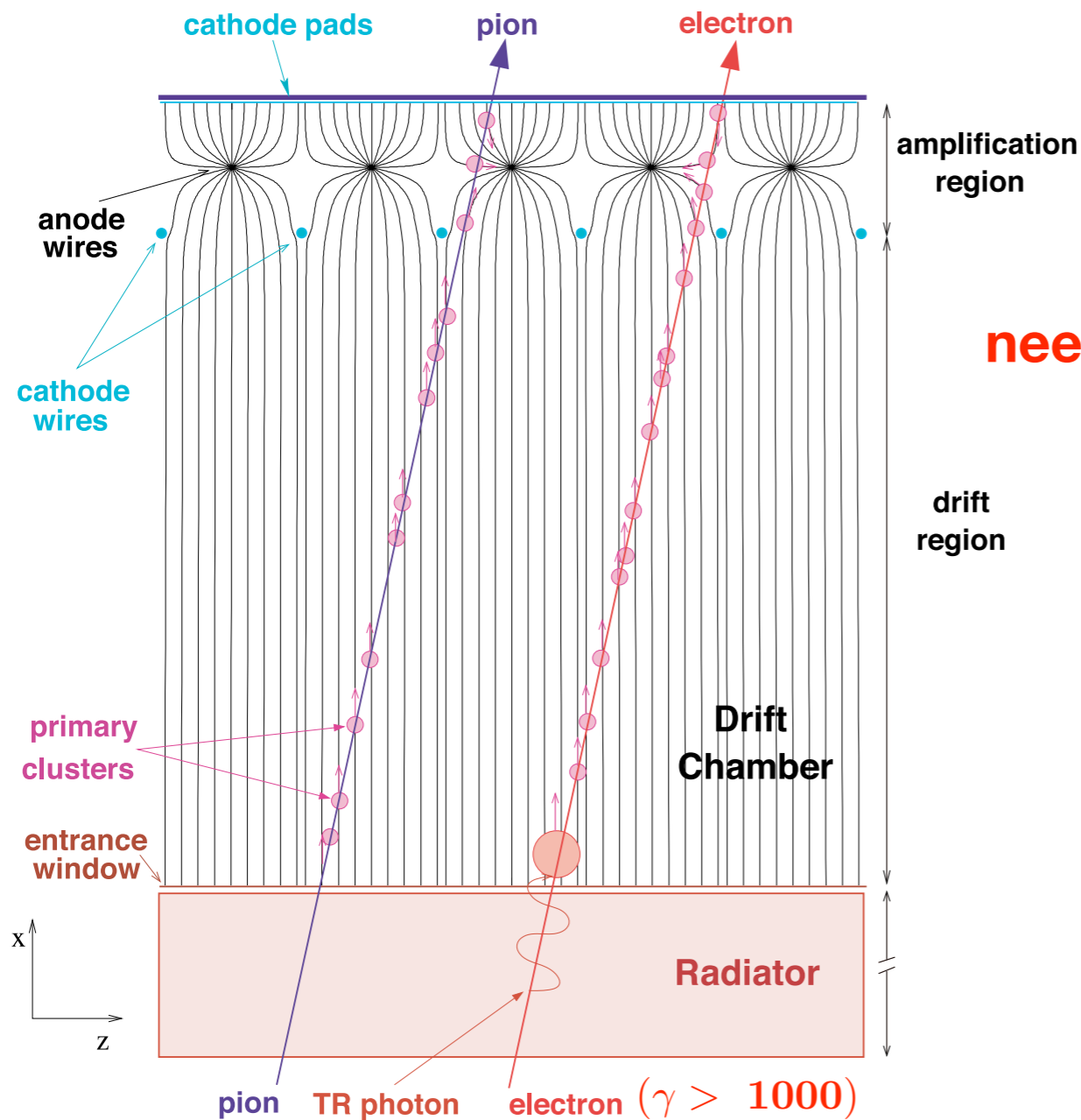
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➔ Requires:

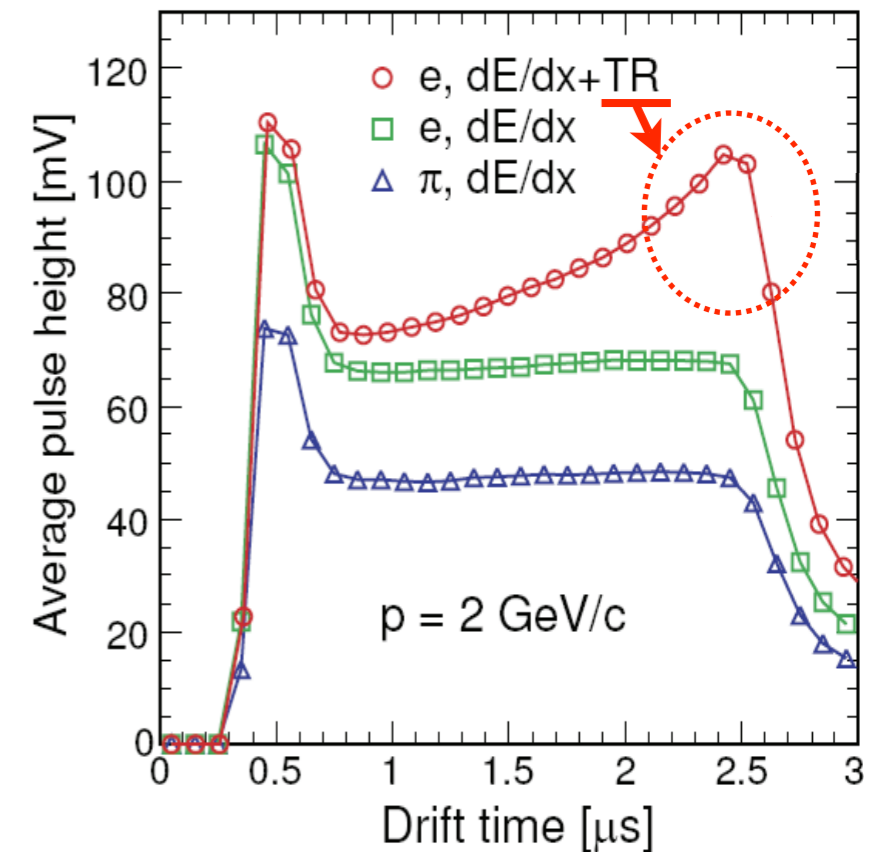
- pion rejection by factor 100 for $p > 1$ GeV/c
- tracking capability
- trigger on cluster of high p_t tracks

Working Principle of TRD

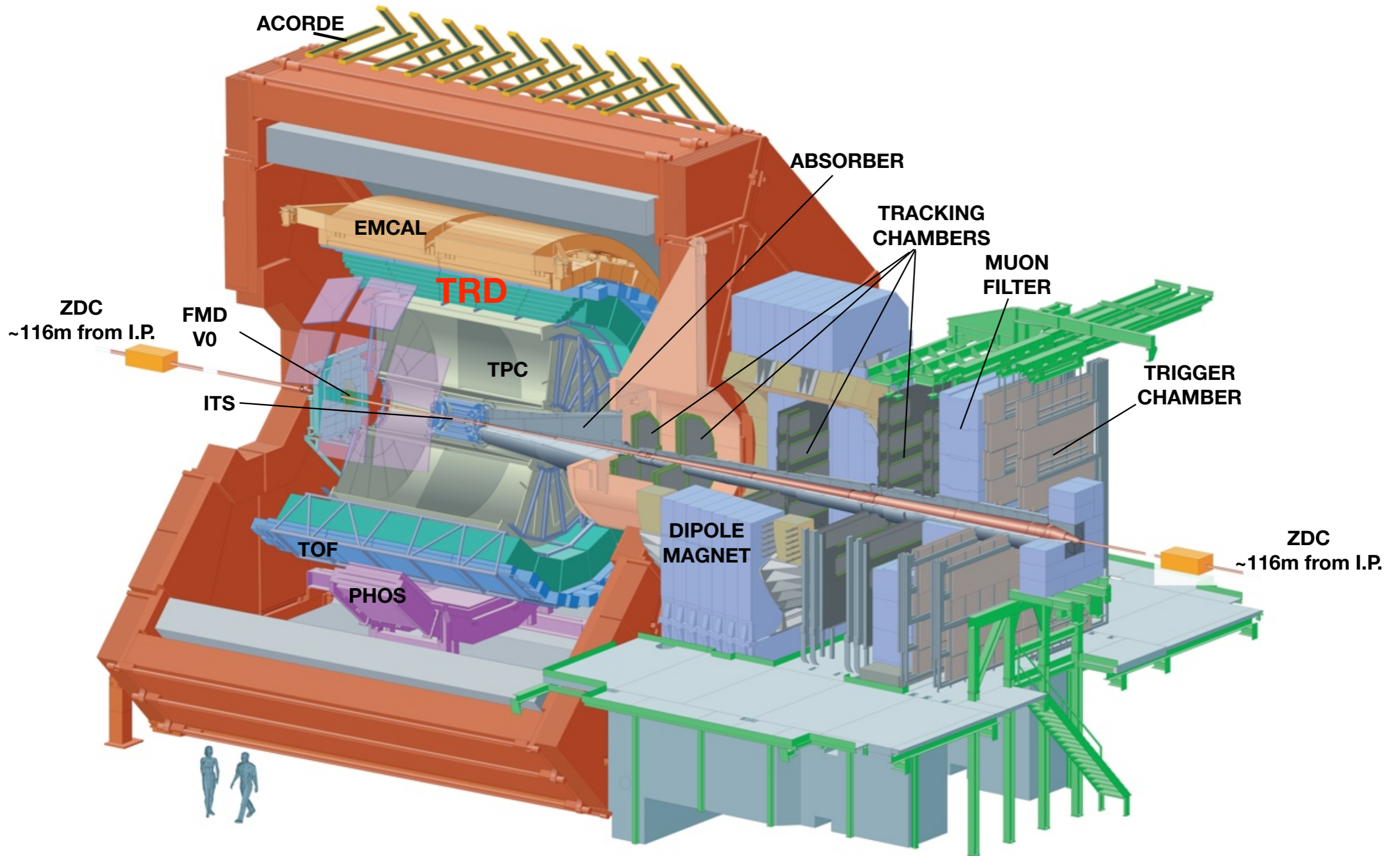
- Drift chambers with cathode pad readout combined with a fiber/foam sandwich radiator in front
- Transition Radiation (TR) photons are absorbed by high-Z gas mixture (Xe + CO₂)



need reference!!!



