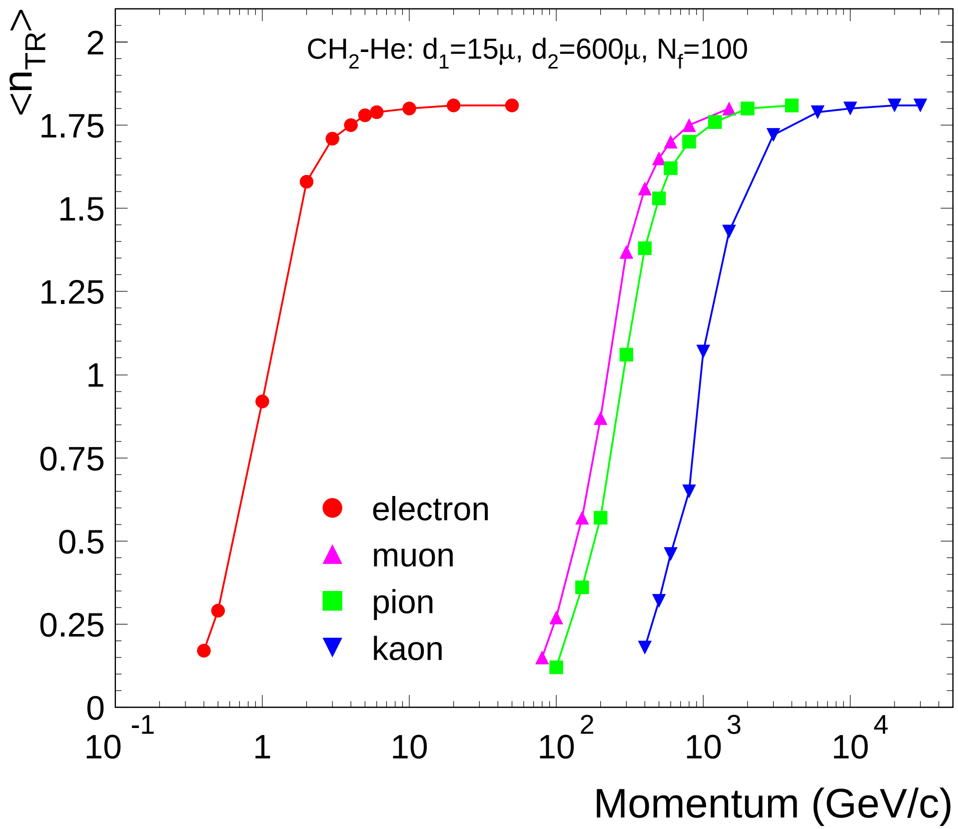
The ALICE Transition Radiation Detector

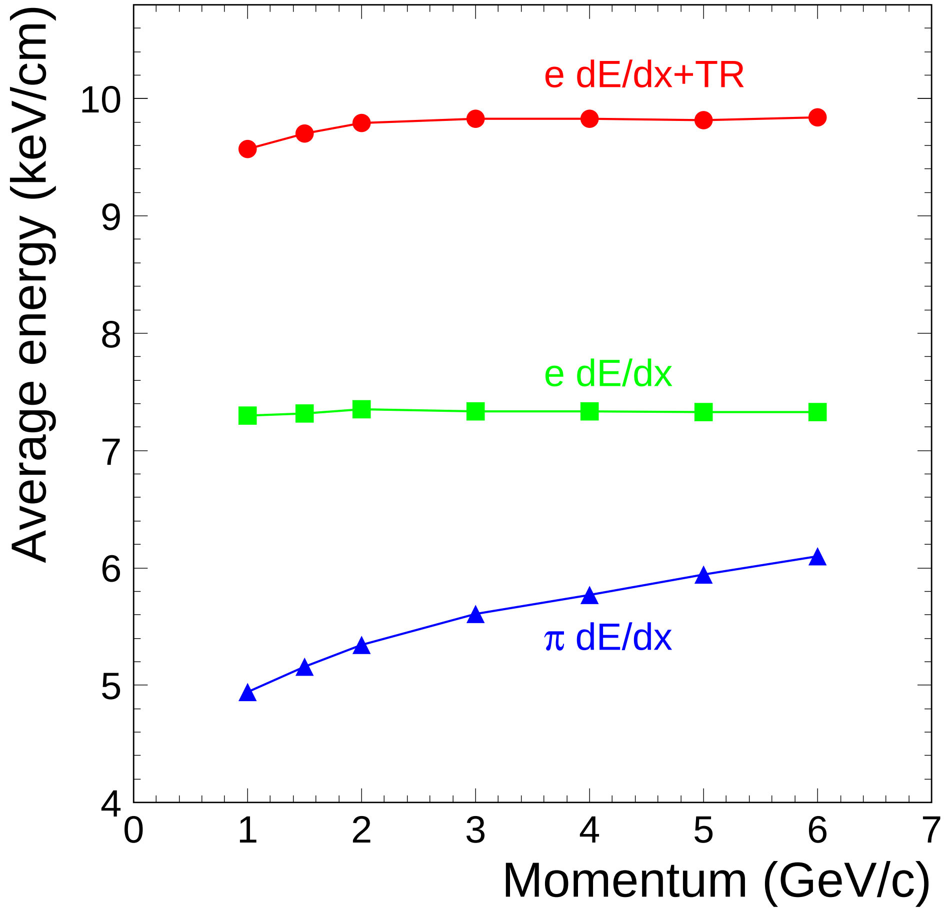
A. Andronic – GSI Darmstadt

- Introduction (TR)
- General characteristics
- Physics motivation
- Prototype development and tests
- Simulations of detector performance
- Status and outlook

How does it work: from TR to TRD

Radiator ... + Detector (Xe) ⟶





▷ TRDs are not "hadron-blind" ! they see all charged particles dE/dx

▷ TR gives a much needed boost to dE/dx of electrons

Meet ALICE TRD: the project

Participating institutions:

- GSI Darmstadt (chambers, gas system)
- IKF/U.Frankfurt (FEE, chambers)
- IKP/U.Münster (radiators)
- JINR Dubna (chambers)
- KIP/U.Heidelberg (FEE, trigger)
- NIPNE Bucharest (chambers)
- PI/U.Heidelberg (chambers, FEE, trigger)
- U.Kaiserslautern (ADC)
- FH Köln (DCS)
- FH Worms (DCS)

~60 people

In-waiting:

