EDIT 2011 — Drift Tubes

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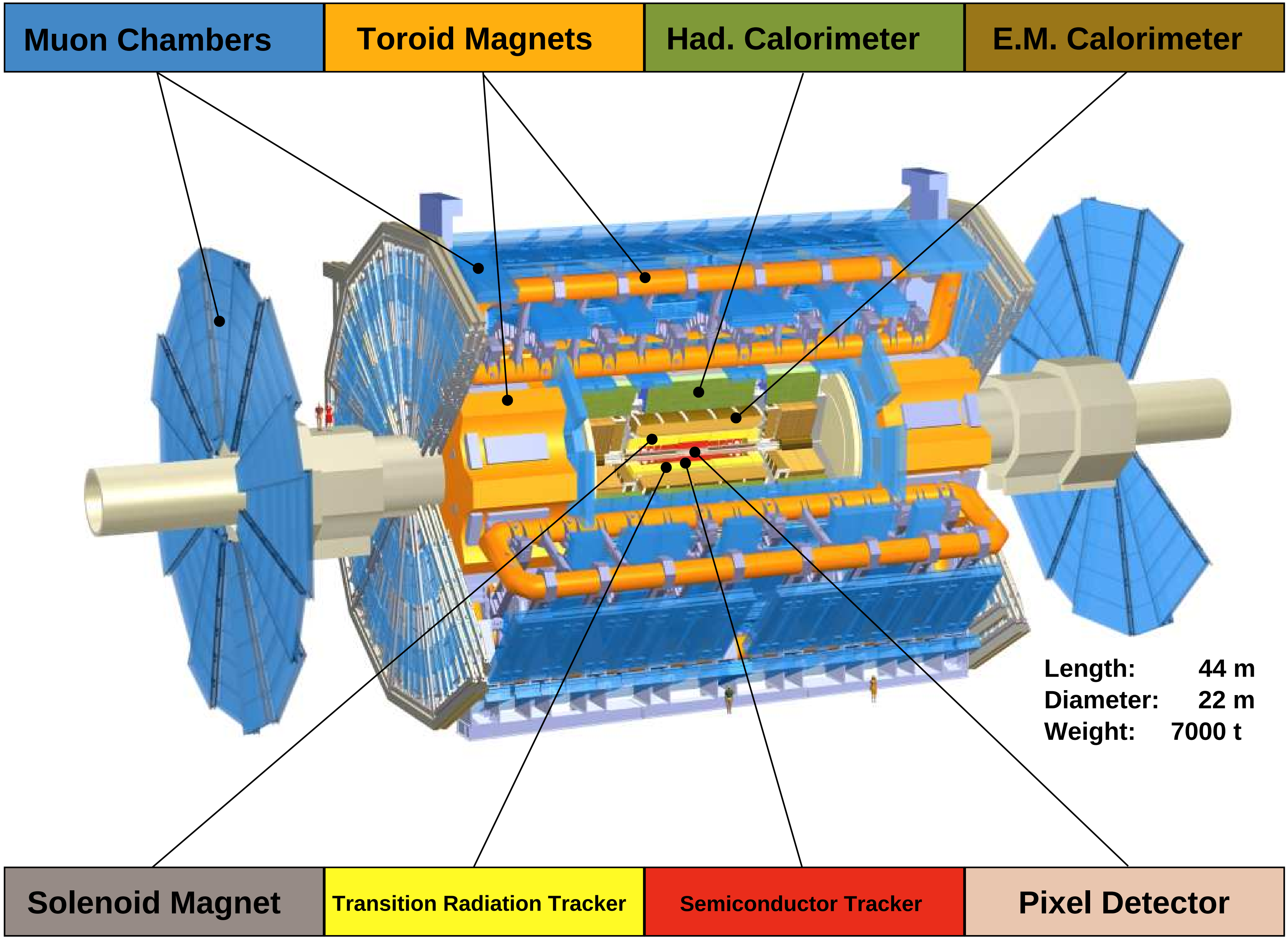
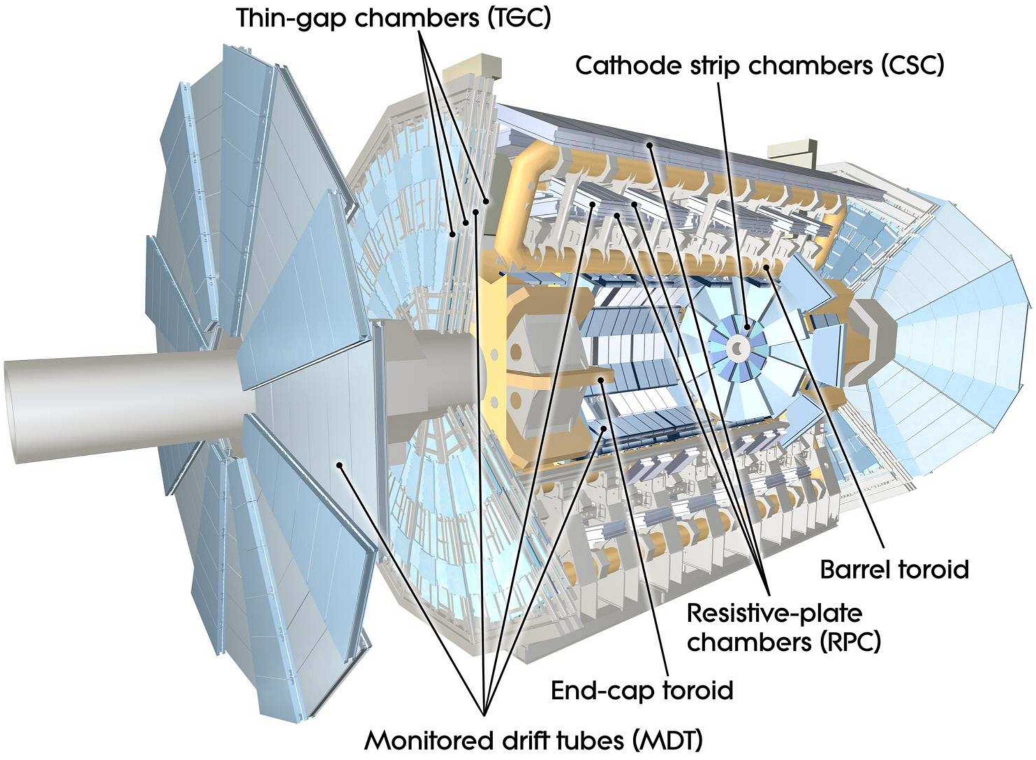
The ATLAS Experiment