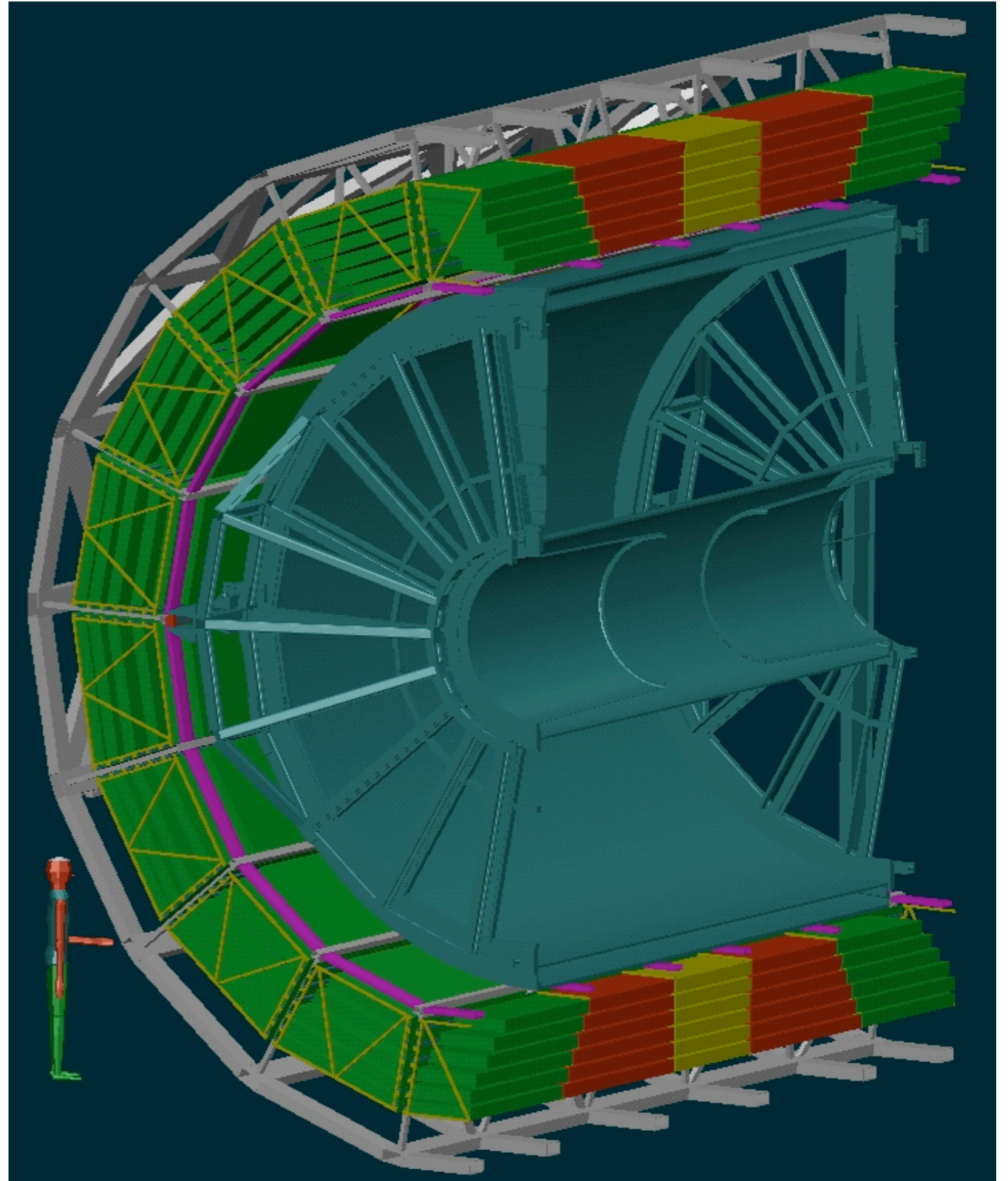
A Large Ion Collider Experiment



Collaboration: 31 countries, 109 institutes, > 1000 people

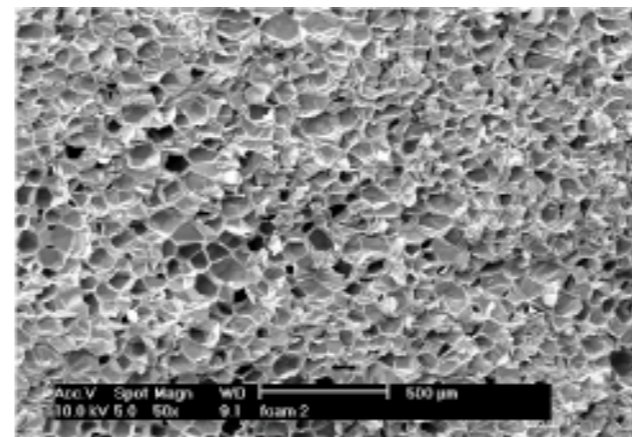
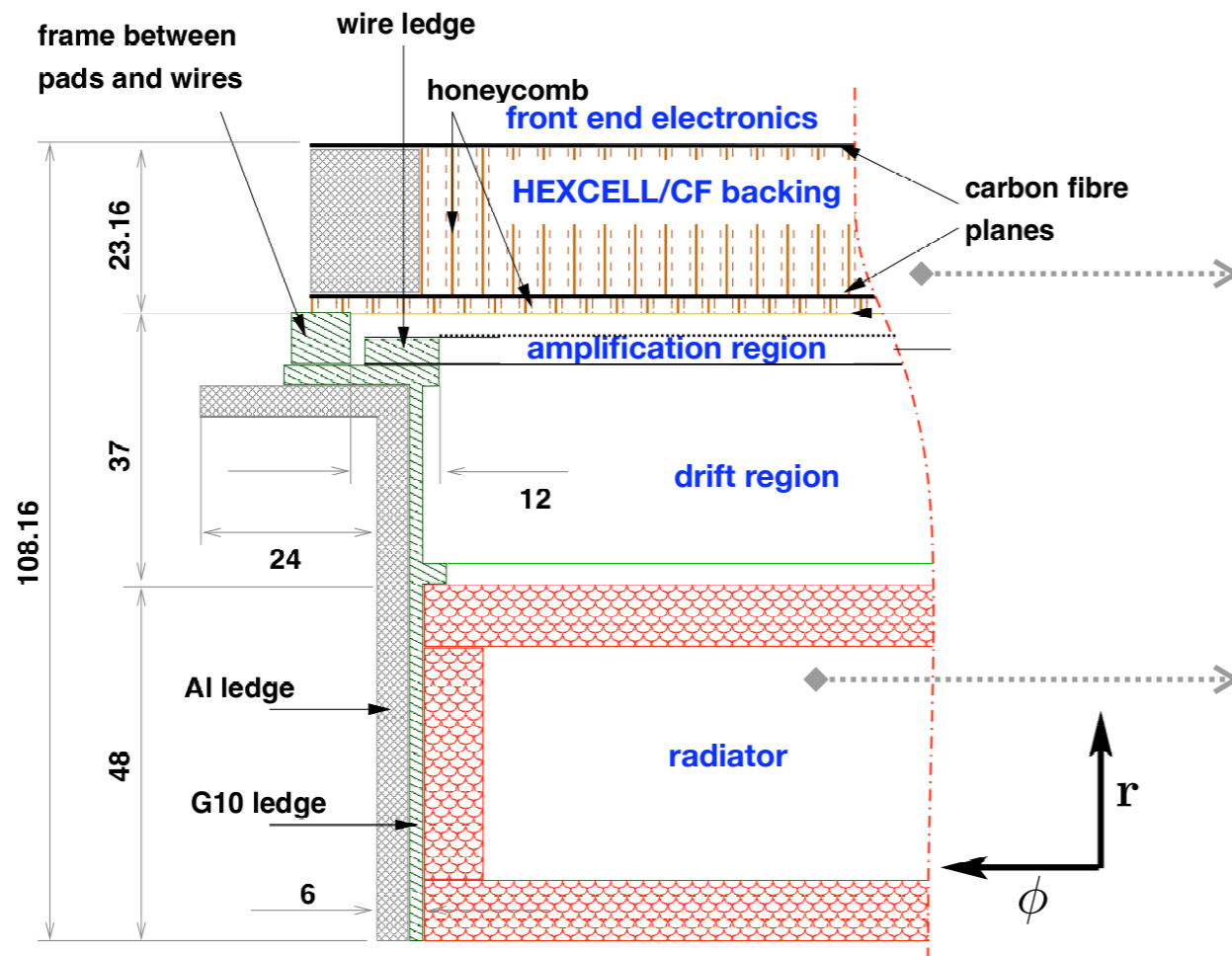
The ALICE TRD

- 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 m² active area
- 25.8 m³ detector gas of Xe/CO₂
- $X/X_0 \sim 24$ %
- 30 tons
- 10 M Euro and 250 persons

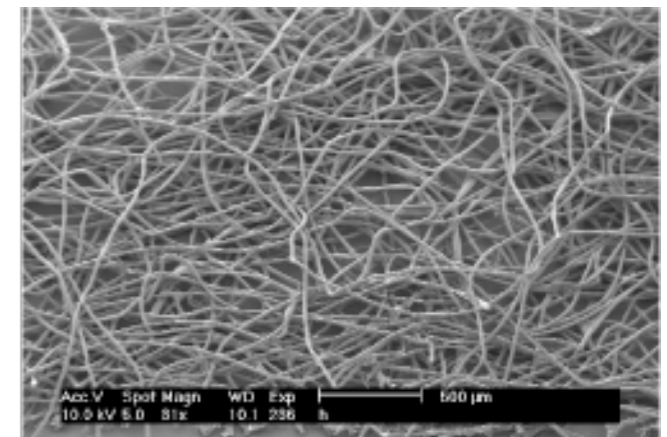


Collaborations for TRD: Bucharest, Darmstadt, Dubna, FH Cologne, Frankfurt, GSI, Heidelberg, Tokyo(CNS), Tsukuba, Worms

TRD Readout Chamber

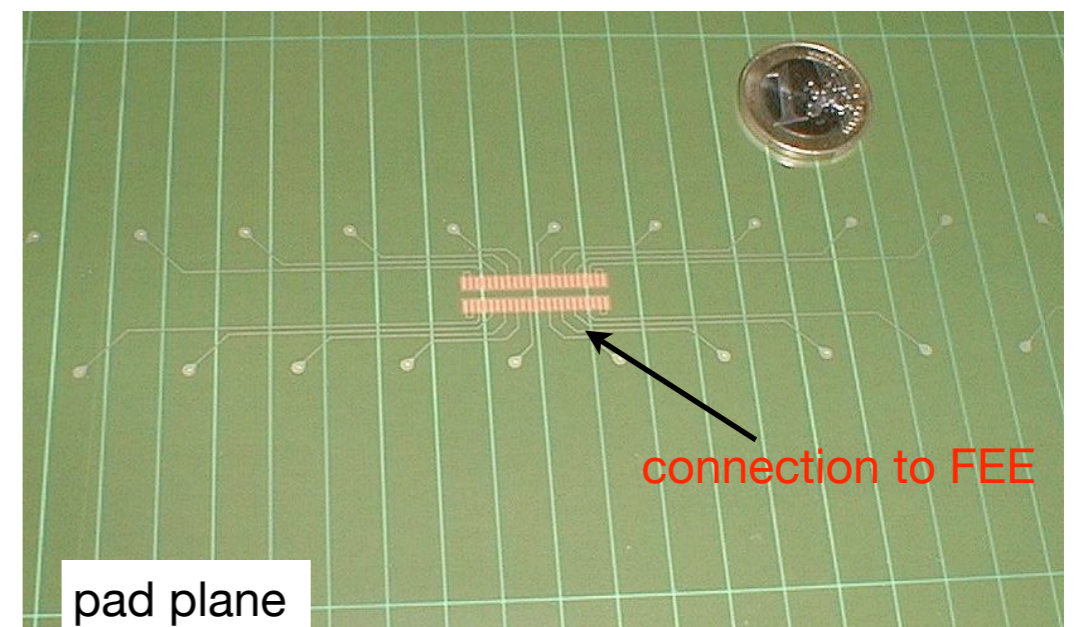


Rohacell

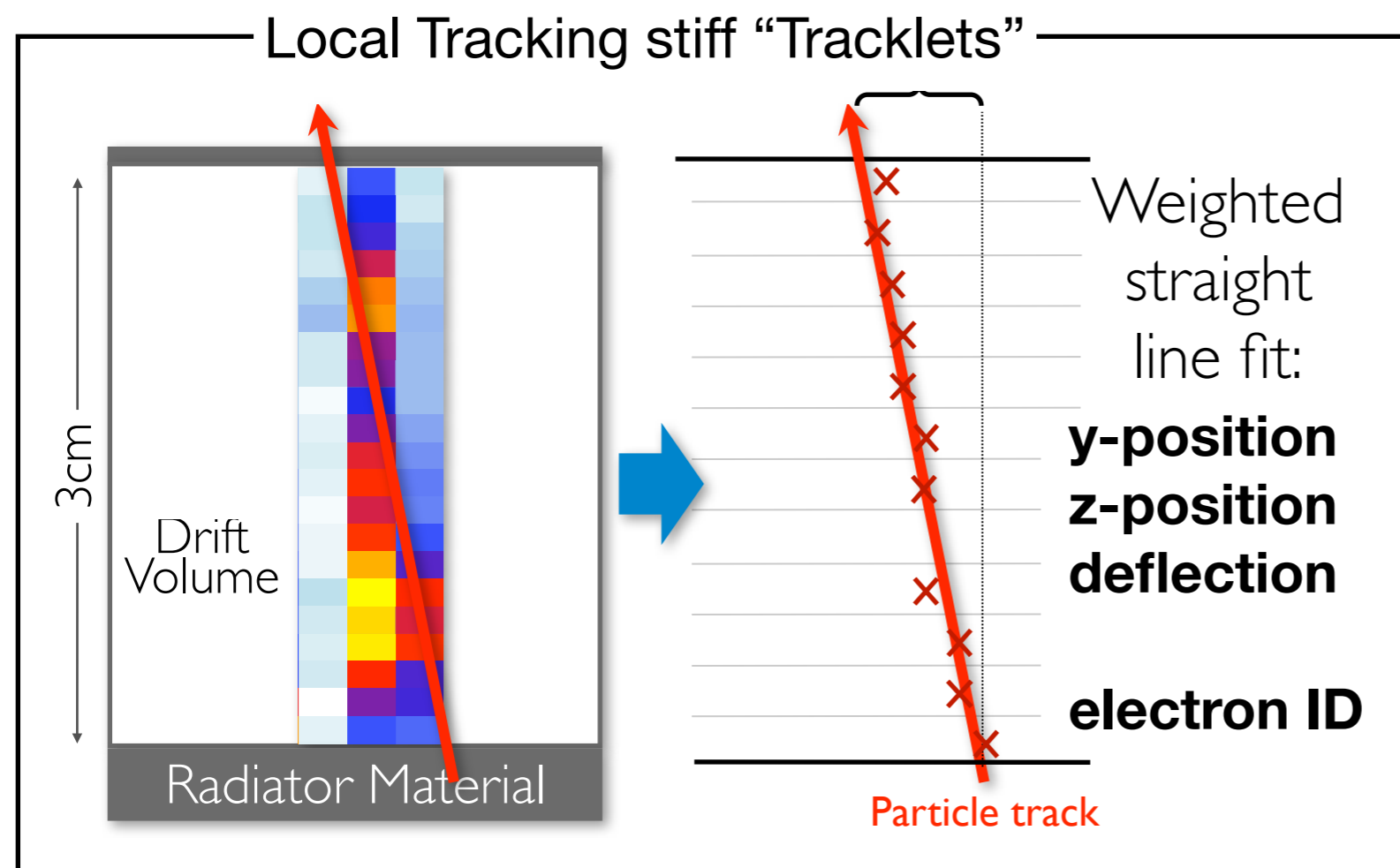
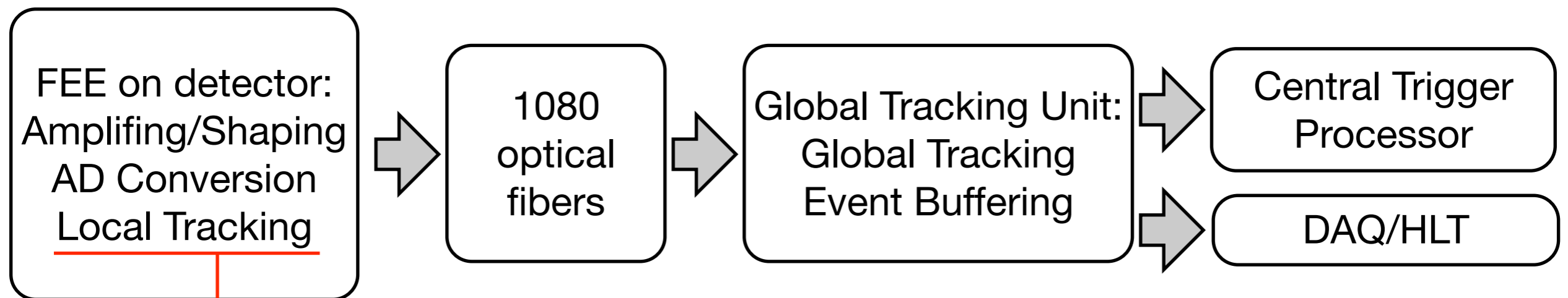


Polypropylene fibers

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



Front-End Electronics Design



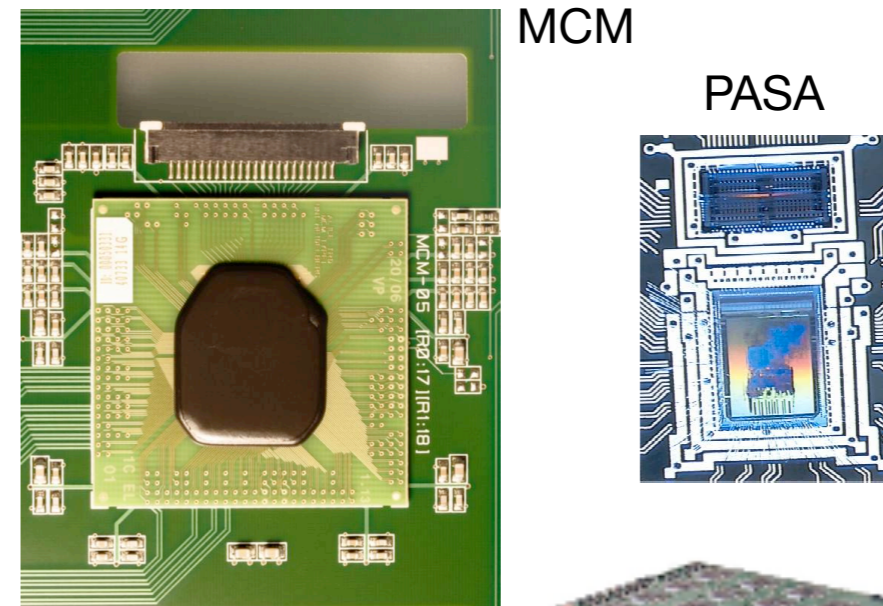
Provide a trigger capability:

- fast track reconstruction and electron PID
- trigger decision available at L1 ($6.5 \mu\text{s}$)
- pretrigger required before ALICE L0

Readout Chamber Electronics

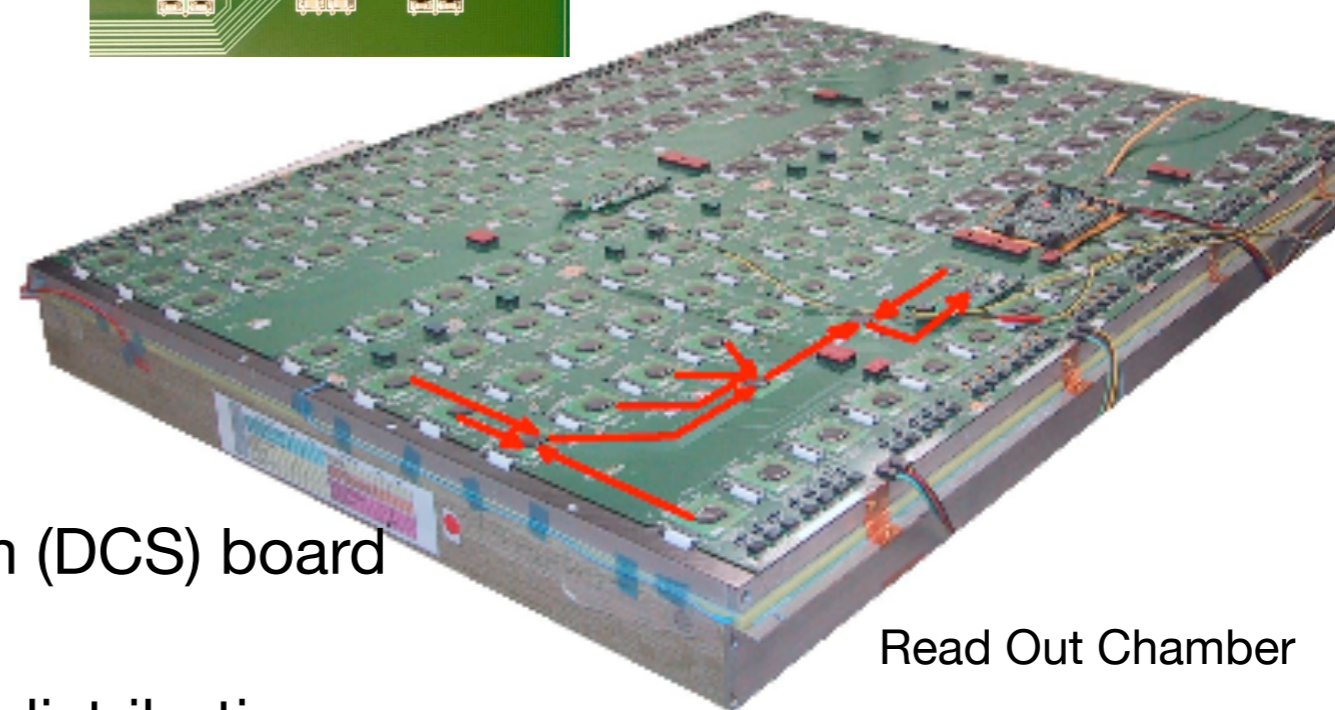
Multi Chip Module (MCM)

- PASA: PreAmplifier/ShAper
- TRAP: TRAcklet Processor
 - ADC, digital filter, clustering
 - tracklets calculation for trigger decision
 - raw data readout



Read Out Chamber (ROC)

- 6/8 Read Out Boards (ROB)
 - MCMs equipped on ROB
- 1 linux based Detector Control System (DCS) board
 - configuration, FEE monitor
 - clock and trigger decoding and its distribution
- 2 Optical Readout Interfaces (ORI) for data shipping



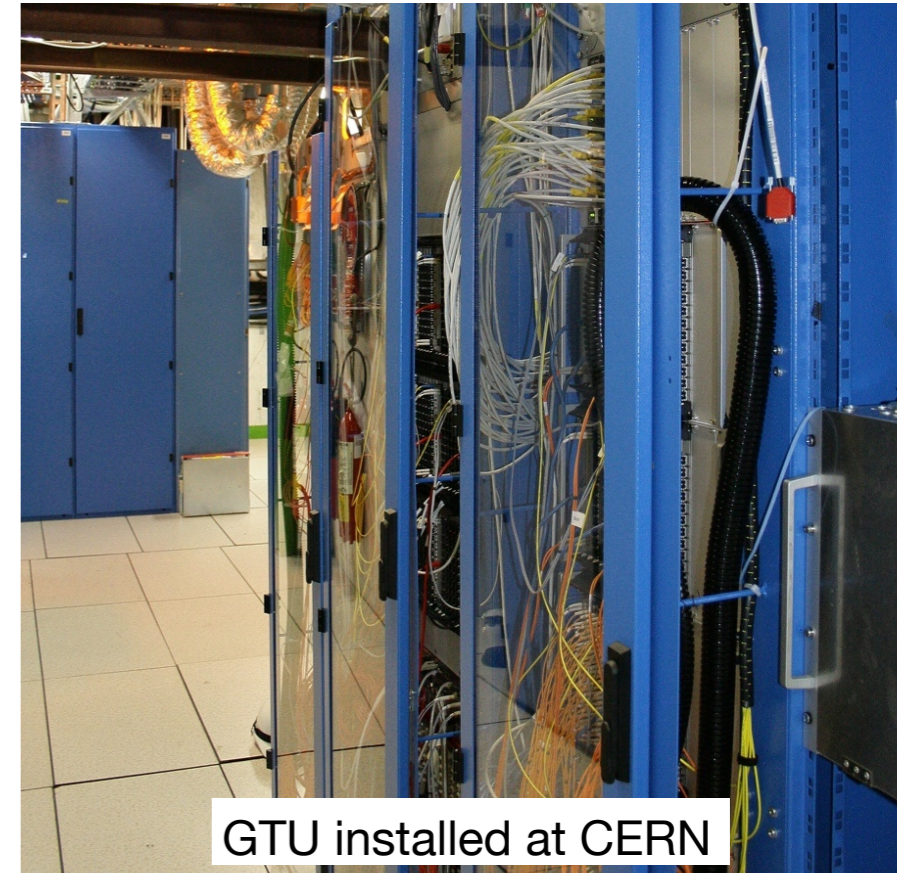
Data readout done in tree structures

Send data via ORI to Global Tracking Unit (GTU)

Global Tracking Unit

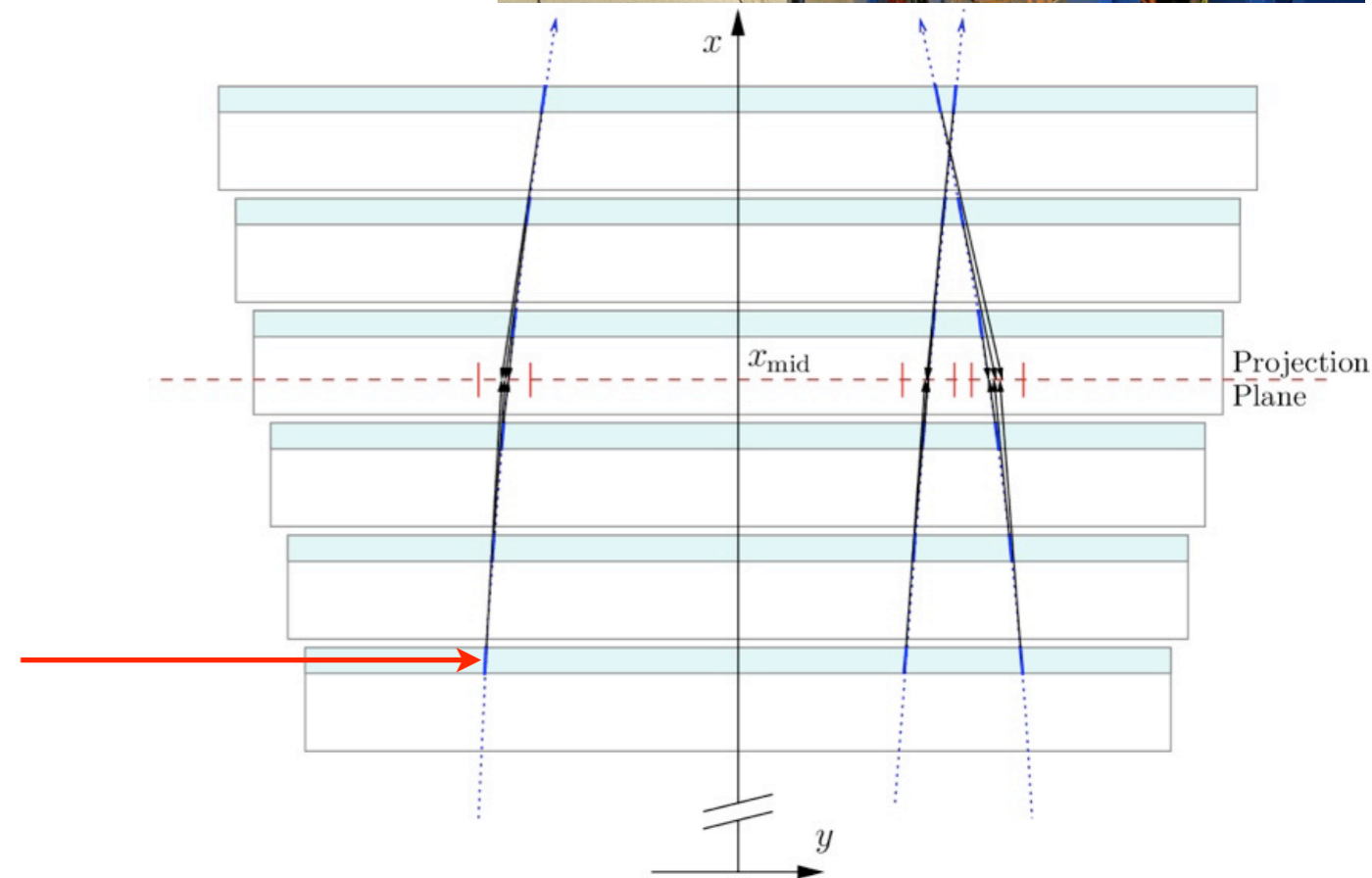
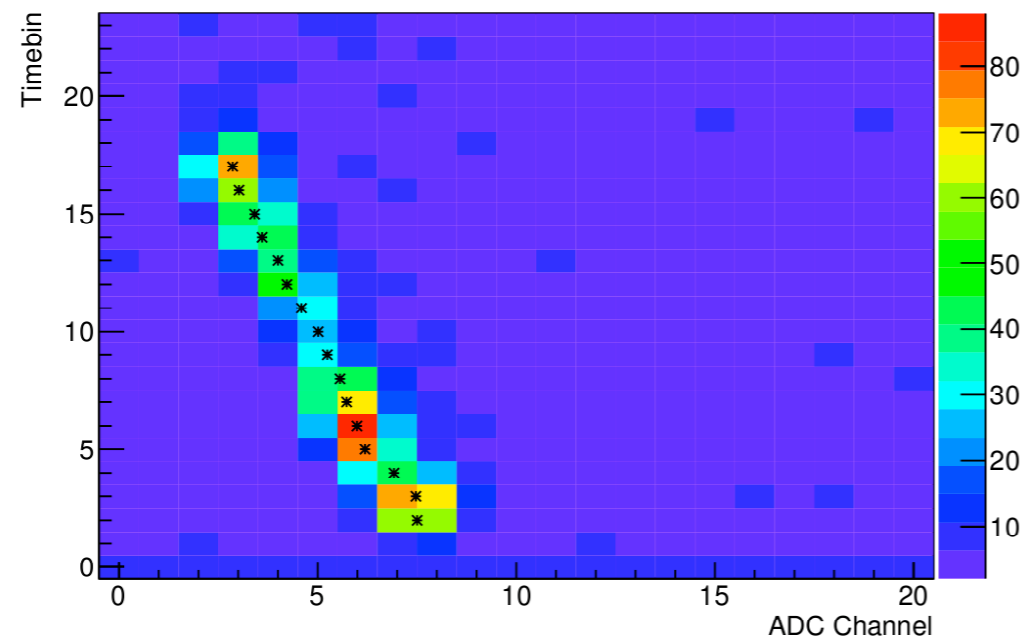
Trigger

- merge tracklets from MCMs
- reconstruct tracks and calculate momentum
- find high- p_t tracks
- apply various trigger schemes: di-lepton decays, jets, cosmics,...
- level-1 trigger decision, done within $6.5 \mu\text{s}$ from collision



