30 years of ALICE TRD

A. Andronic - University of Münster

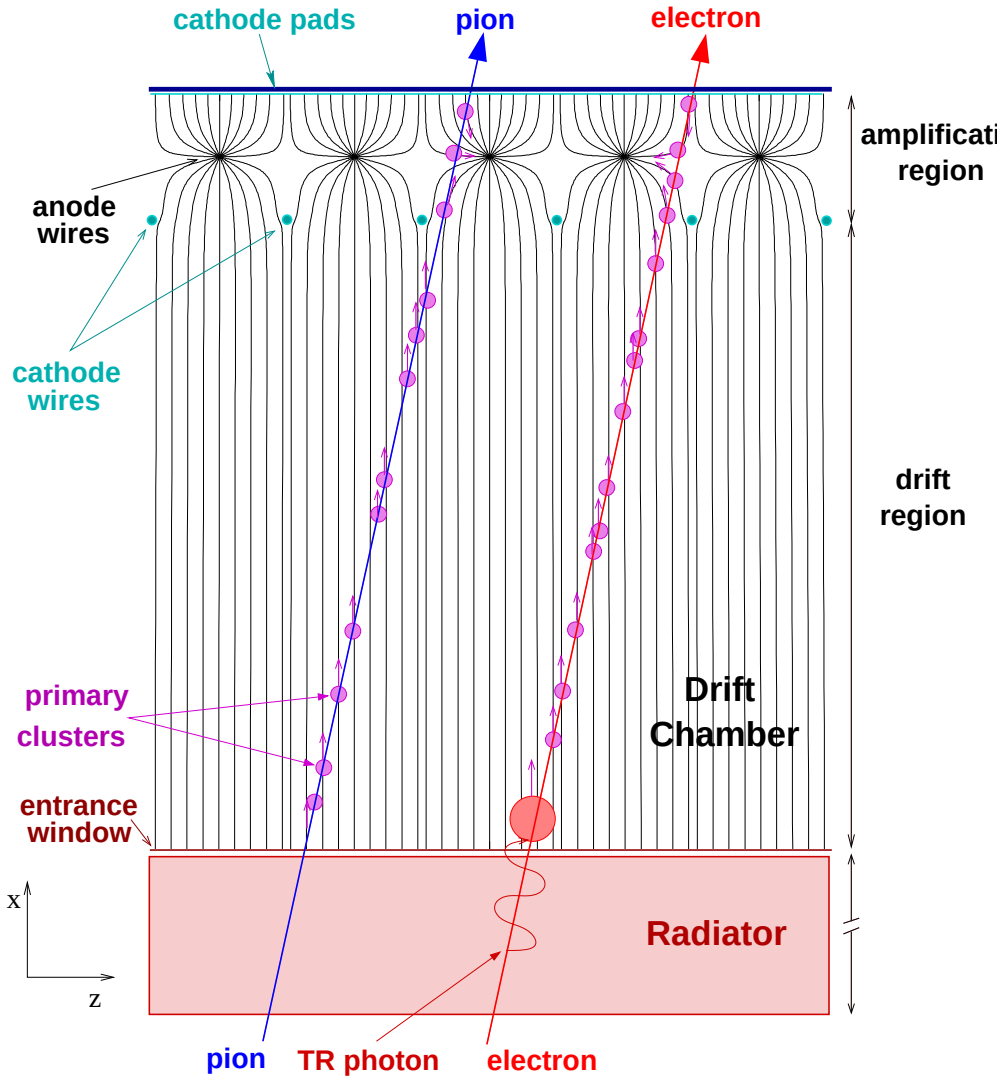


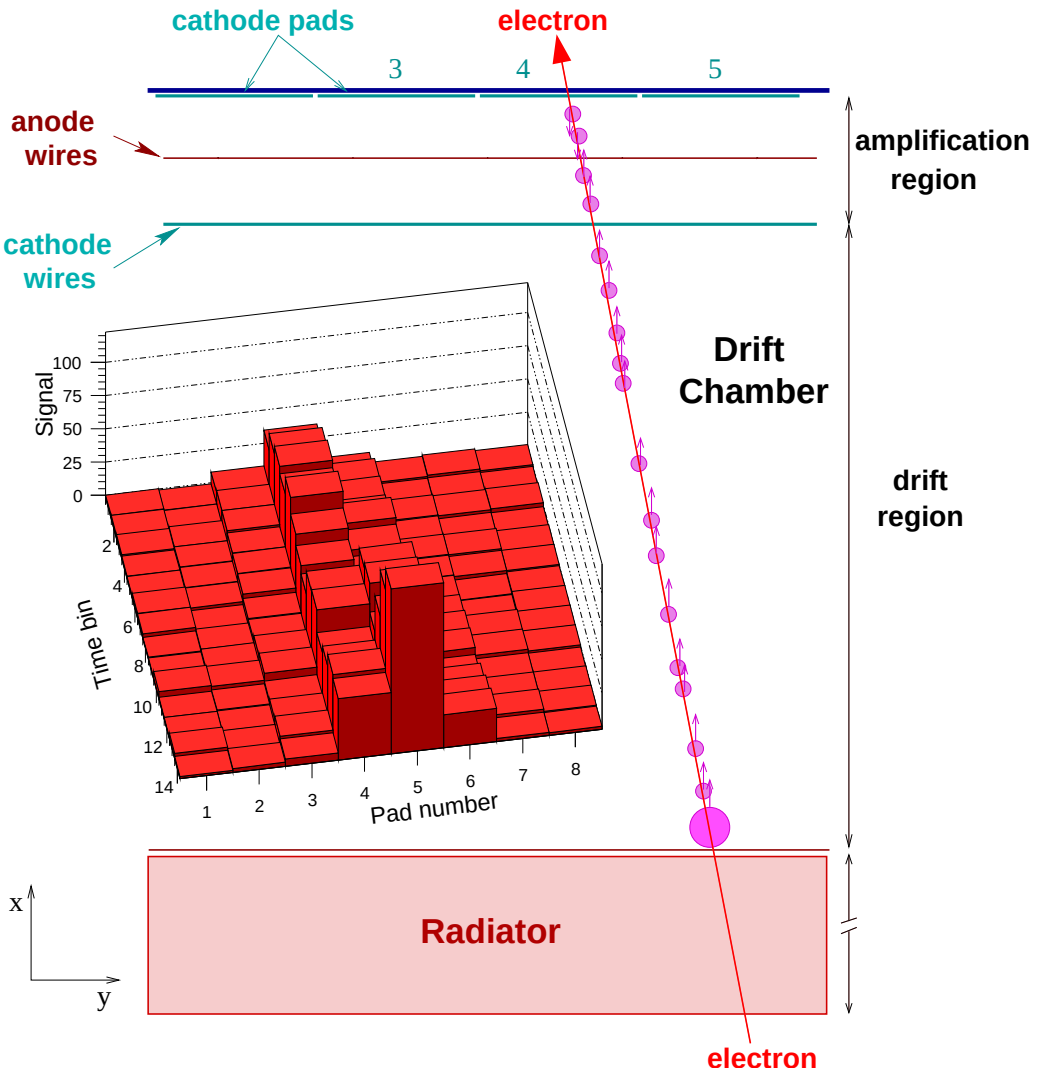
- What is a Transition Radiation Detector
- ALICE TRD: a 30 years history (personal selections)
- ...the hard and the great times

ALICE TRD overview paper, NIM A 881 (2018) 88

What is a Transition Radiation Detector

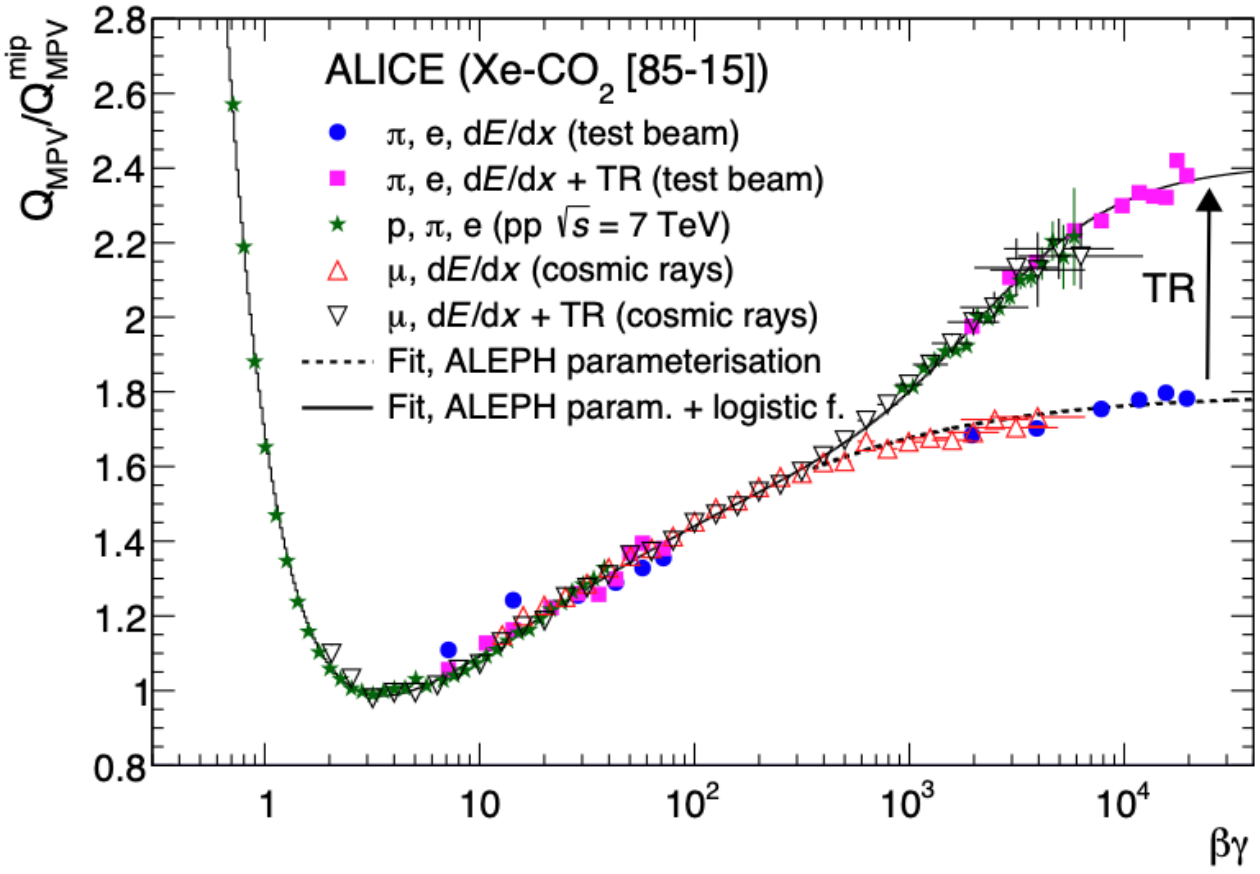
A. Andronic

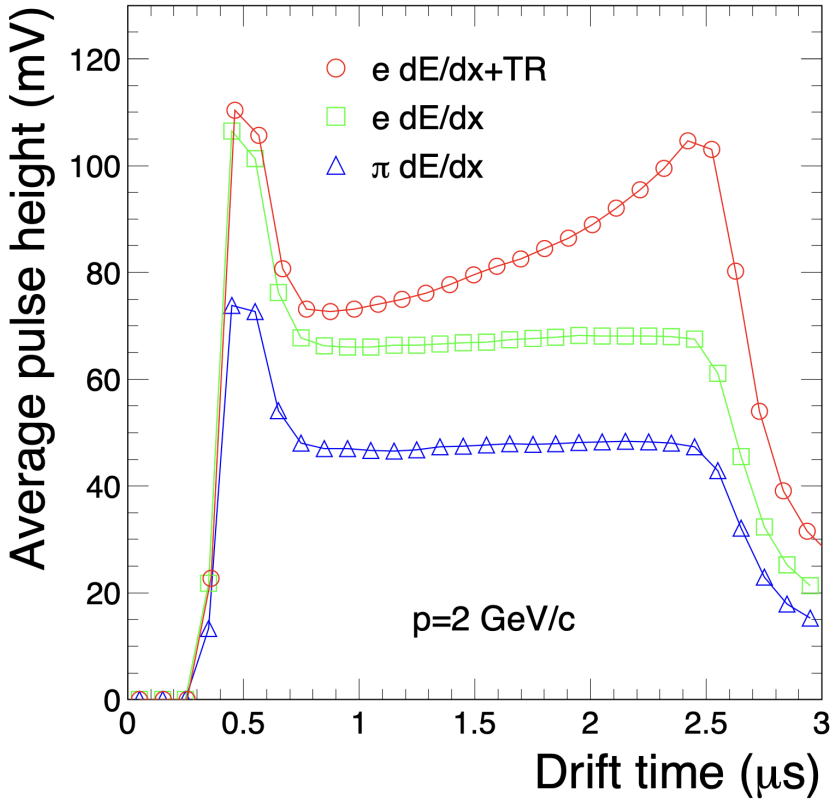




Usually X-rays, TR is detected in Xe-filled MWPCs, overlayed on the ionization energy deposit (dE/dx); several layers needed (dep. on desired pion suppression)

Transition Radiation in practice





ALICE TRD, NIM A 881 (2018) 88 (6 layers; irreg. rad.; pion rejection by a factor of up to 500)

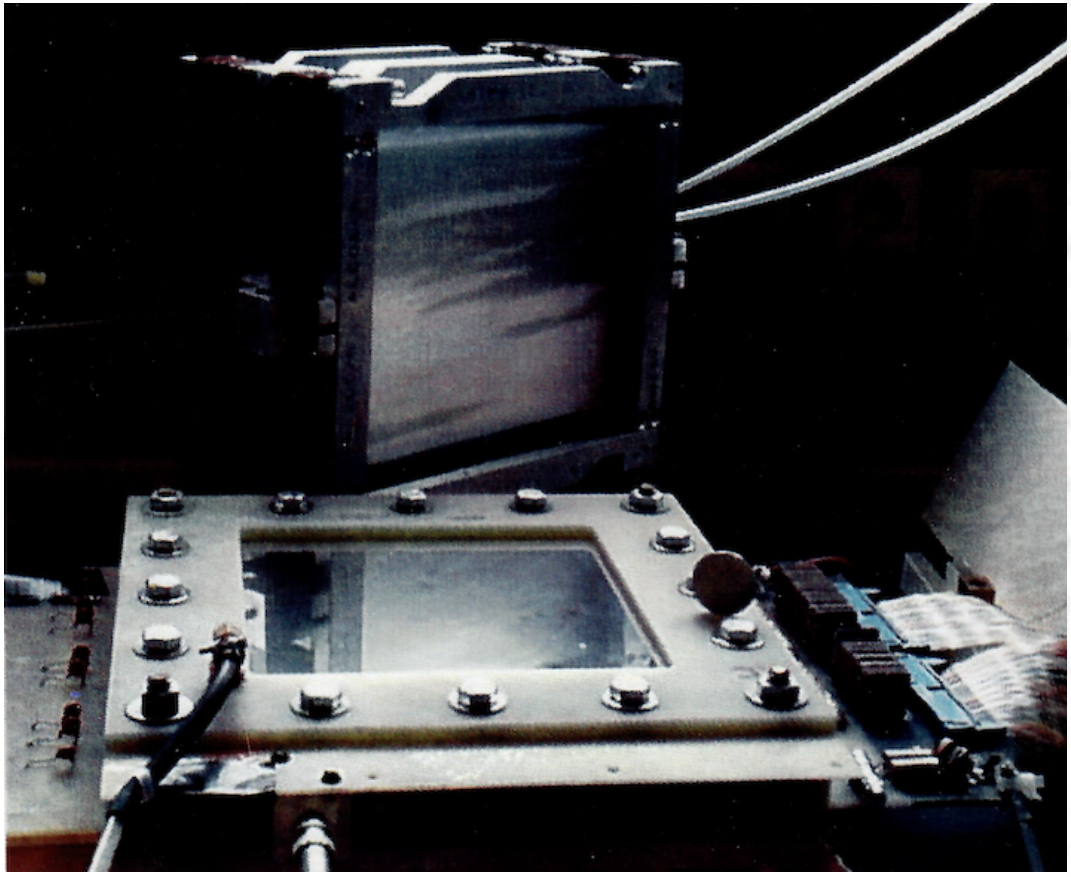
Electrons reach TR saturation around 1 GeV/c, pions at $\sim$250 GeV/c

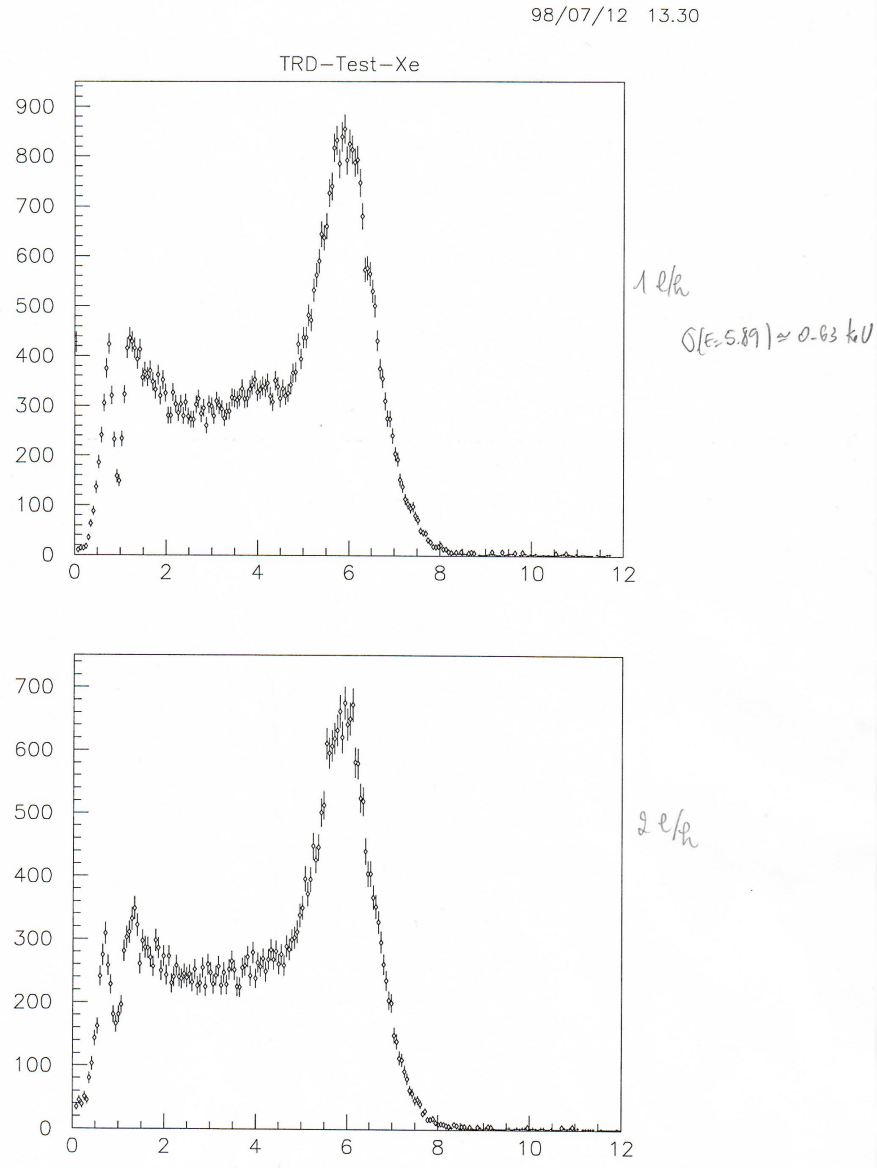
animated ALICE TRD working principle (J.Stiller)

The early days

A. Andronic

The PHENIX (BNL) TRD prototype





The eary days ...first pion beams ...and first TR

A. Andronic

PHENIX TRD Prototype: Beam Test

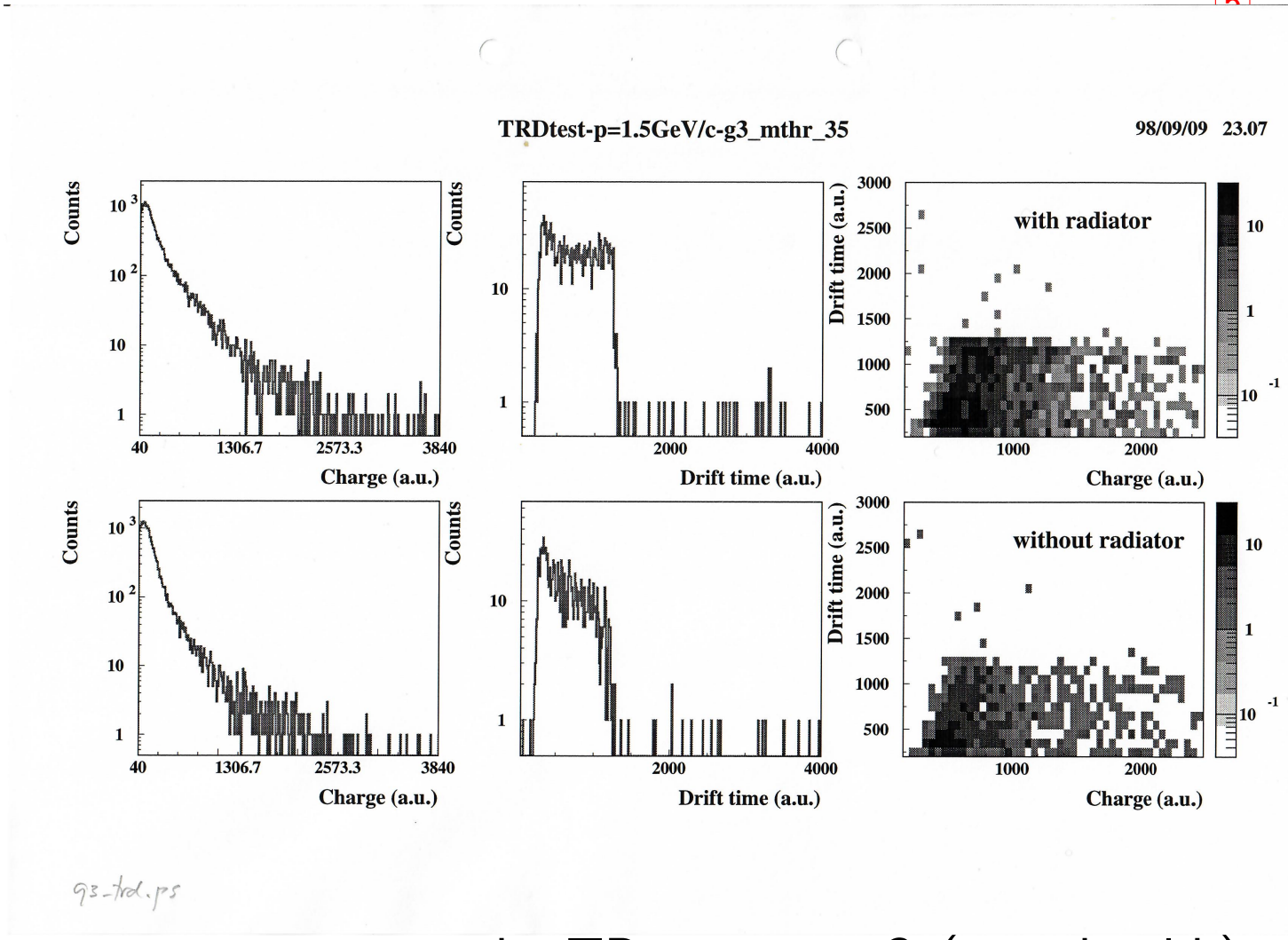
Beamtime Schedule:

Block 4/98 SIS/ESR

Vorschau für Strahlzeitvergabe am 23. 3. 1998, 14 Uhr, Seitenraum Hörsaal

Datum	Tag	Experiment 1	Experiment 2
12. Aug	Mi 6:00	Einst. ^{12}C HLI	
33. KW	Do	Therapie Cave M	Einst. H_3^+ PIG
	Fr		
	Sa		S207 Cave C p 30
	So	2	Grosse
17. Aug	Mo	4 10 Patienten	E = 2.6 GeV
34. KW	Di	6 gestaffelter Beginn	$I = 5\times10^9$/Spill
	Mi	8	
	Do	10 jeweils 2 Felder/Patient	6 – 7 s Spill
	Fr	10	p-induzierte Reaktionen
	Sa	10	
	So	10	
24. Aug	Mo	10	
35. KW	Di	10	
	Mi	10	ab 26.8. E = 3.6 GeV
	Do	10	
	Fr	10	
	Sa	10	
	So	10	
31. Aug	Mo	10	
36. KW	Di	10	
	Mi	10	Com. PION ^{12}C
	Do	10	Murin
	Fr	10	1.5A GeV
	Sa	8	
	So	6	
7. Sep	Mo	4	
37. KW	Di	2	
	Mi		
	Do	(Ende Therapie)	Test Cave H ^{12}C
	Fr	Einst. ^{129}Xe HLI	Averbeck (TRD) 1.5A GeV
	Sa	S185 Cave B ^{129}Xe	
	So	Plagnol	

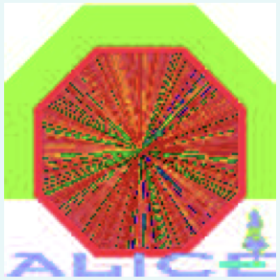
1



can you see the TR signatures? (you should:)

Marian did read ∼200 tracks through an oscilloscope, signal vs. time ...observed huge fluctuations