A TOROIDAL LHC APPARATUS



ATLAS Muon Spectrometer

Stand-alone momentum resolution: $\Delta p_T / p_T < 10\%$ up to 1 TeV (independent of η)



Dedicated fast trigger chambers

- RPC: 544 chambers with 359 K ch.
- TGC: 3588 chambers with 318 K ch.
- 2-dimensional readout
- Time resolution < 20 ns
- Spatial resolution 5–10 mm

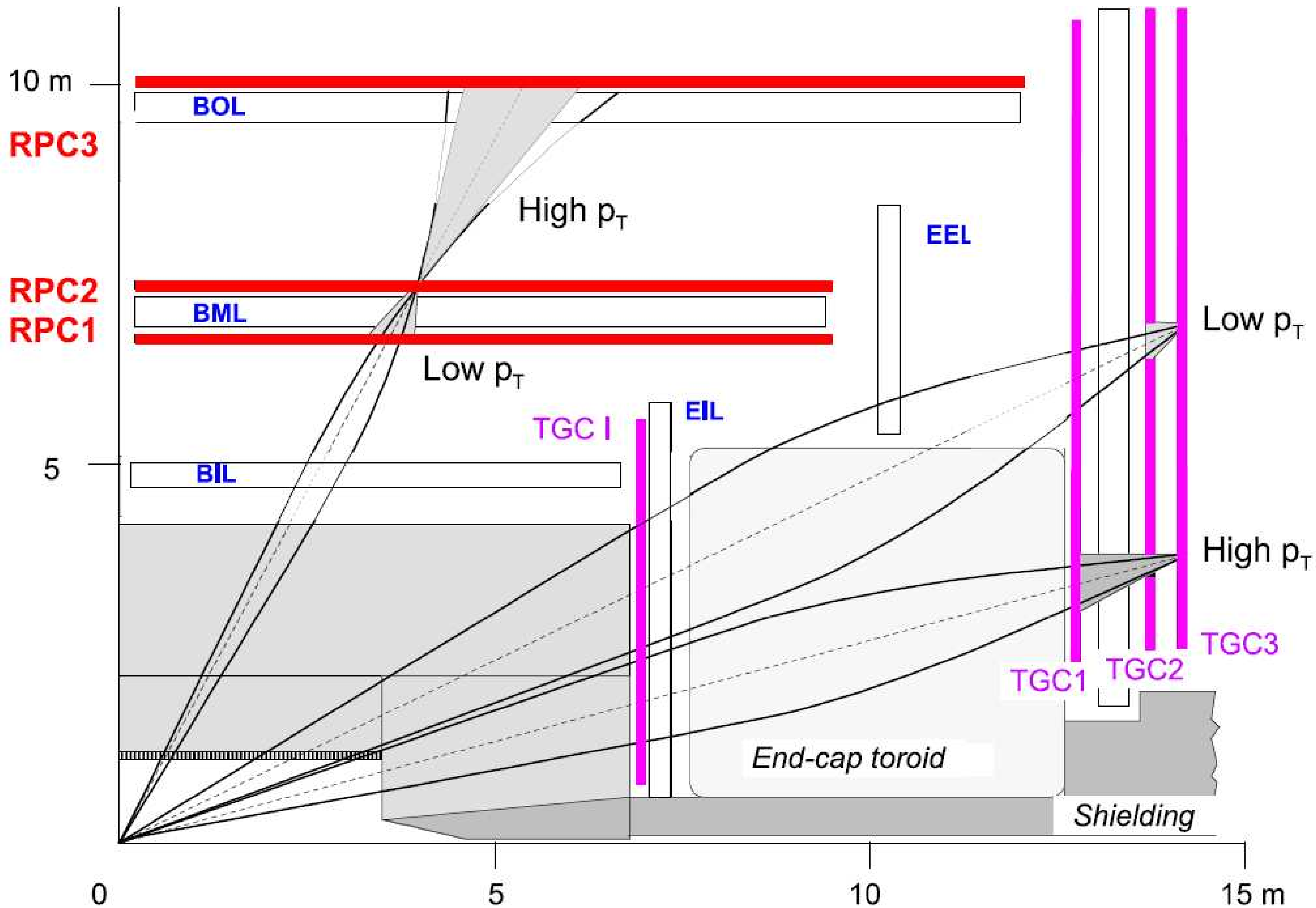