Raw Data Readout

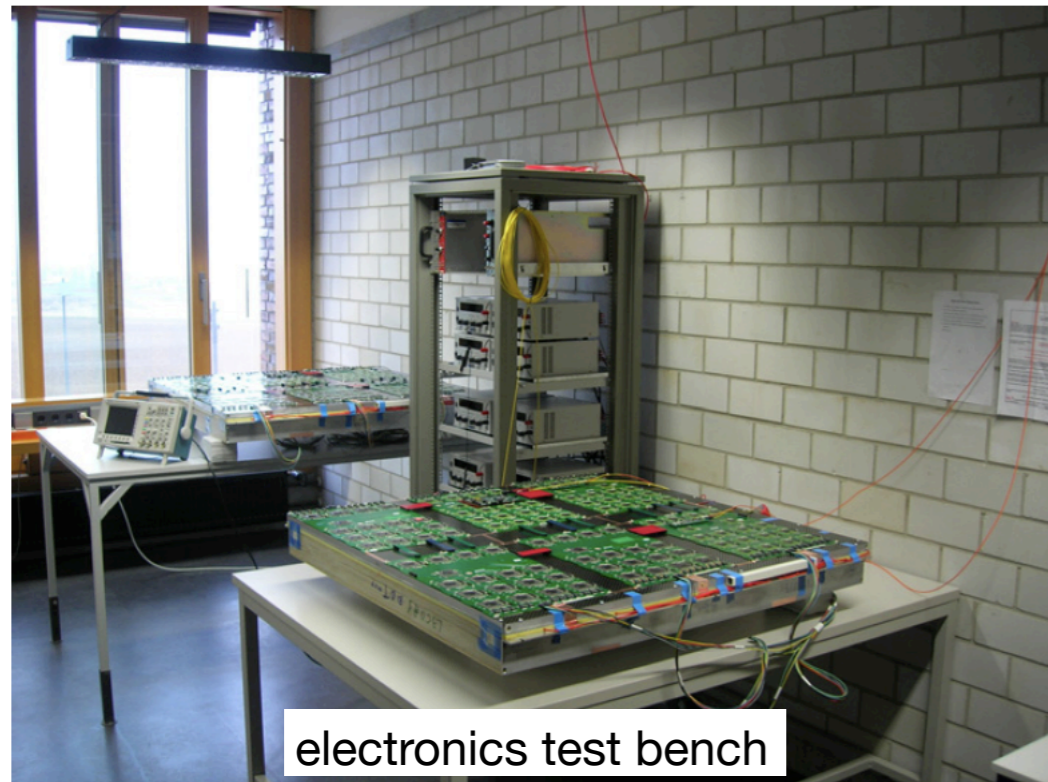
- collect data from ROCs
- forward to DAQ



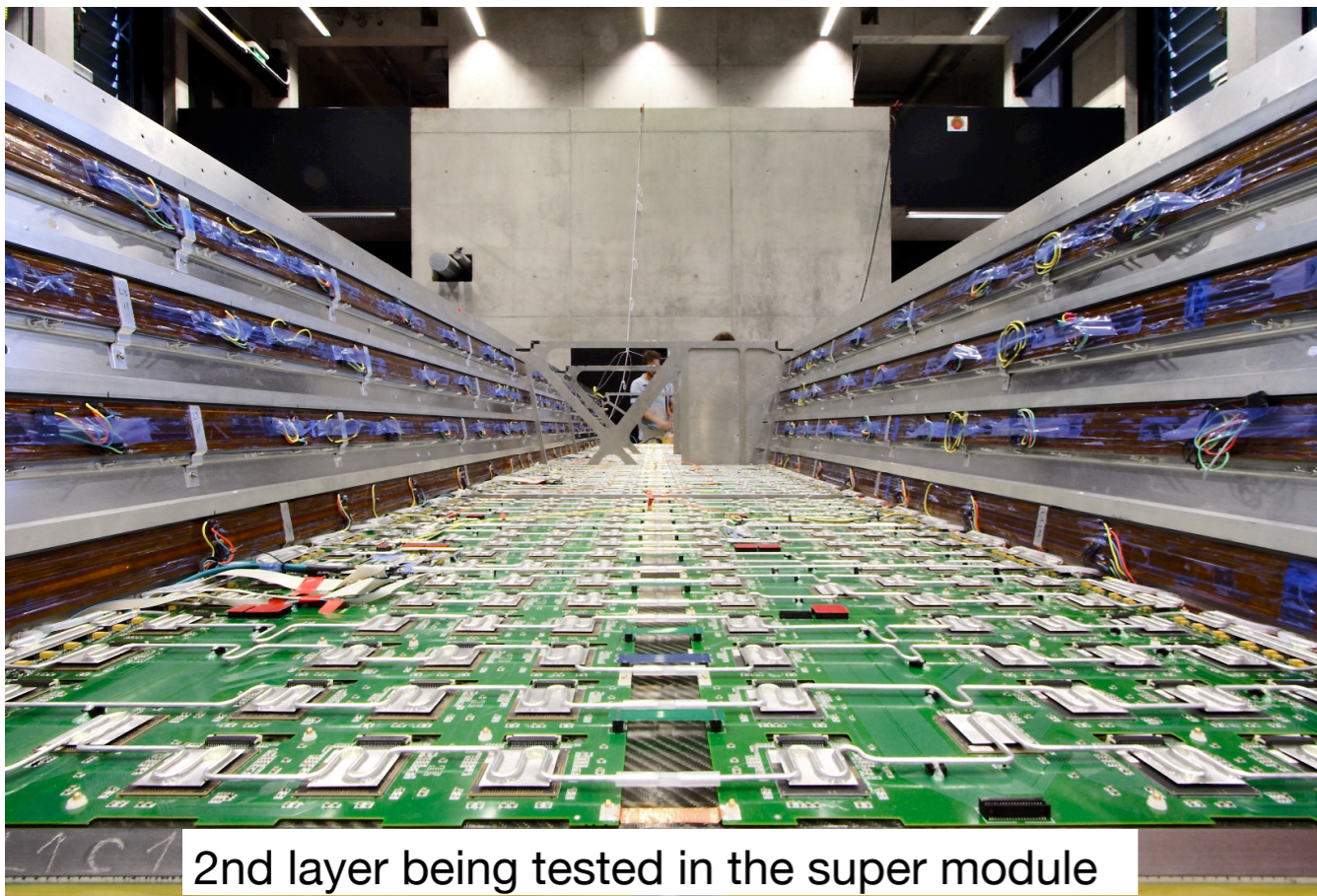
Electronics and Super module Integration

- Installation of electronics and water cooling
- Electronics testing
- Assembles into one super module

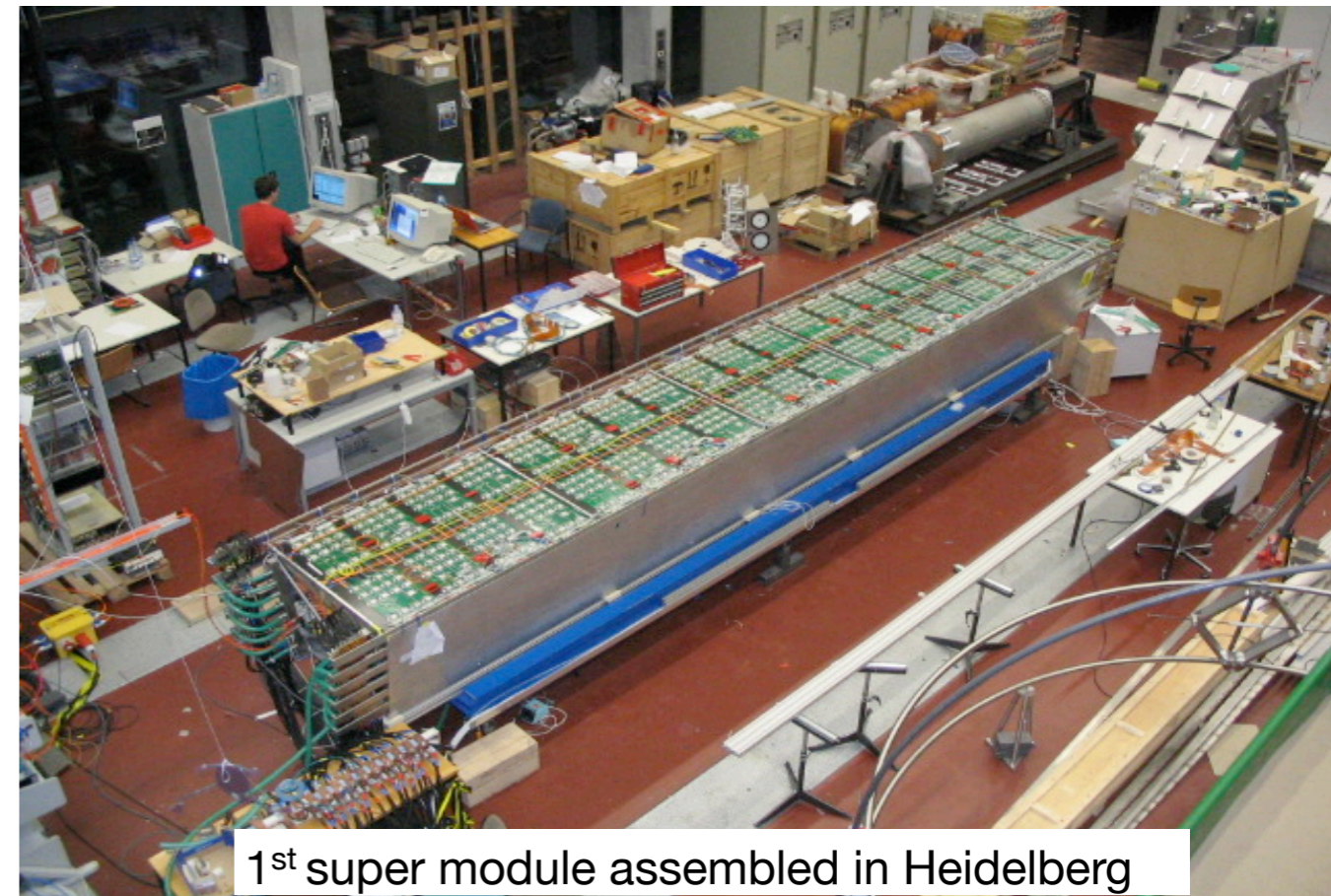
- Assembled in Heidelberg (1st one) and Münster (from 2nd ~)



electronics test bench



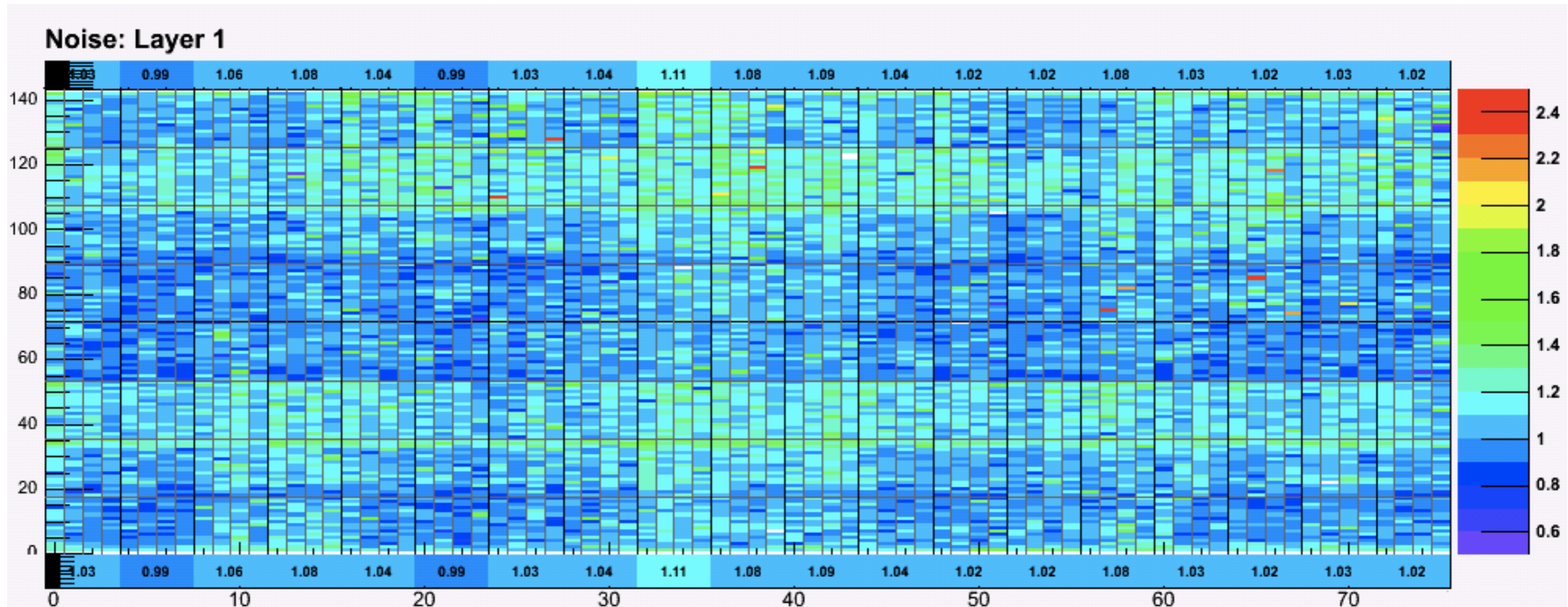
2nd layer being tested in the super module



1st super module assembled in Heidelberg

Electronics Noise

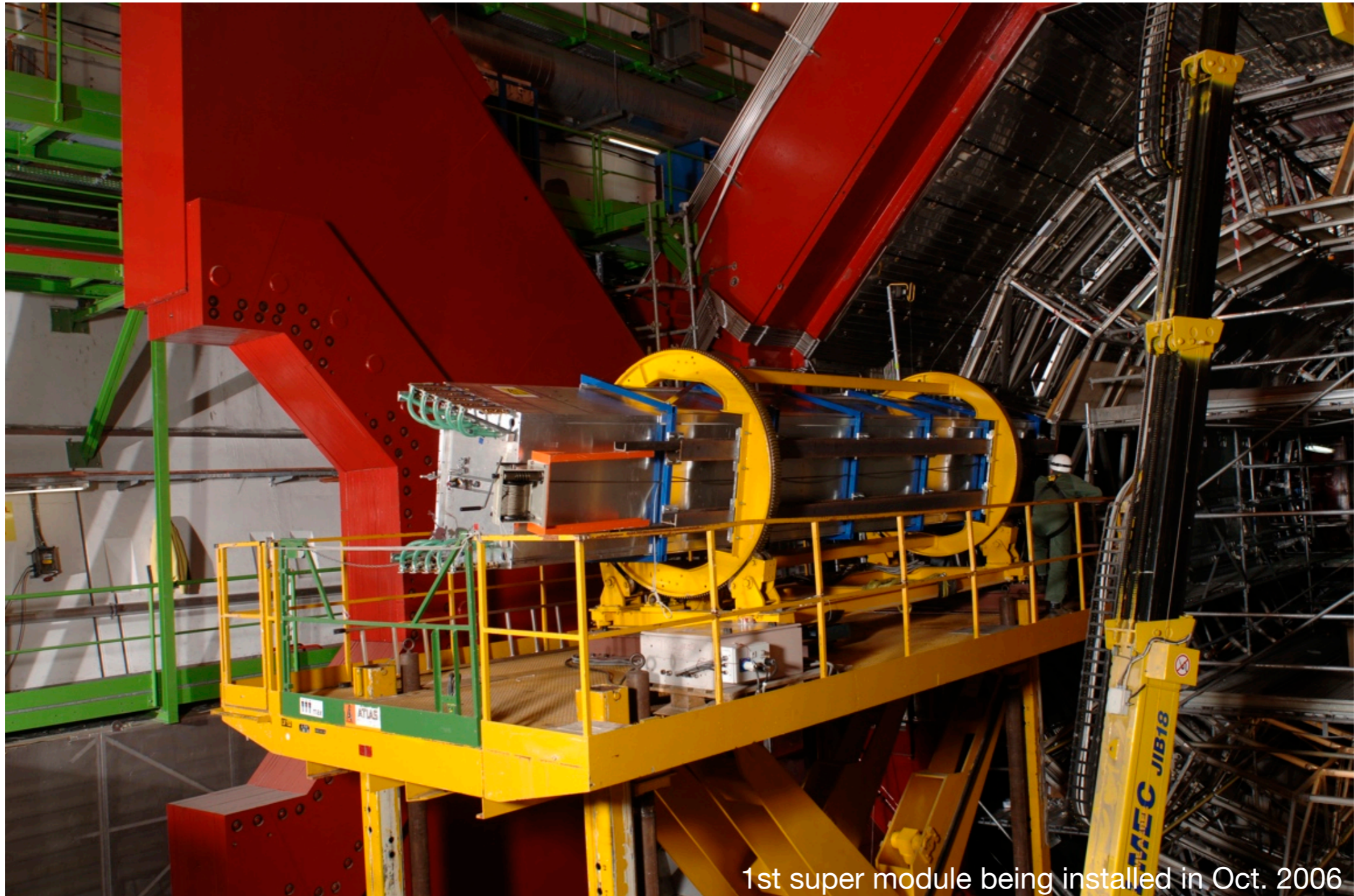
RMS noise map of one layer of a super module