The Technical Proposal of TRD



CERN/LHCC 99-13
LHCC/P3-Addendum 2
7 May 1999

A Transition Radiation Detector

for

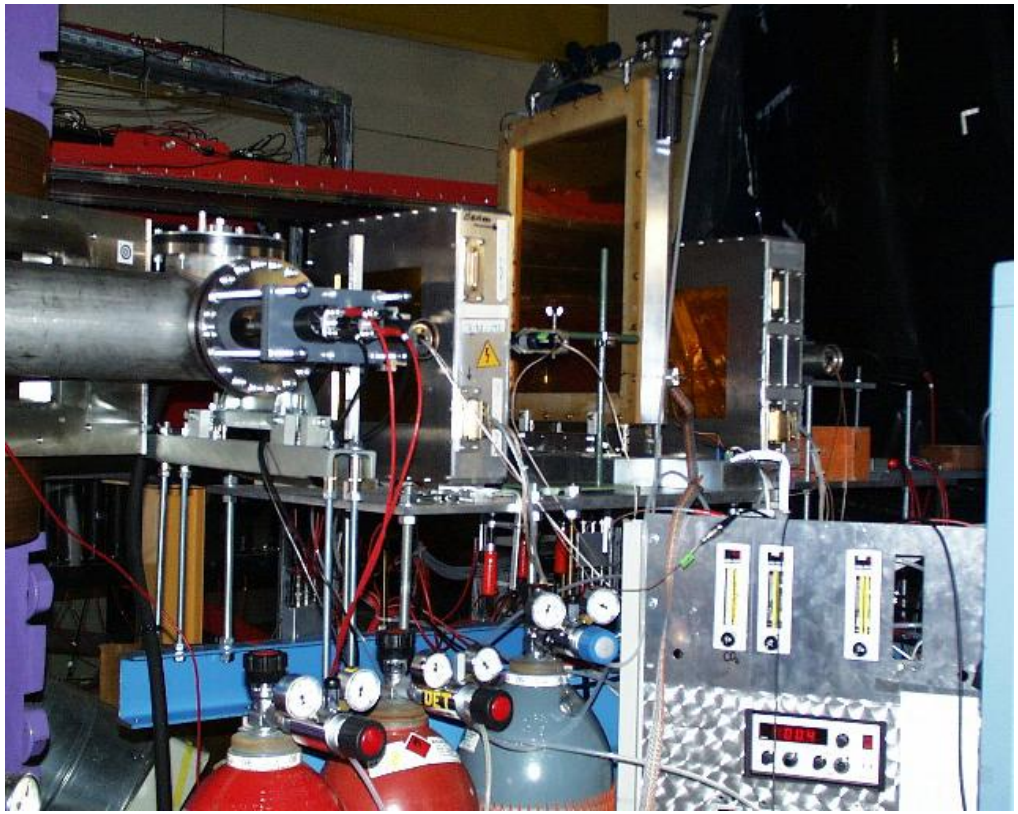
Electron Identification

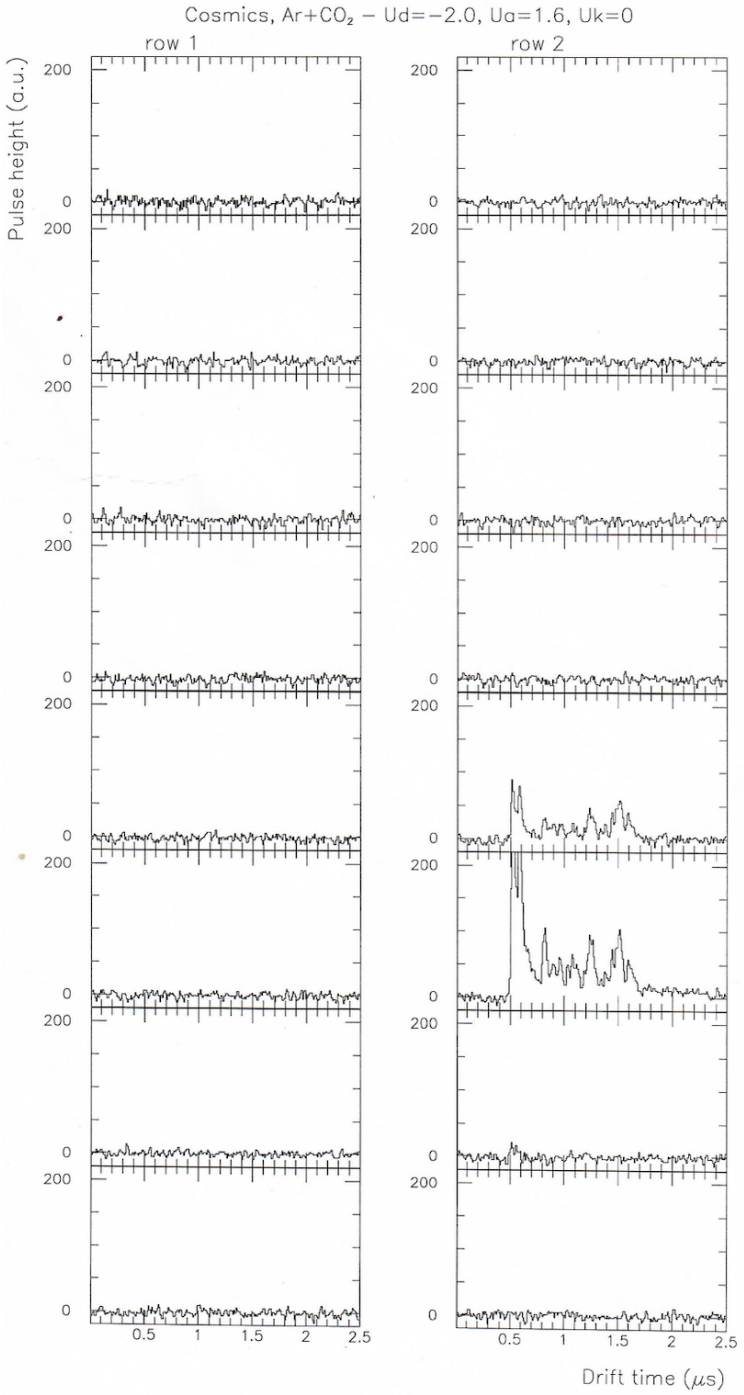
within the ALICE Central Detector

PDF

The first GSI chamber

A. Andronic





...with current-sensitive PA (DVEE, Hr. Schulze)

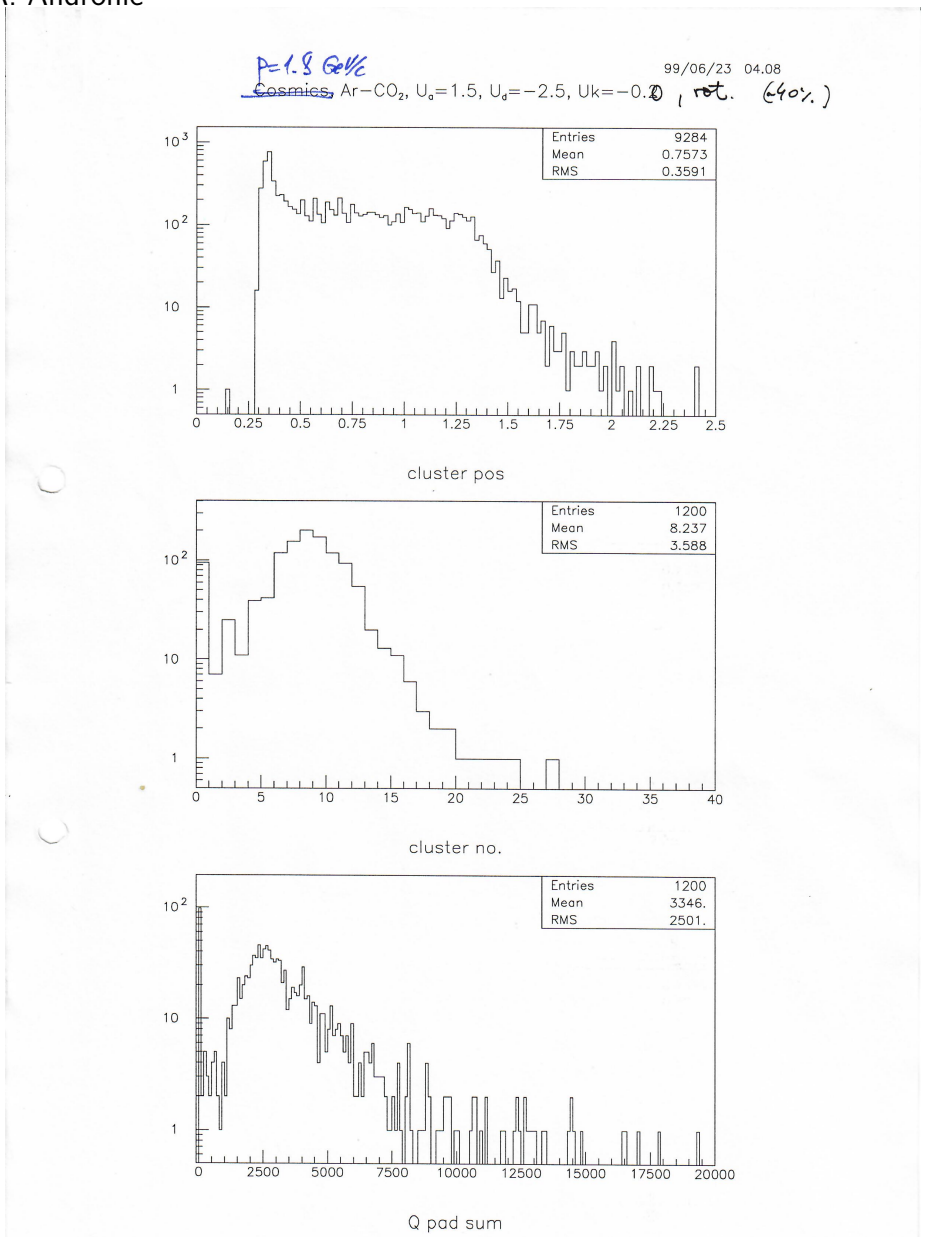
FADC readout (FOPI), MBS DAQ (DVEE, N.Kurz)

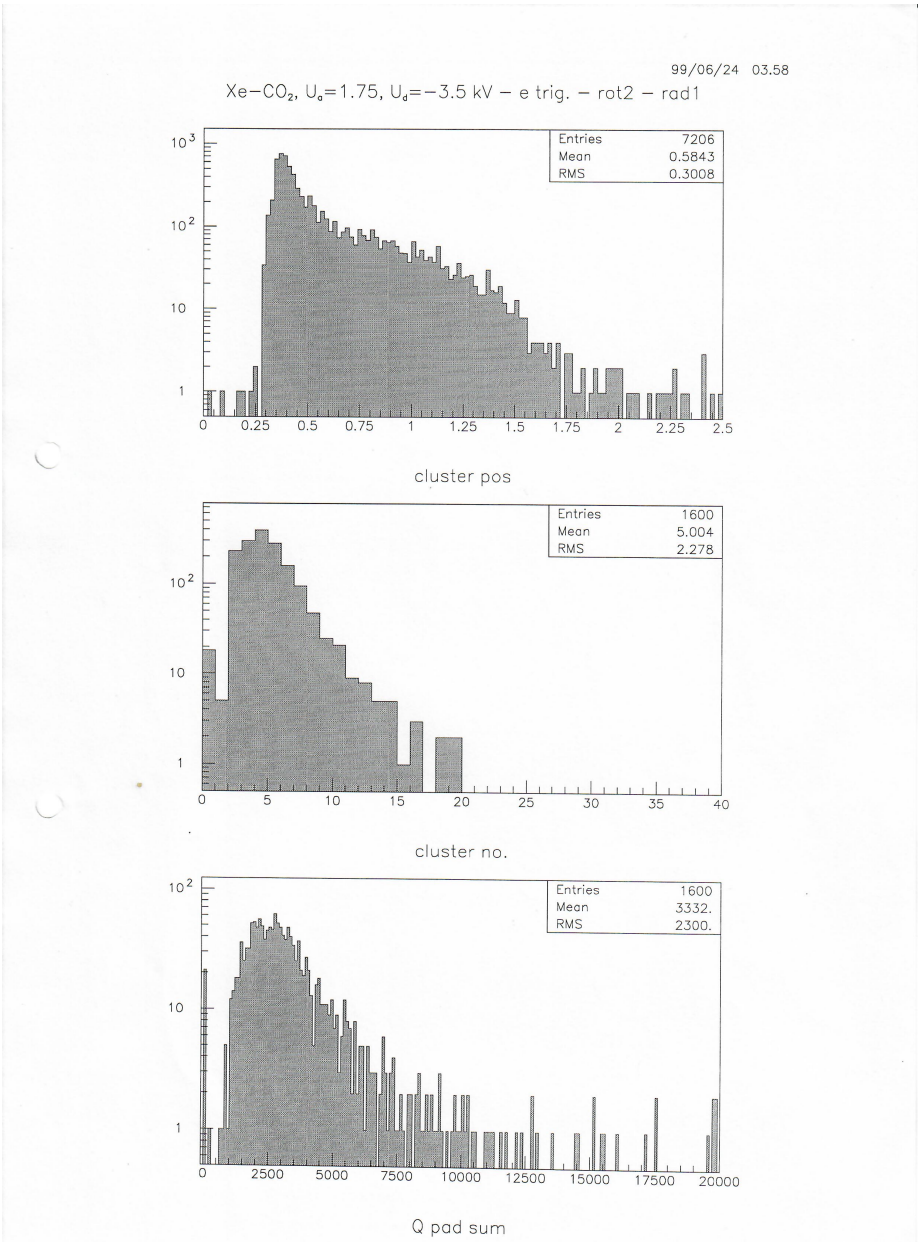
Andreas Reischl's Diploma (2000)

I broke its window (...and wires, ∼5 am in Cave-H)

H.Stelzer: "you cannot call yourself an experimentalist if you haven't broken a detector *once*"

The first GSI chamber ...and challenges

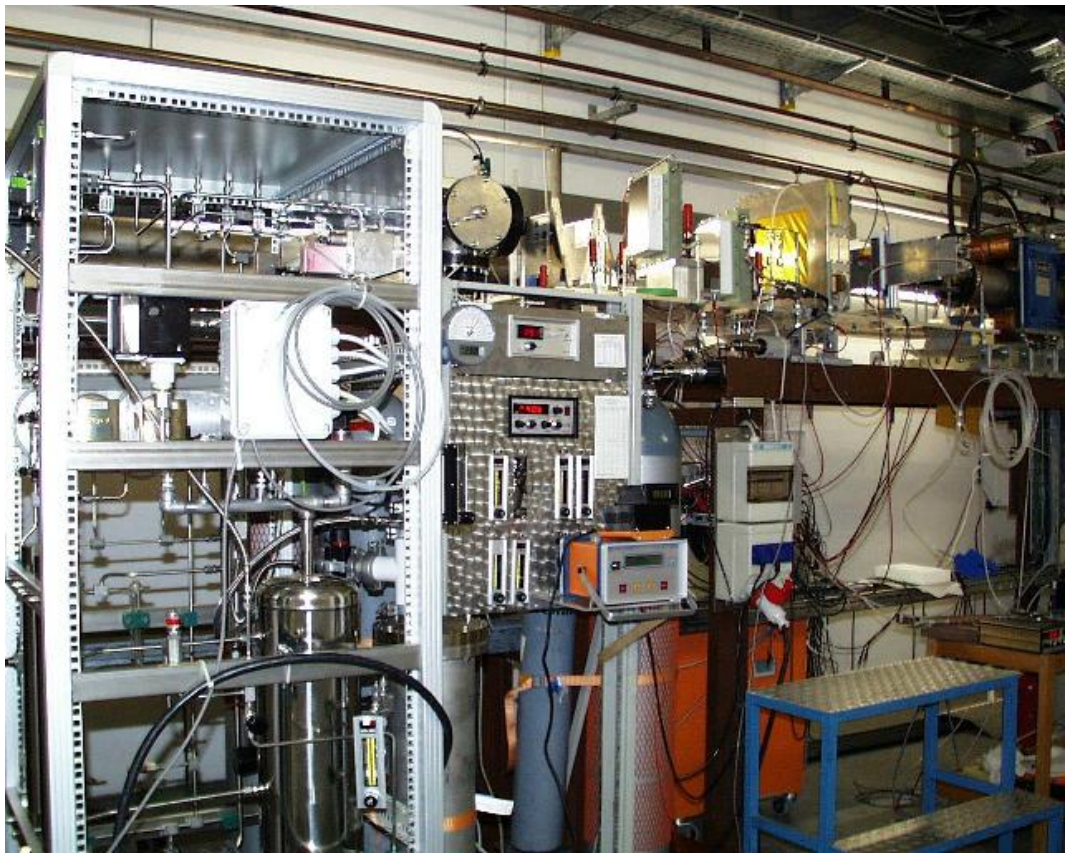


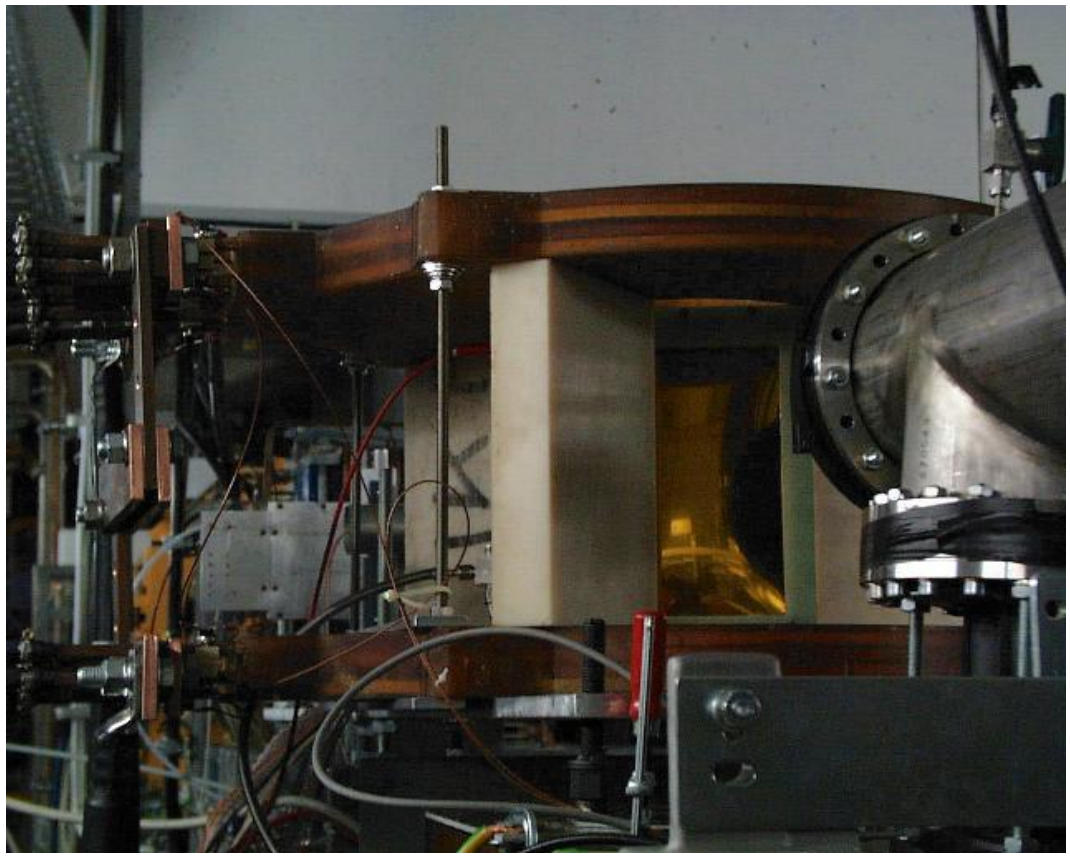


Peter enlisted Fabio Sauli to explain this ...attachment (discussed 3-body in Xe)

We understood it later (in a painful way:)

Testbeam Cave C, Aug. 2001



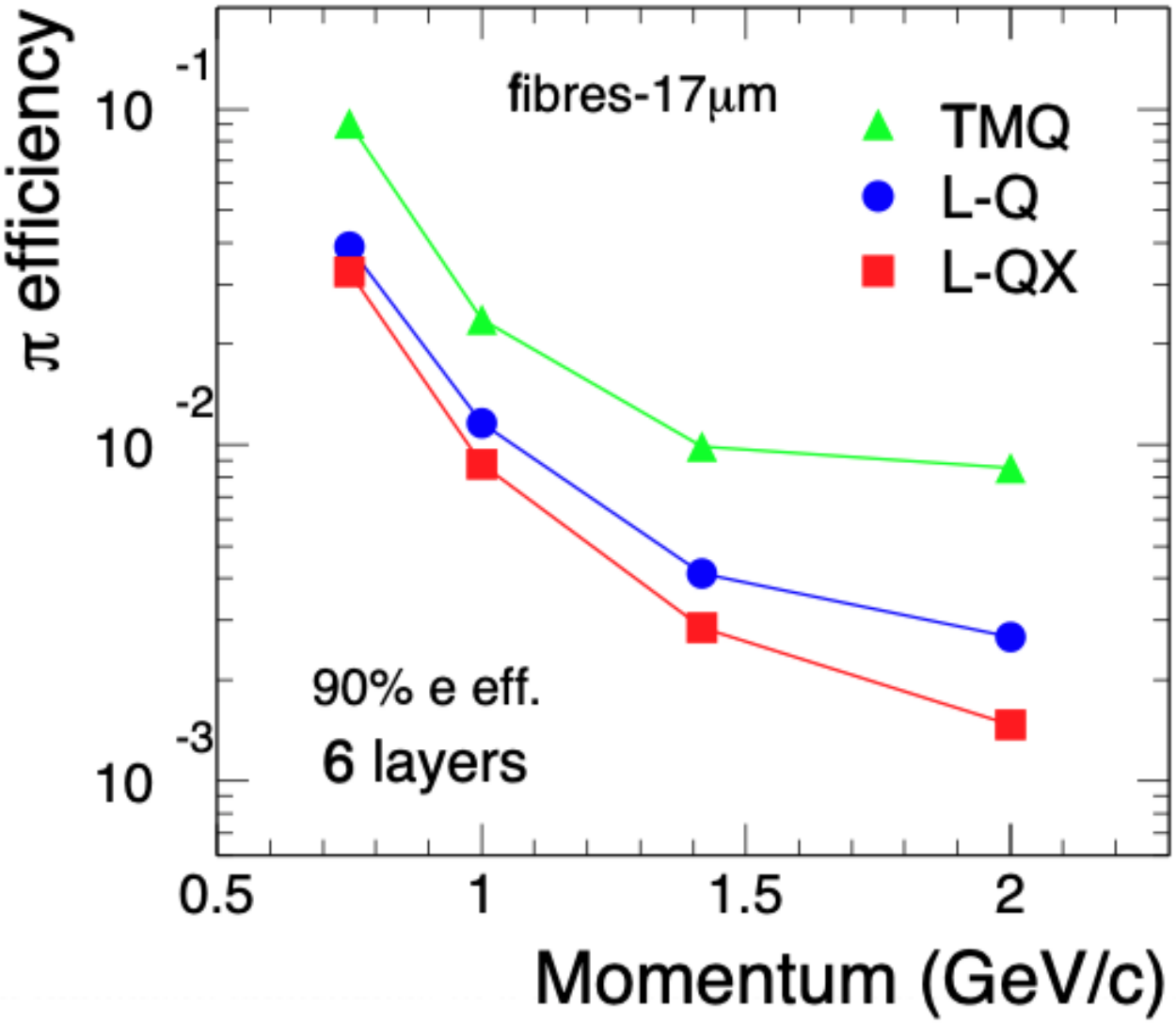


Oliver Busch's Diploma (2002)

We got more professional, ex: gas system (note the Orbisphere device:)

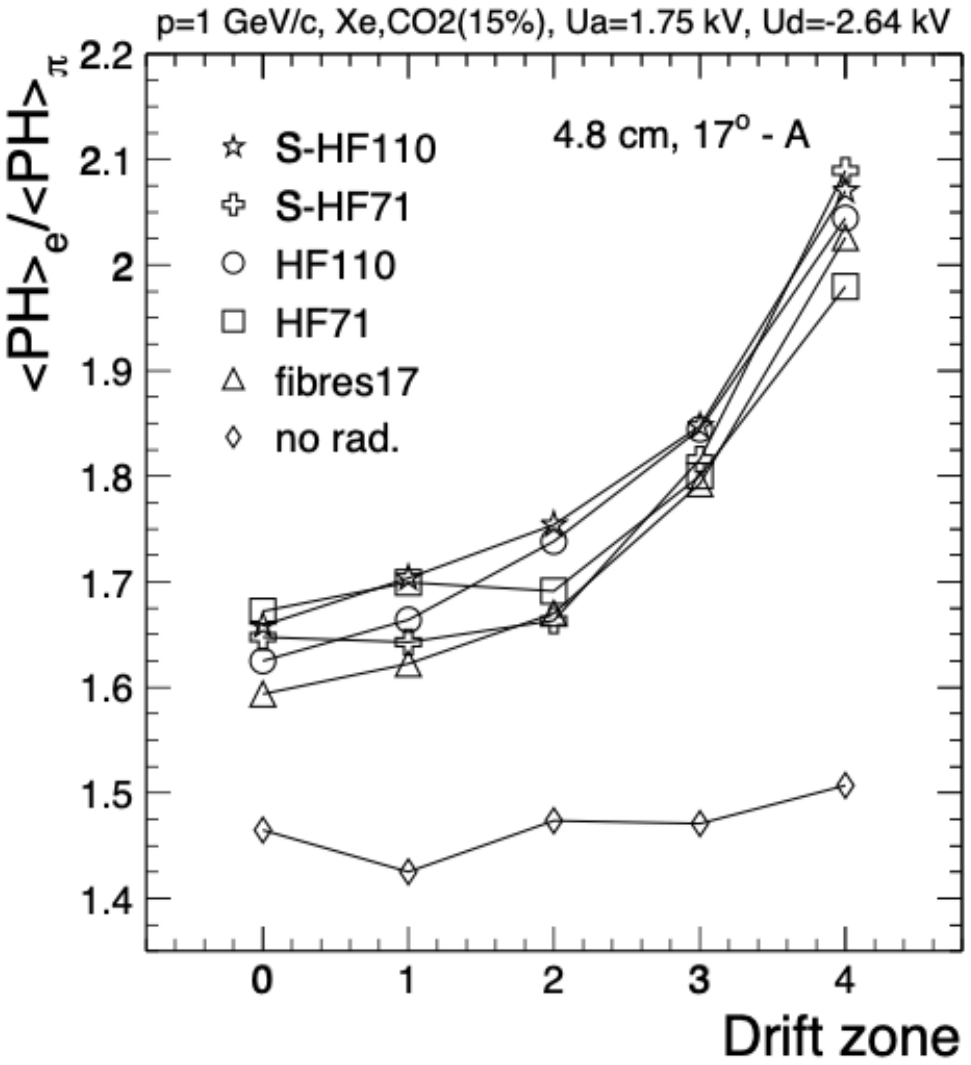
Tested rectangular pads vs. chevrons ...adopted rectangular (tilted, later)
First measurements in B-field, 0.25 T (clearly better position resolution)