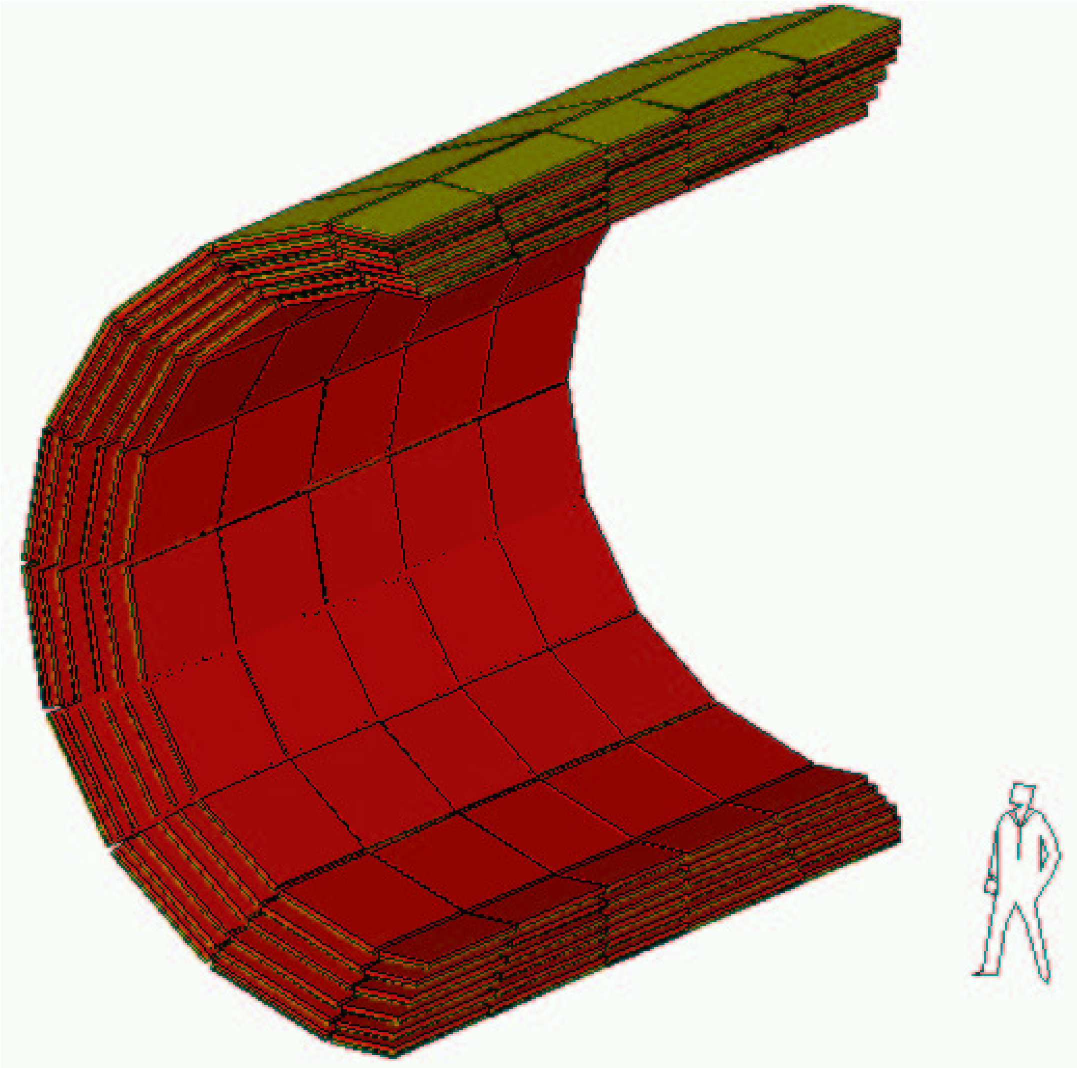
- U.Tokyo
- U.Tsukuba
- U.Nagasaki

Project leader: J. Stachel, Heidelberg

Technical coordinator: J.P. Wessels, Münster

Funded (60%) by: bmb+f - Förderschwerpunkt ALICE Großgeräte der physikalischen Grundlagenforschung

ALICE TRD at a glance



Purpose:

- Pion rejection factor of 100 for p>2 GeV/c
- Fast (6 μs) trigger for high-p_t electrons and jets

Parameters:

- 540 modules (18×5×6)
- Total area: 767 m^2
- Gas volume: 27 m^3 , Xe,CO_2(15%)
- 1.2 million readout channels (17 M pixels)
- 15 TB/s on-detector bandwidth
- Anticipated X/X_0: ∼ 14.3%
- Total weight: 21 tons
- Total power consumption: 75 kW

A comparison of TRDs

Experiment	Radiator (x,cm)	Detector (x,cm)	Area (m^2)	N	L (cm)	N. chan.	Method	π_{rej}
HELIOS	foils (7)	Xe-C_4H_{10} (1.8)	0.5	8	70	1744	N	2000
H1	foils (9.6)	Xe-He-C_2H_6 (6)	1.8	3	60	1728	FADC	10
NA31	foils (21.7)	Xe-He-CH_4 (5)	4.5	4	96	384	Q	70
ZEUS	fibres (7)	Xe-He-CH_4 (2.2)	3	4	40	2112	FADC	100
D0	foils (6.5)	Xe-CH_4 (2.3)	3.7	3	33	1536	FADC	50
NOMAD	foils (8.3)	Xe-CO_2 (1.6)	8.1	9	150	1584	Q	1000
HERMES	fibres (6.4)	Xe-CH_4 (2.54)	4.7	6	60	3072	Q	1400
kTeV	fibres (12)	Xe-CO_2 (2.9)	4.9	8	144	∼10 k	Q	250
PAMELA	fibres (1.5)	Xe-CO_2 (0.4)	0.08	9	28	964	Q,N	50
AMS	fibres (2)	Xe-CO_2 (0.6)	1.5	20	55	5248	Q	1000
PHENIX	fibres (5)	Xe-CH_4 (1.8)	50	6	4	43 k	FADC	∼300
ATLAS	fo/fi (0.8)	Xe-CF_4-CO_2 (0.4)	31	36	51-108	425 k	N,ToT	100
ALICE	fi/foam (4.8)	Xe-CO_2(3.7)	**126**	6	52	**1.2 mil.**	FADC	200

all radiator material CH_2

▷ ALICE TRD is the biggest in **size** and **granularity**

Conditions in ALICE

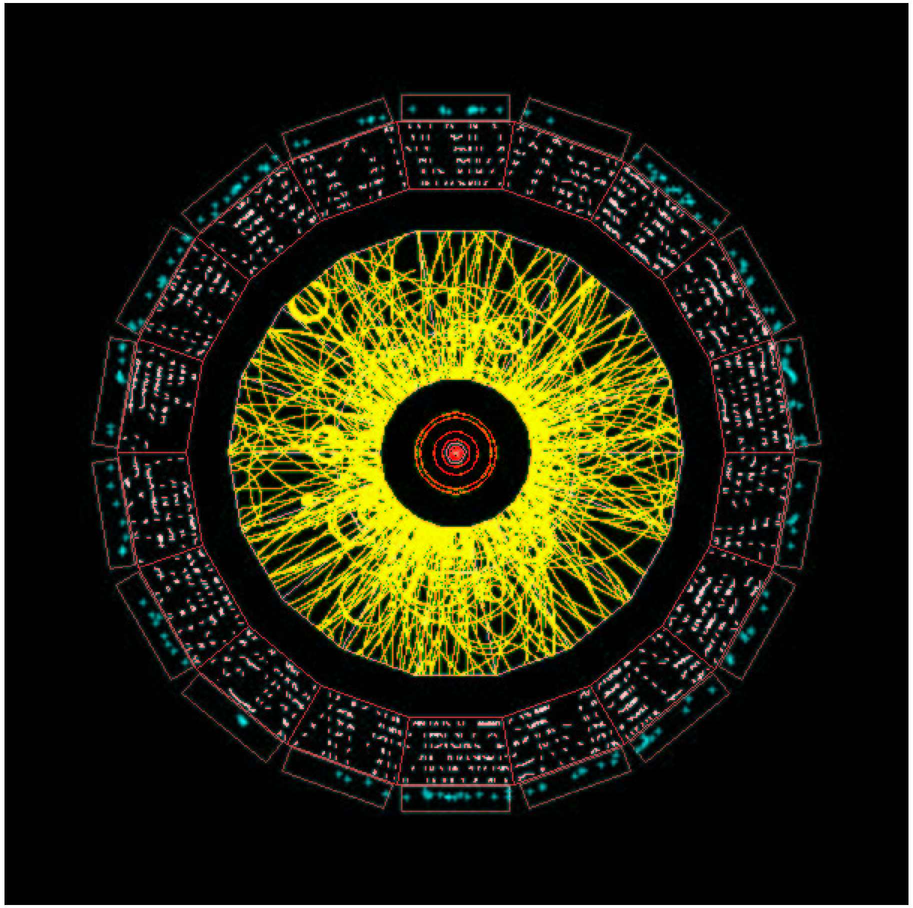
Pb+Pb $\sqrt{s_{NN}} = 5.5$ TeV

- 8 kHz interaction rate (10^{27} $s^{-1}cm^{-2}$)
- design: dN_{ch}/dy=8000 (central)

  1% of a central Pb+Pb event $\longrightarrow$

  extrap. RHIC $\rightarrow$ $dN_{ch}/dy \simeq$2-3000
  $\rightarrow$ improved TRD perf. (trigger)
- TRD will work in conjunction with all central detectors