Very close to design goal

- $1000 e \hat{=} 1 \text{ ADC}$
- dead channels $< 0.1 \%$

Installation at ALICE



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

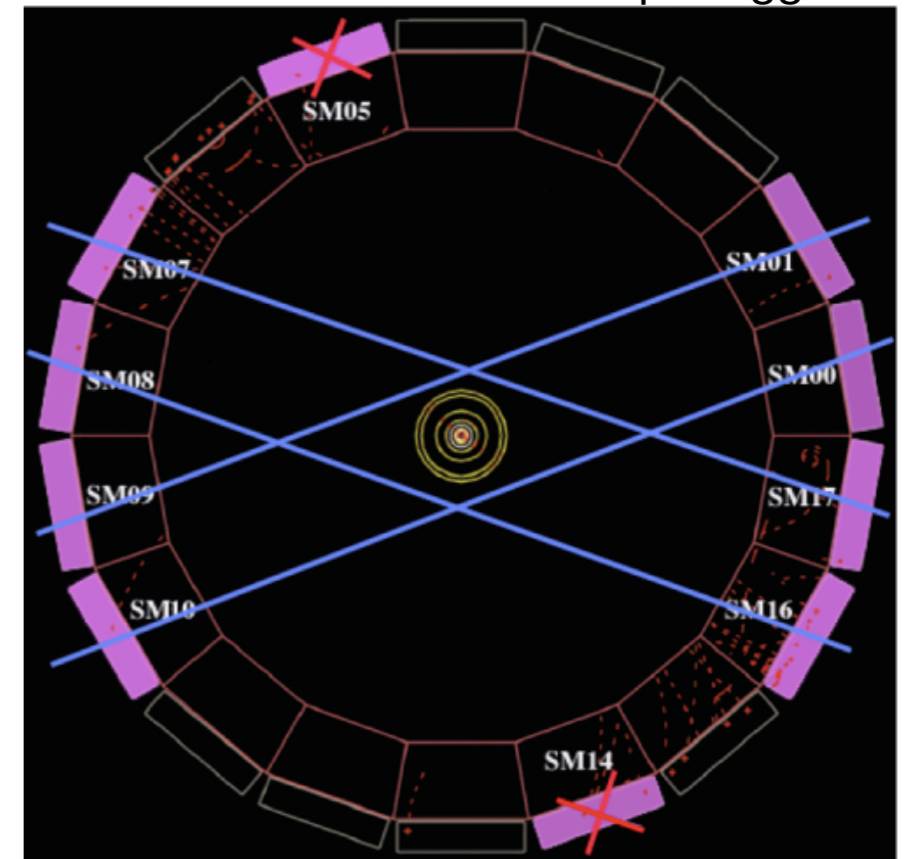
Commissioning

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

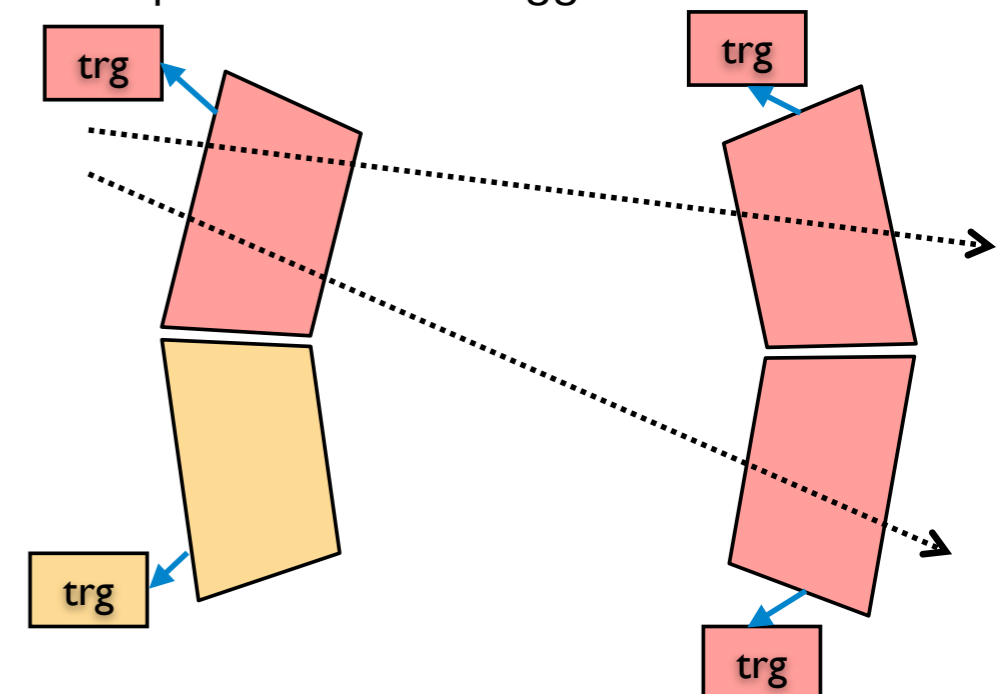
- 4-TRD super modules participated (total $\Delta\phi = 80^\circ$)
- combined running with other detectors
- TOF pretrigger
 - coincidence of two opposite modules
- GTU L1 trigger
 - 4 tracklets in one stack
 - single super module and one-to-many correlations between super modules
 - L1/L0 $\sim 1/20$, L1 rate 0.05 Hz
 - purity $> 85\%$
- 55 k tracks

TRD ready for beam in September 2008

Coincidence condition for pretrigger



Top level GTU L1 trigger condition



Detector Control System

TRD - Main Control Console

FSM Node: TRD_SM17

Software Interlock: STATUS RUN INTERLOCK TEMP 27.0 °C

InterComLayer messages: Message 0 LINK to trd-fee_00_0_0_V_A1V8 Source ztt_dimfee_client

DIM communication status: PVSS00dim is RUNNING as Manager 5 Last Updated: 2008.08.17 16:39:37.030

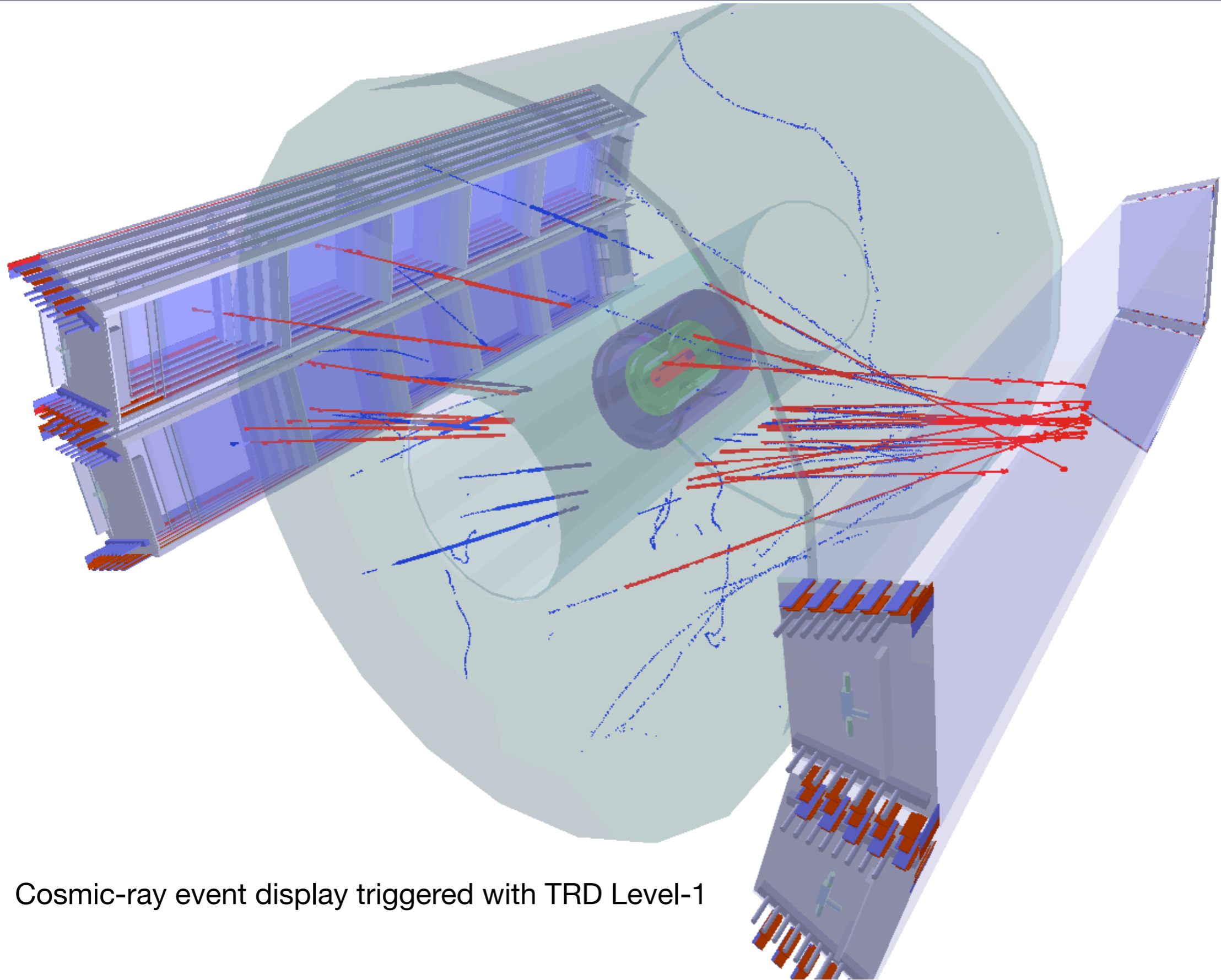
Layer	Stack 0	Stack 1	Stack 2	Stack 3	Stack 4
LAYER 5	CONFIGURED 20.85 °C CONF	CONFIGURED 19.97 °C CONF	CONFIGURED 20.01 °C CONF	CONFIGURED 20.54 °C CONF	CONFIGURED 19.79 °C CONF
LAYER 4	CONFIGURED 20.46 °C CONF	CONFIGURED 22.01 °C CONF	CONFIGURED 20.33 °C CONF	CONFIGURED 21.75 °C CONF	CONFIGURED 20.87 °C CONF
LAYER 3	CONFIGURED 20.32 °C CONF	CONFIGURED 20.94 °C CONF	CONFIGURED 21.54 °C CONF	CONFIGURED 20.04 °C CONF	CONFIGURED 21.09 °C CONF
LAYER 2	CONFIGURED 20.07 °C CONF	CONFIGURED 21.68 °C CONF	CONFIGURED 22.44 °C CONF	CONFIGURED 21.33 °C CONF	CONFIGURED 21.59 °C CONF
LAYER 1	CONFIGURED 20.19 °C CONF	CONFIGURED 20.90 °C CONF	CONFIGURED 22.70 °C CONF	CONFIGURED 21.14 °C CONF	CONFIGURED 23.38 °C CONF
LAYER 0	CONFIGURED 22.57 °C CONF	CONFIGURED 22.51 °C CONF	CONFIGURED 23.62 °C CONF	CONFIGURED 22.04 °C CONF	CONFIGURED 22.00 °C CONF

DCS system for TRD

Component	SM00	SM08	SM09	SM17
LV	SM00	SM08	SM09	SM17
FED	SM00	SM08	SM09	SM17
HV	SM00	SM08	SM09	SM17
INFRA	Plant&Loops	PCU	DCS_PDB	PT_LV
PT/GTU	GTU			

- User friendly detector control system based on PVSS-II
- Ensure safe/stable detector operation and monitoring:
 - 90 low voltage power supplies
 - 1080 HV channels
 - 280 k on-detector CPUs
 - 1.2 M channels of preamplifiers and ADCs and digital filters
 - gas systems
 - cooling systems
 - 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)