High precision tracking chambers

- MDT: 1150 chambers with 341 K ch.
- CSC: 32 chambers with 31 K ch.
- Spatial resolution 35–40 µm
- Second coordinate meas. in forward chambers

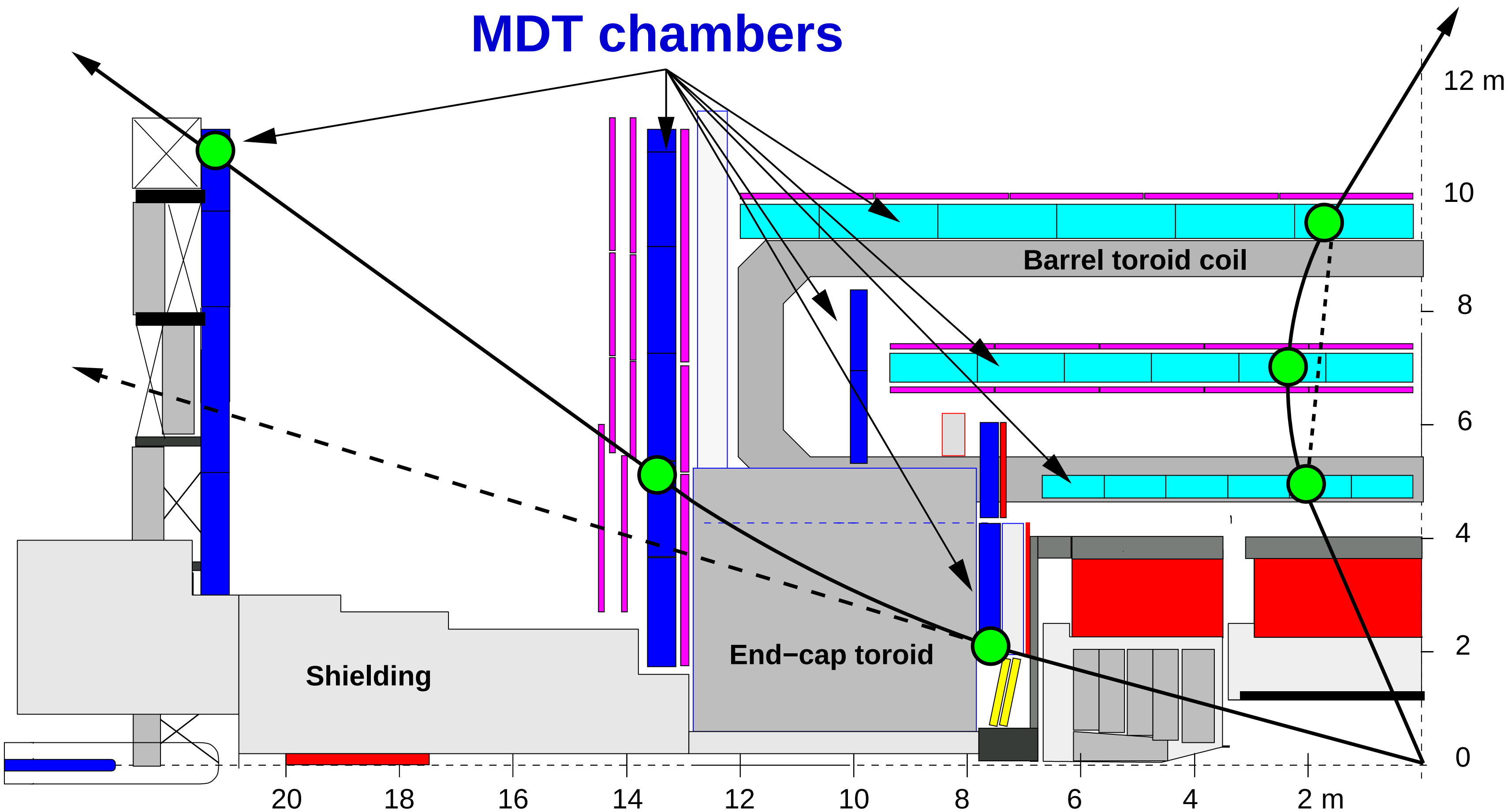
Optical alignment system, 12232 sensors

Coverage: $\eta < 2.7$ (trigger $\eta < 2.4$)

Air-core toroid magnet system: 1.5–5.5 Tm ($\eta < 1.4$), 1–7.5 Tm ($1.6 < \eta < 2.7$)