  (TRD+ITS in high-rate pp, C+C)



Dielectron measurements with TRD in ALICE

Simulations: Pb+Pb $\sqrt{s_{NN}} = 5.5$ TeV, $dN_{ch}/dy=8000$

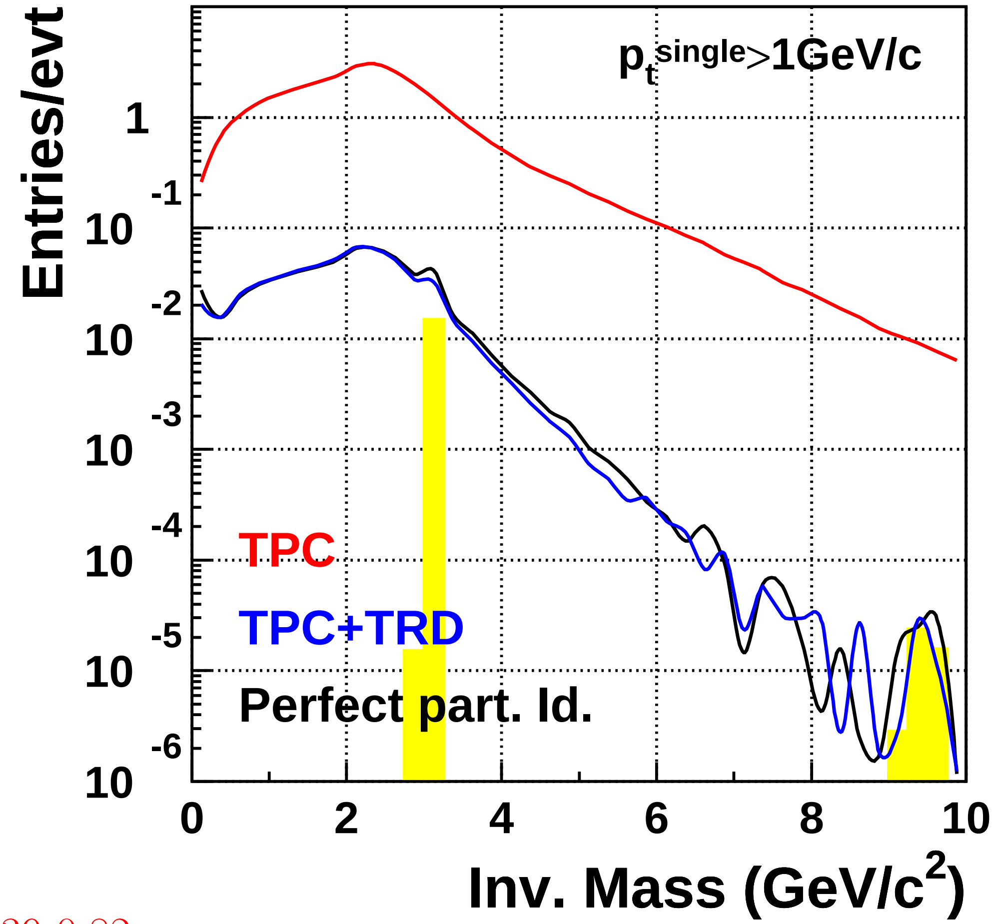
Cuts: $45^\circ < \Theta < 135^\circ$ ($|\eta| < 0.88$) ; $0.25 < p_t < 15$ GeV/c ; $v_t < 3$ cm

⇒ (per event)

6440 π's (860, p_t >1 GeV/c)

30 electrons (+ conversions)

particle	No. $e^{\pm}$	$\langle p_t \rangle$ (GeV/c)
π^0,η,ω	17.4	0.47
Ds	11.7	0.55
Bs	0.5	1.25
J/Ψ	0.1	1.59
Υ	0.0002	4.41

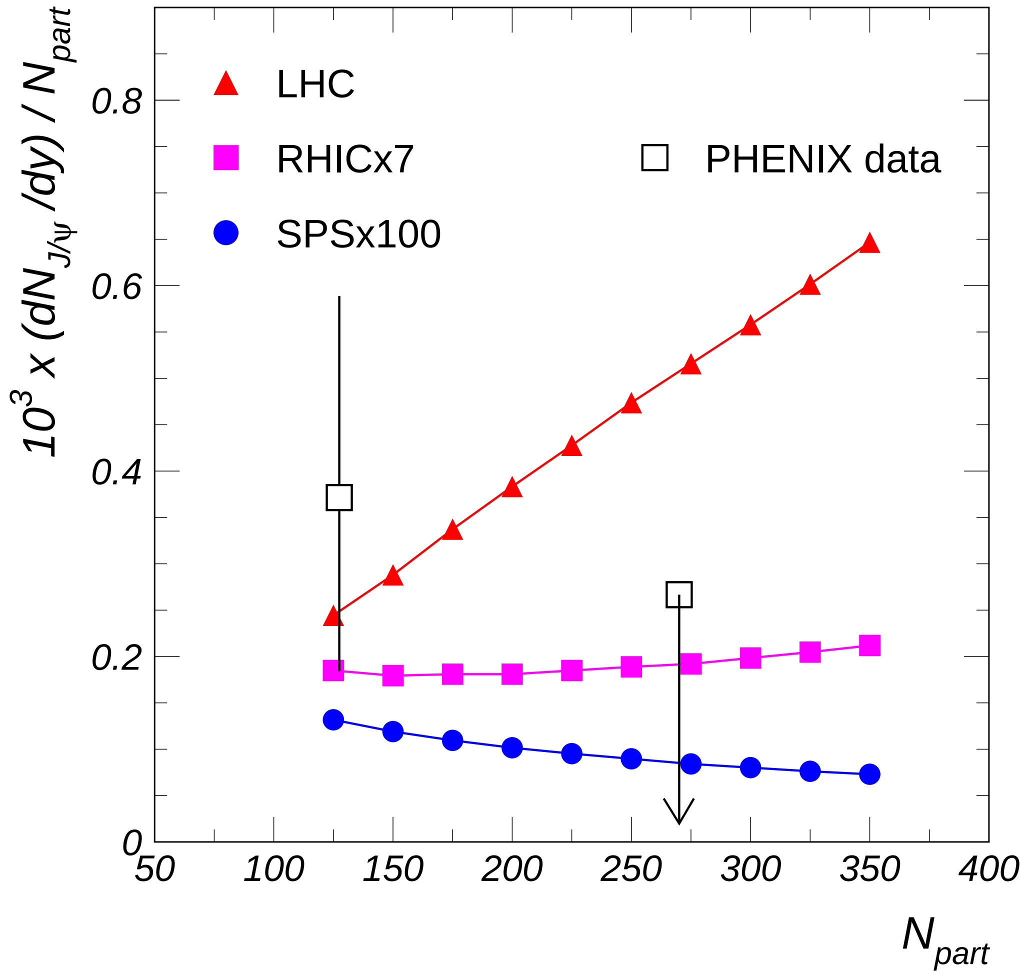


• 2σ around the mean value; p_t^{single} >1 GeV/c:

1 year @ 40 Hz central: ⇒ Signal=0.5×10^6, S/B=0.39-0.82

ALICE TRD Proposal, CERN/LHCC 99-13, *http://www.gsi.de/~alice*

J/Ψ and QGP



Statistical hadronization of charm quarks:
A.Andronic et al., nucl-th/0303036

assumes total melting of J/Ψ in QGP

◁ does a good job at RHIC

◁ dramatic centrality dependence at LHC

▷ Υ may be even more interesting ! LHC may be the only place to measure...
(requires sophisticated TRD trigger - also good for jets)

Prototype construction and tests

Phase I:

- First-guess detectors
- Various radiator materials
- Discrete FEE

Technical Design Report
October, 2001

Phase II:

- Final detector geometry
- Real-size chamber
- Final radiator materials
- ASIC PASA