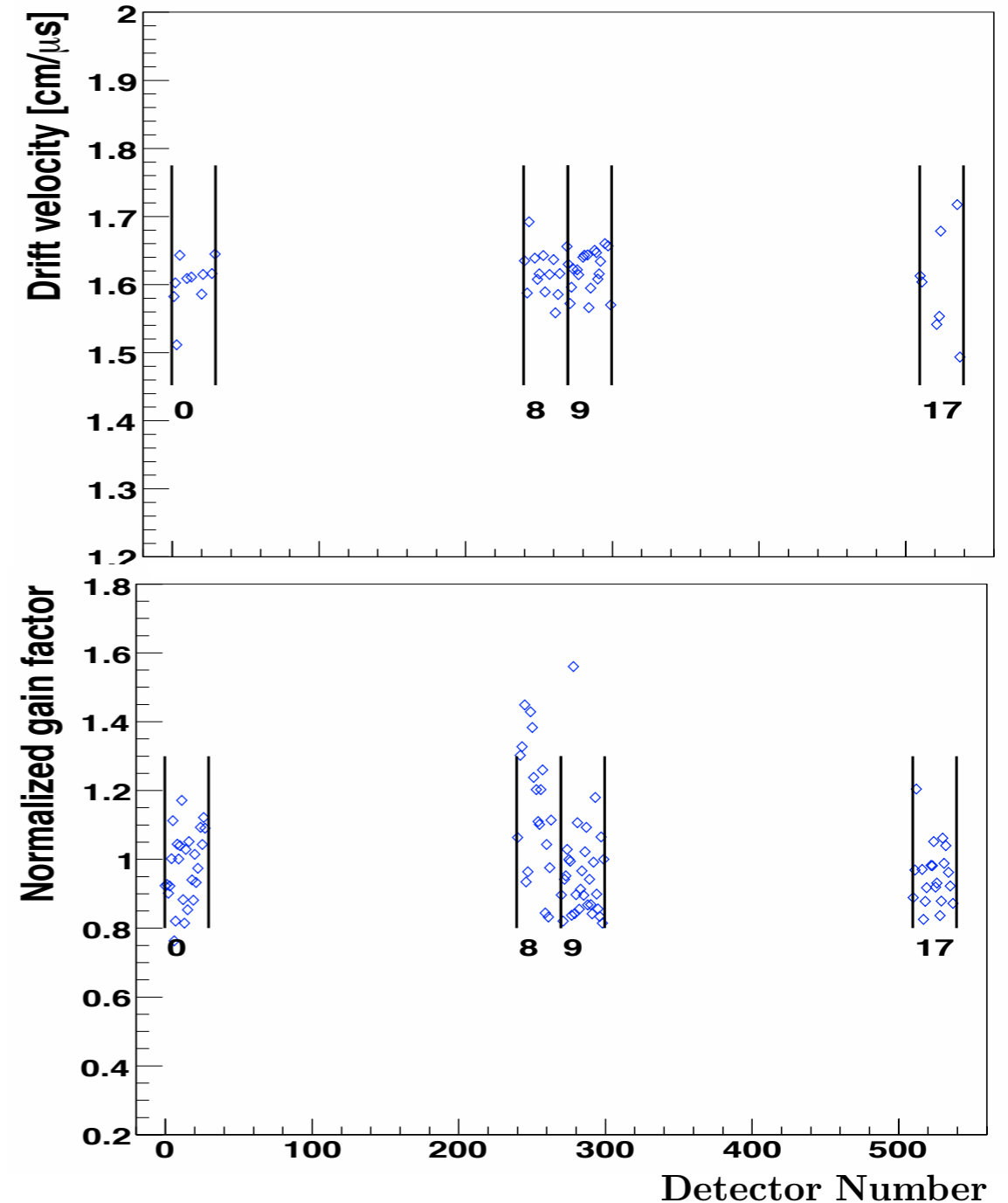
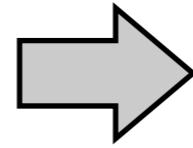
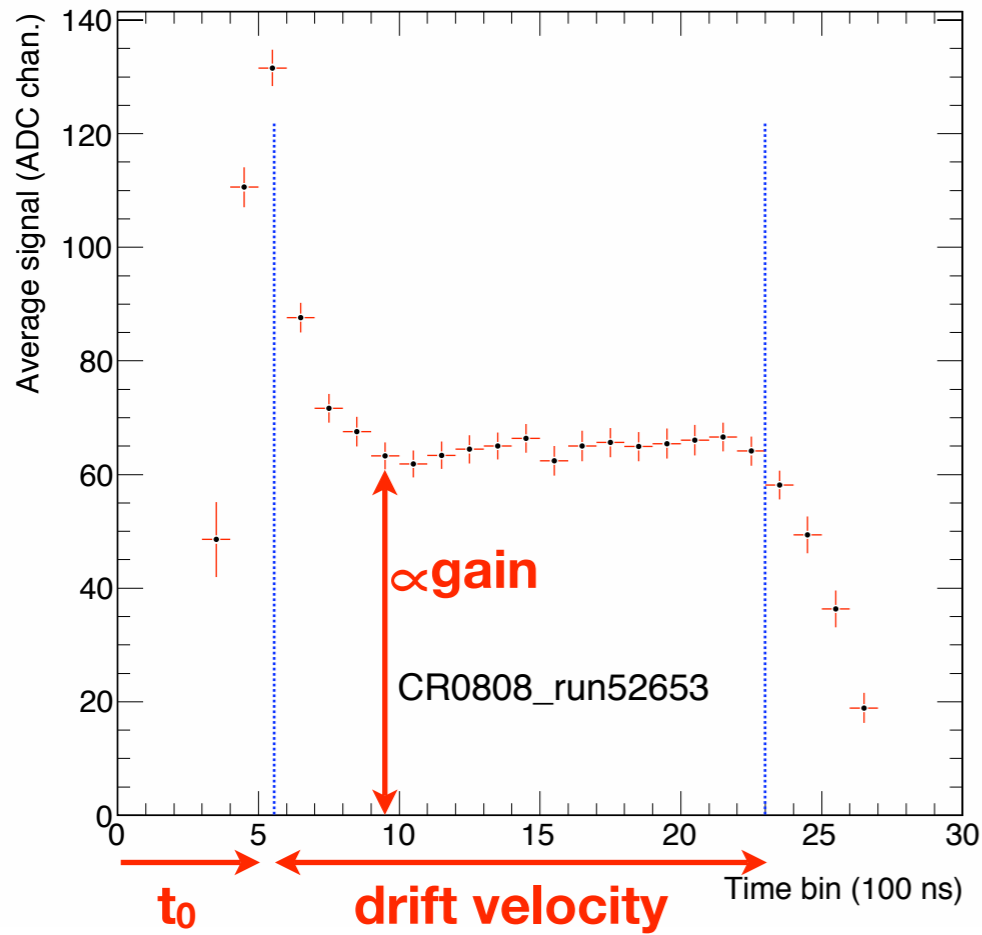
Cosmic Event Triggered



Cosmic-ray event display triggered with TRD Level-1

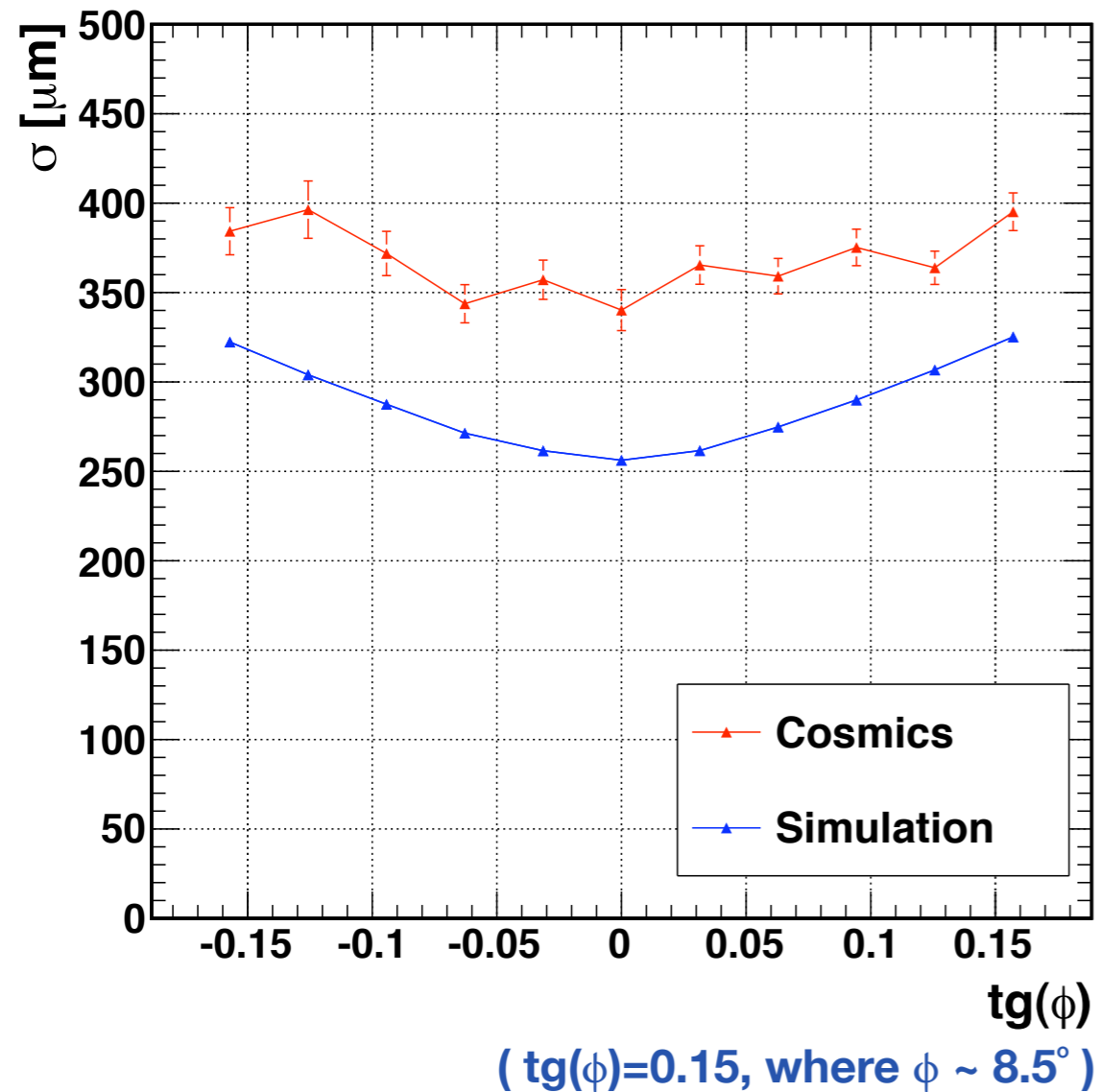
Calibration

	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



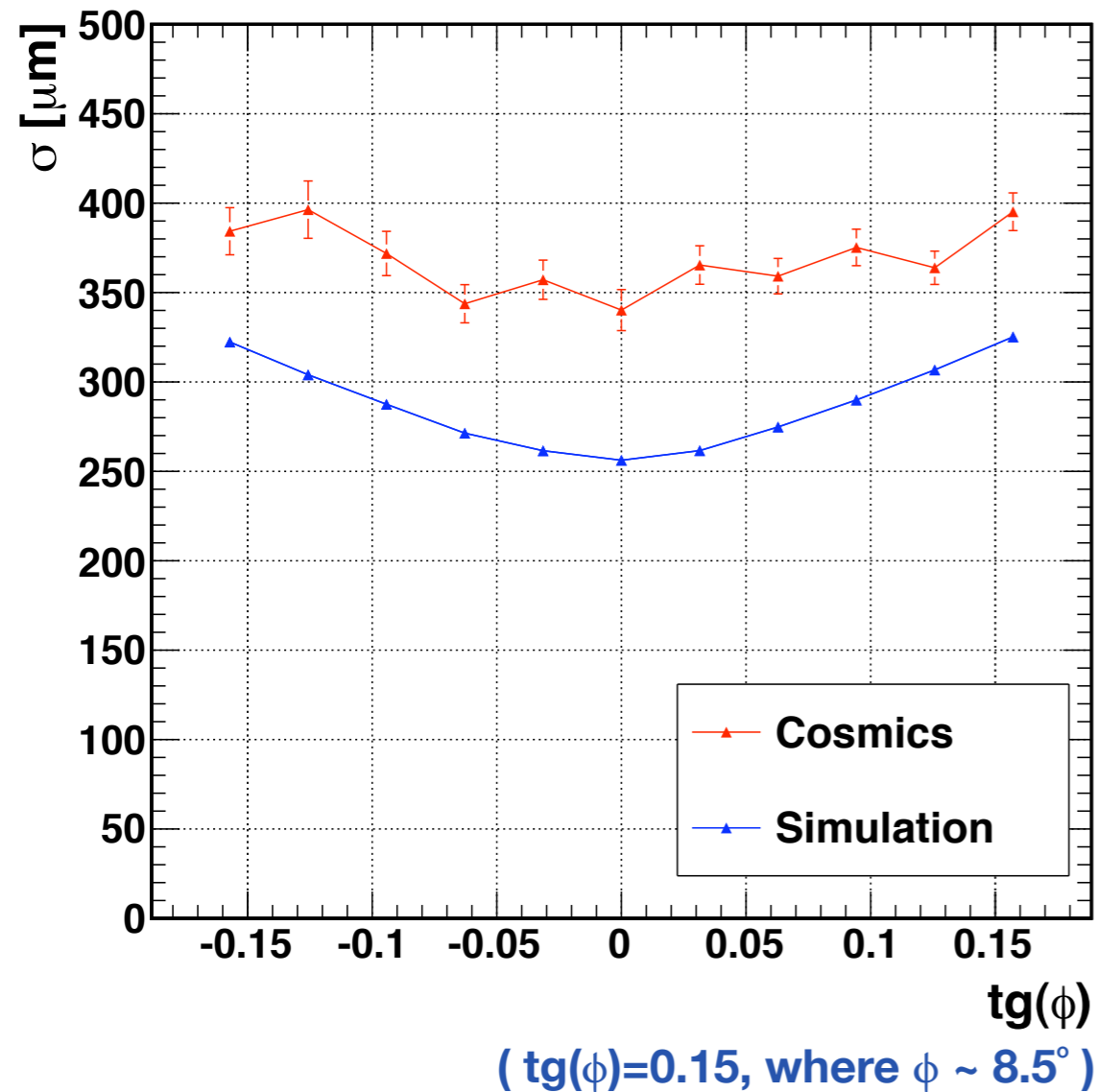
- Drift velocity ≈ 1.62 cm/μs and variation ≈ 3.3 %, in the expected range from simulation
- Gain variation ≈ 16 %, better than the expected ± 20 % \rightarrow important for trigger

Tracking Performance



- $r\phi$ directional position resolution $\approx 350 \mu\text{m}$ at 0° incident angle
- position resolution close to design goal

