Remarks on fast transition radiation detectors

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- A high rate detector: ATLAS TRT *
- A useful comparison: ALICE vs. ATLAS
- Possible (arranged) marriages
- Summary

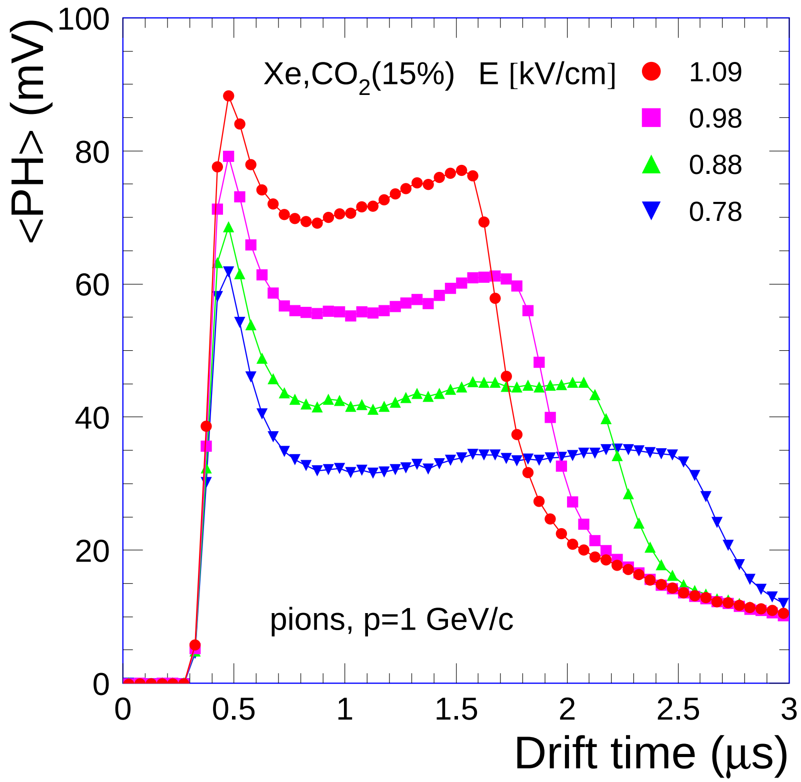
* Thanks to Anatoli Romaniouk for making available his slides on ATLAS TRT

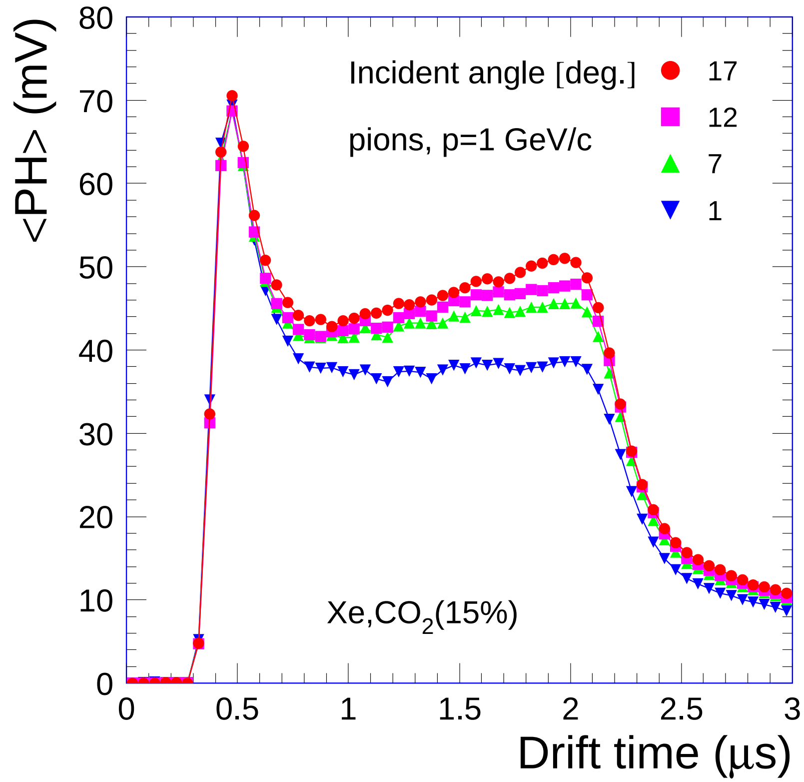
What makes a TRD slow ? (...could make it fast ?)