Engineering Design Review
September, 2002

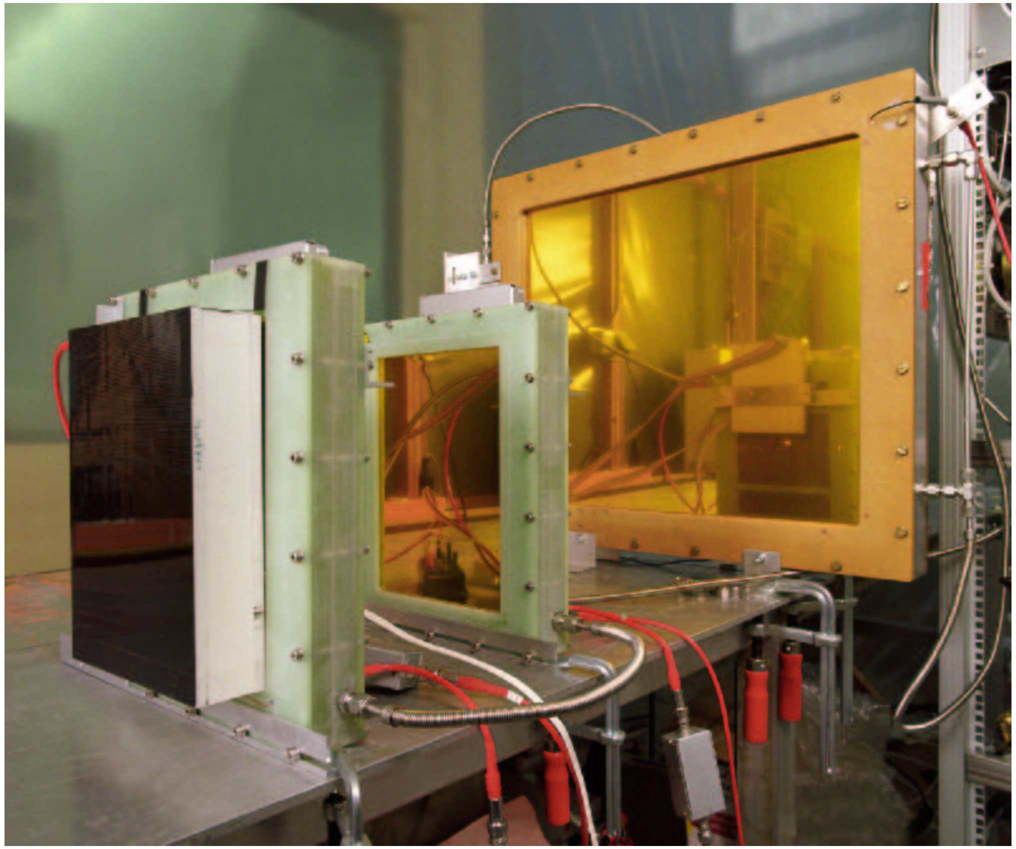
Phase III:

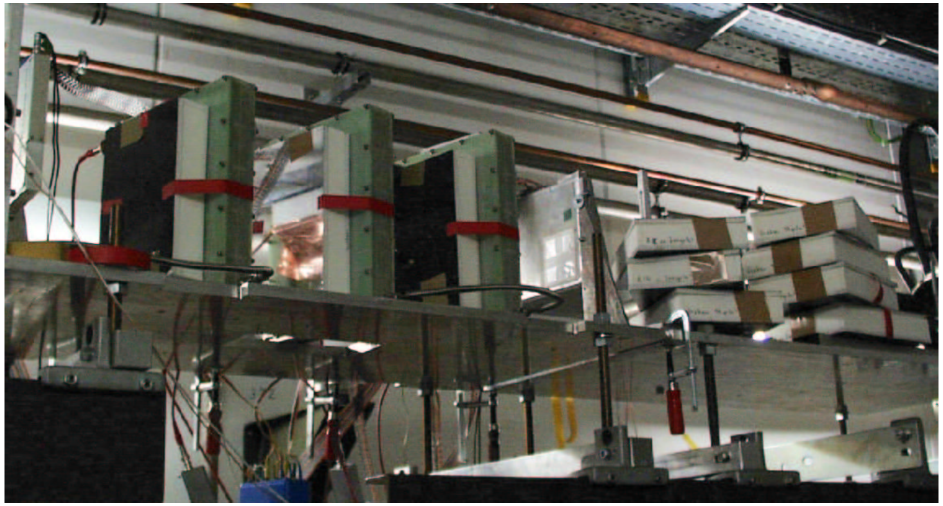
- Optimized real-size detectors
- Grounding scheme
- ASIC PASA and digital processor
- Custom ADC
- Final radiators
- Final detector dimensions
- Services (LV, HV, cooling)