Tracking Performance



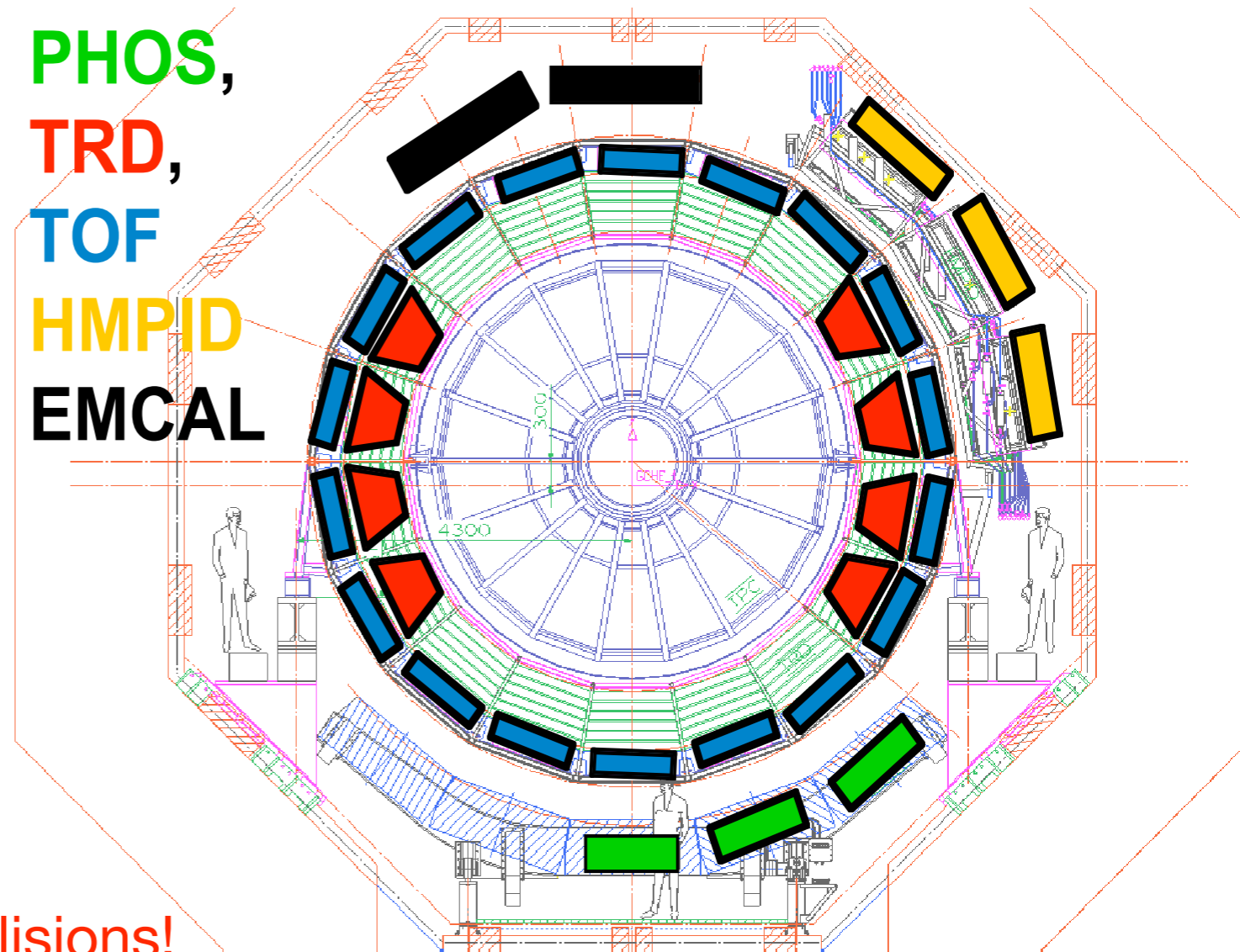
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Various analysis on going:

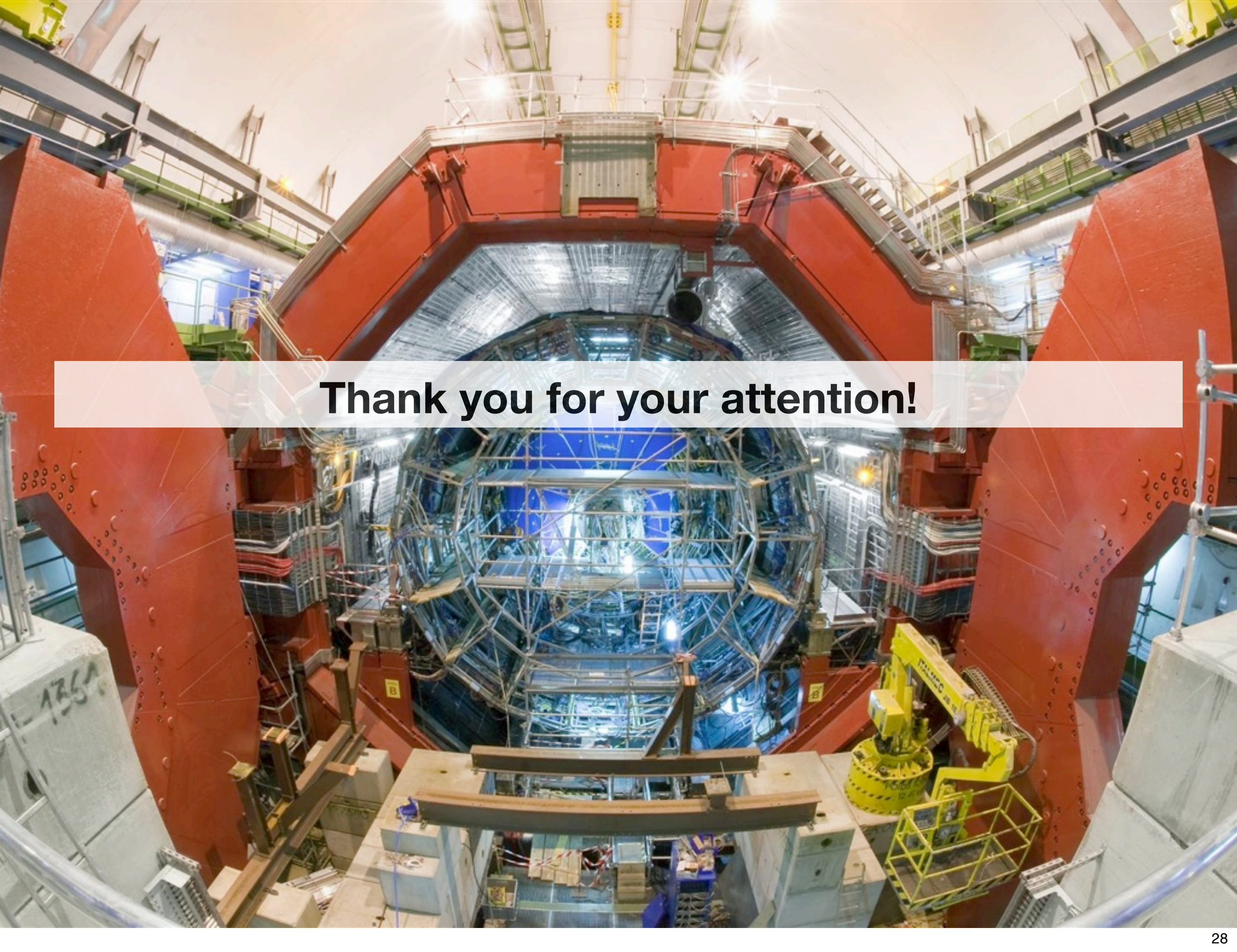
- TPC-TRD track matching resolution
- alignment

Summary and Outlook

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



Thank you for your attention!

BACKUP - Different version of plots or pictures

A wide-angle, low-perspective shot looking down the length of the ALICE Transition Radiation Detector (TRD) at the Large Hadron Collider (LHC). The detector is a large, cylindrical structure with a complex internal arrangement of blue and silver components. The outer shell is painted a bright orange-red. The interior is filled with a dense network of blue pipes and silver structural elements. The lighting is bright, coming from overhead fixtures, creating a high-contrast environment. The perspective is from the top of the detector, looking down towards the center.

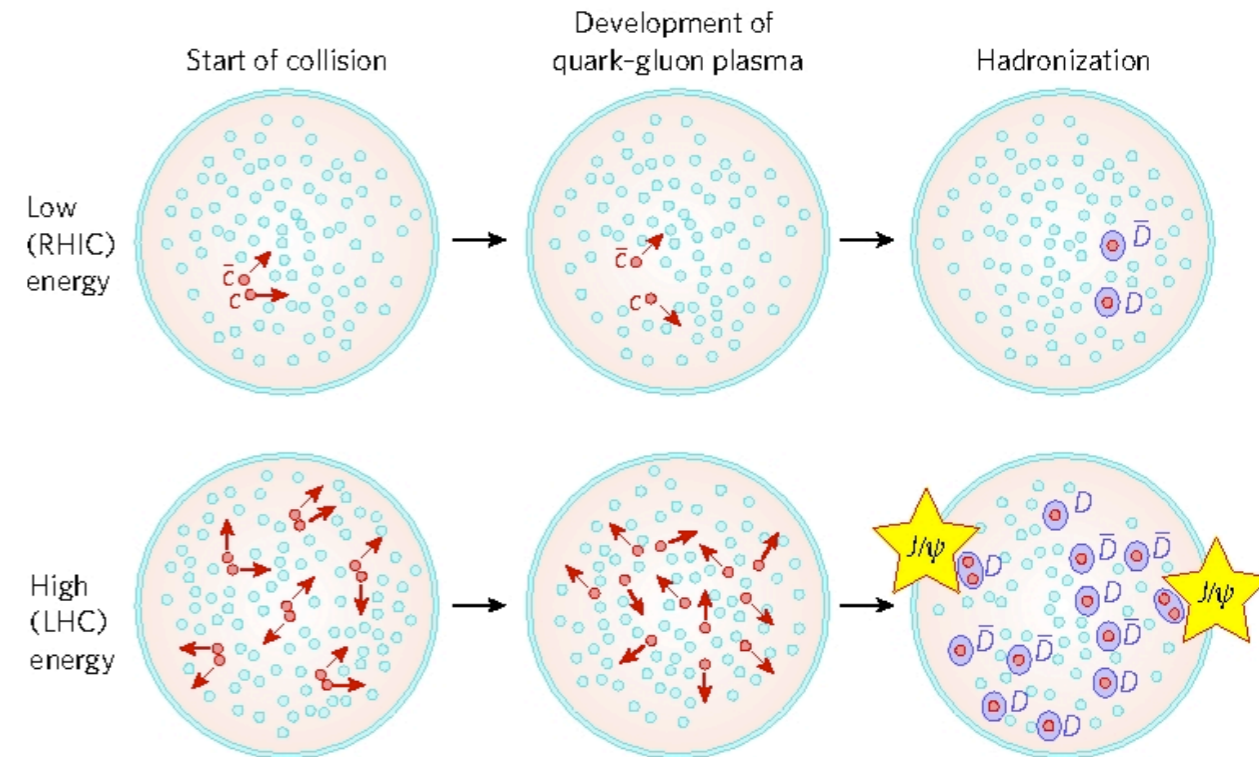
The Transition Radiation Detector for ALICE at LHC

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Quarkonia Production

J/ψ Suppression

- screening of color charges
- “melting” of cc , bb bound state
- at SPS, RHIC, LHC