For efficient TR (∼2-20 keV) absorption one needs:

Some detector thickness (∼2 cm)
→ long drift times

Xenon (∼3x slower than Ar)
→ space charge effects





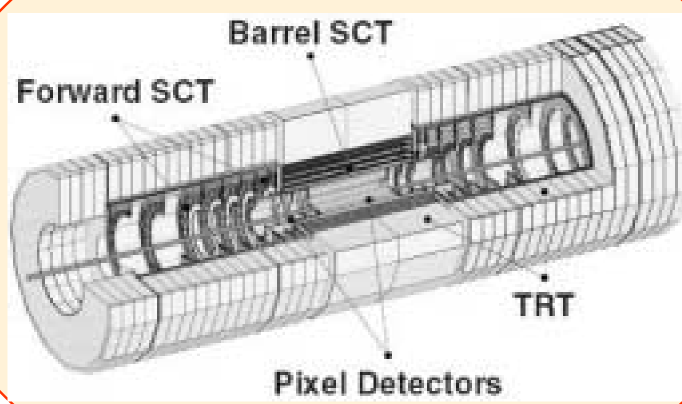
→ Get a faster gas mixture and/or slice the detector

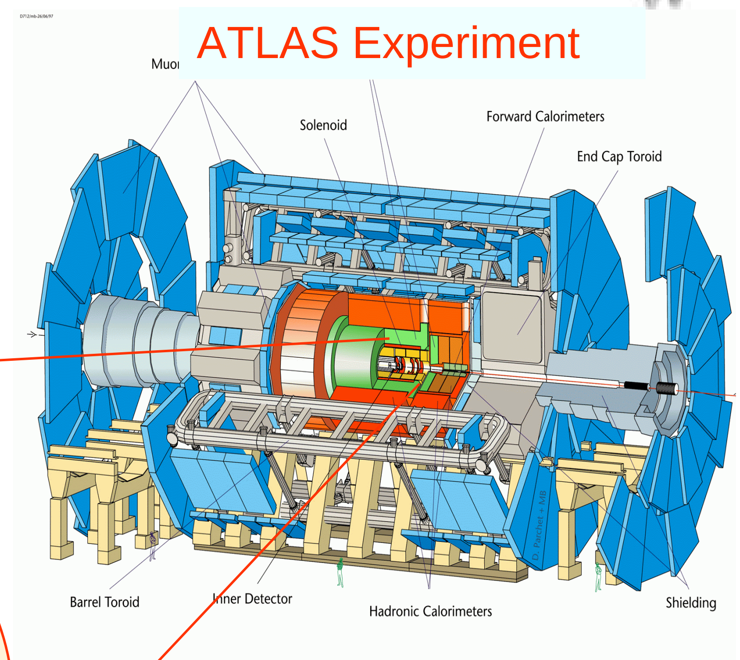
→ Get a gas mixture with working point at high field

ATLAS Inner detector concept

<u>**General requirements:**</u>

- **Combination of Central Tracker and TRD features**
- **Robust pattern recognition**



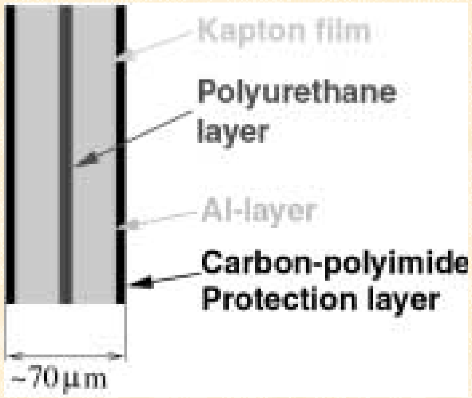


- **Bunch crossing rate - 40 MHz (25 ns between interactions)**
- **Interactions per year - 10^{16}**
- **Selection level (Higgs) ~ $1:10^{13}$**