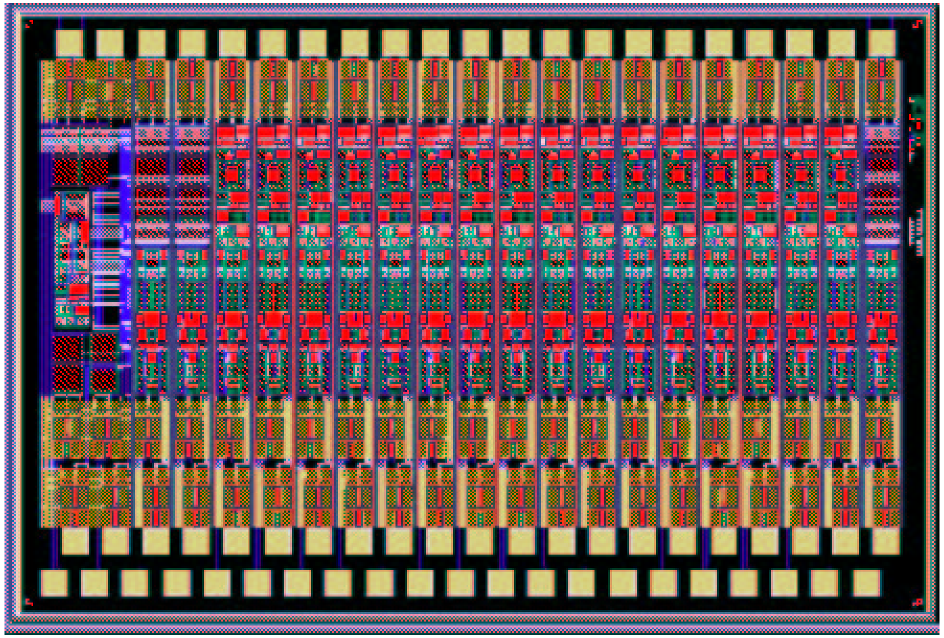
Production Readiness Review
April, 2003

ALICE TRD Prototypes

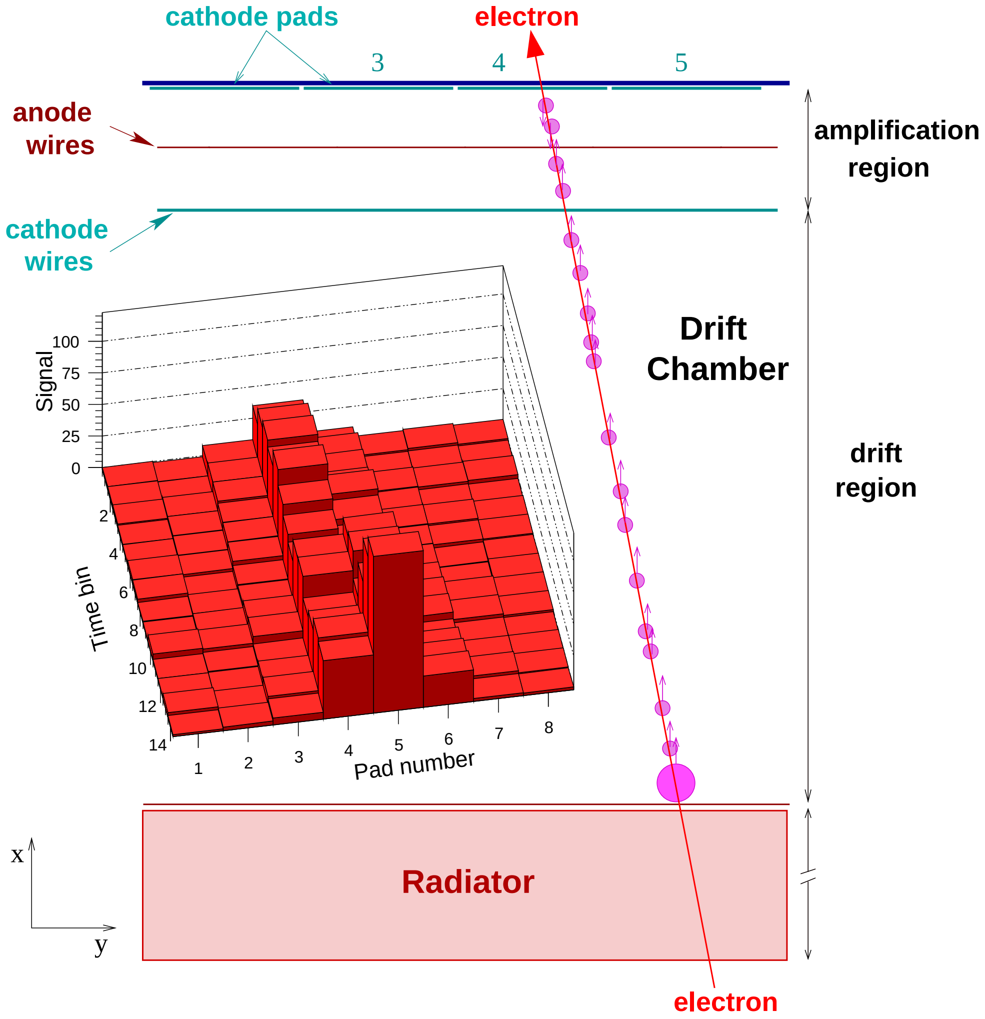
- Detectors: GSI, Heidelberg
- Radiators: Münster
- FEE: Heidelberg, Bucharest

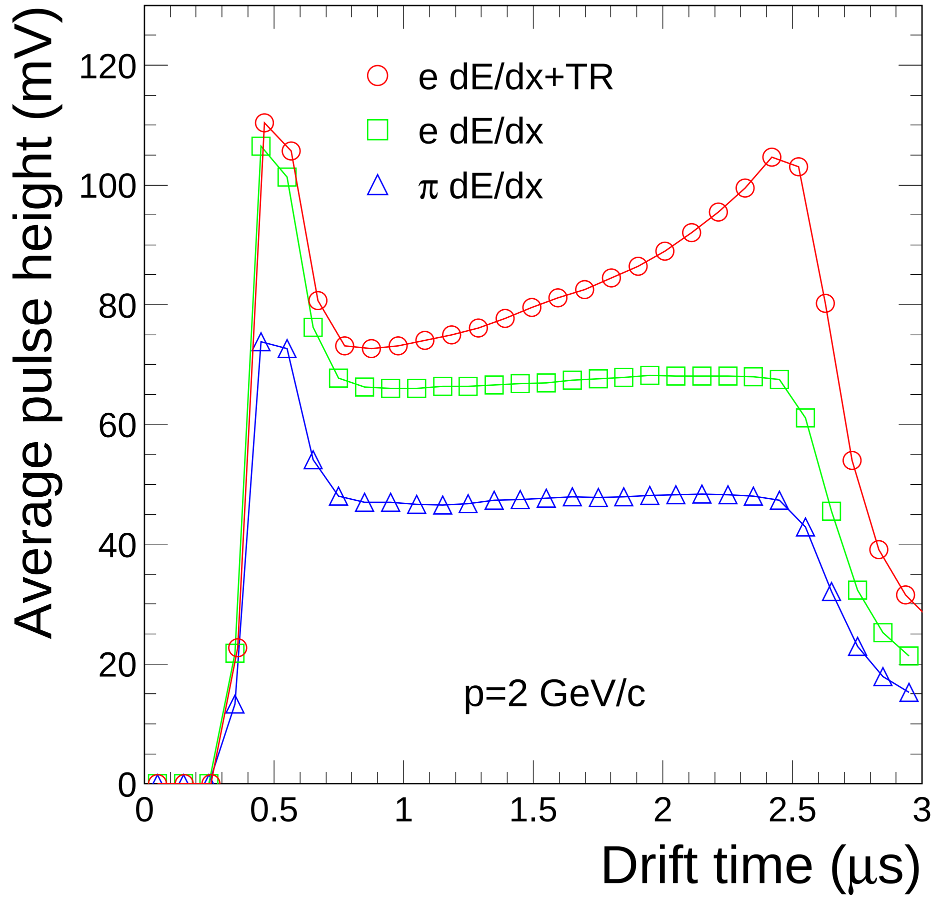






ALICE TRD – What do we measure



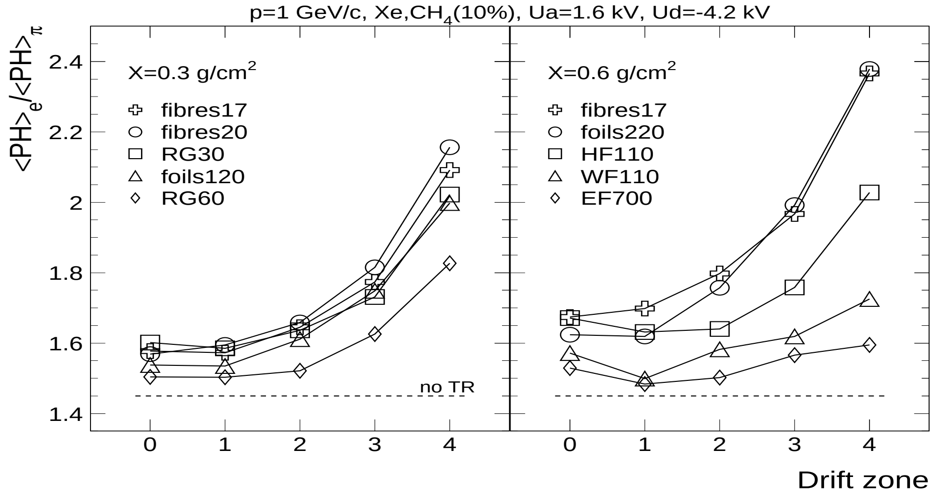


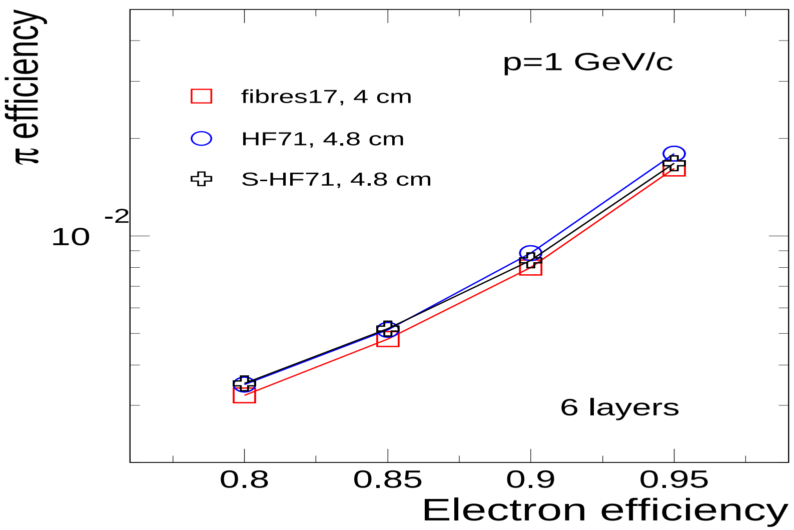
Phase I: establishing the basics (GSI, '99-'01)