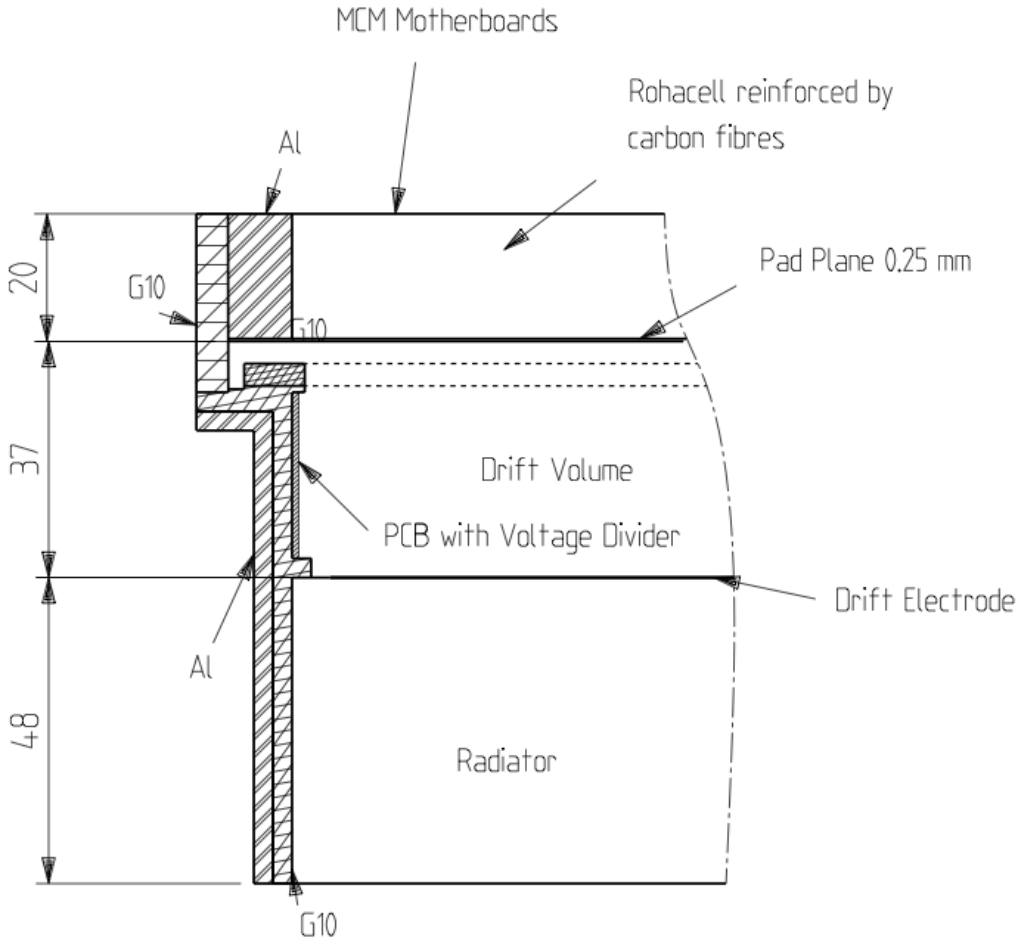
TRD: getting quantitative (2001)



TRD: the radiator ...getting practical

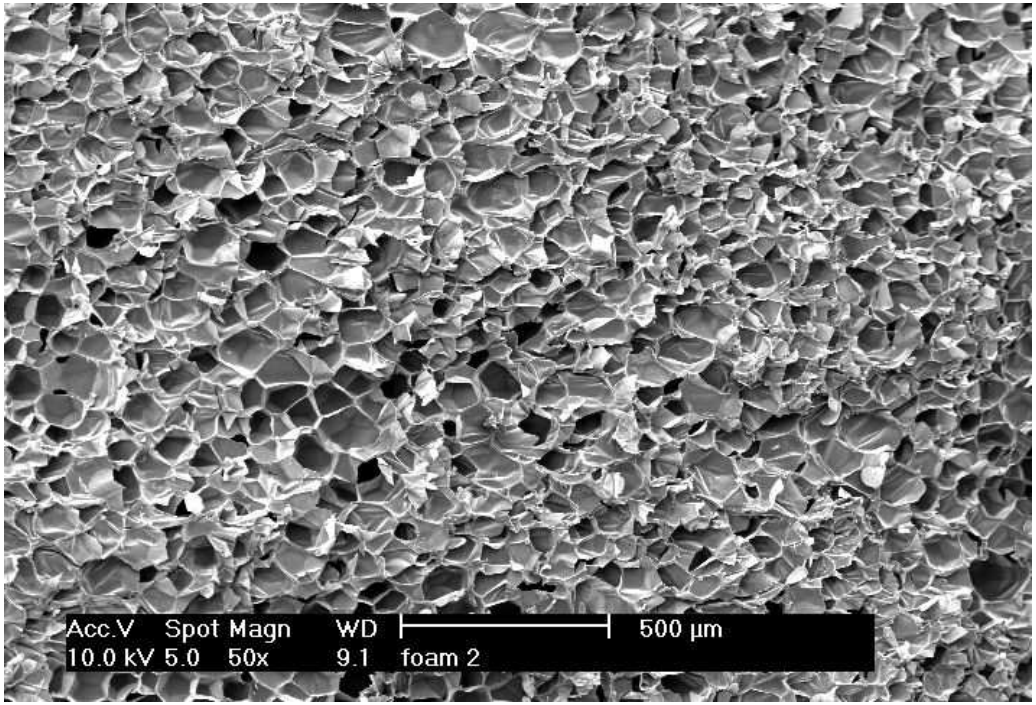
A. Andronic

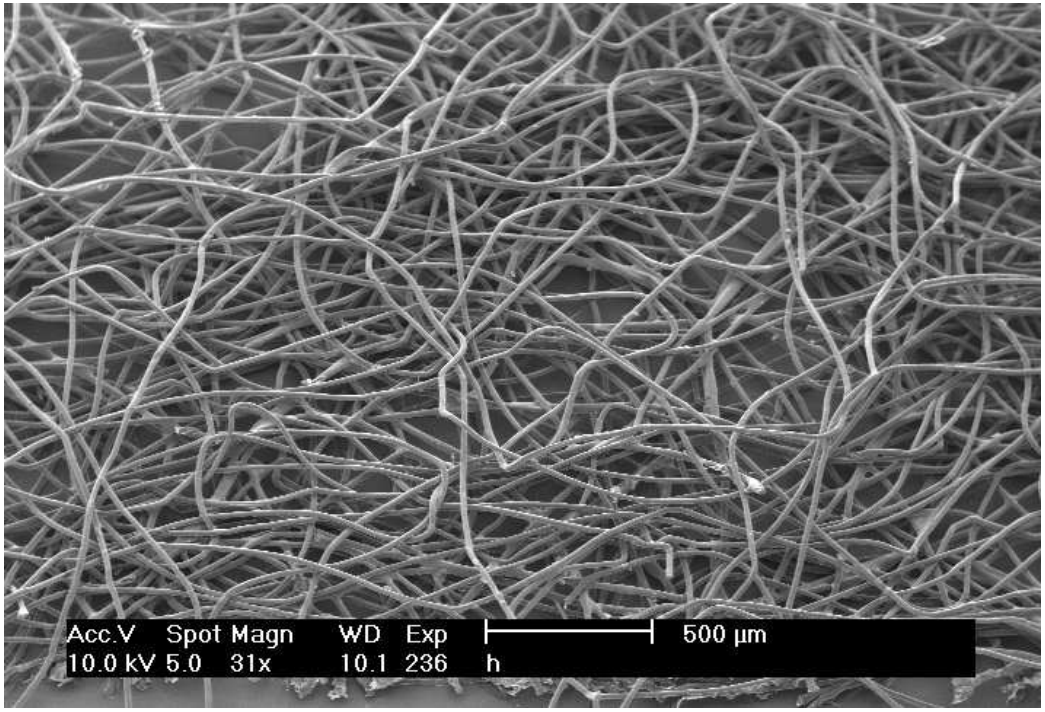




a sandwich of foams and fibres was the solution ...we kept improving it

Irregular radiators





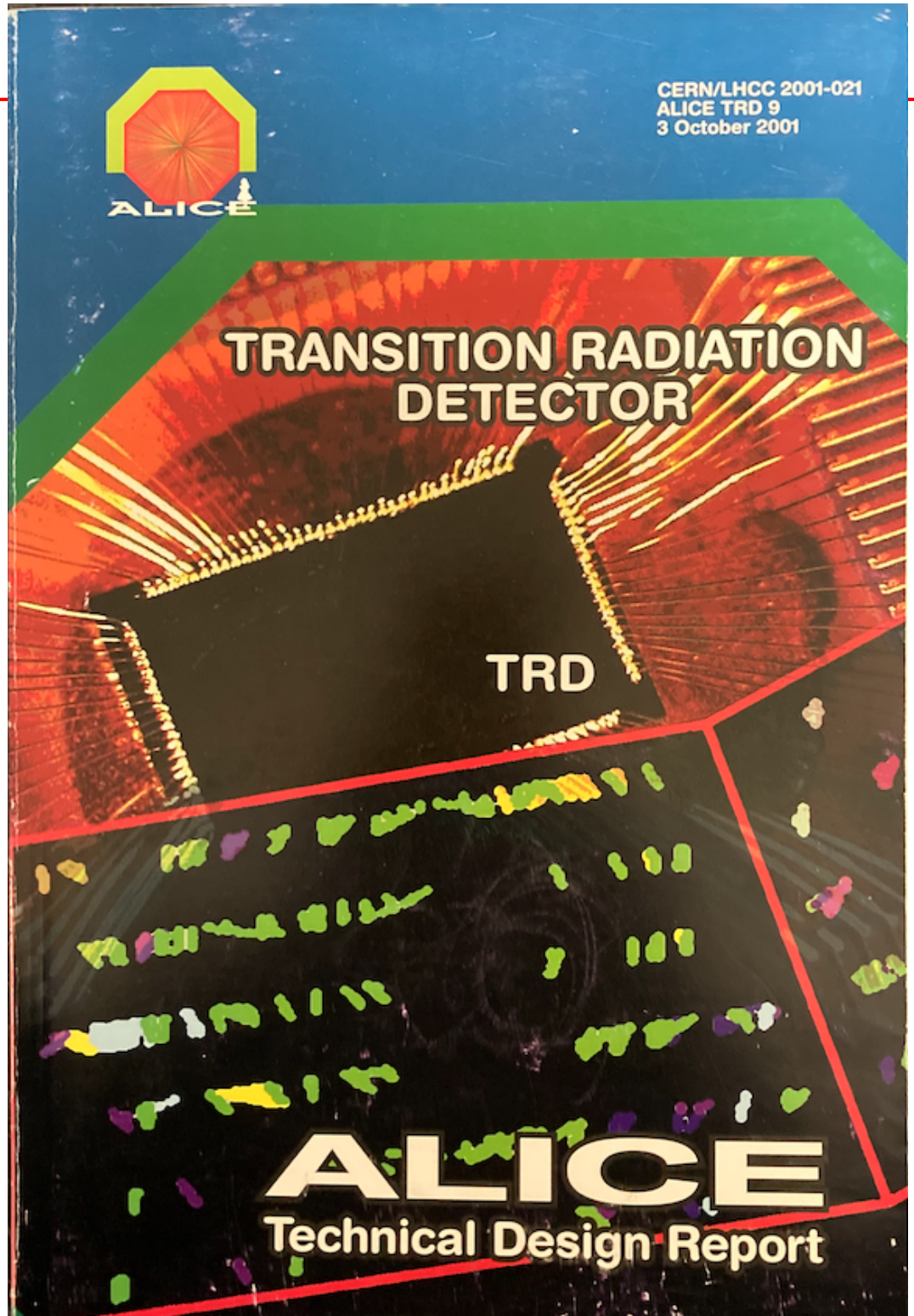
ALICE TRD, NIM A 881 (2018) 88

(Credit: Ionut Enculescu, GSI Mat.Dept. ...Fig. 12.11 in the Kolanoski-Wermes textbook:)

For large-scale detectors irregular radiators have a practical advantage

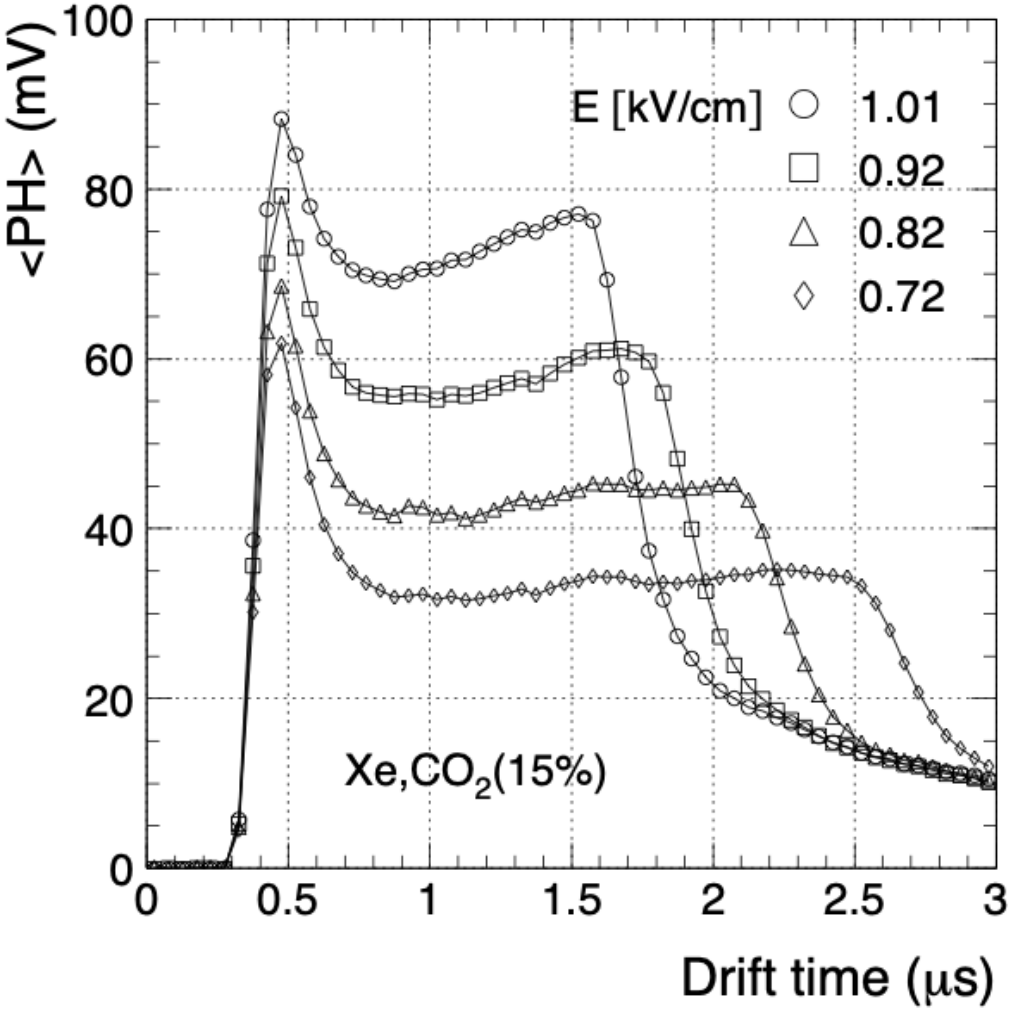
The TDR of TRD

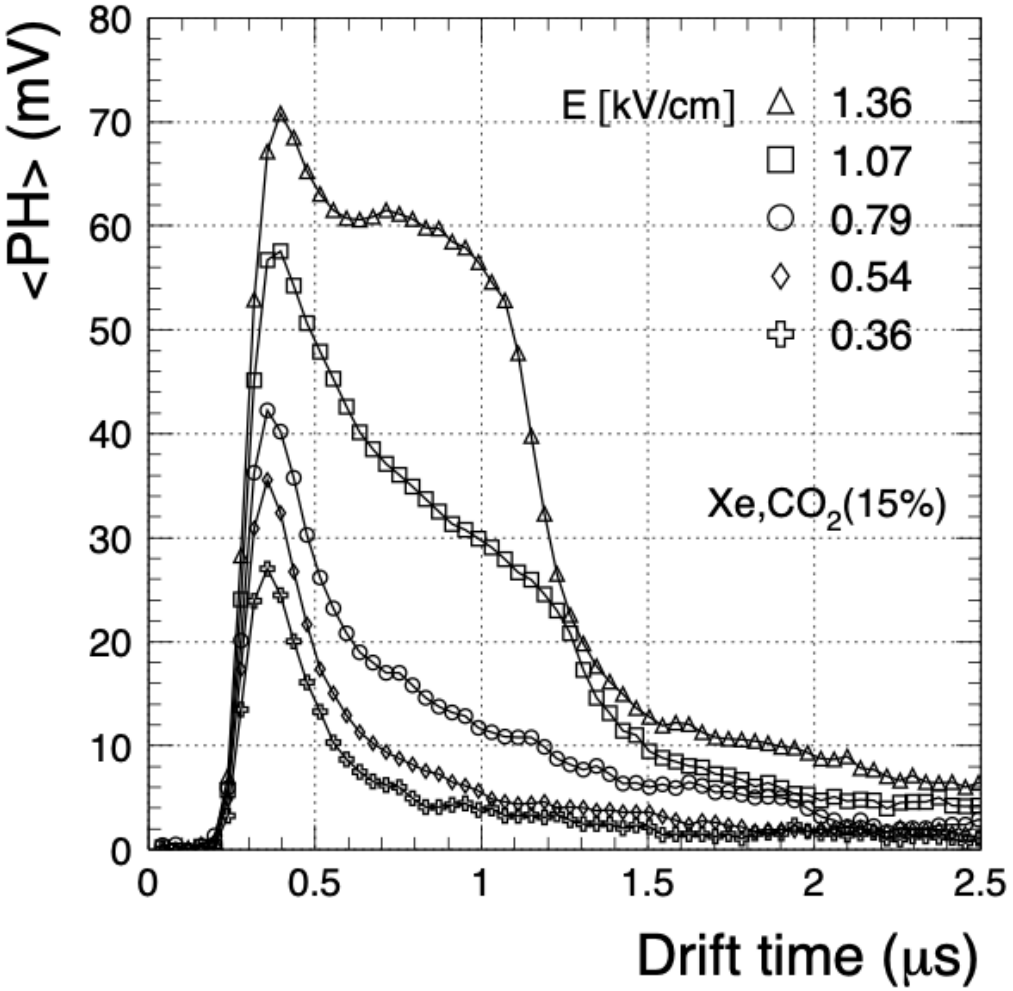
A. Andronic



CDS

TRD: attachment, an unwanted effect (CERN, 2001)

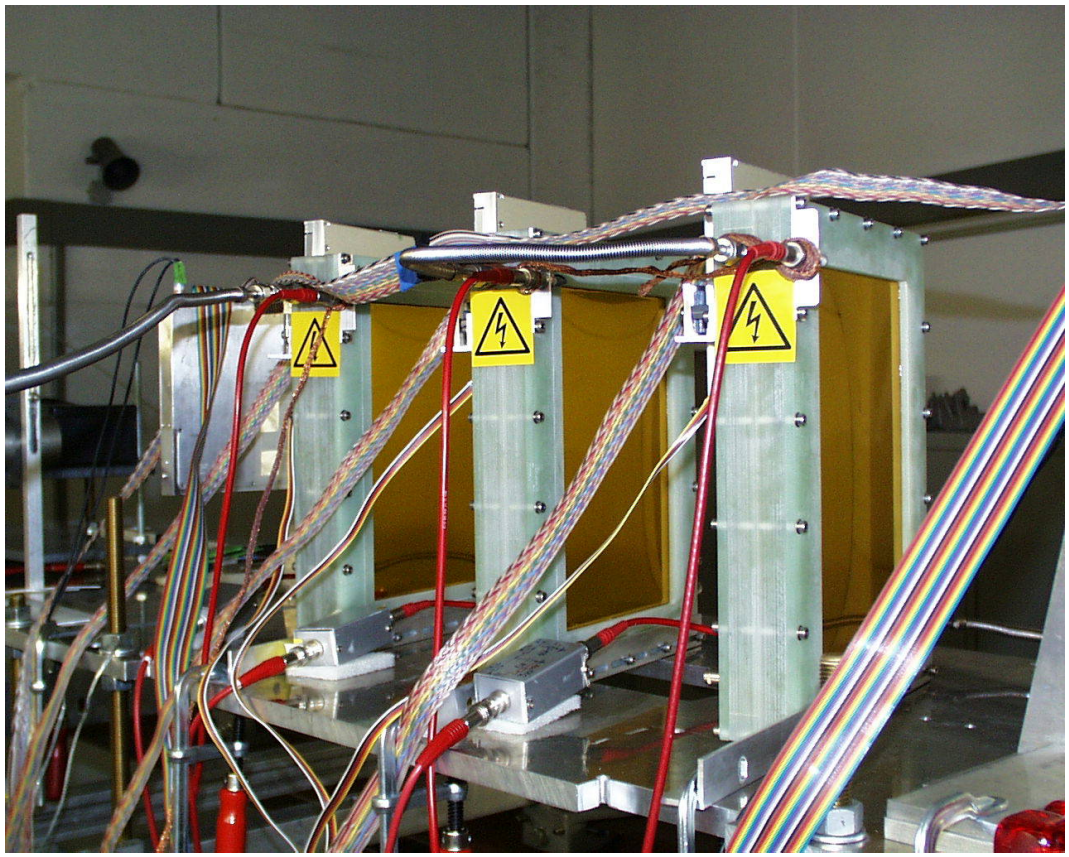


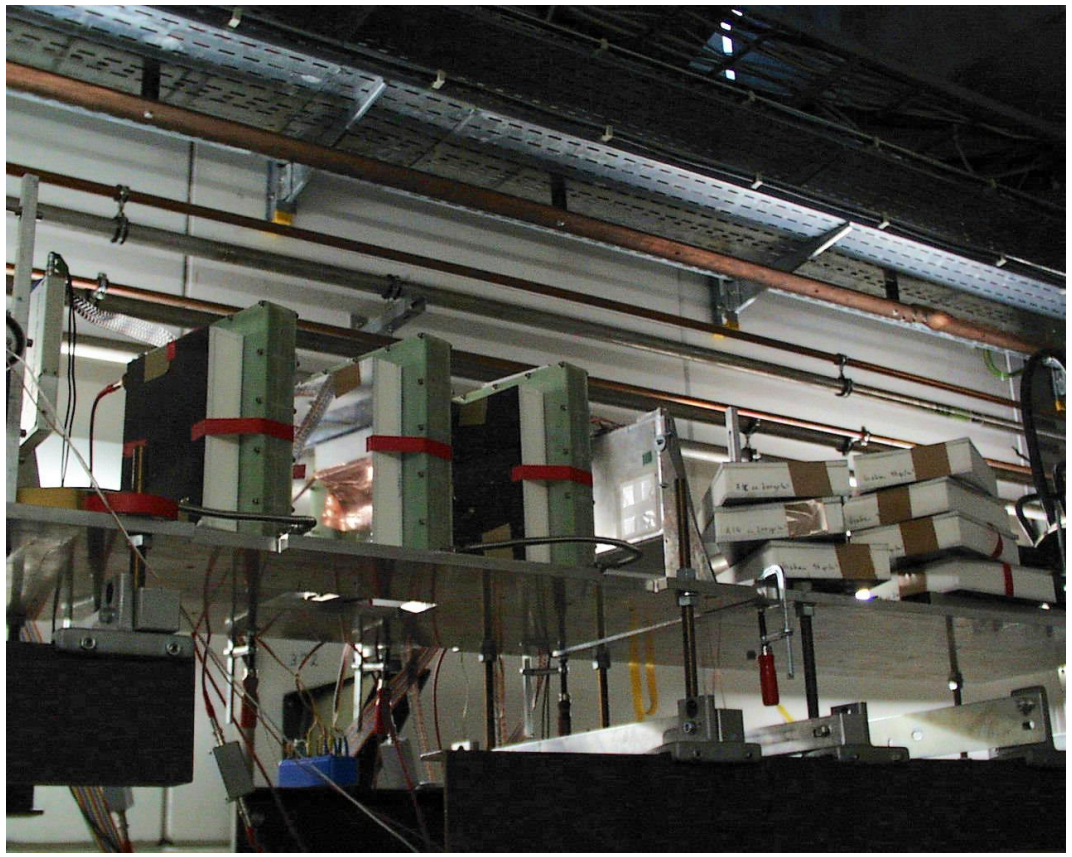


Attachment on 1 ppm SF_6 ...O_2 also measured, much less critical; imposes O_2 below $\sim$100 ppm

Left plot: Fig. 4.44 in the Sauli textbook (text, p.112: "for soft X-rays" wrong:)