Detector elements: Straws

Straw design

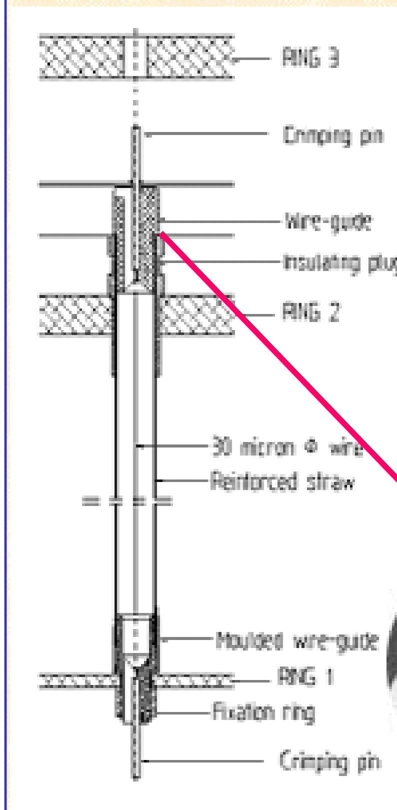
Straw wall



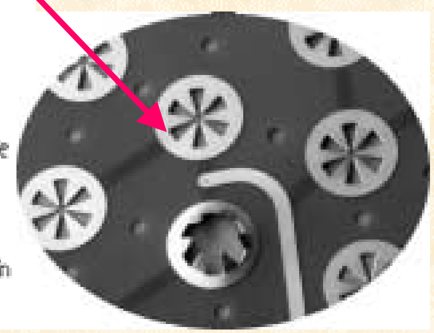
Reinforced straw

In order to make straw rigid 4 C-fibres are attached along the straw

Straw connection in the End-Cap TRT



HV contacts to the straw inner surface



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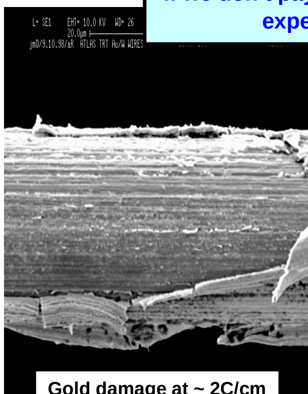
Detection gas: 70% Xe + 20% CF_4 + 10% CO_2

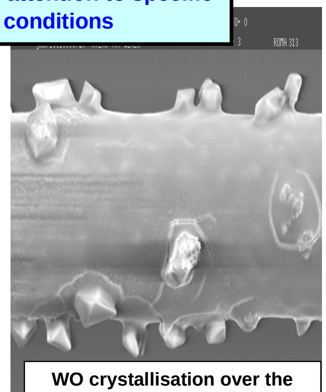
Detector elements: Ageing effects

Wire ageing effects

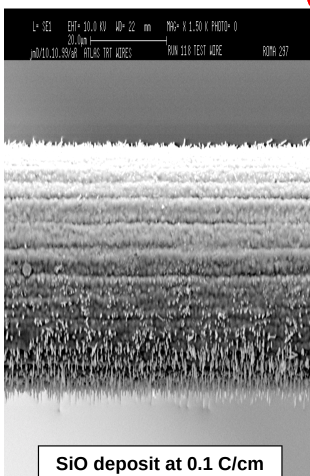
If we don't pay enough attention to specific experimental conditions



Gold damage at ~ 2C/cm



WO crystallisation over the gold surface at ~ 3-4 C/cm



SiO deposit at 0.1 C/cm

When we know exactly what we are doing

21 C/cm

I. Gold damage

- Effect is strong if water content is 1-1.5%
- Effect even stronger if there are H_2O and O_2 in the mixture
- Very little effect at ~10 C/cm if water content is ~0.4-0.5%
- NO effect up to 20 C/cm if water content below 0.1%.

II. Silicon deposits

- This effect is observed for rather low dose rates corresponding to a luminosity of 10^{33}-10^{34}
- Can the detector materials be a source of Si contamination? What are the possible external sources of Si contamination (gas system, gas itself, etc)?