Requirements: ▷ good TR ▷ stiff ▷ light

Name	Material	ρ (g/cm^3)	d (μm)
foils120	PP	120 foils	20/500
foils220	PP	220 foils	25/250
fibres17	PP	0.074	17
fibres20	PP	0.05	15-20
RG30	PP	0.03	1300
RG60	PP	0.06	700
WF110	RC	0.11	700
HF110	RC	0.11	≈75
HF71	RC	0.07	≈75
IG51	RC	0.05	≈75
HF31	RC	0.03	≈75
EF700	PE	0.12	800
S-HF110	RC/PP	0.086	sandwich
S-HF71	RC/PP	0.073	sandwich

IEEE Trans. Nucl. Sc. 48, 1259 (2001)

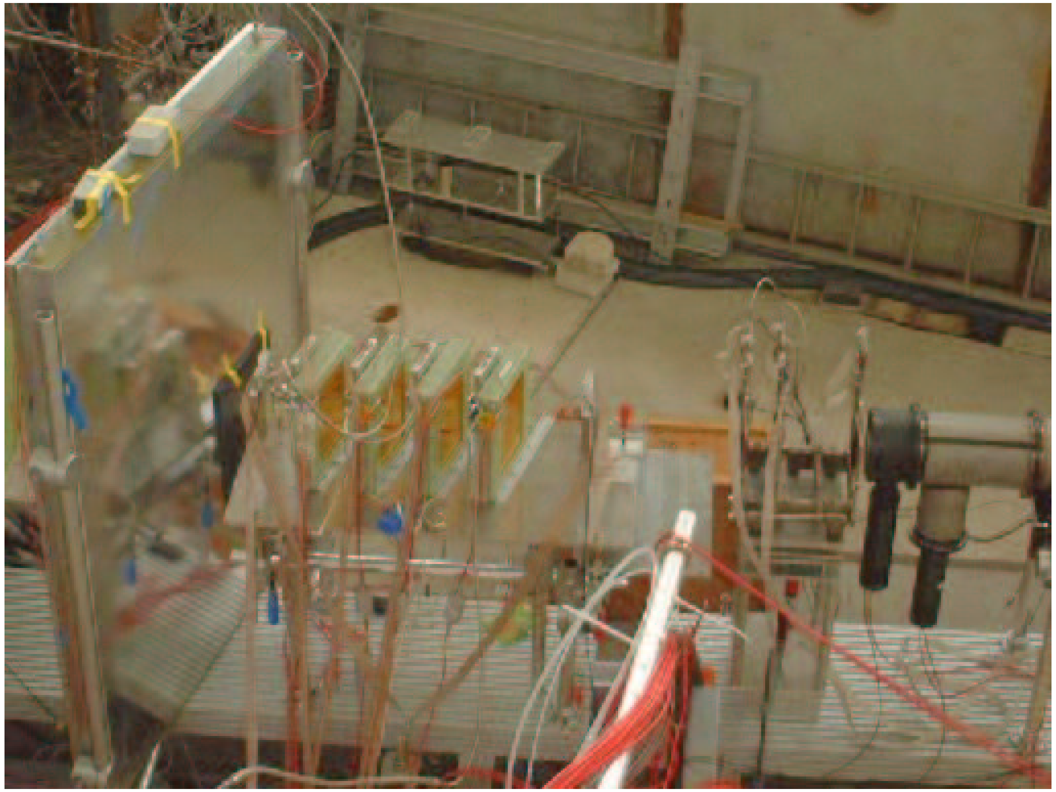




Phase II: reference results (CERN '02)

Equipment:

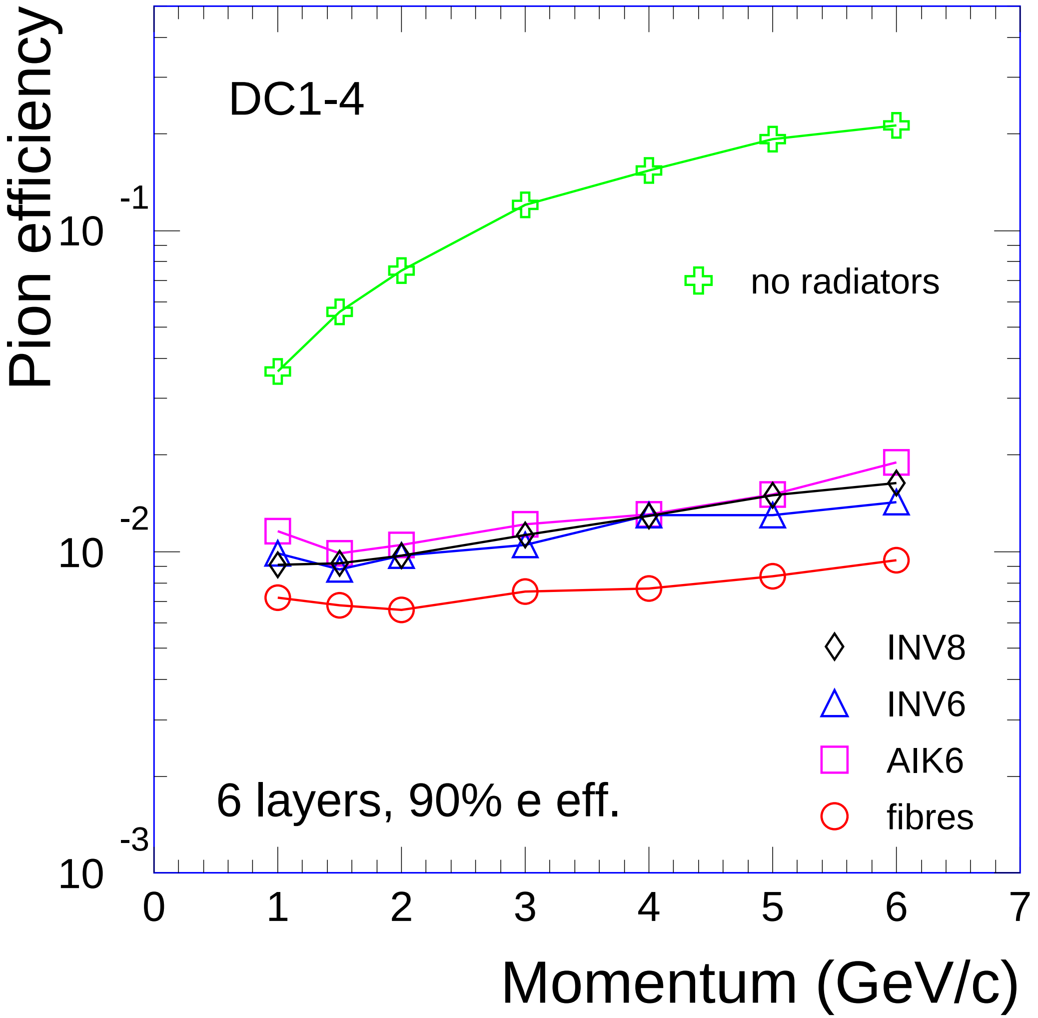
- 4 small-size prototypes + real-size prototype
- PASA v.2 (quasi-final)
- Fully-functional gas system
- Improved beam diagnostics (Dubna)



Results:

- Pion rejection - radiator and multi-layer performance
- Position resolution (B≤0.56 T)
- TR spectrum