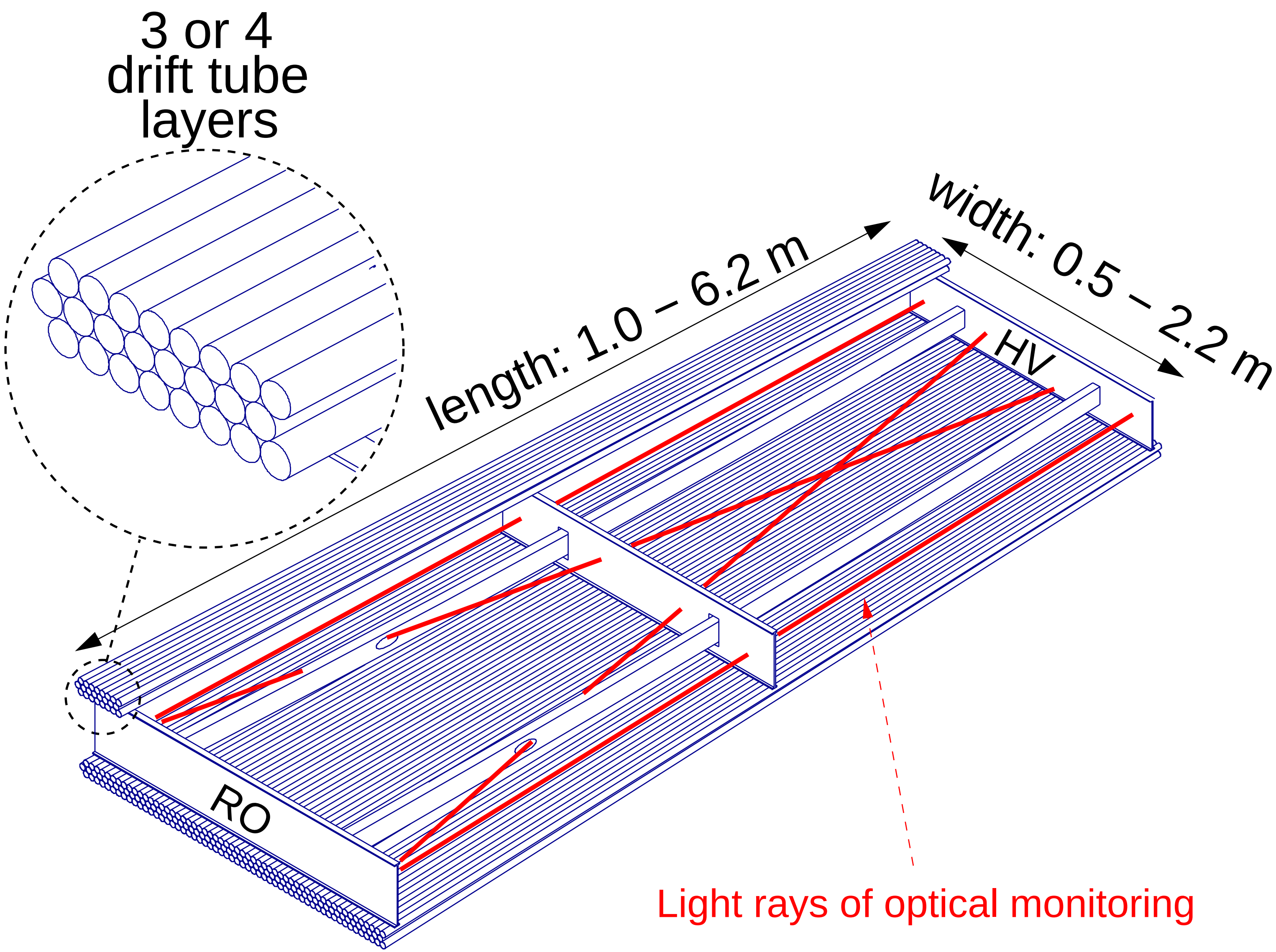


- Low p_T trigger: 2 neighboring planes
- High p_T trigger: 1 additional plane
- Bunch crossing period: 25 ns @ LHC
- Trigger chamber time resolution $<$ 10 ns

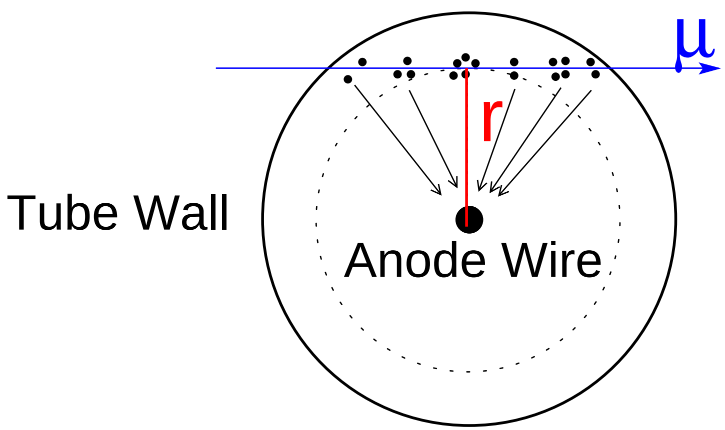


- 3 planes of precision chambers
- Barrel: 3 point sagitta measurement
- Endcap: point-angle measurement