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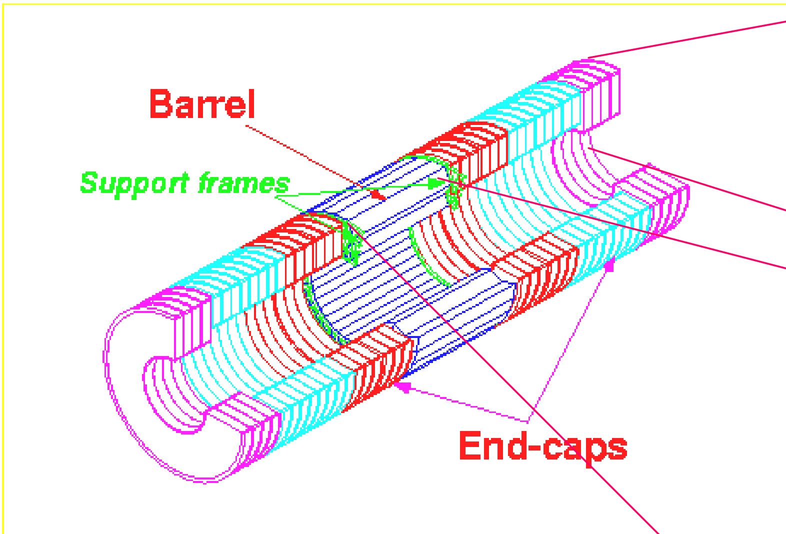
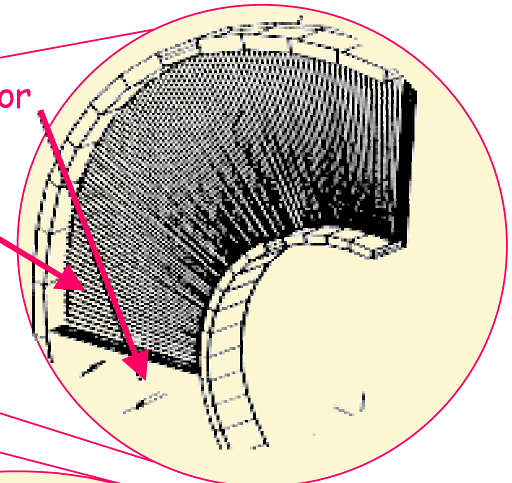
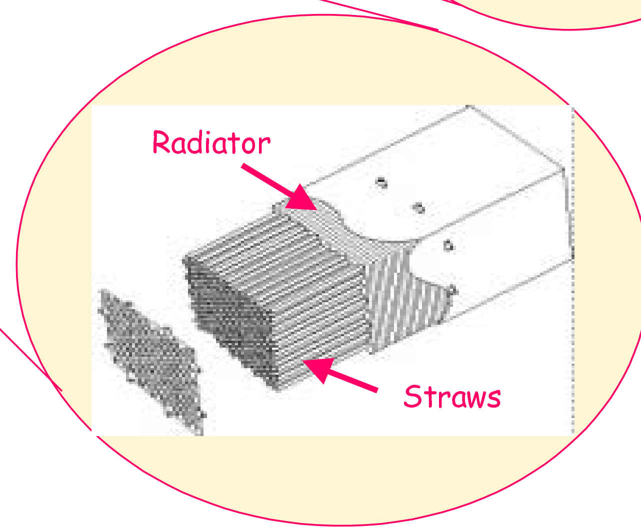
See also: M.Capéans, C.Garabatos,... NIM A 337 (1993) 122

Detector concept

TRT global parameters







Length: Total	6802 cm	N straws: Total	372032
Barrel	148 cm	Barrel	52544
End-cap	257 cm	End-cap	319488
Outer diameter	206 cm	N electronics channels	424576
Inner diameter	96-128 cm	Weight	~ 1500 kg

Operation conditions

TRT conditions in the ATLAS experiment

Number of particles at a distance of 1 *m* from interaction point:

Charged ~ 10^5 hadrons/cm^2 sec

Photons ~ 10^6 photons/cm^2 sec

Neutrons ~10^6 n/cm^2 sec

Total dose for detector parts after 10 years of LHC operation:

Neutron ~10^{14} n/cm^2

Charged particles ~10 MRad

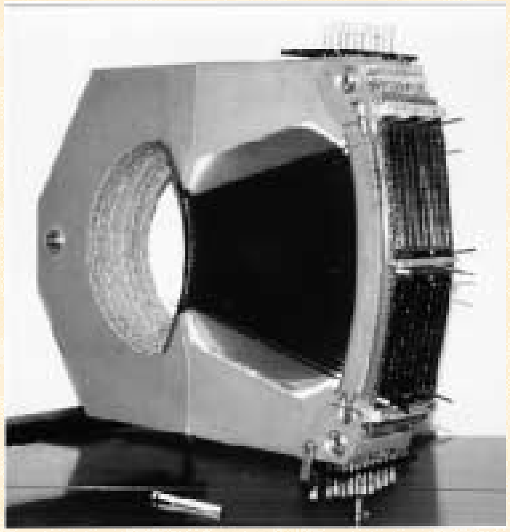
Some operation parameters for gas detector