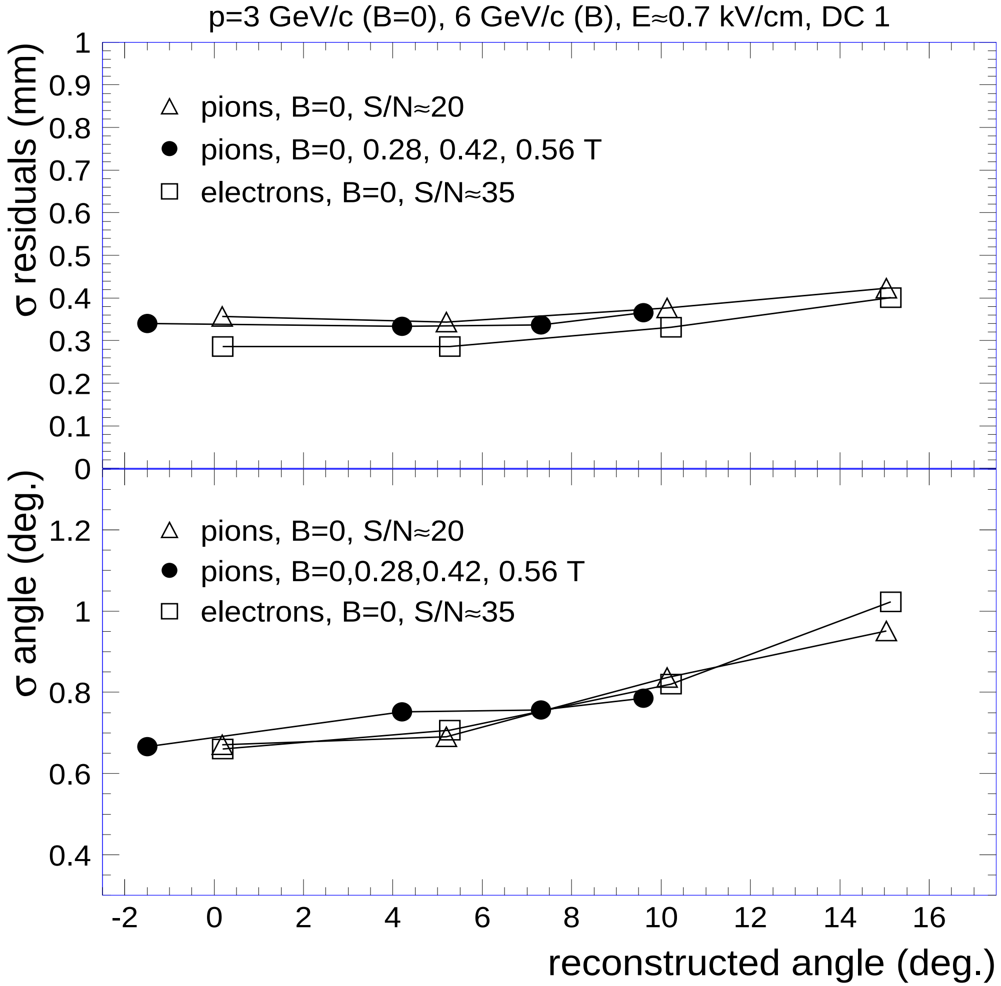
Radiator performance



- Likelihood on total charge averaged over four detectors
- Measured for 4 layers, simulated for 6 layers
- Performance not critical on radiator manufacturer choice (3 sandwiches, final design, different C-fibre coating)
- Pion rejection of 100 achieved (need improvement for deterioration in real life)
- Further improvements by exploiting the time information

Position resolution

small-size prototypes, B-field (angle=Lorentz)



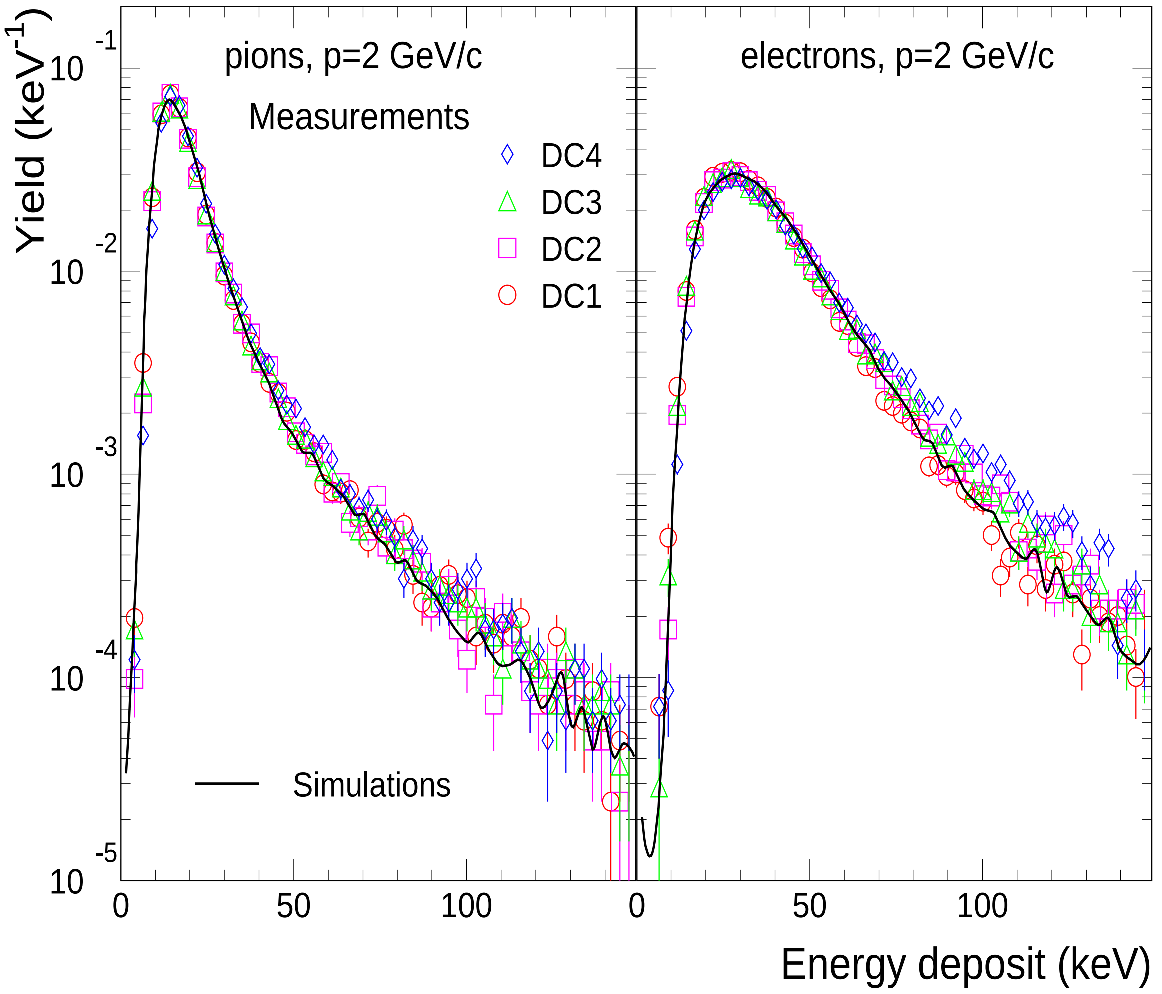
- Electrons: same resolution as pions (larger S/N)
- Point and angle resolution are within specs
- Same resolutions with or without B-field
- Lorentz angles as expected (GARFIELD)
- Real-size prototype has similar resolution

Prototype tests: other results

- **Attachment** (on O_2 and SF_6): NIM A498, 143 (2003)
- **dE/dx**: submitted to NIM
- **Space charge**: submitted to NIM
- **TR spectrum:** to be submitted
- **Drift velocities:** to be submitted