- $p_T = 1$ TeV $\Rightarrow$ 500 µm sagitta
- 50 µm point resolution needed (including alignment across 5–10 m)


3 or 4
drift tube
layers
length: 1.0 – 6.2 m
width: 0.5 – 2.2 m
HV
RO
Light rays of optical monitoring

Drift Tubes



- Measures drift time of electrons to wire
  - Drift circle, ambiguity
  - Needs external trigger
- Not (very) sensitive in wire direction

Electric field:

$$E = \frac{U}{\ln(b/a)} \frac{1}{r}$$

Gas amplification (gas gain):

$$G = \frac{N}{N_0} = \exp \int \alpha(s)\, ds$$

Signal shape of single drifting ion:

$$I(r) = -q \frac{\mathbf{v}(r) \cdot \mathbf{E}(r)}{U}$$

$$I(t) = -\frac{q}{2 \ln(b/a)} \cdot \frac{1}{t+t_0}$$

Time constant:

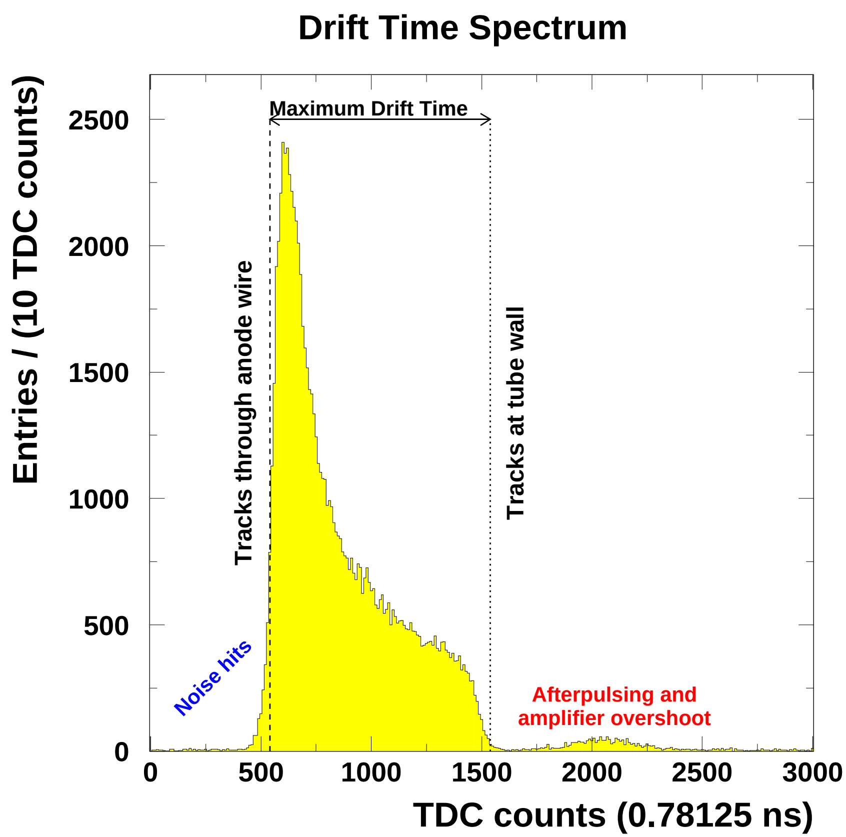
$$t_0 \equiv \frac{a^2}{2\, \mu\, U} \ln(b/a)$$

Order of ns

Drift time to tube wall:

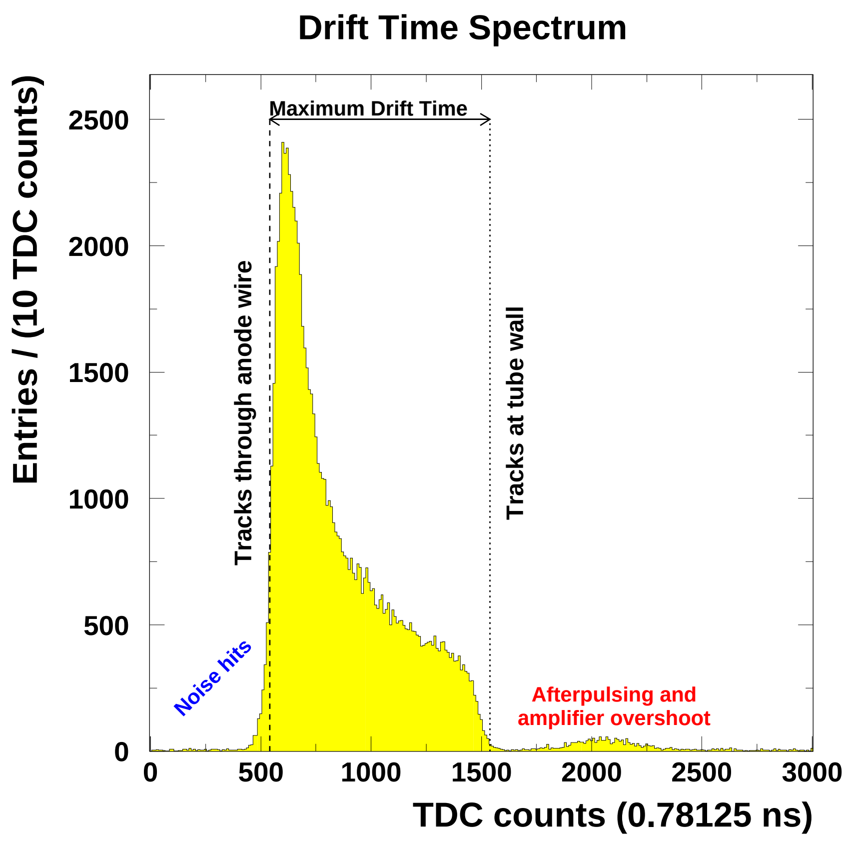
$$t_{max} \equiv \frac{b^2 - a^2}{2\, \mu\, U} \ln(b/a) \approx \frac{b^2}{2\, \mu\, U} \ln(b/a)$$