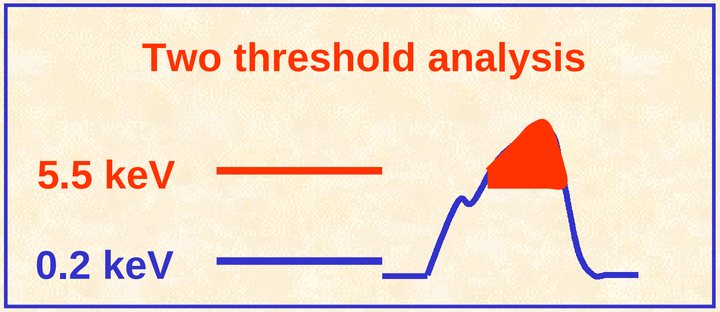
- *Counting rate per wire up to 20 MHz*
- *Ionis. current density up to 0.15 μA/cm*
- *Ionis. current per wire up to 10 μA*
- *Power dissipated by ionisation current per straw ~15 mW*
- *Charge collected over 10 years of LHC operation ~10 C/cm*
- *Total charge per 1 m of wire ~1000 C*
- *Total ionisation current in the detector volume ~ 3 A*
- *Total dissipated energy in the detector volume from ionising particles ~5 kW*

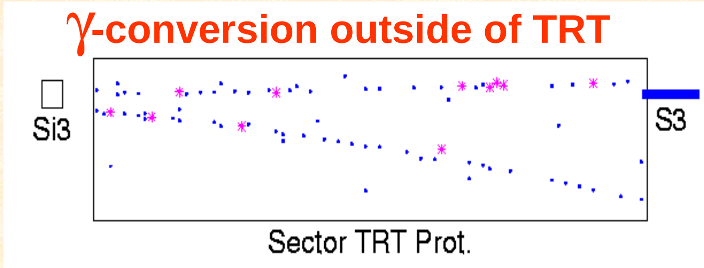
Accessibility is very limited during ATLAS operation

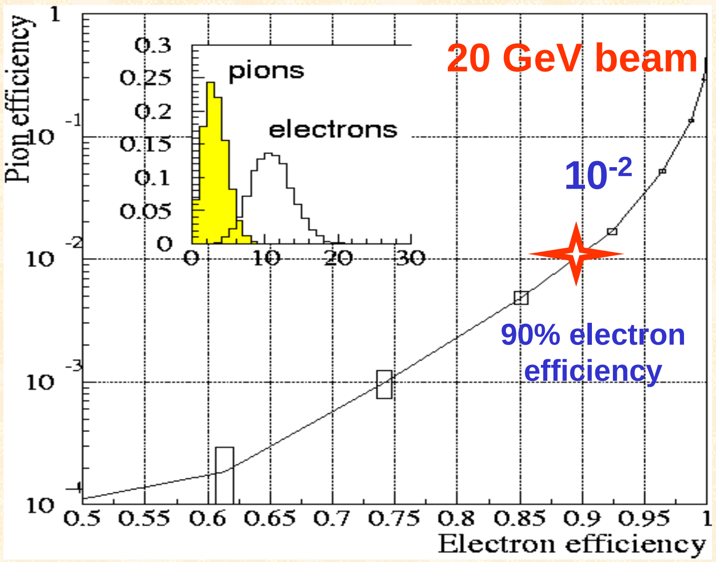
☛ **Detector must be very stable operationally!**