Testbeam Cave C, June 2002



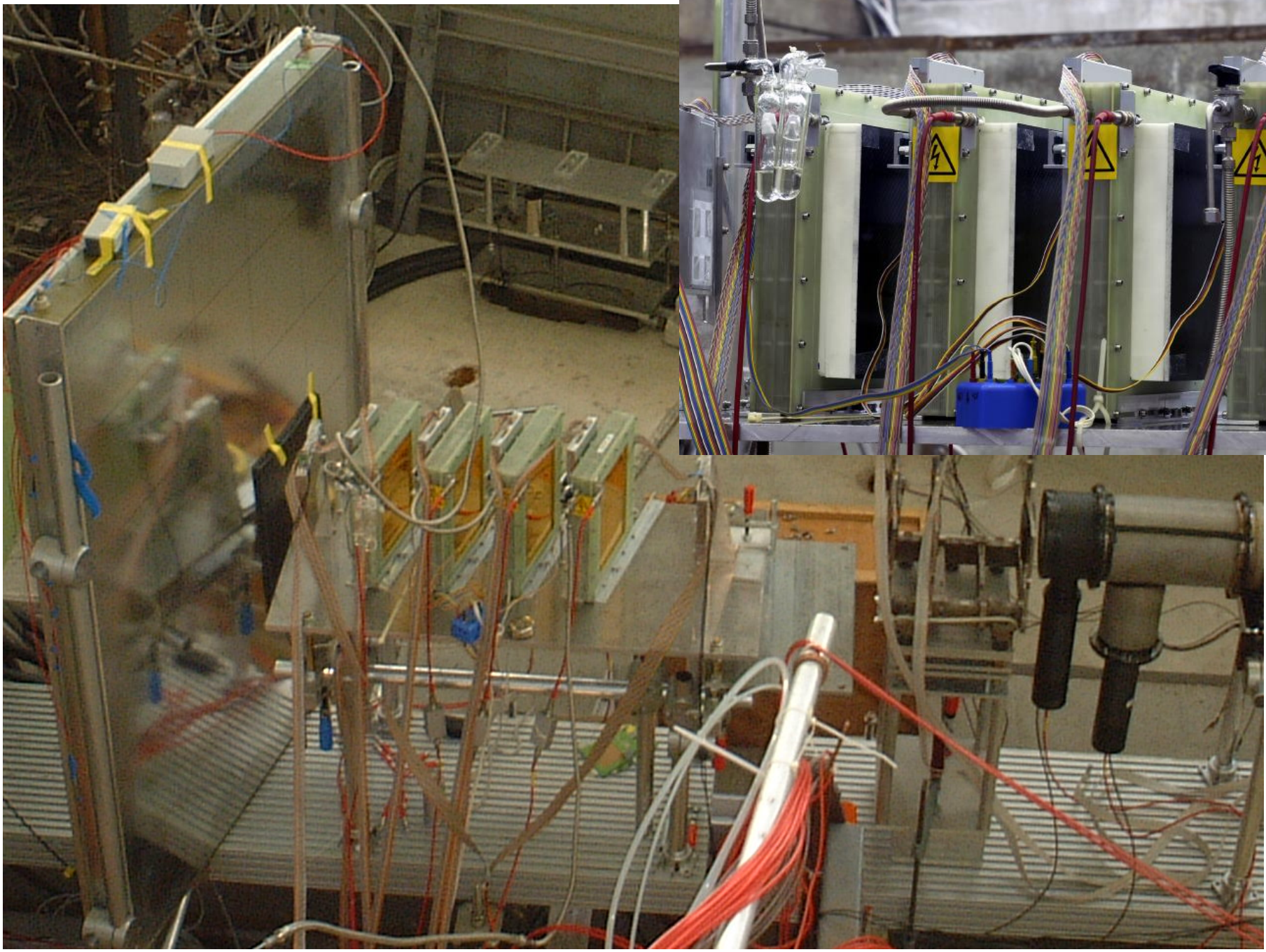


...in preparation for CERN PS (tested in particular that the Xe mixture is good:)

First measurements with PASA prototype (Hans-Christian, Ivan, Venelin, Mircea, Vasile)

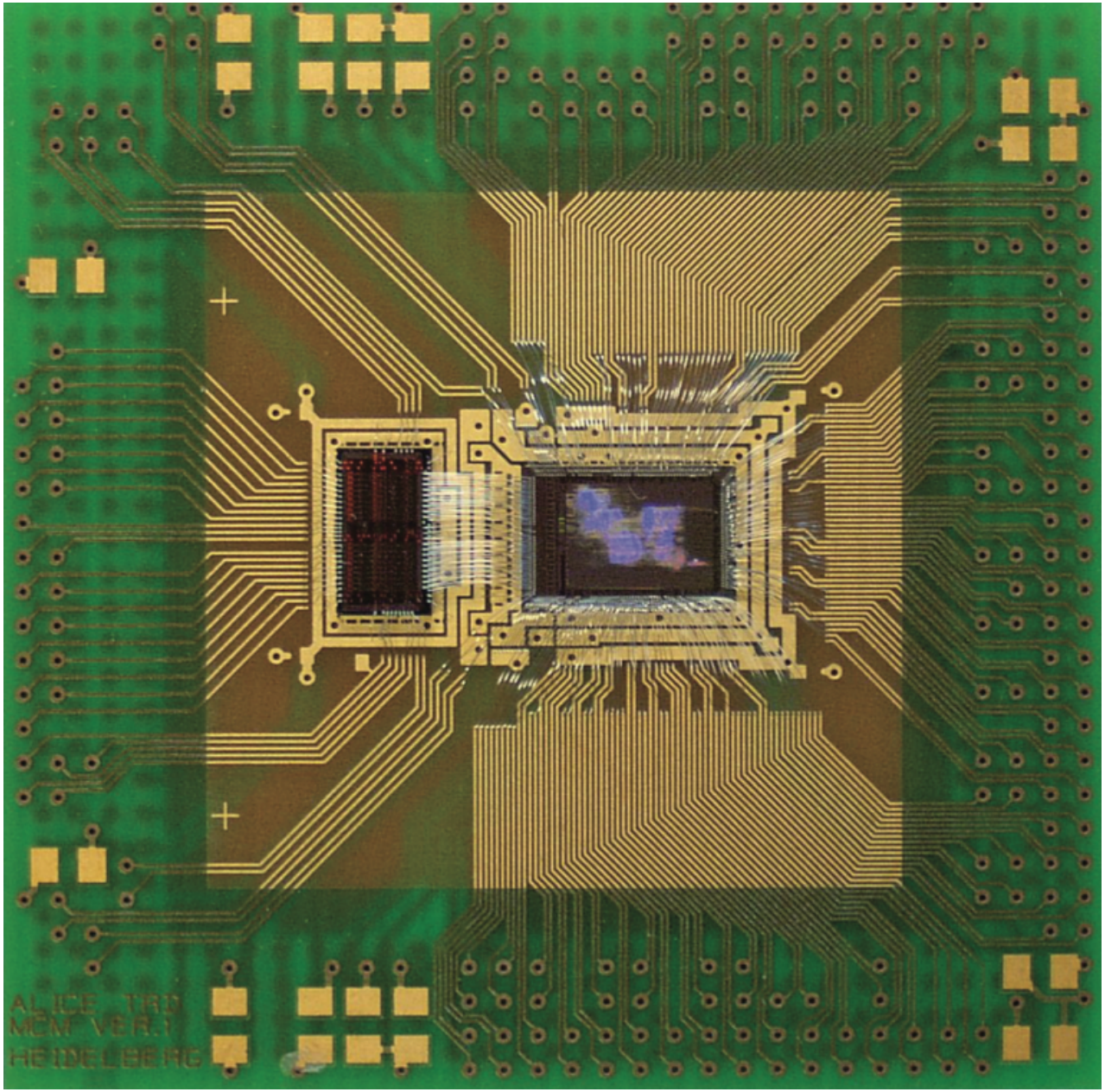
(Gen.4 PA ...after 2 I-sens PA, 1 Q-sens PASA w. discrete components)

Testbeam PS, 2002: first big chamber, final rad, TR, B-field



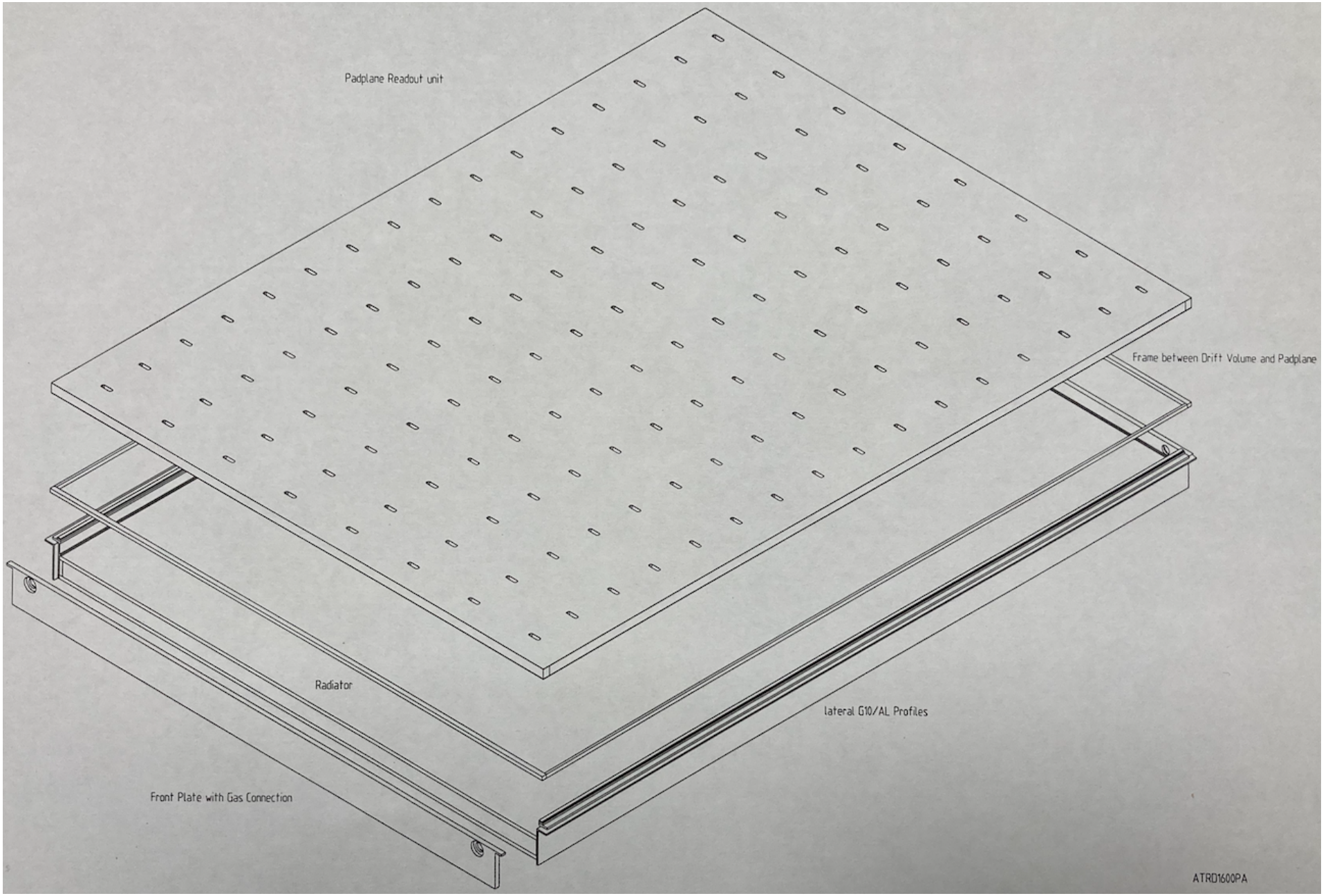
ALICE TRD: the MCM (PASA+ADC+TRAP)

A. Andronic

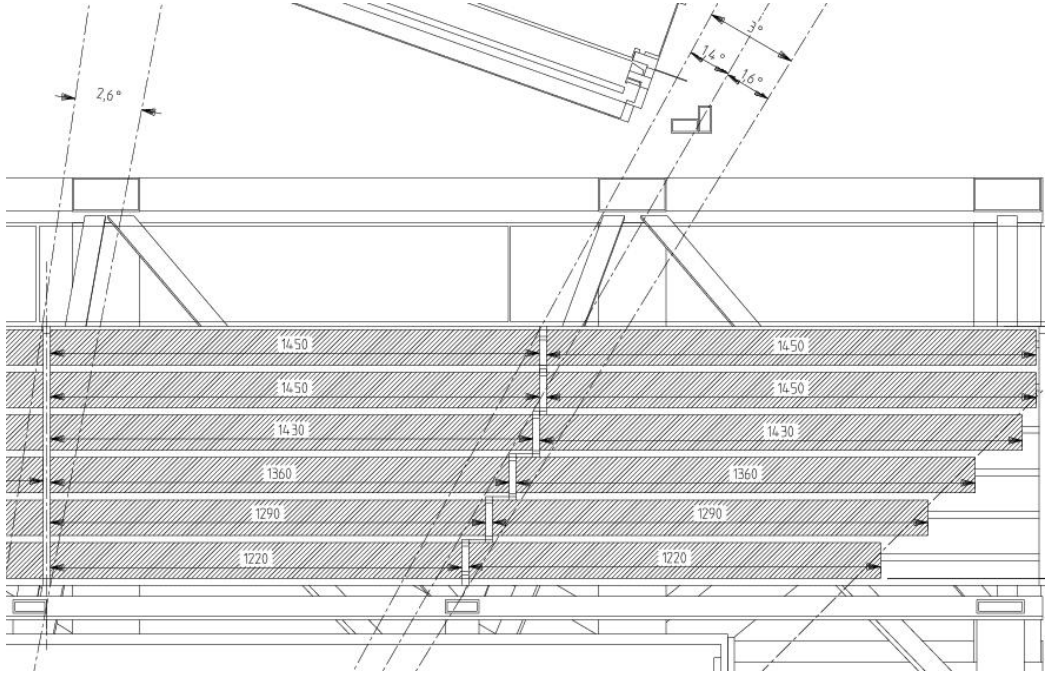


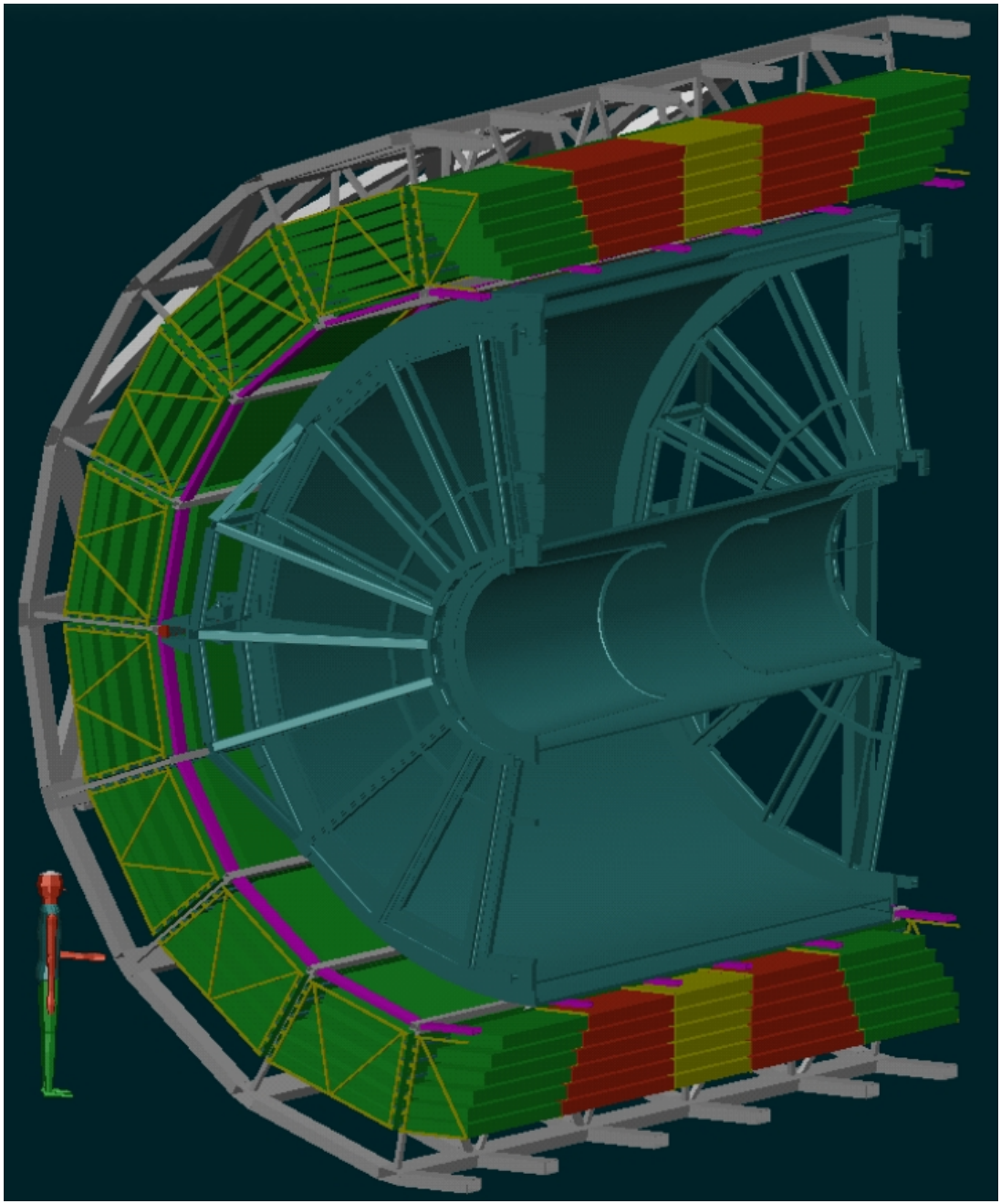
TRD: the chamber construction

A. Andronic

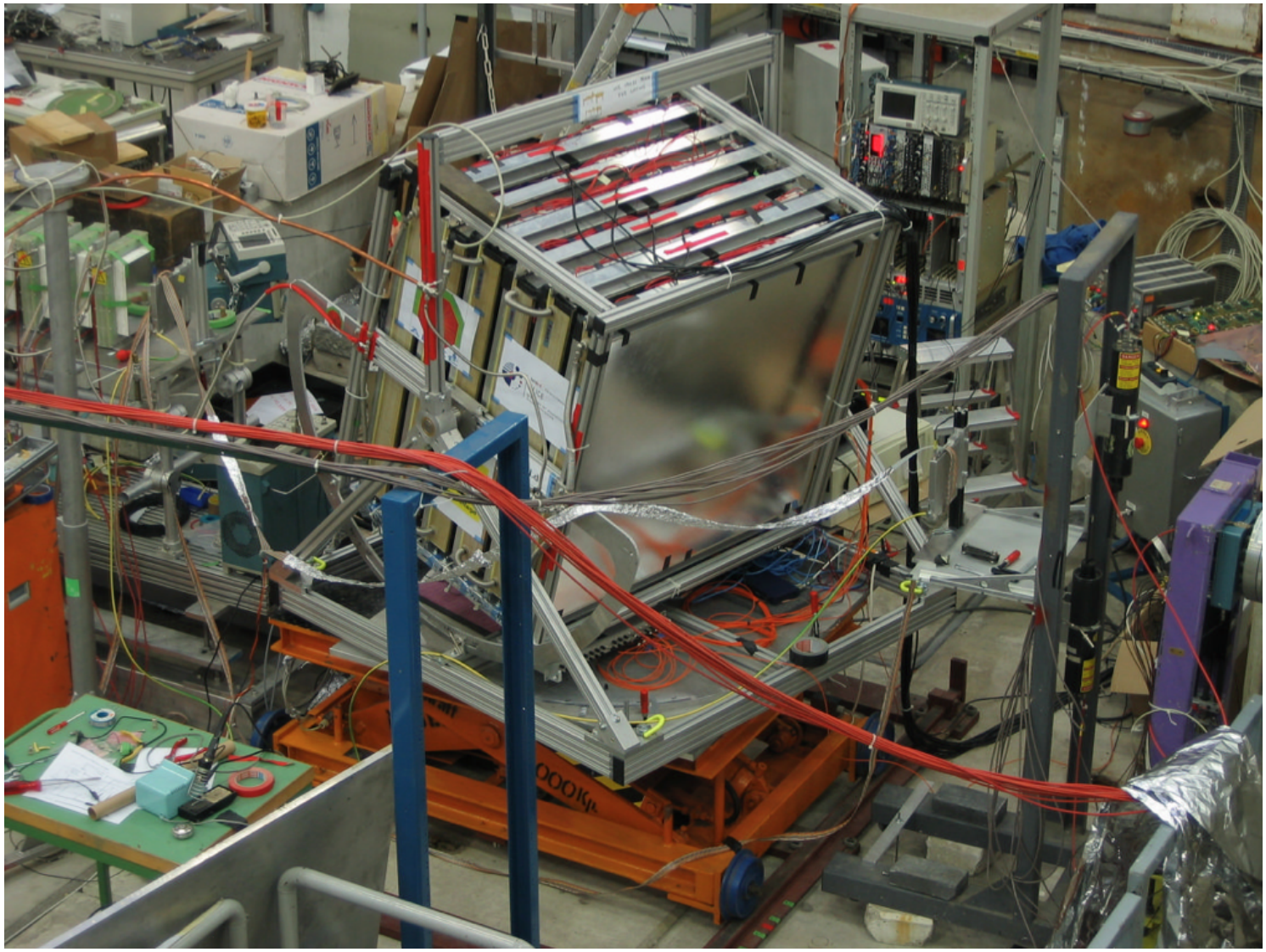


TRD: the final geometry





Testbeam PS, 2004: first stack (+TR, etc, 1 month beamtime!)

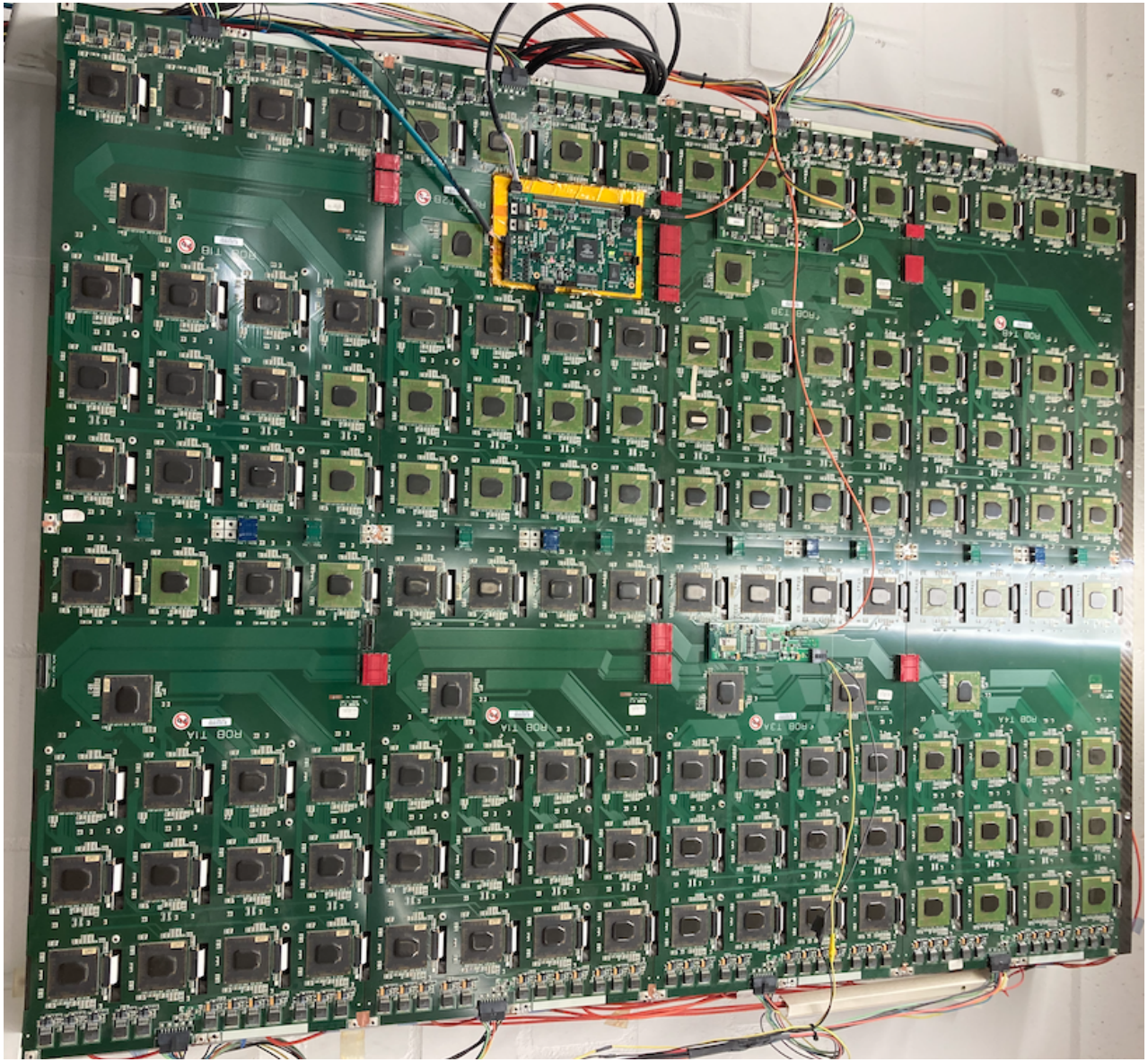


"David E.'s stack"; ...Raphaelle's Diploma (2005) ...+Christian L. (first postdoc to join me for data analysis:)