Order of ms



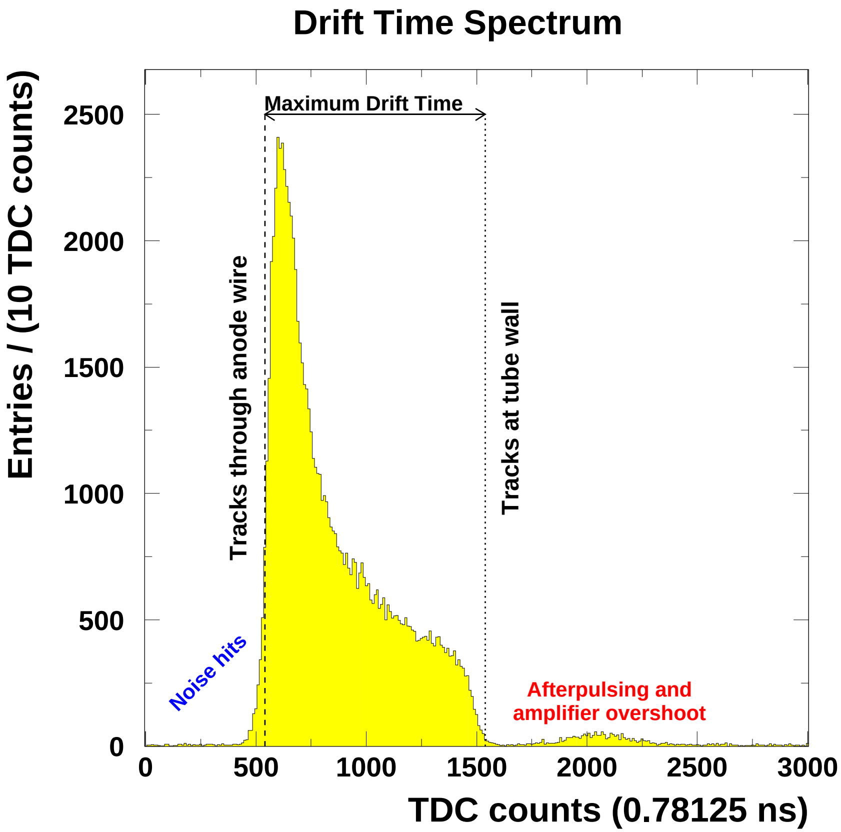
Example parameters: ATLAS drift tubes

- Outer tube diameter: 30 mm
- Wall thickness: 0.4 mm
- Wire diameter: 50 µm
- Gas mixture: Ar/CO_2=93/7 (+750 ppm H_2O)
- Pressure: 3 bar absolute
- Gas gain: 2 10^4 (at 3080 V)
- Maximum drift time: $\sim$750 ns
- Rate limit: $\sim$1000 Hz / cm^2 (1 m long tubes) $\longrightarrow$ 25% occupancy



Assuming homogeneous illumination of tubes (i.e. equal number of tracks at all radii)

- Drift time spectrum has characteristic shape
  - Gas mixture and operating conditions
- Gives number of hits per time: dN/dt