TRT Test beam prototypes









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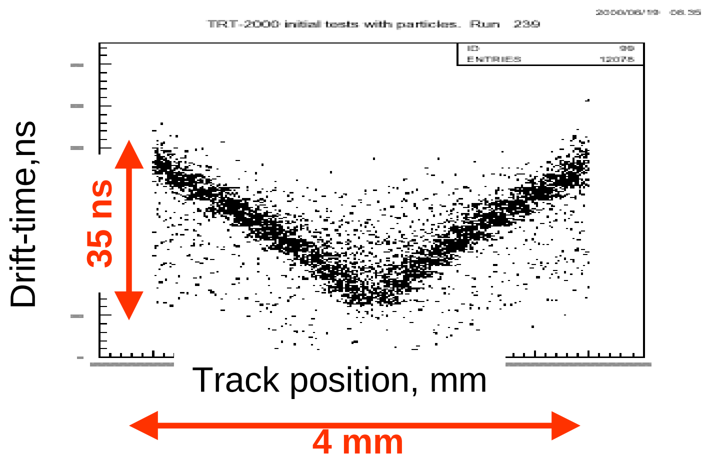
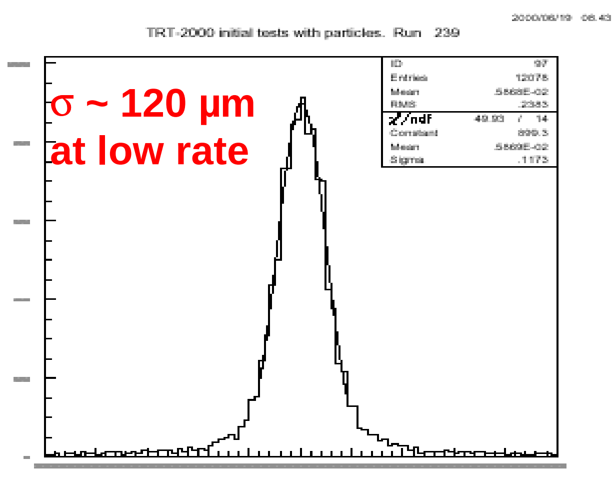
TRT prototypes: Drift-Time Accuracy

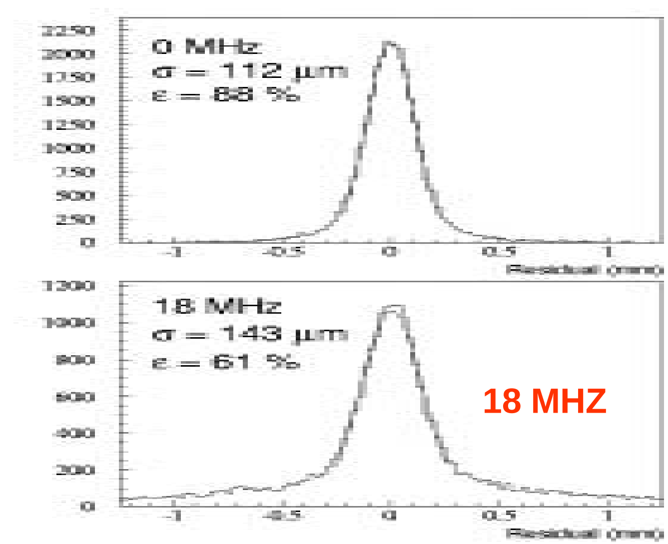




Track-to-measured position residual, mm

End-cap sector prototype with the LHC electronics in the 25 ns beam (May 2000)

- Threshold: 200 eV (~2fC)
- Hit registration efficiency: 97%
- Drift-time measurement efficiency within ± 2.5 σ road: 87%



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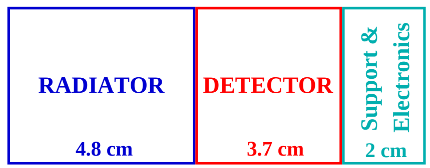
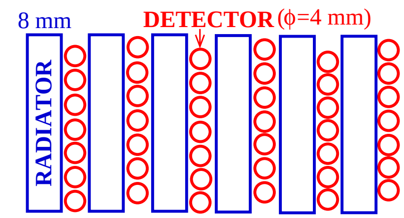
A comparison of TRDs: the high-granularity and the high-rate