Chamber construction and tests: Bucharest, Dubna, Frankfurt, GSI, Heidelberg

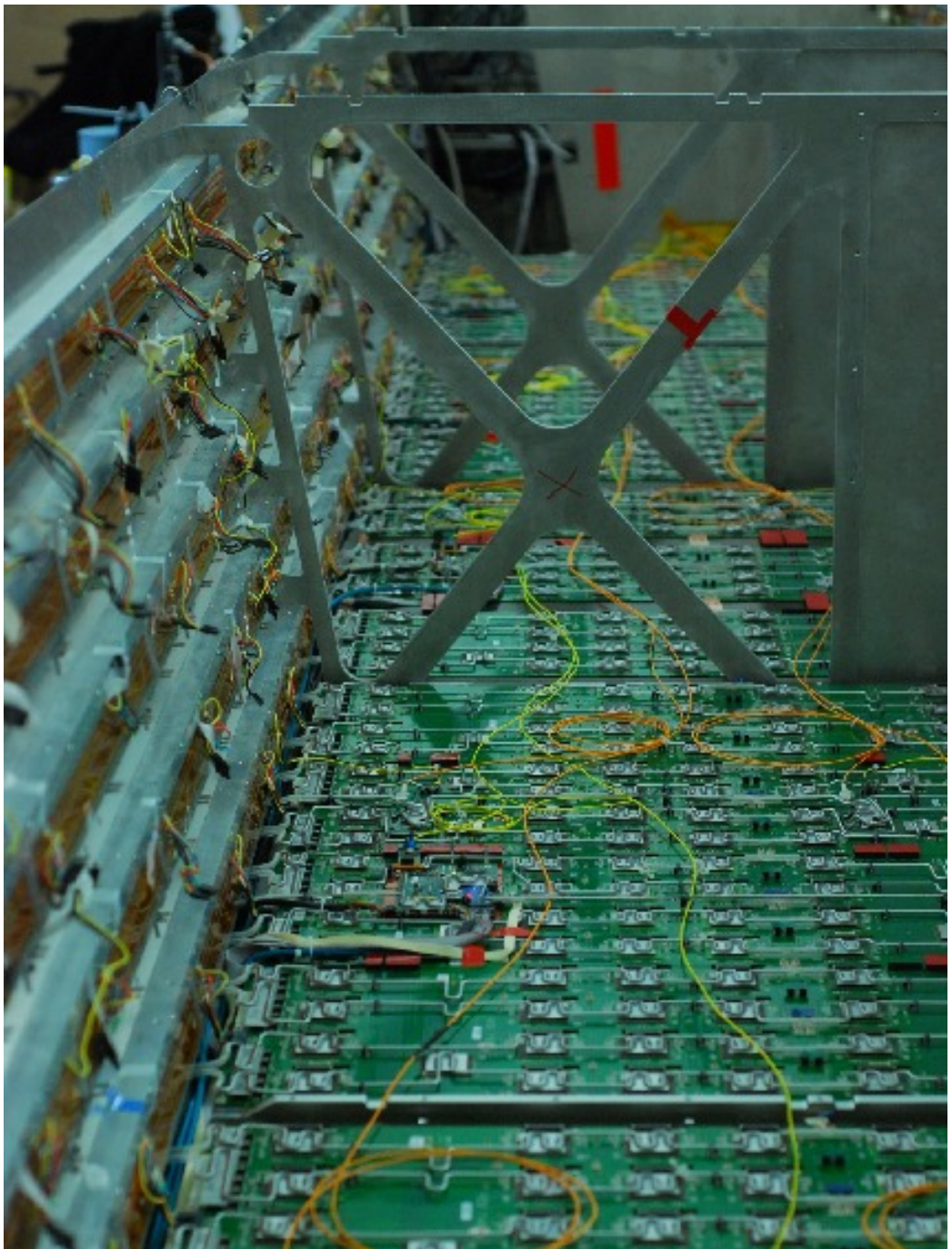
All components ordered at GSI and shipped to production sites

ALICE TRD: a chamber

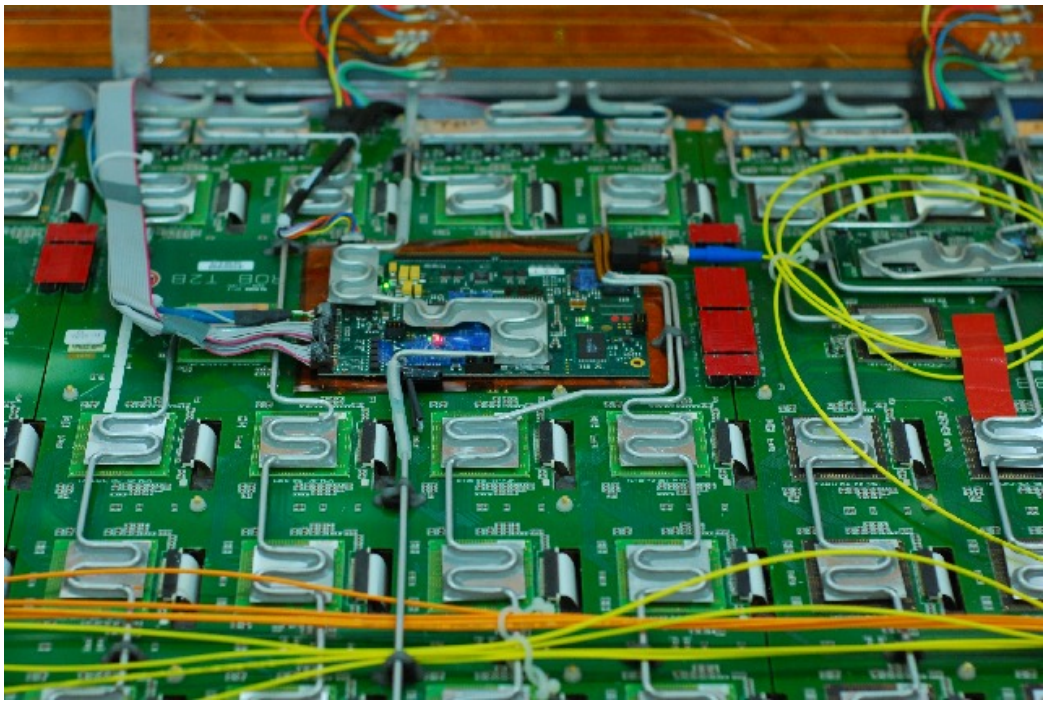


MCMs ship tracklets (position and charge deposits), to GTU for triggering (Runs 1,2) or CRU (Run 3), via ORIs all configured through the DCS board

ALICE TRD: the first supermodule (Heidelberg)



assembly movie



Chamber/SM readout tests established

Benjamin's Diploma (2007)

ALICE TRD: SM1 at P2, Oct. 2006



CDS

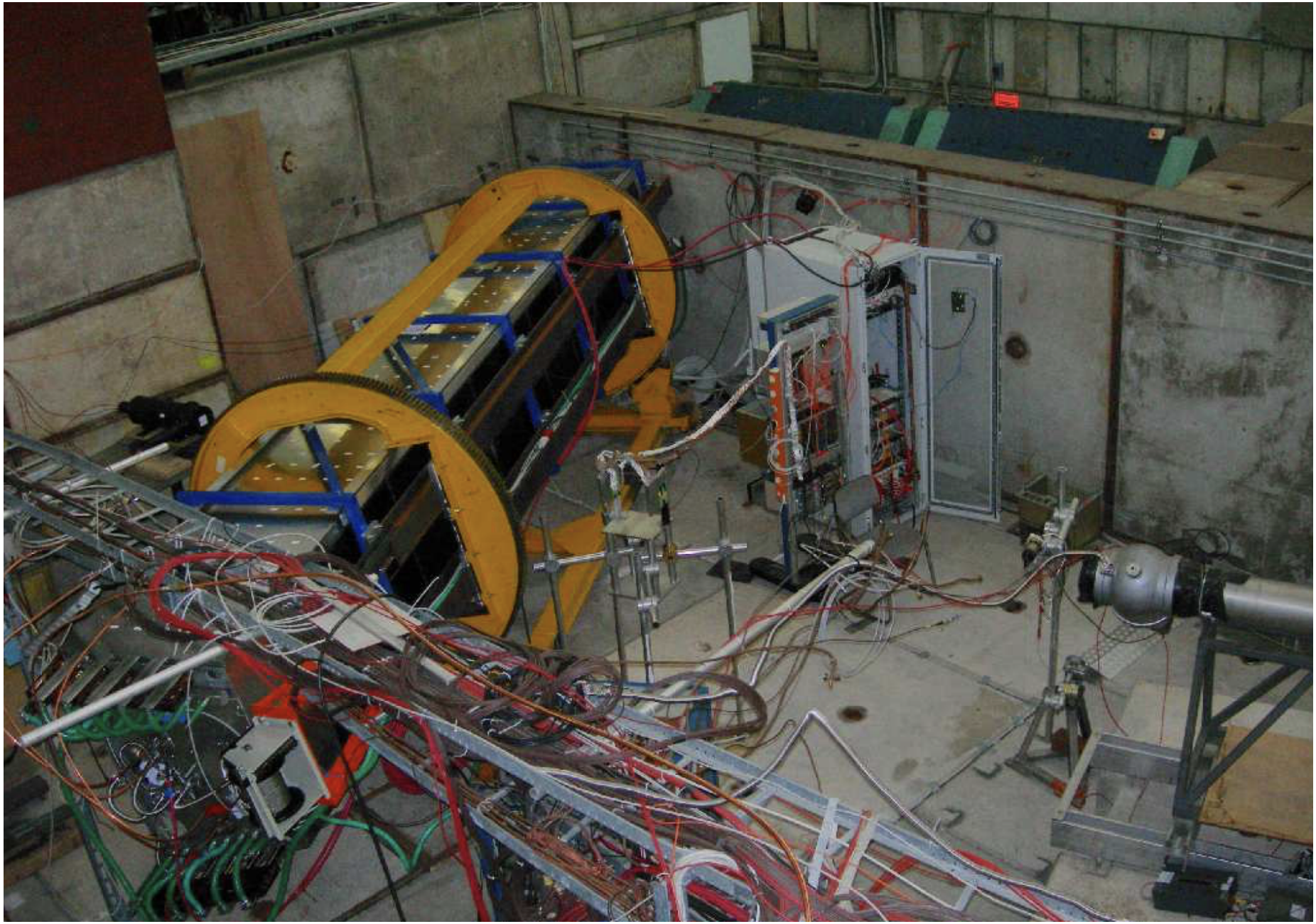
ALICE TRD: SM1 ...getting there, Oct. 2006



CDS

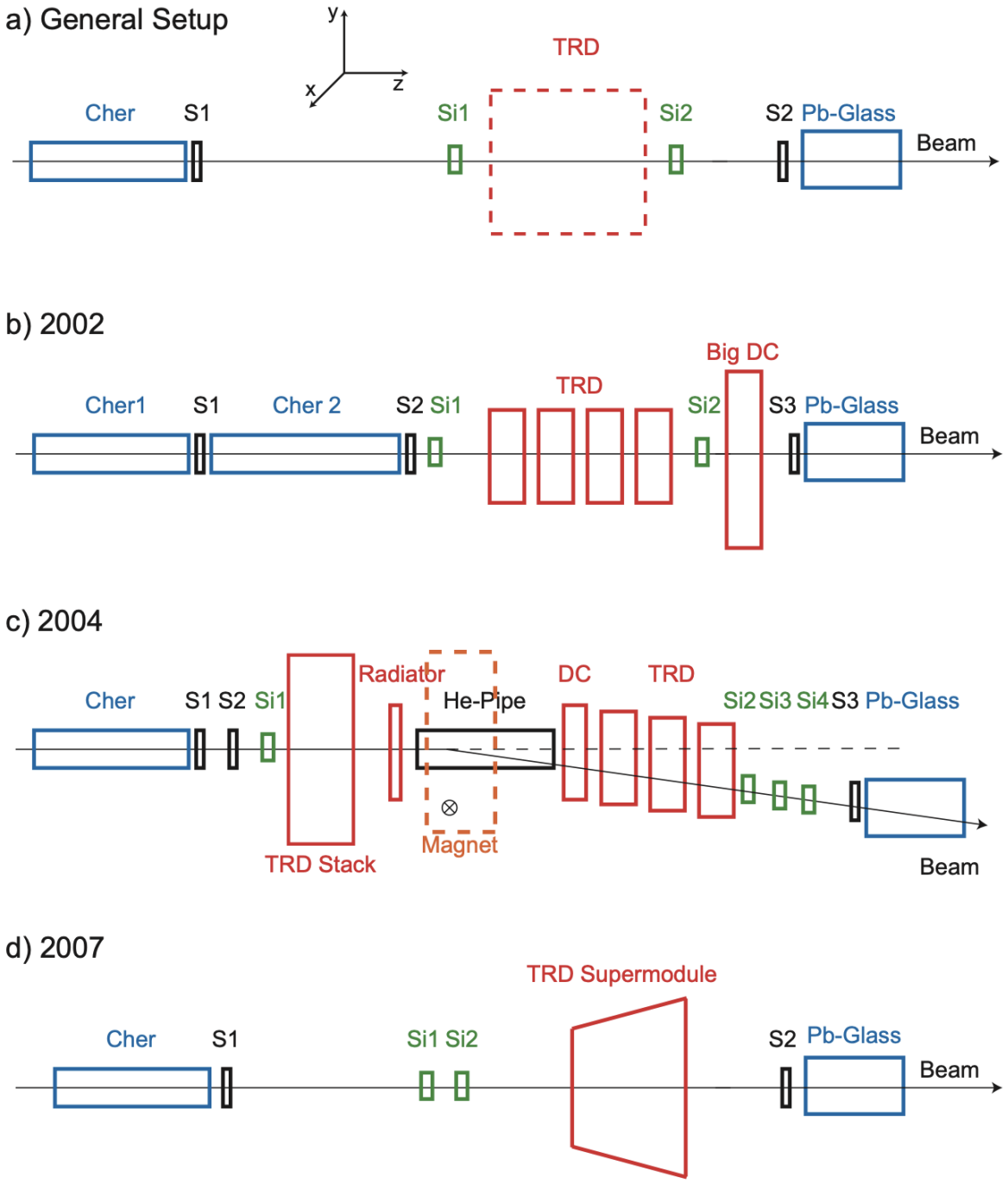
Next 17 SMs: Münster; "non-D" chambers collected first at GSI, to mount ROBs (1st transport from Dubna was special, radiator repairs needed to be done at GSI:)

ALICE TRD: SM3 at PS (T10), Nov. 2007



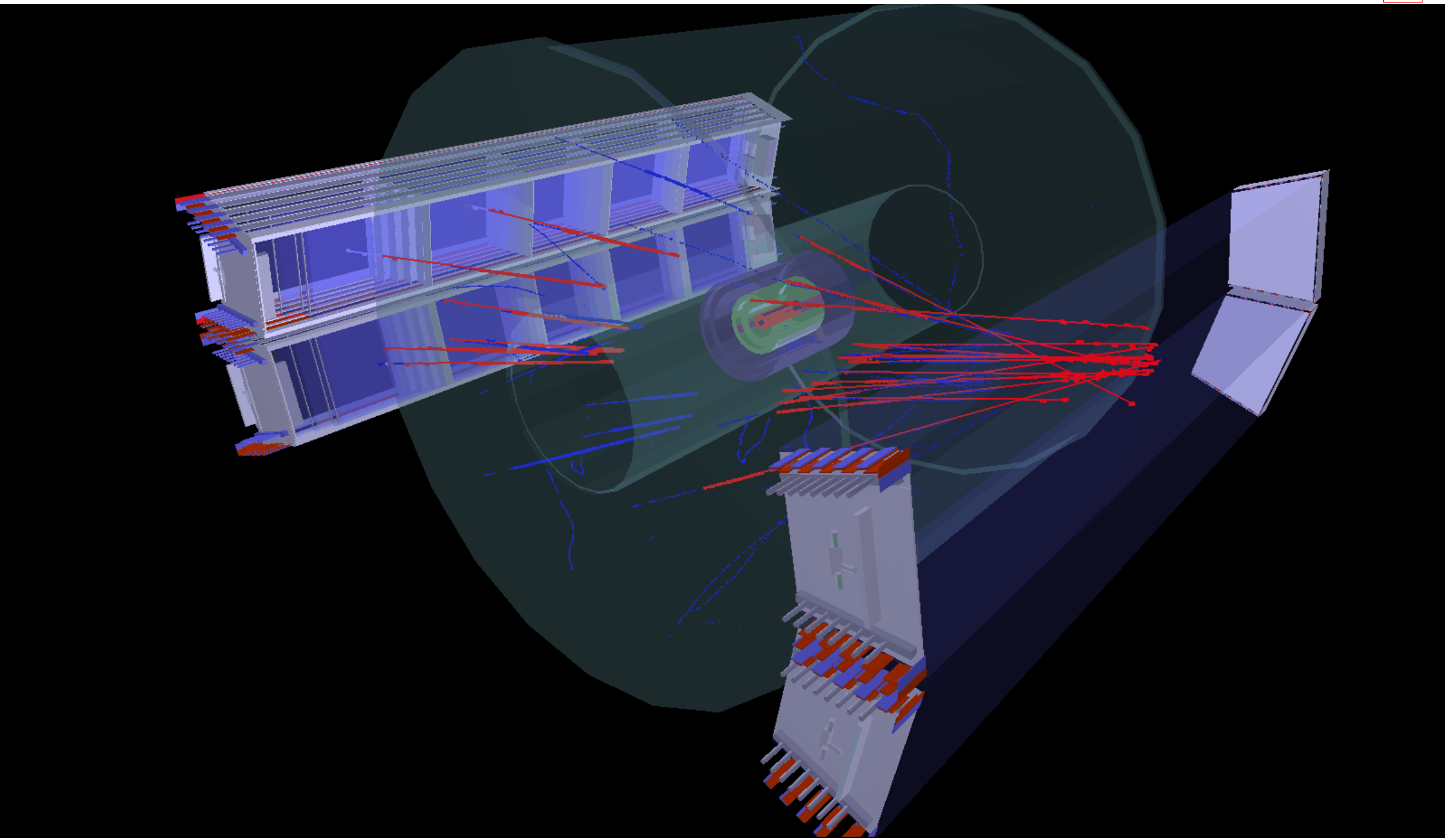
ALICE TRD: setups beamtimes PS

A. Andronic



PhD A. Wilk (2010)

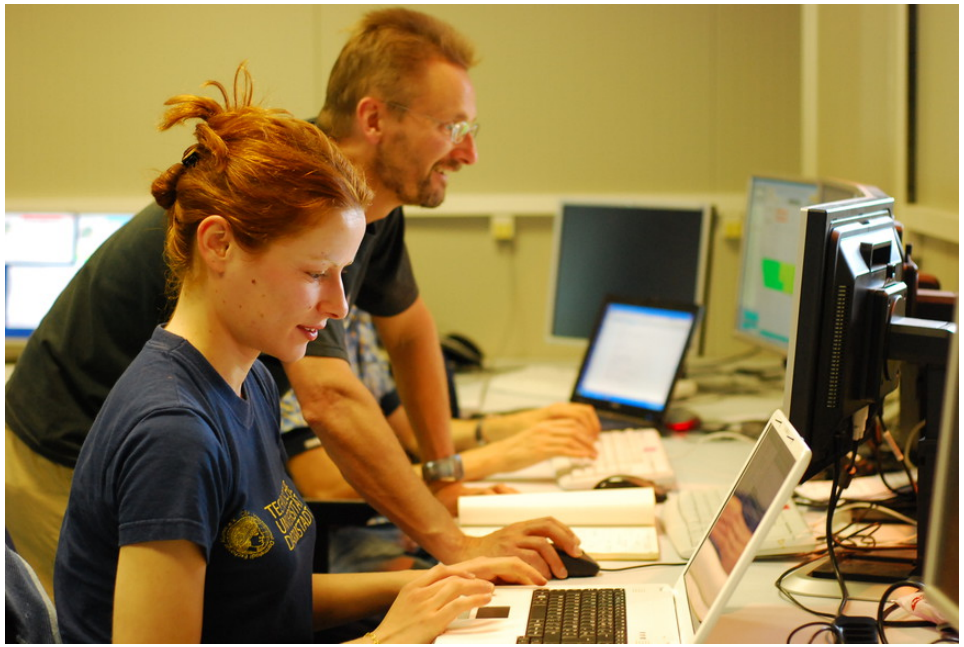
ALICE TRD: first tracks in situ, 2007



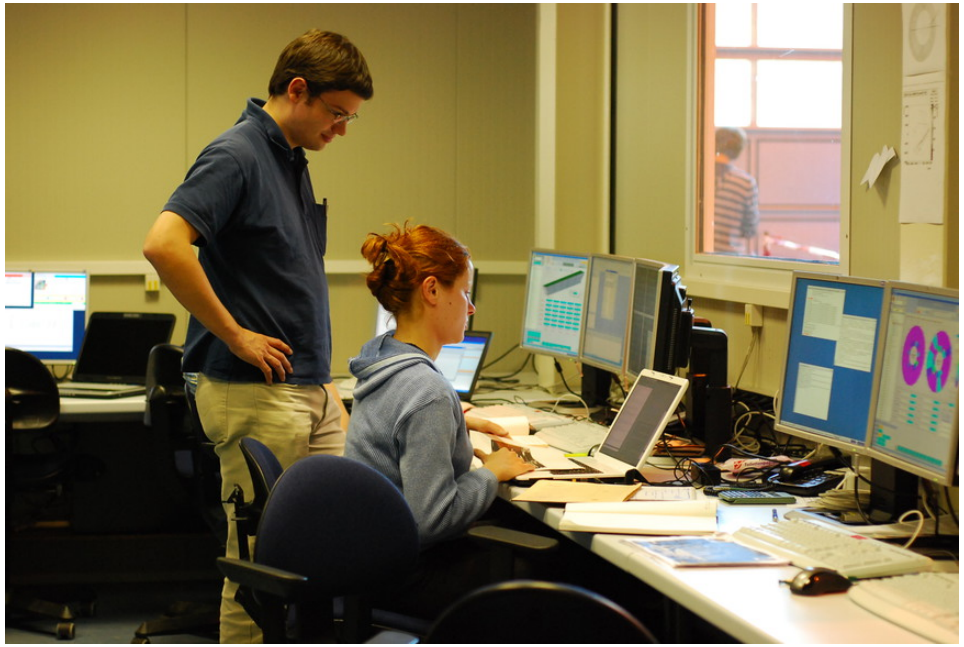
Reconstruction: Alexandru, Markus F. (Diploma), Marian