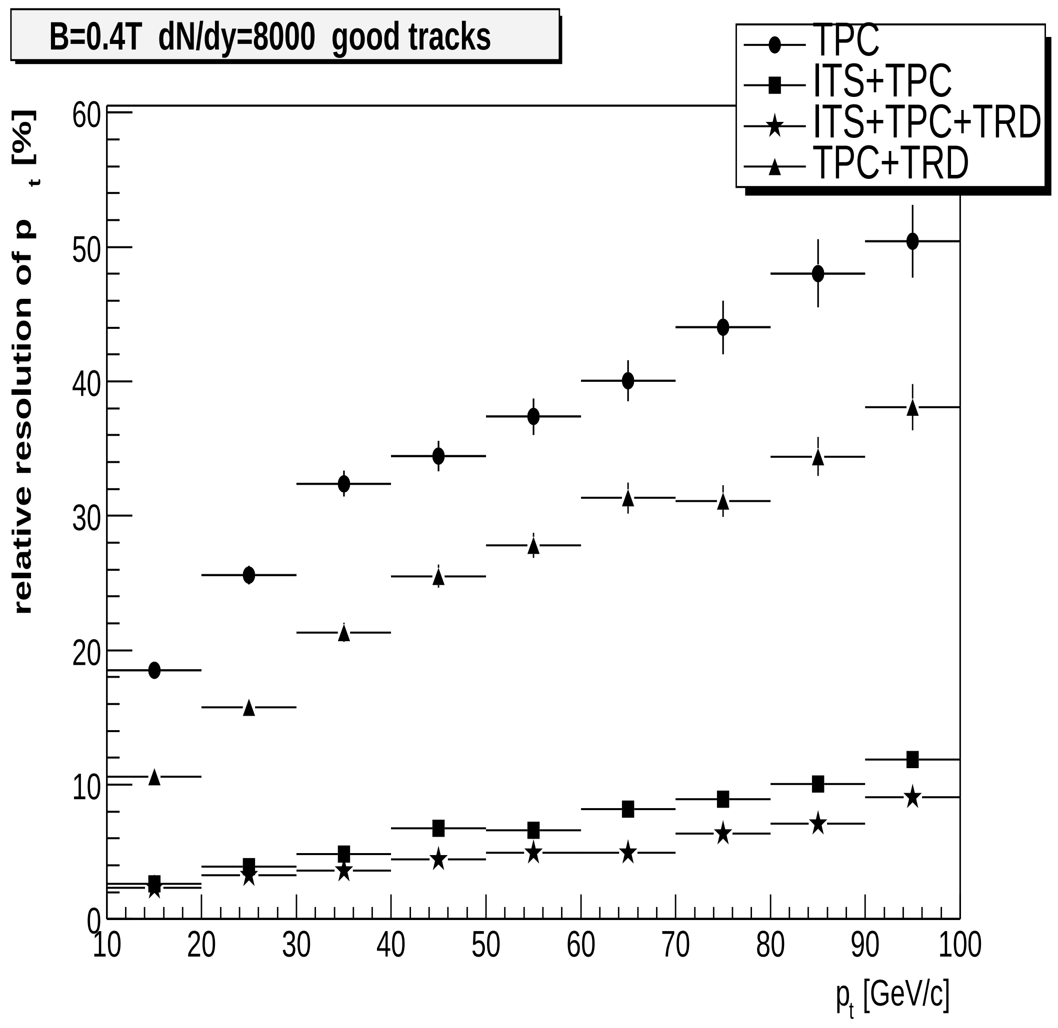
More to come...

Data and simulations: Charge spectra



- dE/dx well reproduced by simulations
- total TR yield well reproduced (tuned regular radiator parametrization)
- the momentum dependence is not reproduced by simulations

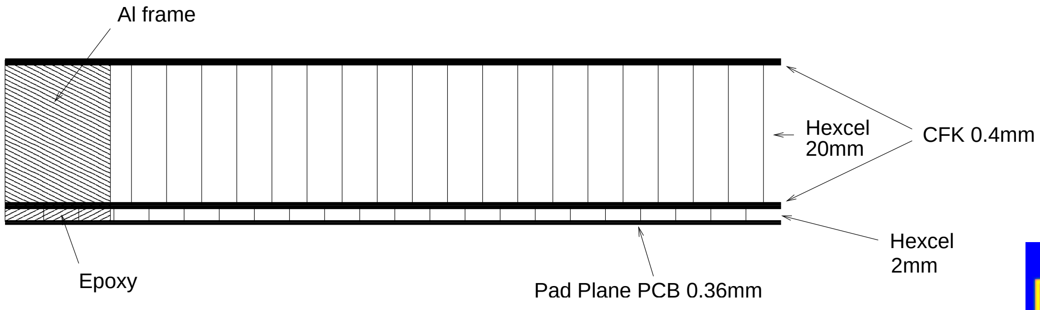
Global performance simulations



- TRD substantially improves the momentum resolution in ALICE

$\rightarrow \sigma \simeq$100 MeV/c^2 for Υ

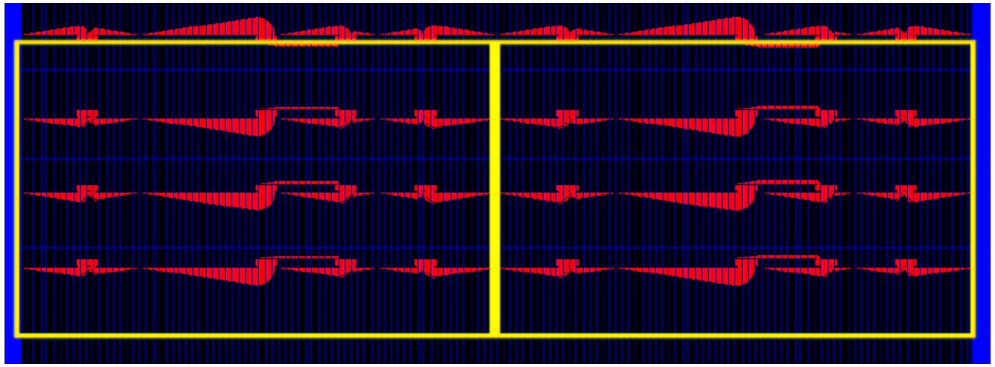
Phase III: fine tuning - pad planes



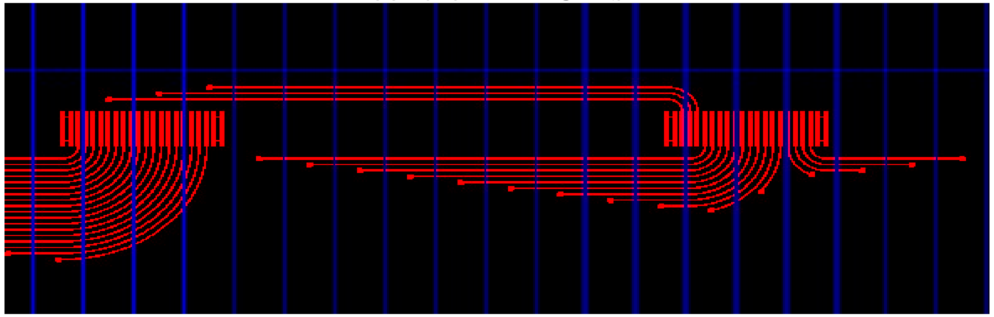
- Improved sandwich
  - mechanical stability
    (fully decoupled from readout boards)
    X/X_0=0.8% per layer
  - reduce capacitances (pad-pad, pad-ground)
- Adoption of tilted pad option (discussed in TDR)
- Optimize wire traces to reduce crosstalk
- Full: 1512 pieces, 30 different layouts
  (flexible design: C program to generate all)
- Kapton cable to FEE, soldered to chamber

1/4 of a chamber

blue: pad borders, red: signal traces, yellow: readout boards



central 2 MCMs



Status and outlook

Radiators:

- Production started in February 2003
- 10% ready: end of October 2003

Chambers:

- PRR: April 2003
- All parts in hand, production ready to start
- Production of 10% within 1 year (one production site, Heidelberg)
- 90 chambers (3 supermodules) ready for installation spring 2005; allows for 100% installation provided funds are secured (3 production sites: +GSI, Dubna)

FEE:

- Preamp/Shaper:
  - PRR: January 2003
  - Engineering run: July 2003
- ADC, Digital processor:
  - Final design, version 2 submitted
- MCM, Readout board:
  - Final design

Simulations:

- Global detector performance established
- Physics performance underway

Looking forward to exciting physics at LHC in 2007 !