6 of the detector	ALICE TRD	ATLAS TRT
		
nnels / Number of layers	1.16×10^6 / 6	4.25×10^5 / 36
ered area / Occupancy	100 m^2 / 10-34%	26 m^2 / 13-38%
rage channel size	**<u>5.2 cm</u>^{2}** ($\searrow$ 1-2 cm^2)	**<u>22 cm</u>^{2}** ($\searrow$ ~10 cm^2)
nting rates per channel	**<u>100-500 Hz</u>** ($\nearrow$ 2-4 kHz)	**<u>10-12 MHz</u>**
ction gas	Xe + 15% CO_2	Xe+ 20% CF_4 + 10% CO_2
$_t$ [cm/μs]	4.0 (@ 1.5 kV/cm)	6.6 (@ 3 kV/cm) ; 4.5 @ 1.6 kV/cm
dout	FADC (12 time bins)	TOT (2 threshold values)
(at 90% e efficiency)	100	100
p	<6% (p <10 GeV/c; B=0.4 T)	<4% (p <100 GeV/c; B=2 T)
ght [tons] / Volume [m^3] / X [X_0]	21 / 96 / 15%	1.5 / 17 / 10%
) timespan	4 years	10 years

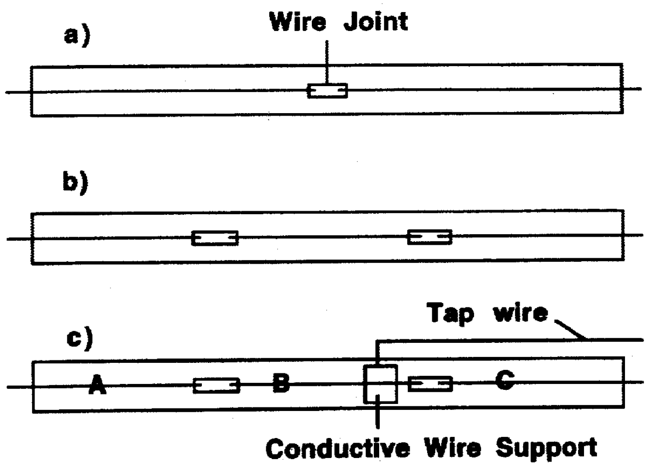
Is it possible to realize a cross breeding ?

(... hopefully getting a high-rate and high-granularity and NOT a low-rate and low-granularity !)

Towards high-granularity straws

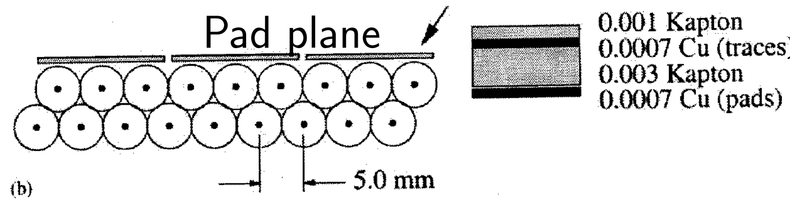
Segmented wires: NIM A425 (1999) 75

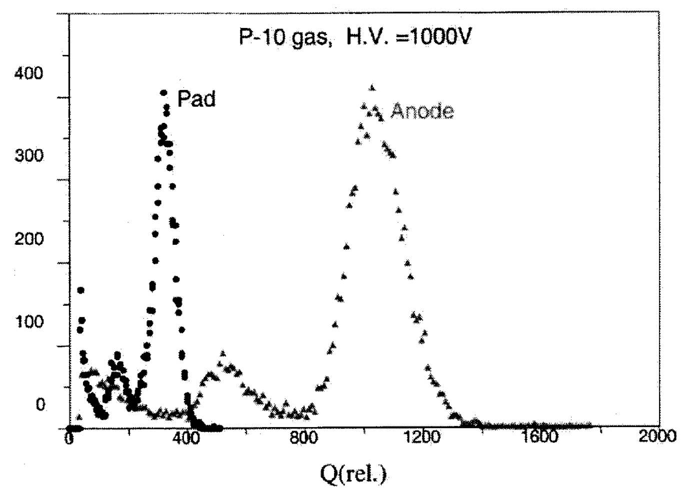
↙ ATLAS,PHENIX



wbacks: - dead zones (∼1cm, @ wire joints)
- tedious manufacturing

Pickup pad readout: NIM A427 (1999) 465





To minimize noise and cross-talk the electronics has to be local (like ALICE TRD)

Summary

- Both high-granularity and high-rate TRDs have demonstrated concepts (large scale)
- A hybrid is possible in principle, but is not straightforward in practice
- Detailed optimizations are needed (to find the best compromise)
  - pion rejection using TR (or $\pi/K/p$ identification via dE/dx)
  - position resolution (matching, tracking)
- As always, mechanical realization and price constraints will impose additional compromises