First LHC beams: Sunday, Aug.24, 2008









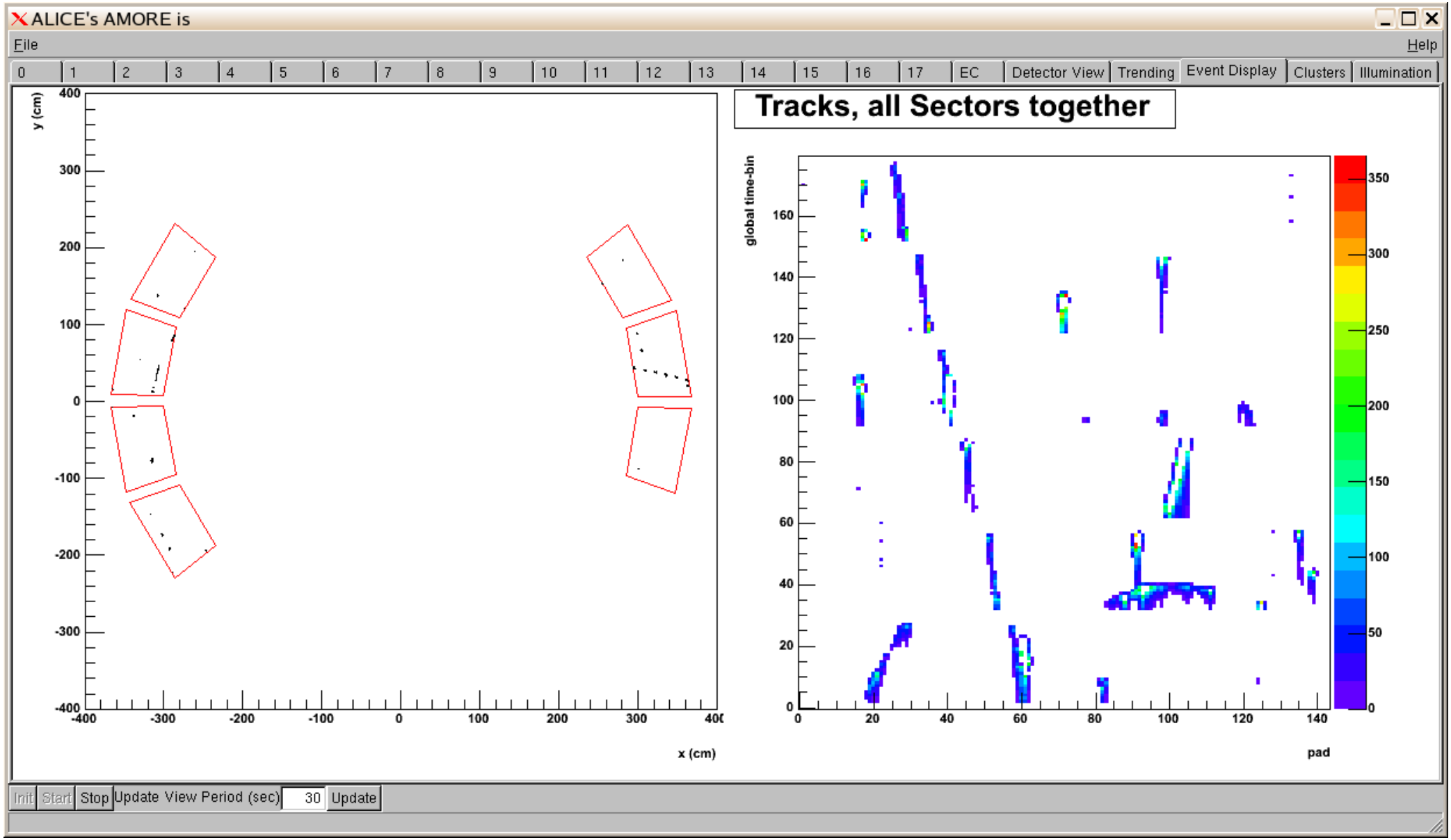
ALICE TRD, GSI gallery

ALICE TRD: chambers completed, Dec. 2008

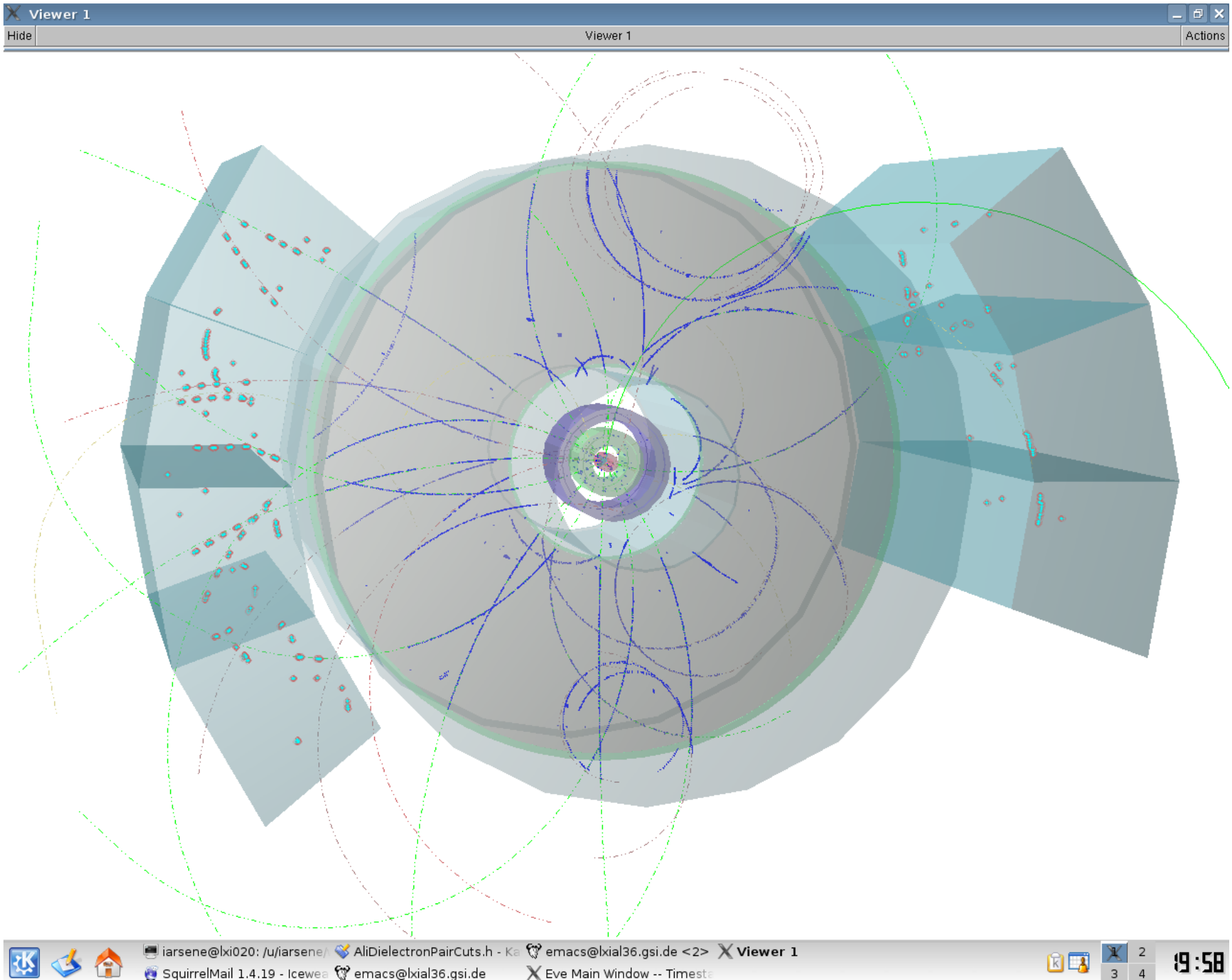


TRD: first collision tracks (Sun, 6 Dec 2009 08:53)

A. Andronic

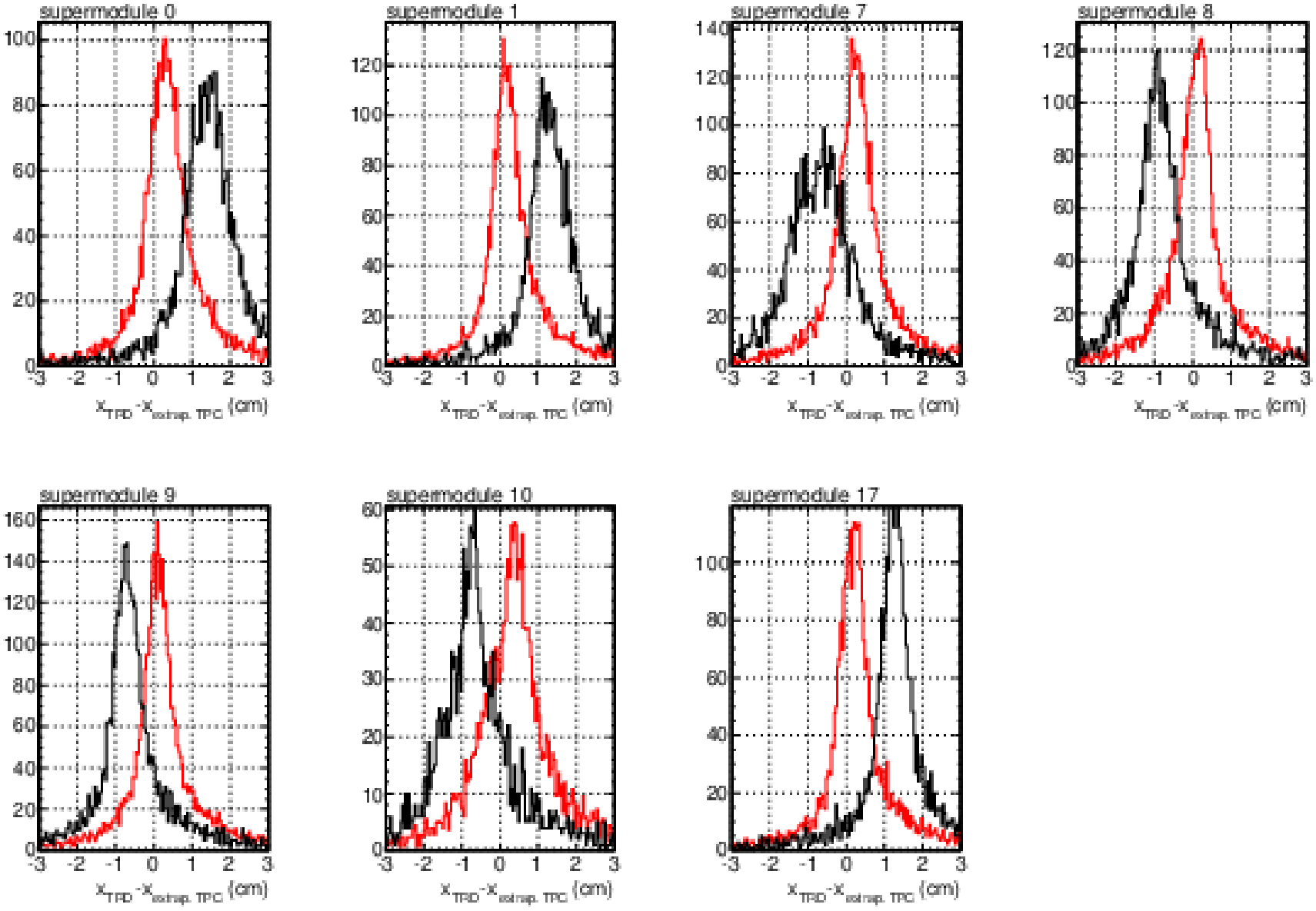


ALICE: Dec. 2009 tracks



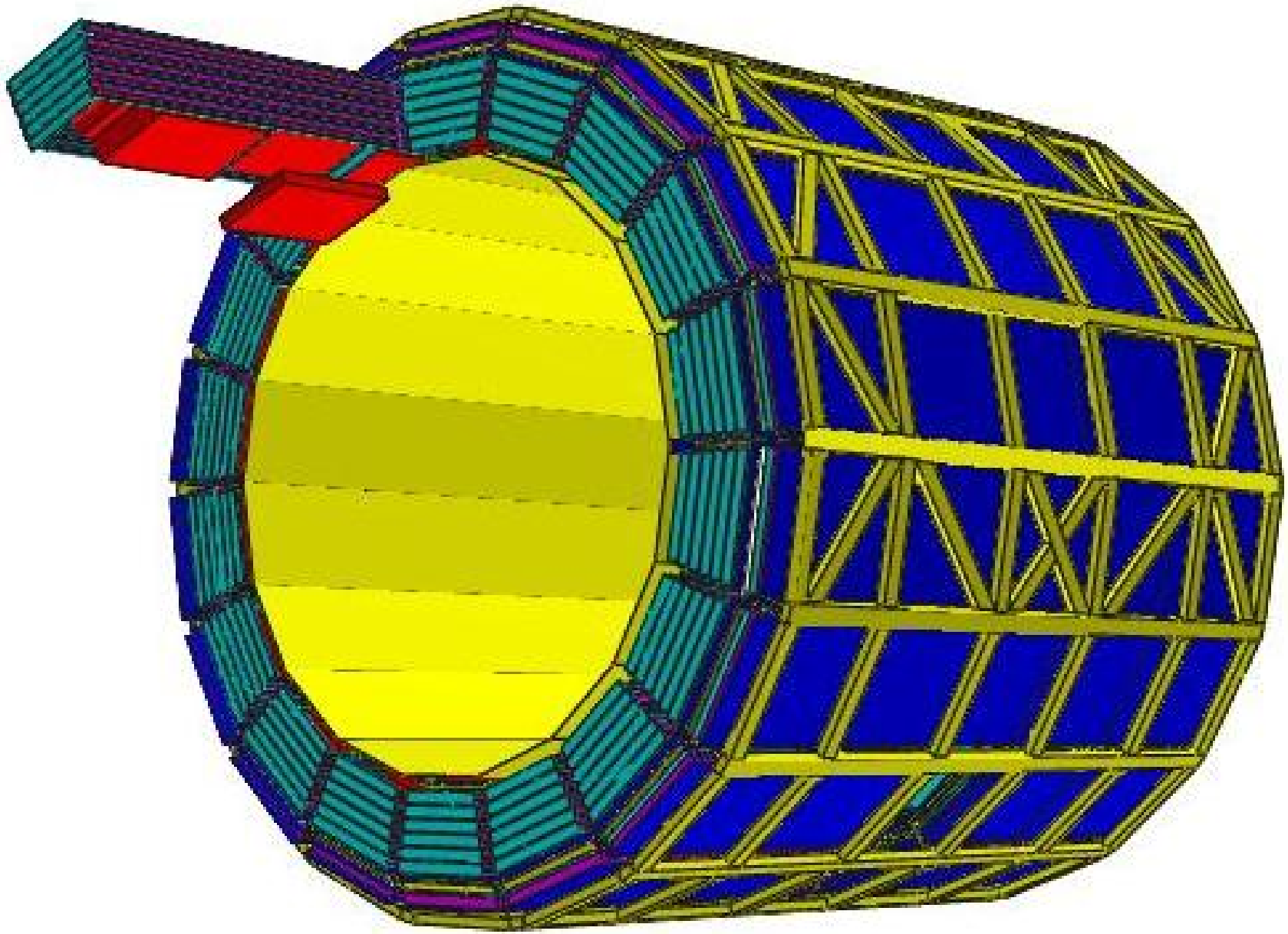
ALICE TRD in beams: alignment

A. Andronic

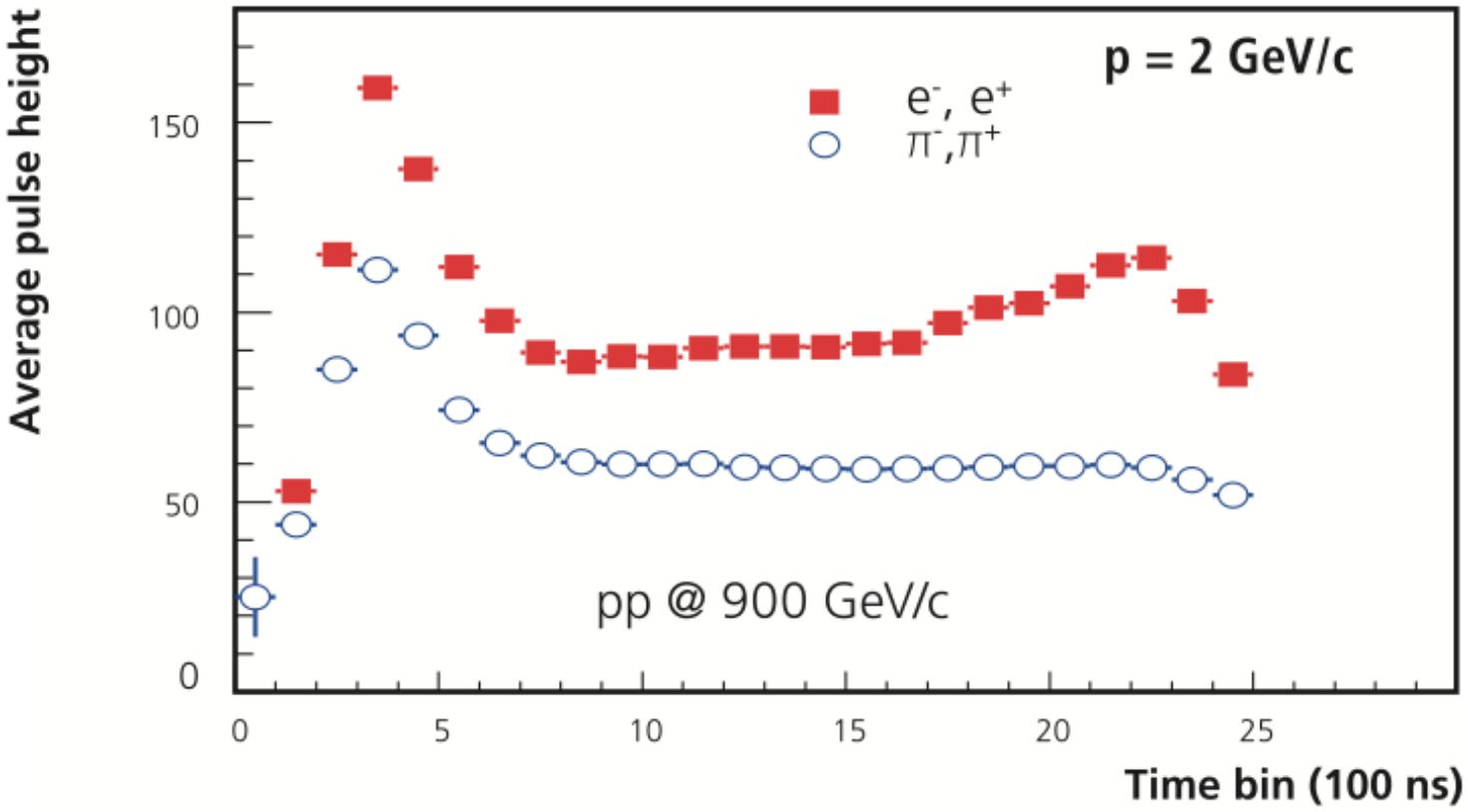


(Filname: `darek_align.eps` :)

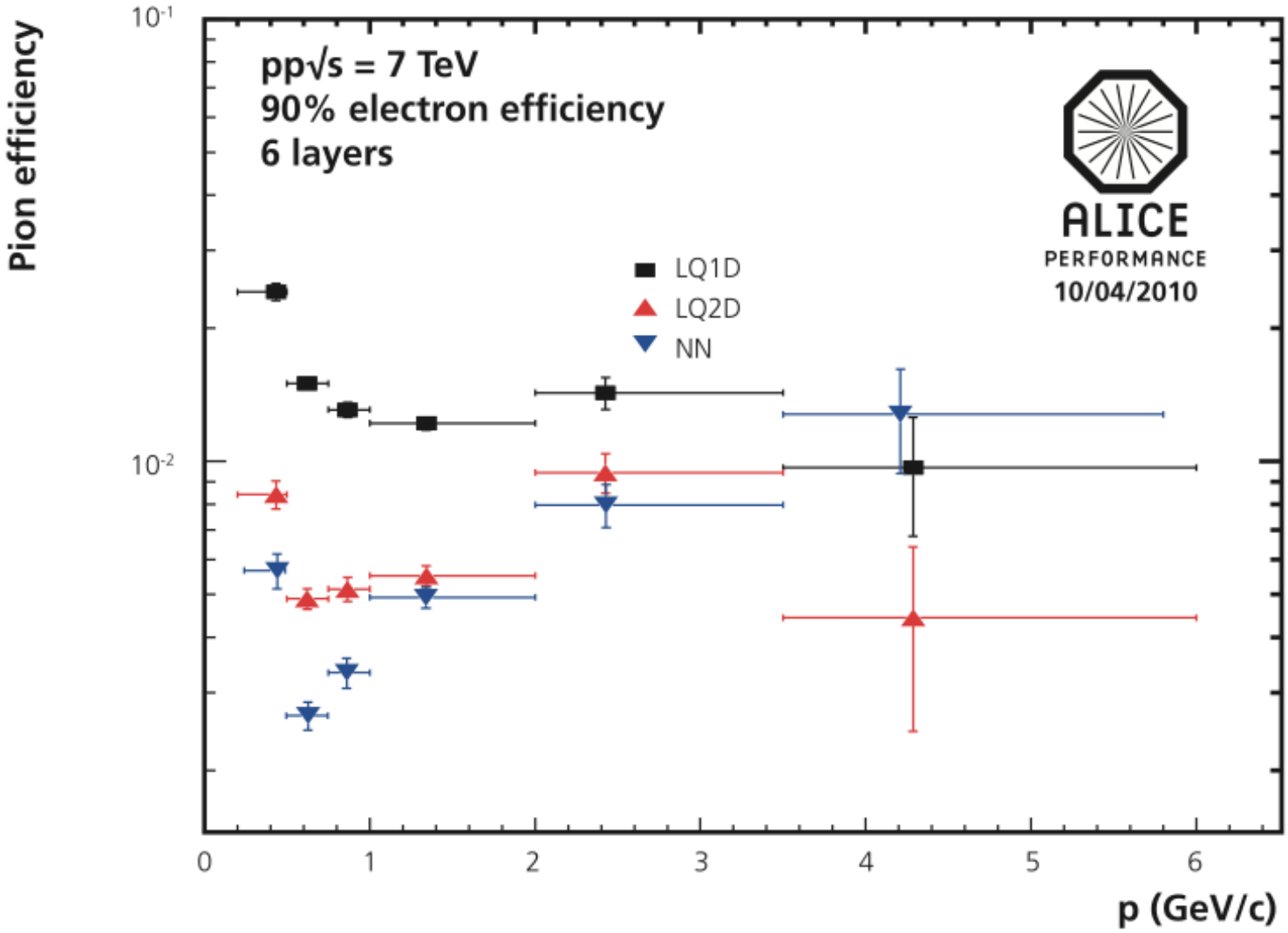
ALICE TRD: alignable objects



ALICE TRD: first collisions, PH

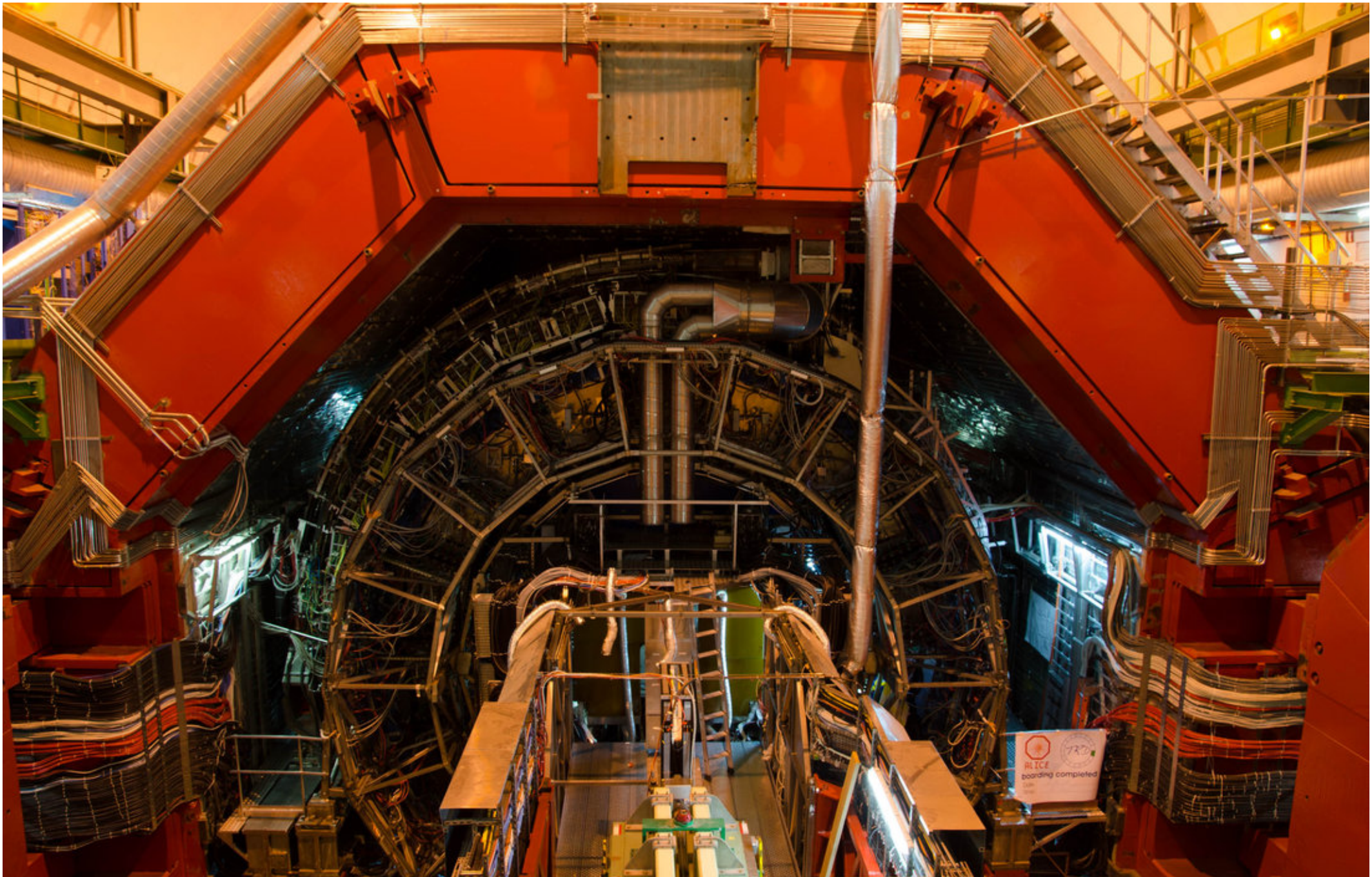


ALICE TRD: first collisions, PID



CDS

ALICE TRD completed: nov. 2014



ALICE TRD completed: nov. 2014



full gallery (GSI)