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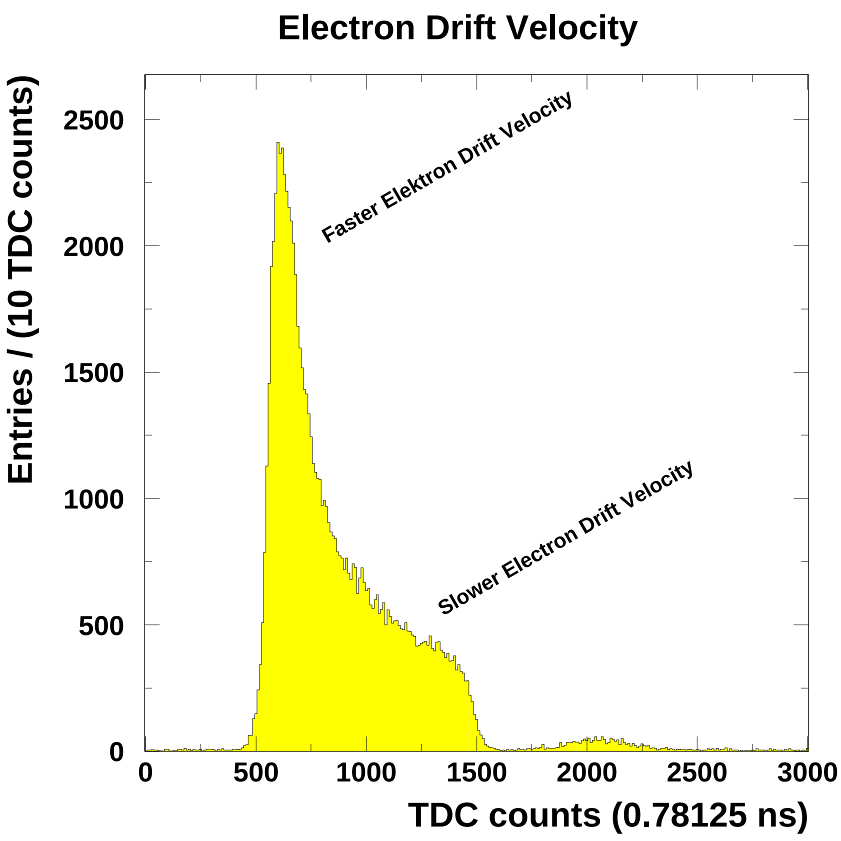
From the drift time spectrum we can derive

$$\frac{dN}{dt} = \frac{dN}{dr} \cdot \frac{dr}{dt}$$



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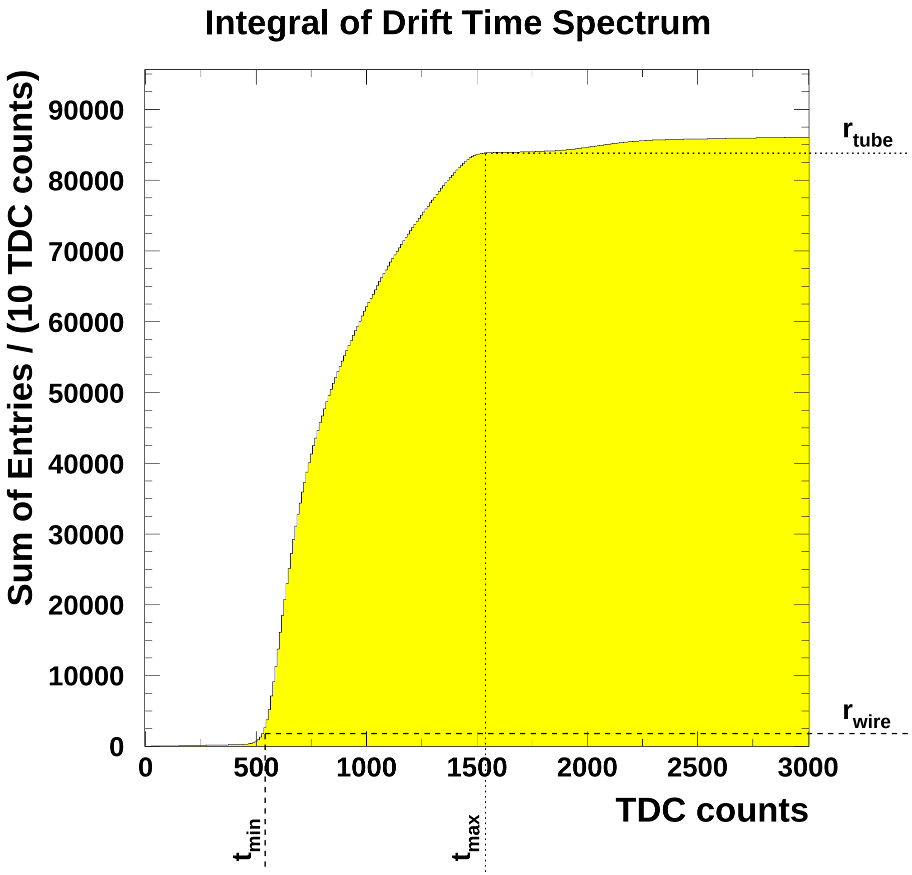
$$\frac{dN}{dt} = \frac{dN}{dr} \cdot \frac{dr}{dt} = \text{const.} \cdot v_{\text{drift}}(r),$$