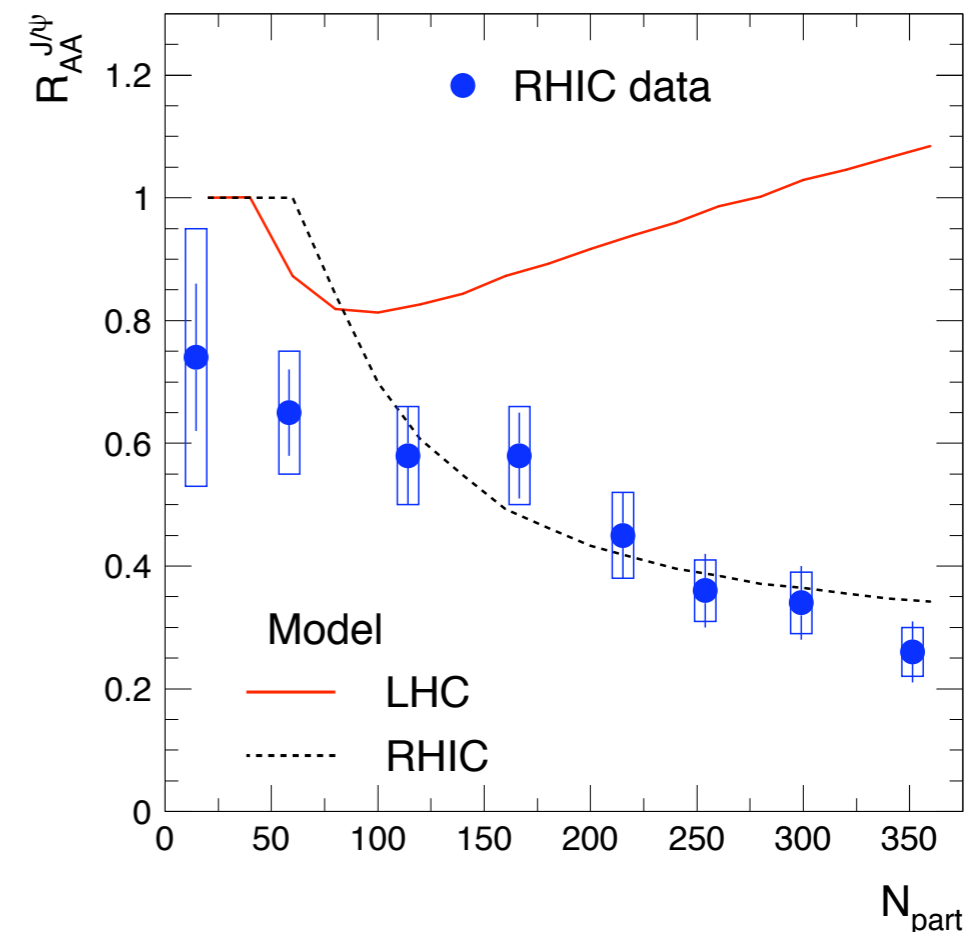


J/ψ Enhancement

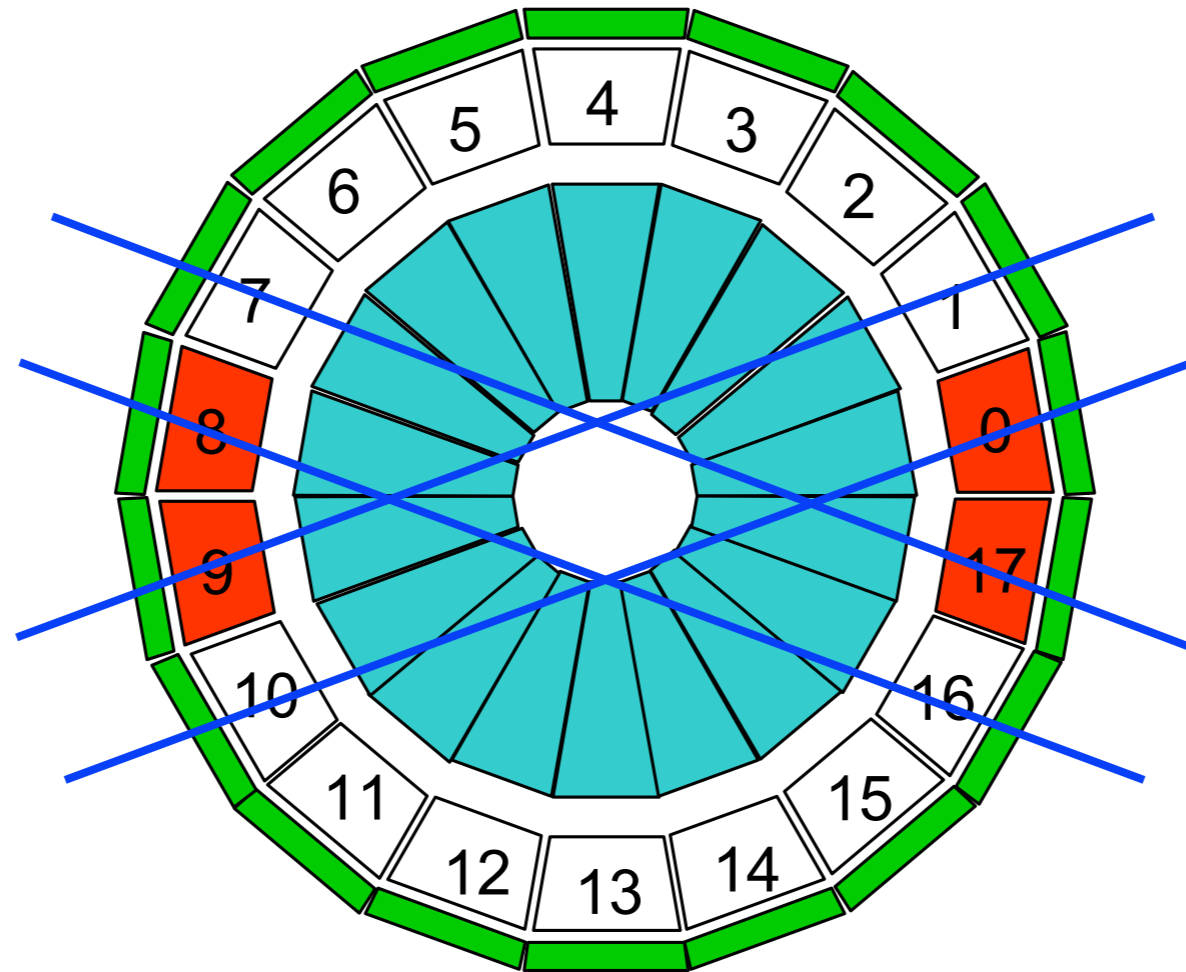
- large abundance of c-quark at LHC
- statistical combination to J/ψ

Reconstruction: $J/\psi, \Upsilon \rightarrow e^+e^-$

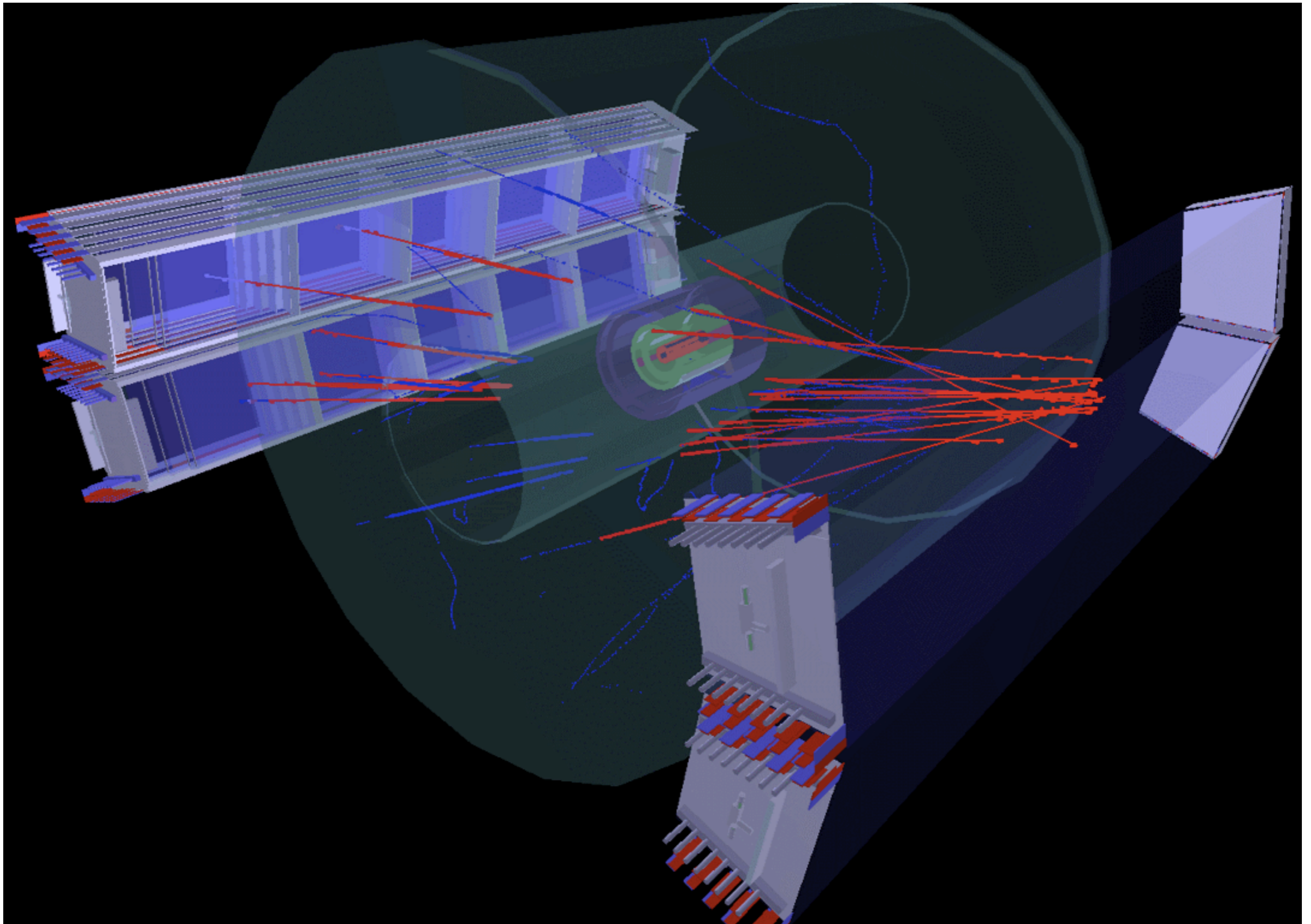
- good electron PID
- large acceptance



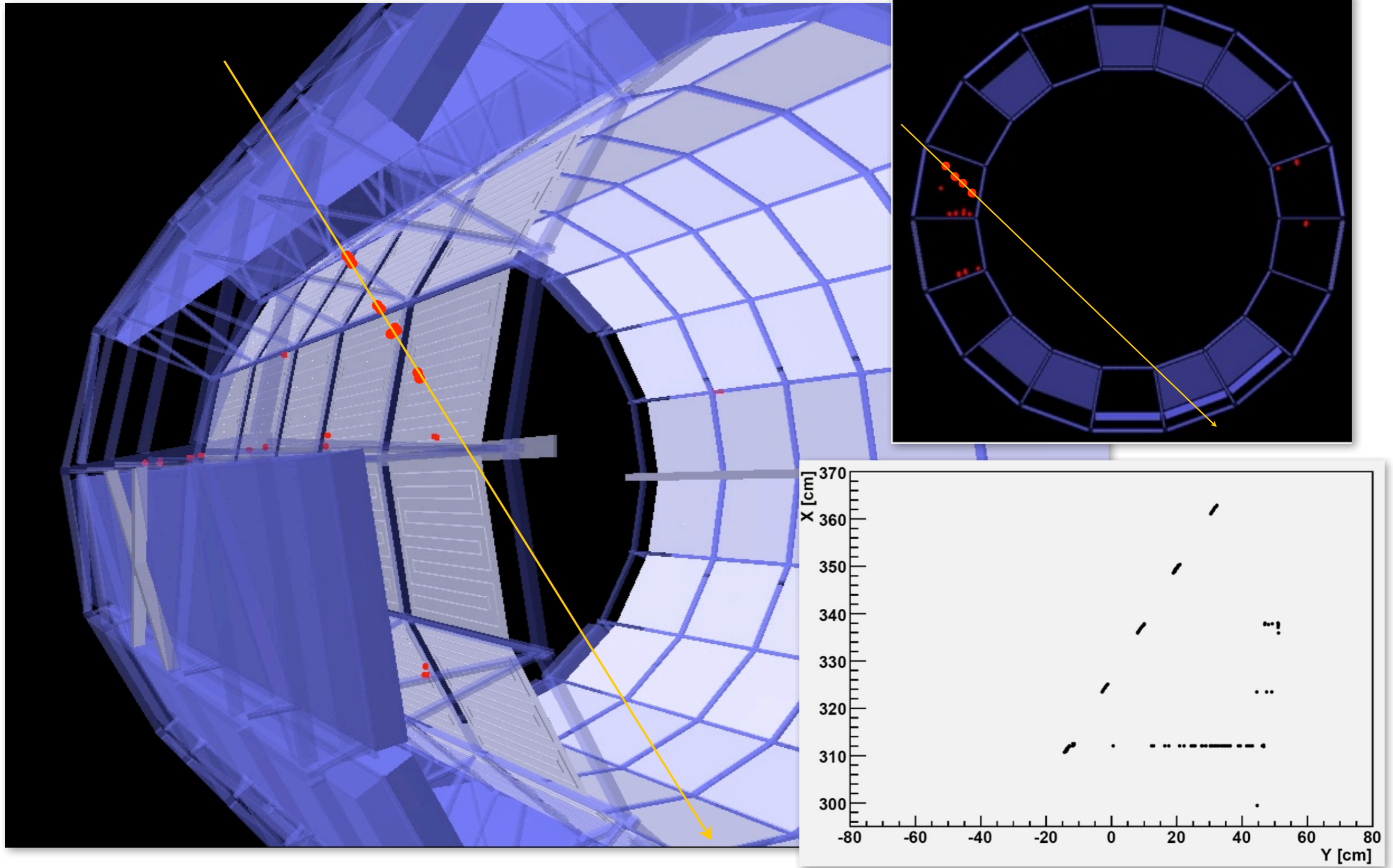
- TOF pre-trigger setup



Cosmic Event Triggered

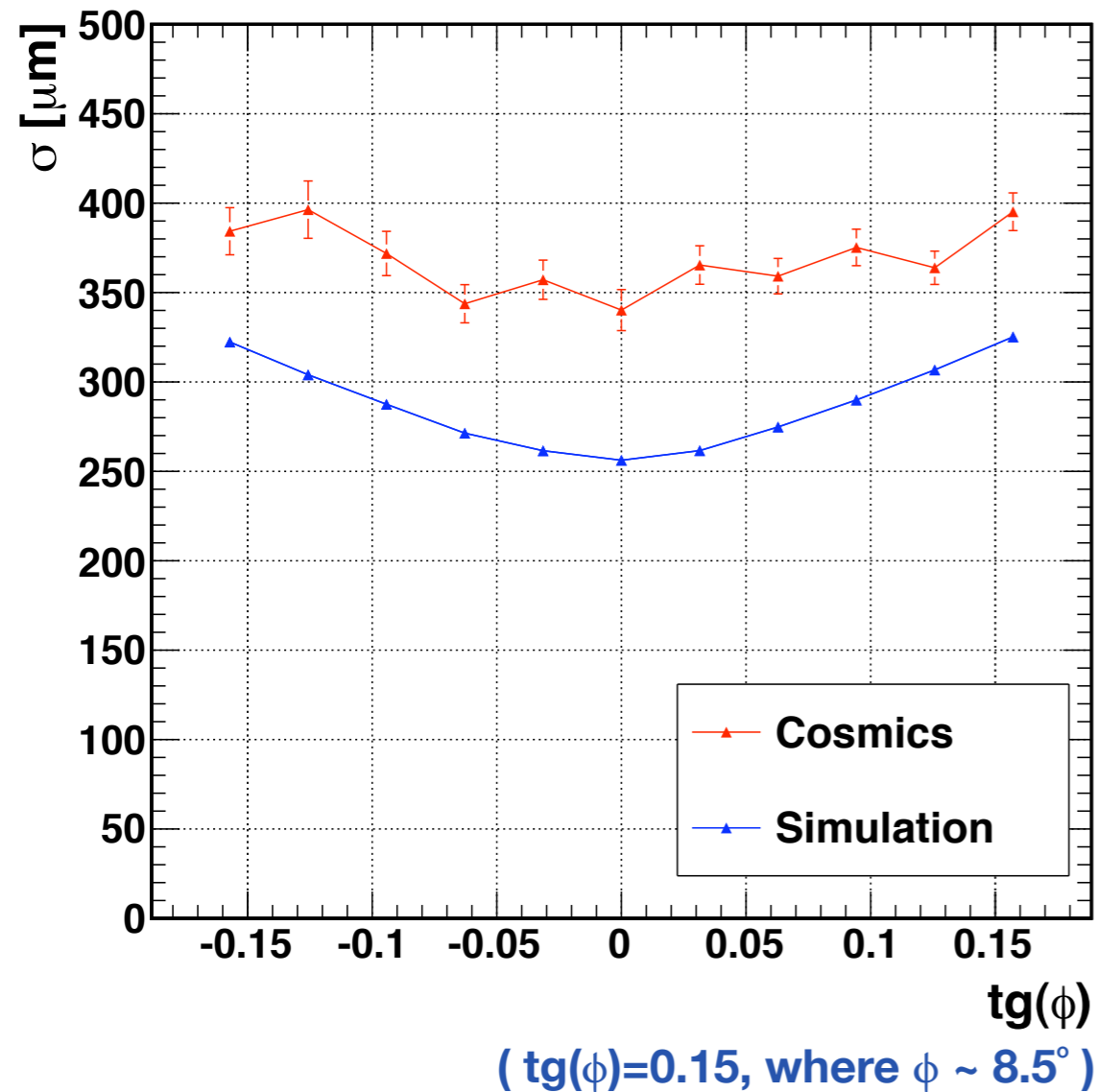


Cosmic Event Triggered



- typical chamber size:
 - $\approx 1.35 \times 1.03 \text{ m}^2$
 - $\approx 12 \text{ cm}$ thick (incl. radiators and electronics)
- in total 1.16 million read-out channels

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Various analysis on going:

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