ALICE TRD: completion party, Münster, Apr. 2015

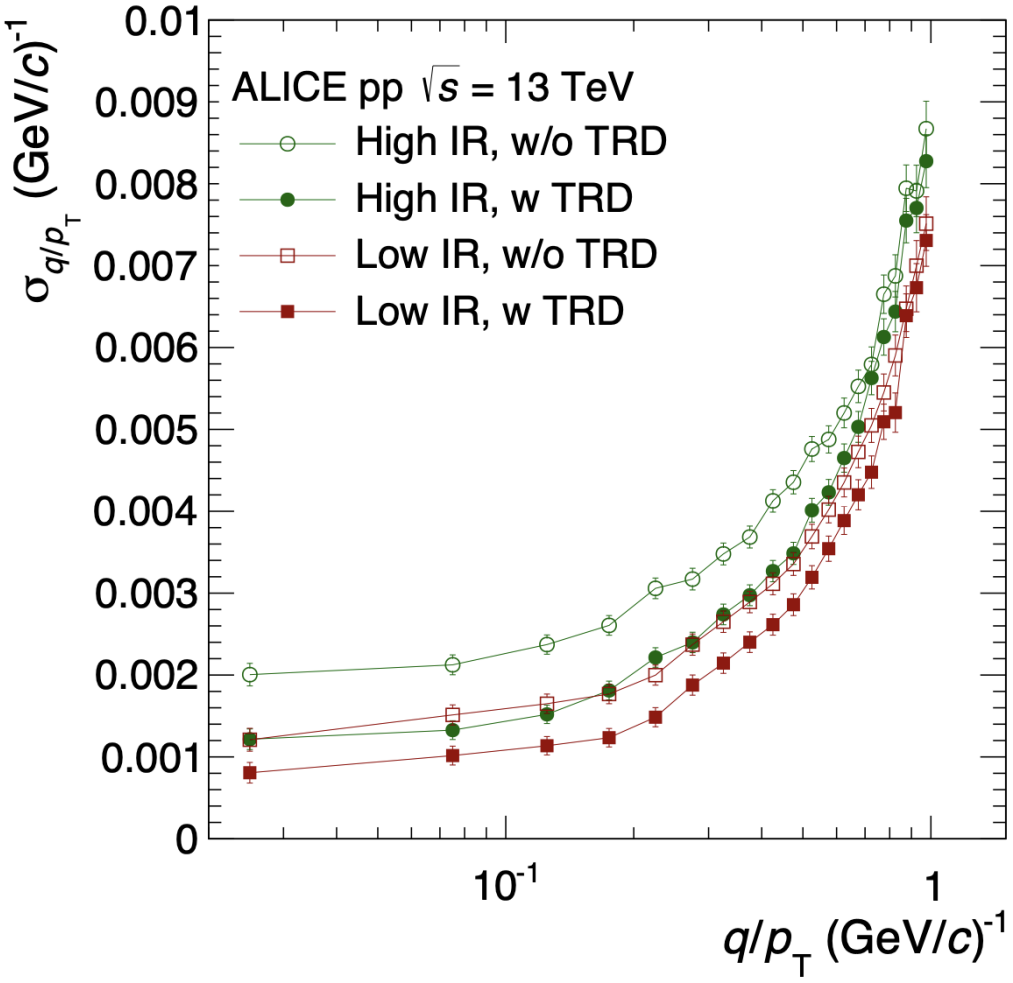


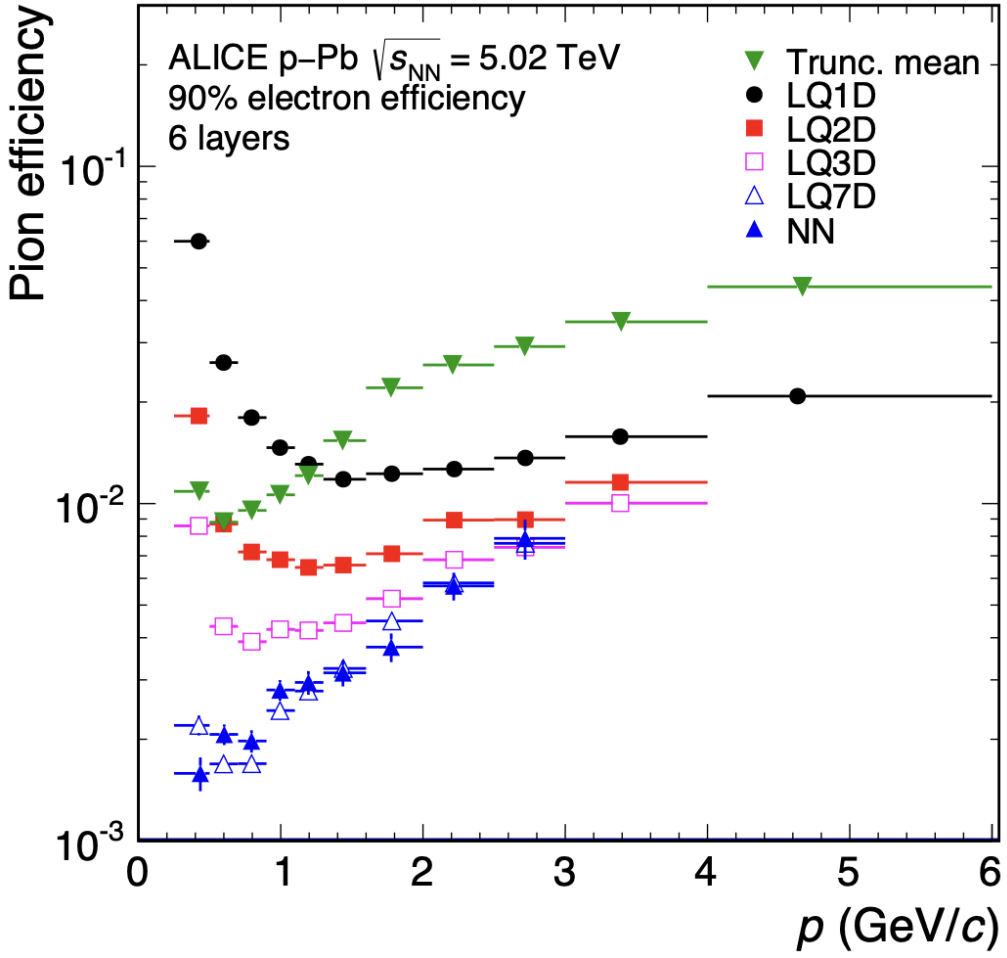






ALICE TRD: performance in Run 2





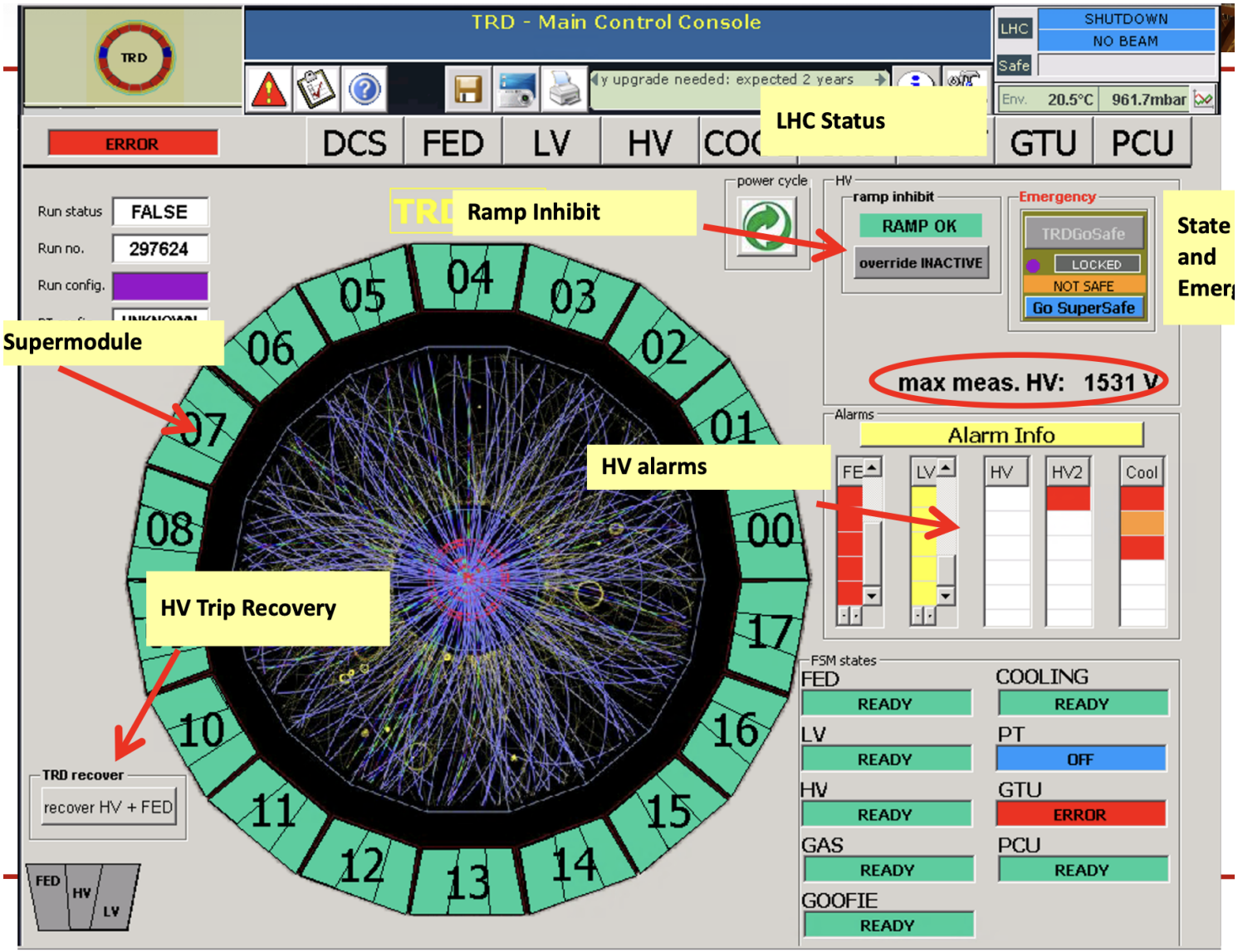
Design performance achieved (surpassed)

ALICE TRD: removal of faulty capacitors, 2018 (9 SMs)





DCS and readout renewed in LS2

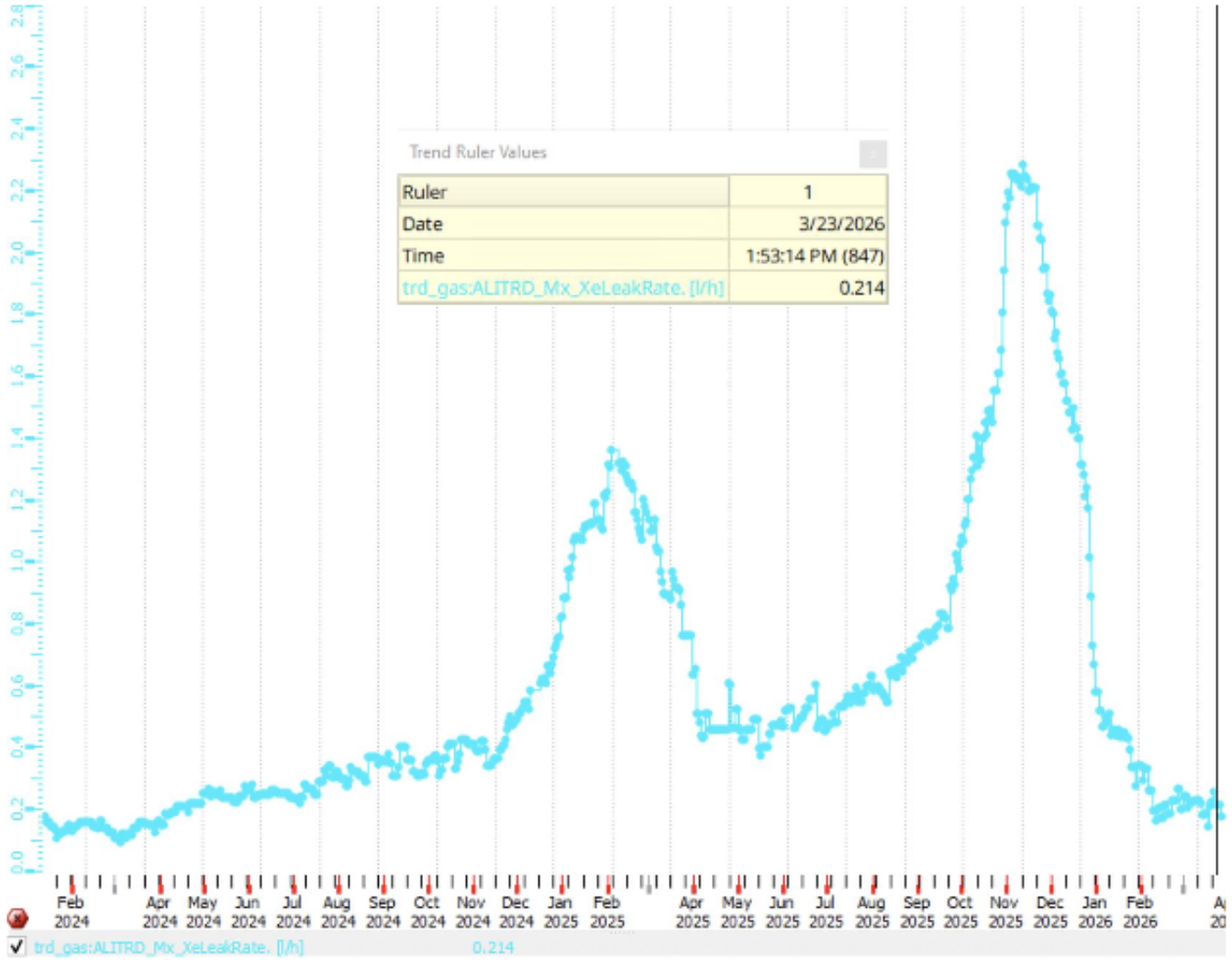


Exploiting the TRD data in global reconstruction: an effort for the next 3 years

ALICE TRD: not all is always smooth

Finally back to 0.2 l/h!

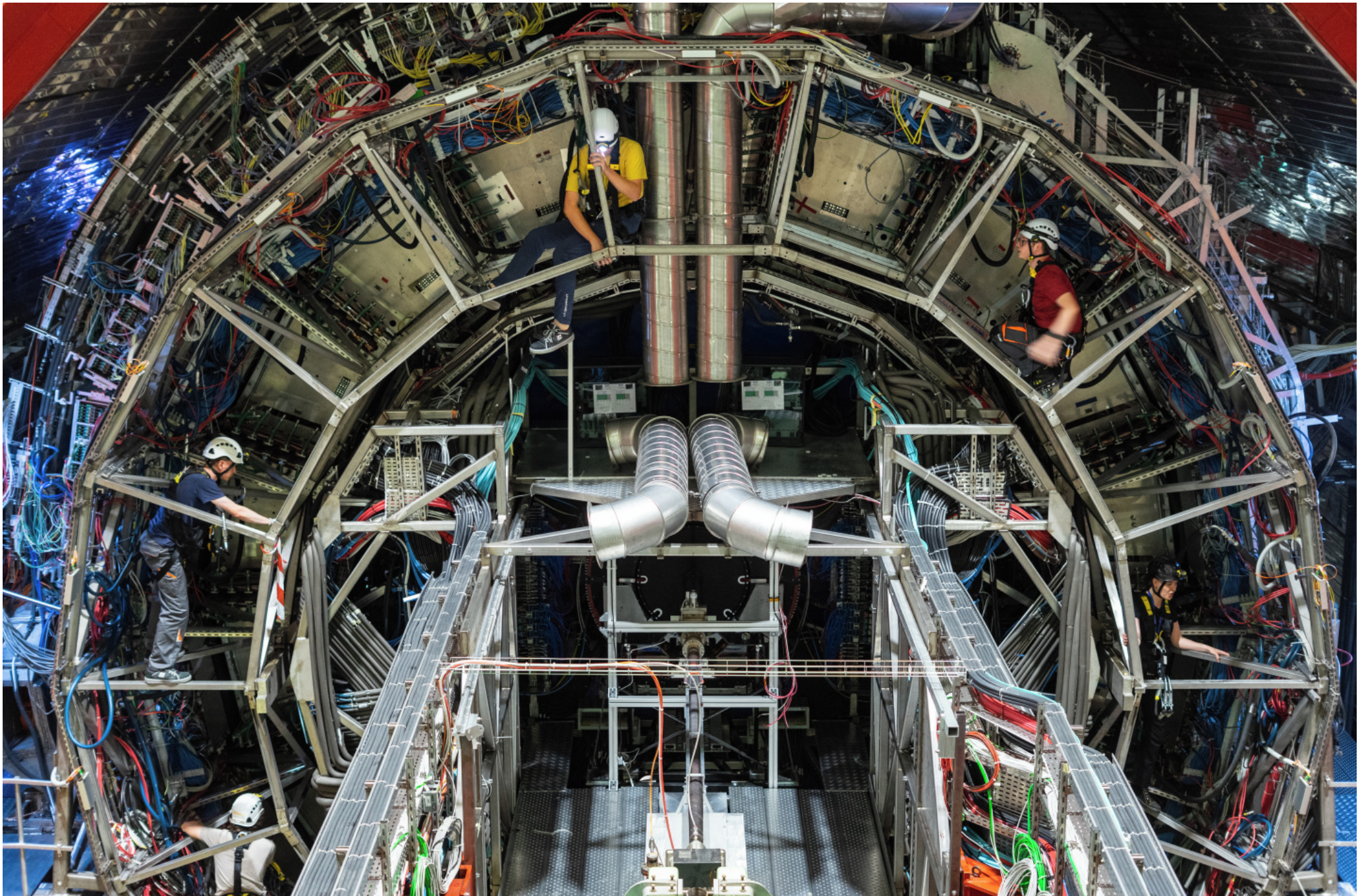
Xenon will last till end of run



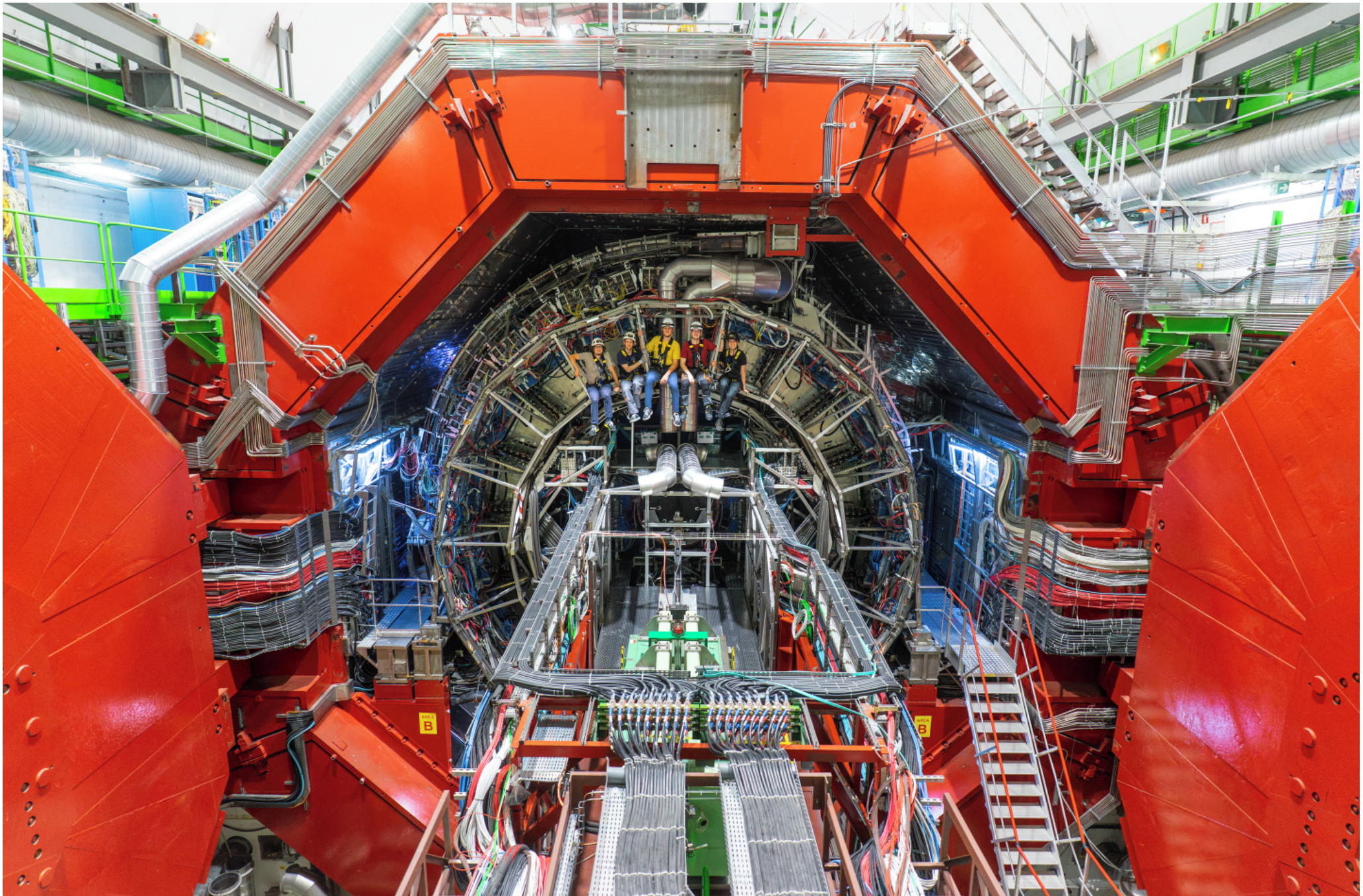
30.03.26 I live in a world of leaks

(guess who is the stoic author?:)

ALICE TRD: disconnected, Aug. 2026



ALICE TRD: ready to extract SMs (Jan-Mar 2027)



ALICE TRD: instrumentation papers

- *Prototype tests for the ALICE TRD*
  IEEE Trans. Nucl. Sci. 48 (2001) 1259 [arXiv:nucl-ex/0102017]
- *Pulse height measurements and electron attachment in drift chambers operated with Xe,CO_2 mixtures*
  Nucl. Instr. Meth. A 498 (2003) 143 [arXiv:physics/0303059]
- *Energy loss of pions and electrons of 1 to 6 GeV/c in drift chambers operated with Xe,CO_2(15%)*
  Nucl. Instrum. Meth. A 519 (2004) 508 [arXiv:physics/0310122]
- *Space charge in drift chambers operated with the Xe,CO2(15%) mixture*
  Nucl. Instrum. Meth. A 525 (2004) 447 [arXiv:physics/0402043]
- *Position reconstruction in drift chambers operated with Xe,CO_2(15%)*
  Nucl. Instrum. Meth. A 540 (2005) 140 [arXiv:physics/0511233]
- *Electron/pion identification with ALICE TRD prototypes using a neural network algorithm*
  Nucl. Instrum. Meth. A 552 (2005) 364 [arXiv:physics/0506202]
- *Transition radiation spectra of electrons from 1 to 10 GeV/c in regular and irregular radiators*
  Nucl. Instrum. Meth. A 558 (2006) 516 [arXiv:physics/0511229]
- *The ALICE Transition Radiation Detector: construction, operation, and performance*
  Nucl. Instr. Meth. A 881 (2018) 88, [arXiv:1709.02743]

ALICE TRD: physics papers

...a selection, trigger-oriented (mostly)

- *Multiplicity dependence of prompt and non-prompt J/ψ production at midrapidity in pp collisions at $\sqrt{s} = 13$ TeV*
  JHEP 07 (2026) 051 [arXiv:2604.07968]
- *Wave-Function Femtometry: Hypertriton - The Ultimate Halo Nucleus*
  [arXiv:2604.07949]
- *Inclusive $\psi(2S)$ production at midrapidity in pp collisions at $\sqrt{s} = 13$ TeV*
  [arXiv:2602.22848]
- *Measurement of anti-$^3\mathrm{He}$ nuclei absorption in matter and impact on their propagation in the Galaxy*
  Nature Phys. 19 (2023) 61 [arXiv:2202.01549] ...TRD as absorber
- *Measurement of electrons from semileptonic heavy-flavour hadron decays in pp collisions at $\sqrt{s} = 7$ TeV*
  Phys. Rev. D 86 (2012) 112007 [arXiv:1205.5423]

Many thanks!

...to all contributing along the journey, doing:

- Prototypes and their beamtests (detectors, electronics, radiators, gas system)
- Design and construction of: chambers, radiators, FEE and readout, trigger, gas system, cooling, DCS
- Mounting in ALICE (inserting, cabling, testing)
- Simulations and reconstruction; detector performance
- Readout, trigger, and DCS (LV,HV; gas system and cooling) over so many shifts
- Calibration (t0, gain, vdrift) with MC, cosmics, collisions, and Kr
- Physics

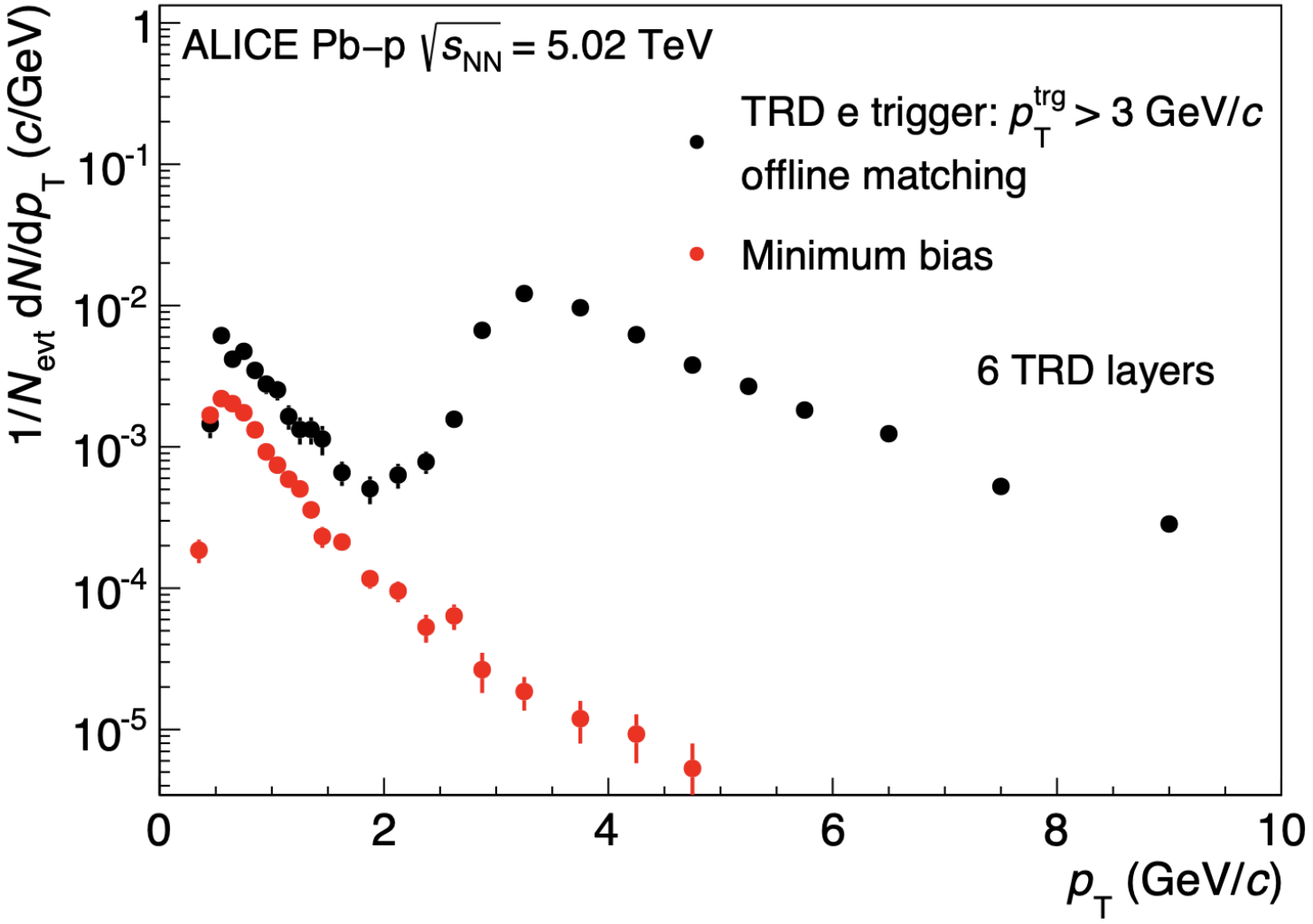
A great journey it was! ...with great team work:

Bucharest-Dubna-Frankfurt-GSI-Heidelberg-Köln-Münster-Worms

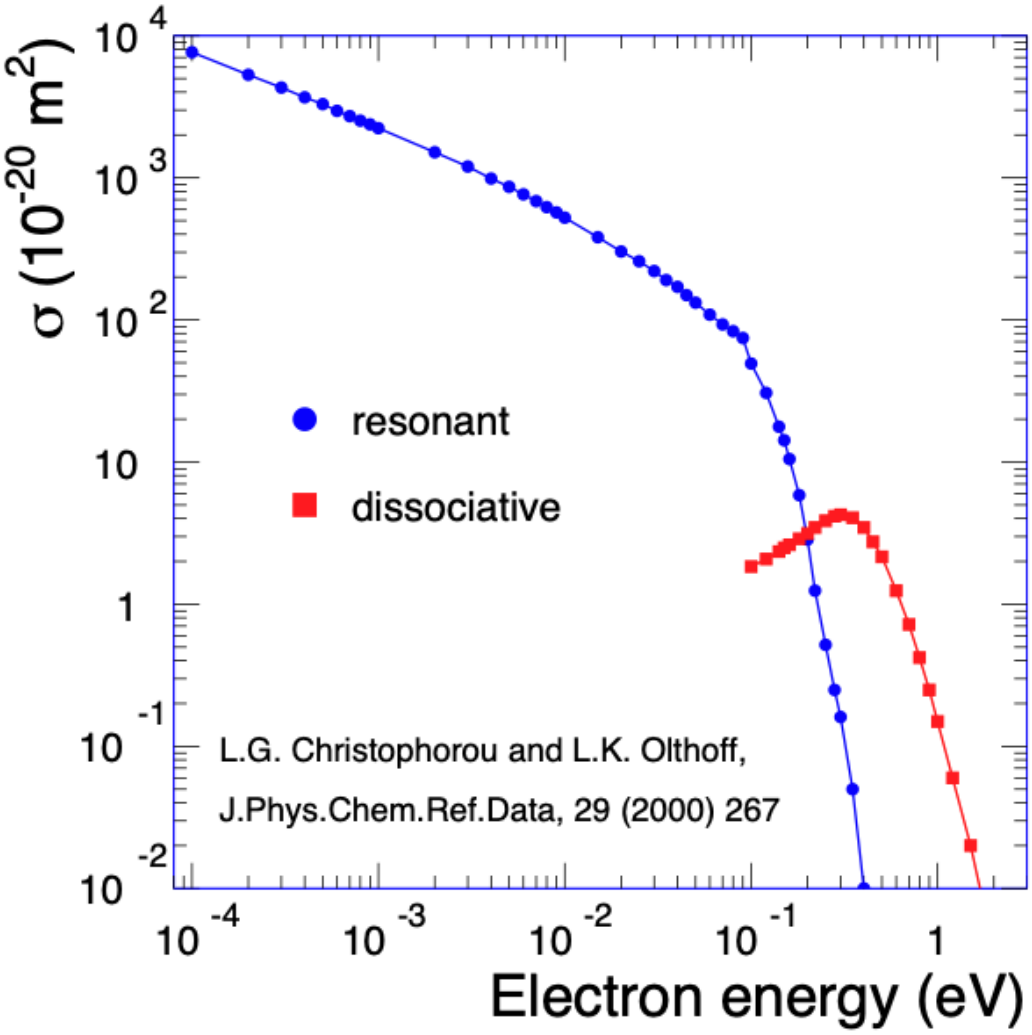
see all our publications and theses

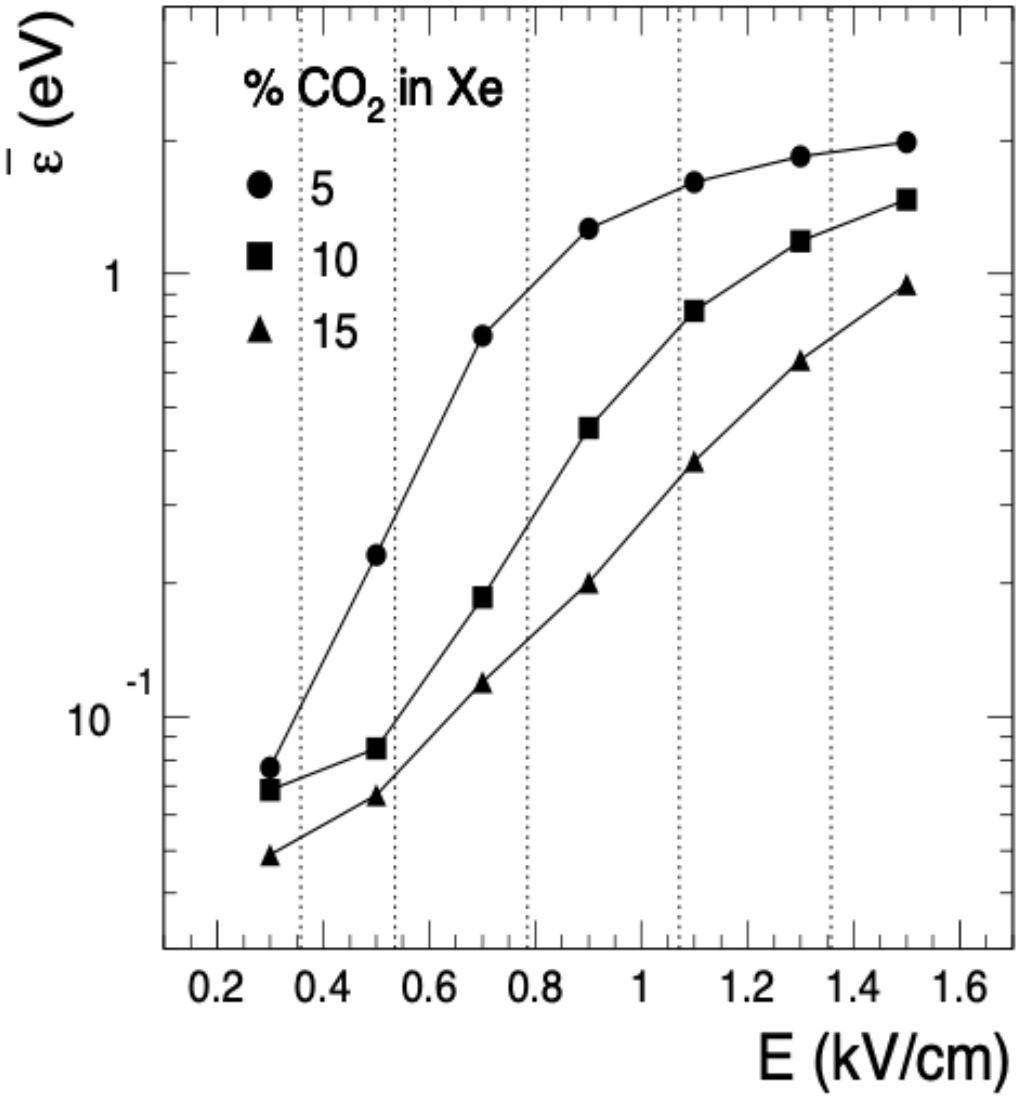
For the nerds: more on TRDs

TRD: trigger on electrons



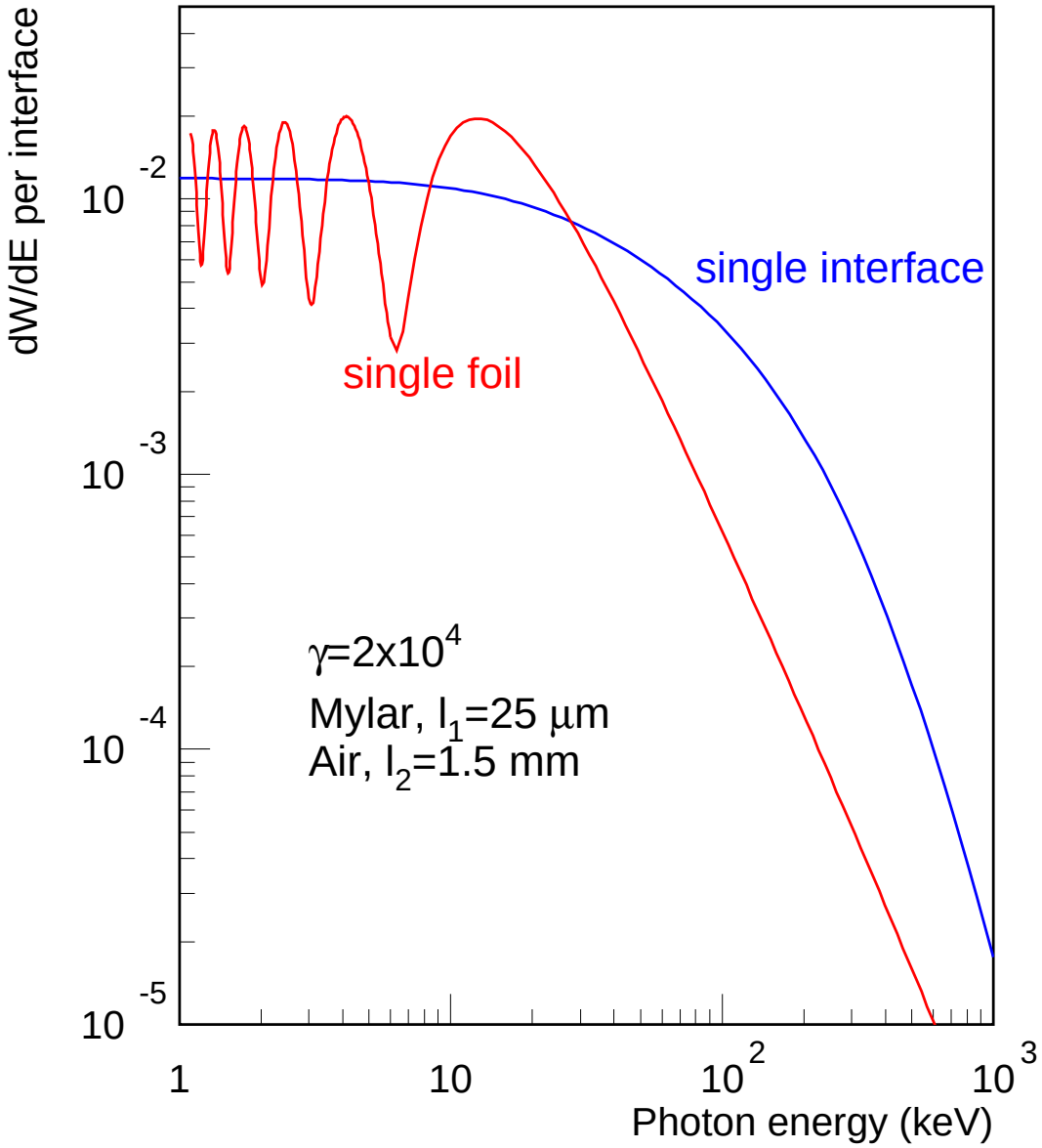
More on attachment (on SF_6)





ALICE TRD, Nucl. Instr. Meth. A 498 (2003) 143 [arXiv:physics/0303059]

What is Transition Radiation?



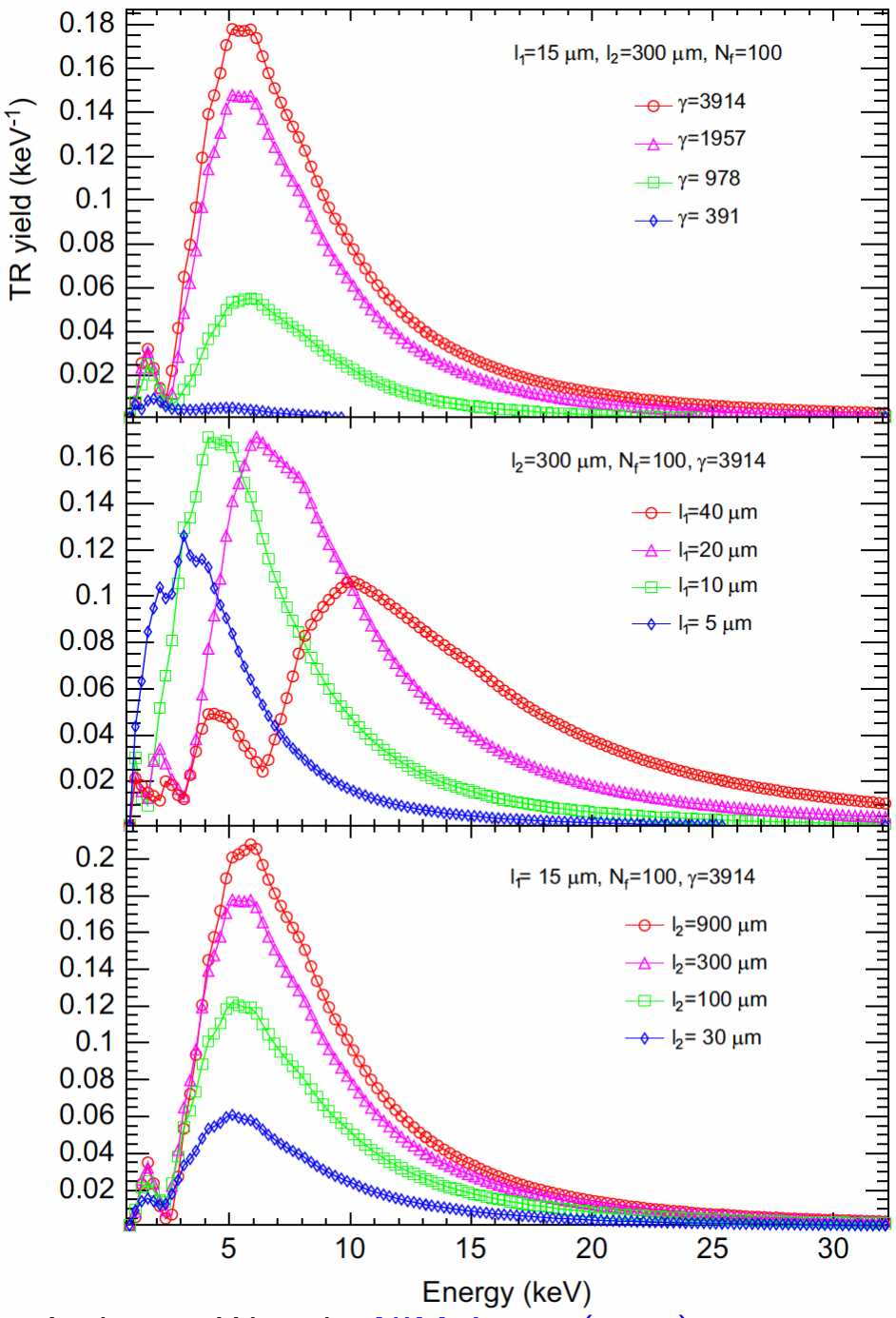
Photons (X-ray) emitted by charged particles with $\gamma \gtrsim 1000$ at interface of 2 media (different dielectric constants)

Interference can occur for multiple interfaces

Emission probability is small, $\sim \alpha$

Andronic, Wessels, NIM A 666 (2012) 130

What is Transition Radiation?



In practice a radiator is realized as a stack of N_f foils of thickness l_1 (μm), equally-spaced at l_2 (μm)

TR is a threshold phenomenon

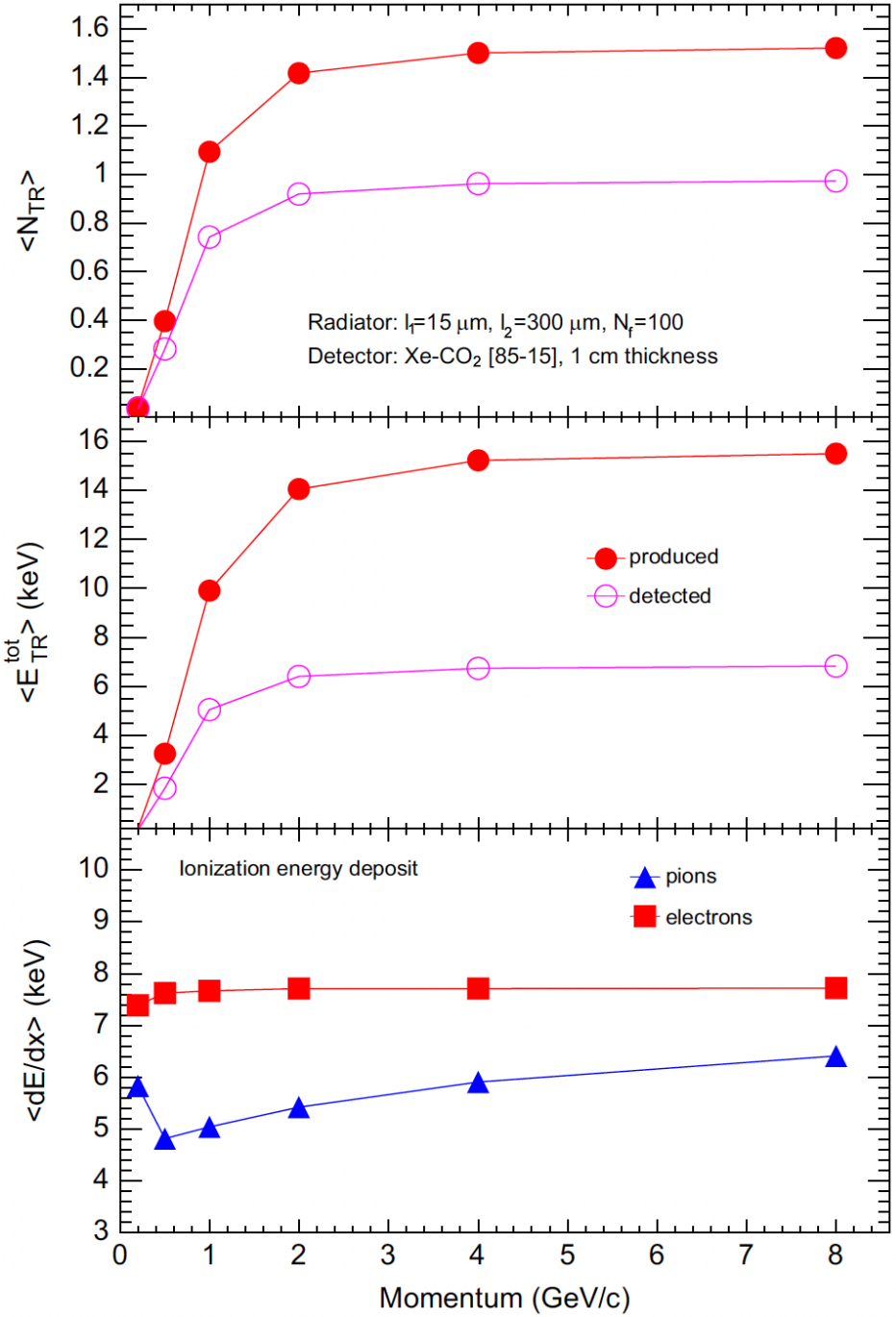
Saturation above $\gamma \simeq 2000$
(in detail dependent on radiator)

Yield and spectrum determined by l_1, l_2

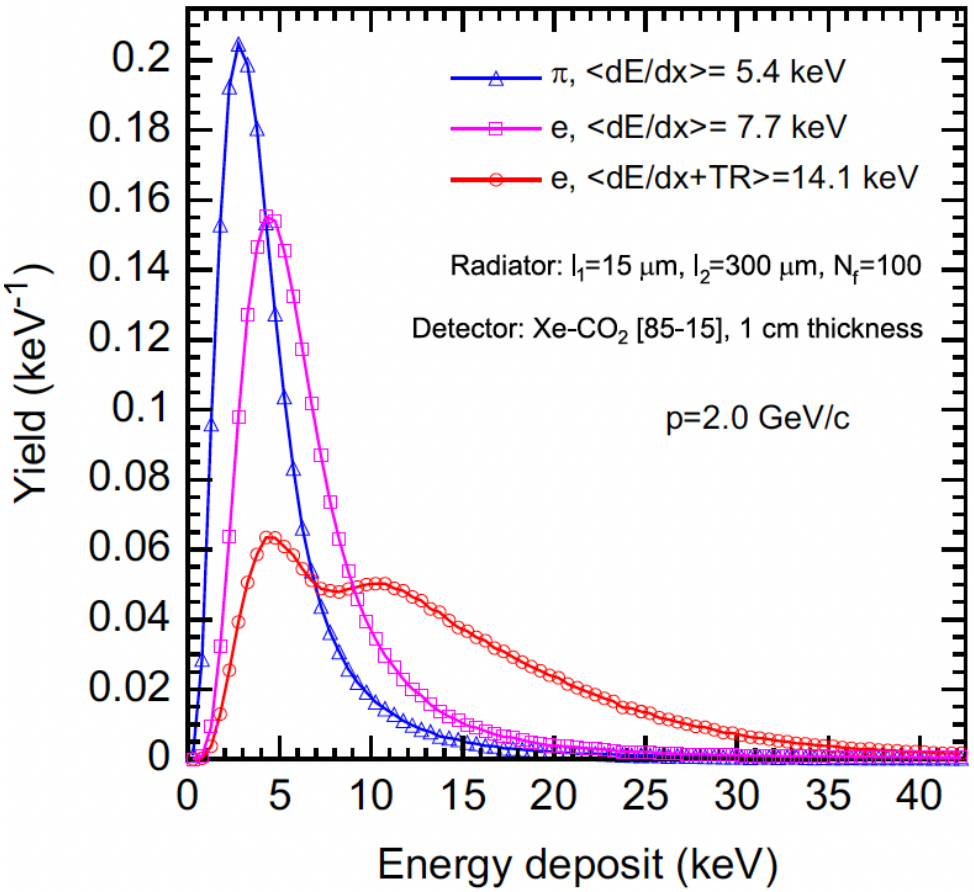
Absorption in radiator is significant

Transition Radiation Detector

A. Andronic

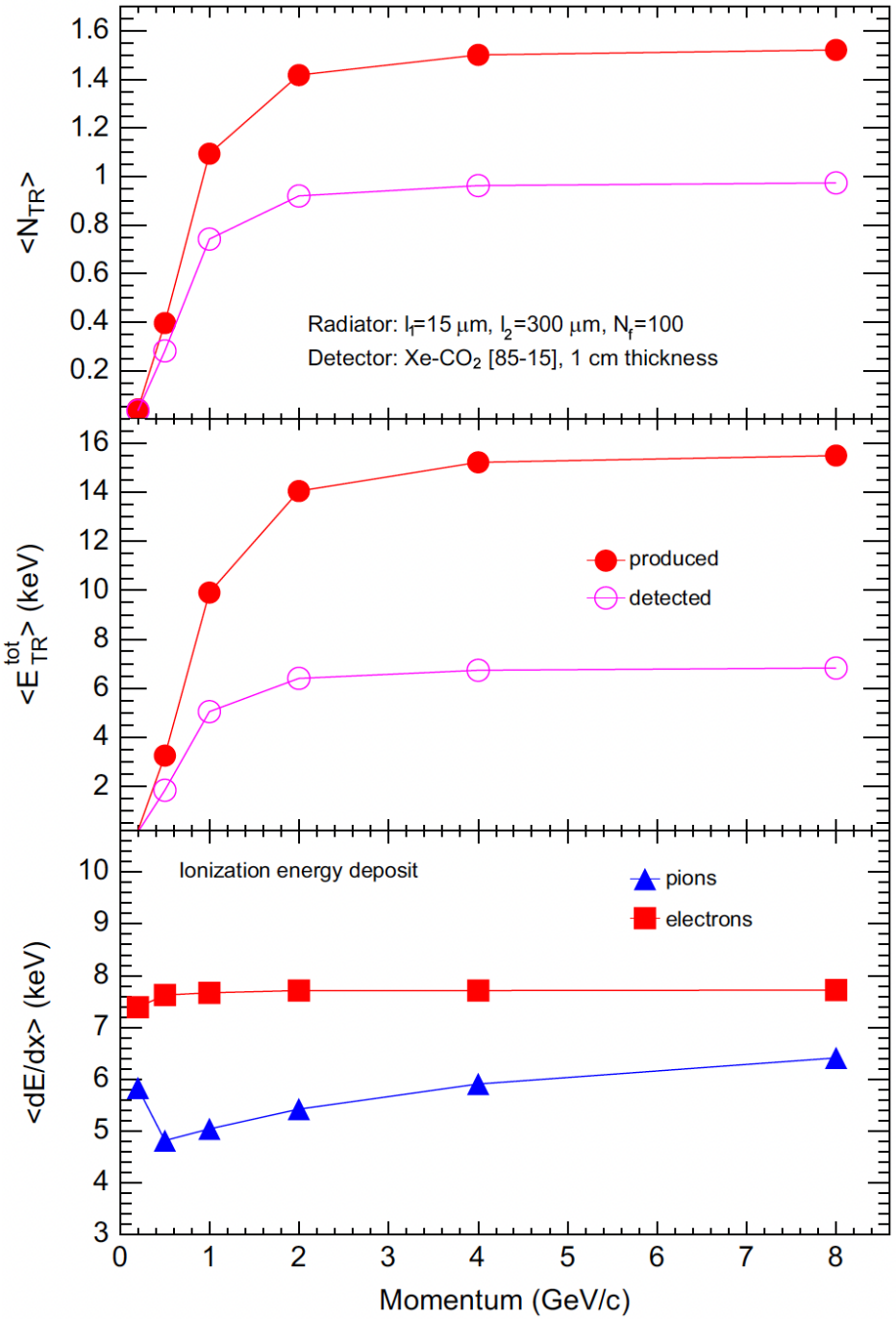


Fluctuations are large



Transition Radiation Detector

A. Andronic



To beat fluctuations, several layers (radiator-detector) are needed