the electron drift velocity as function of the distance to the anode wire



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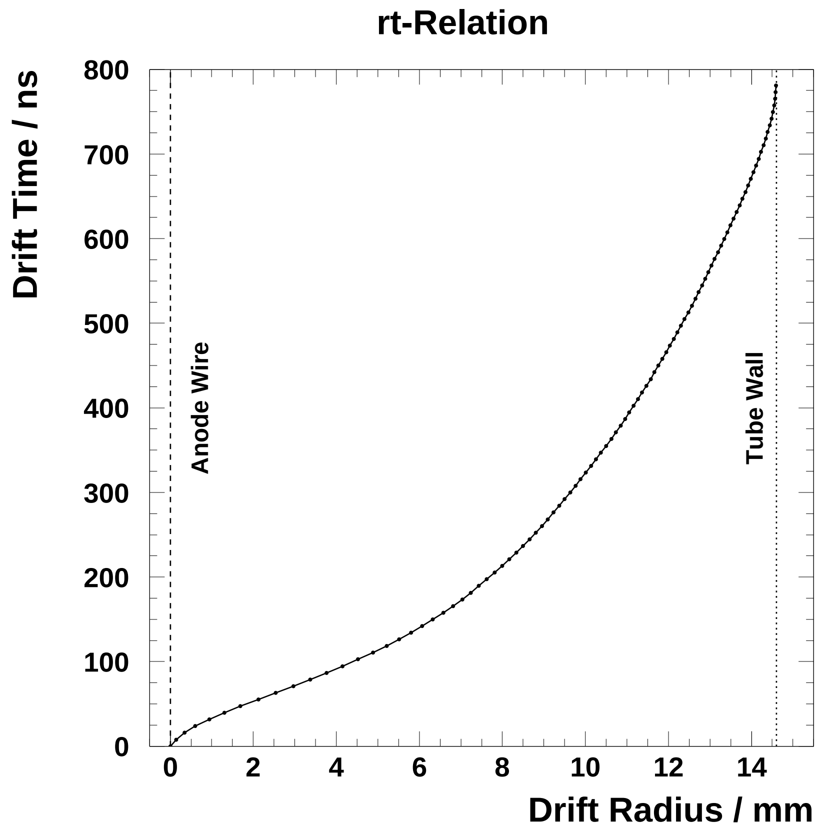
And by integration

$$\int_0^t \frac{dN}{dt'}\, dt' \quad = \quad \int_0^t \frac{dN}{dr} \cdot \frac{dr}{dt'}\, dt',$$



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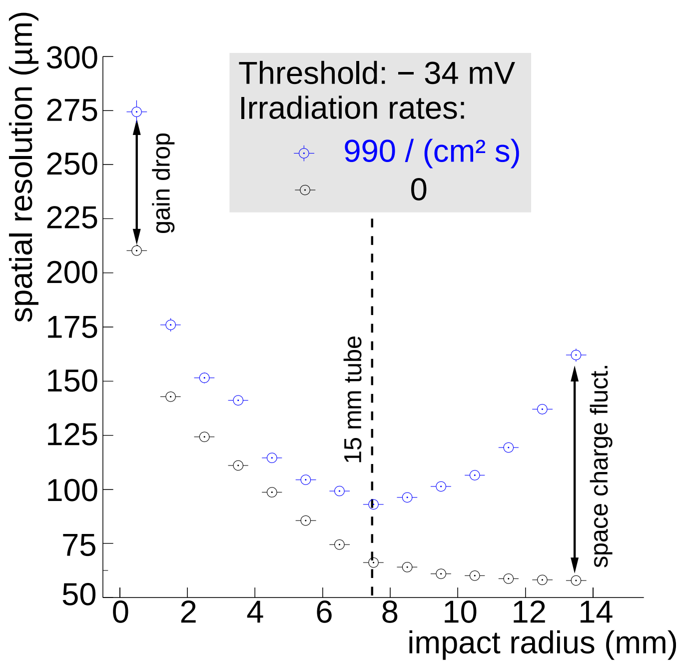
$$\begin{aligned} \int_0^t \frac{dN}{dt'}\, dt' &= \int_0^t \frac{dN}{dr} \cdot \frac{dr}{dt'}\, dt' \\ &= \text{const.} \cdot \int_0^t \frac{dr}{dt'}\, dt' \\ &= \text{const.} \cdot r(t), \end{aligned}$$

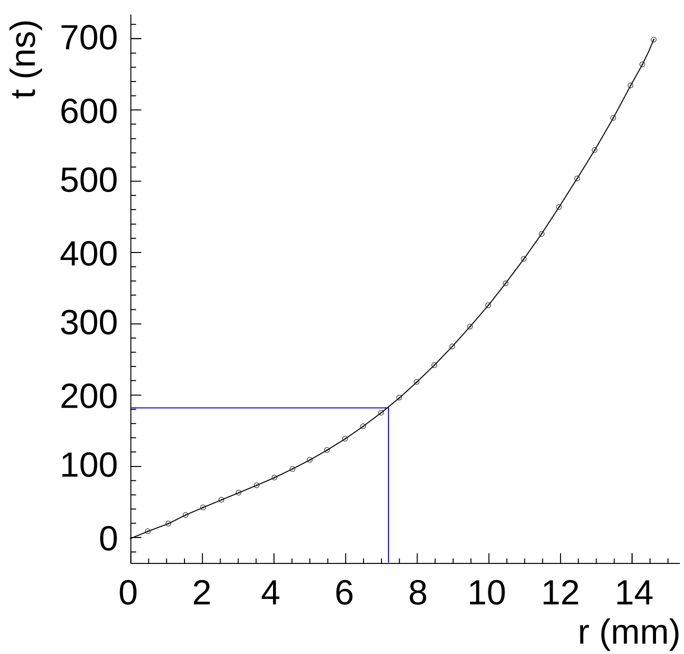
the space-to-drift time (rt-)relation

Drift Tubes

Spatial resolution



rt-Relation

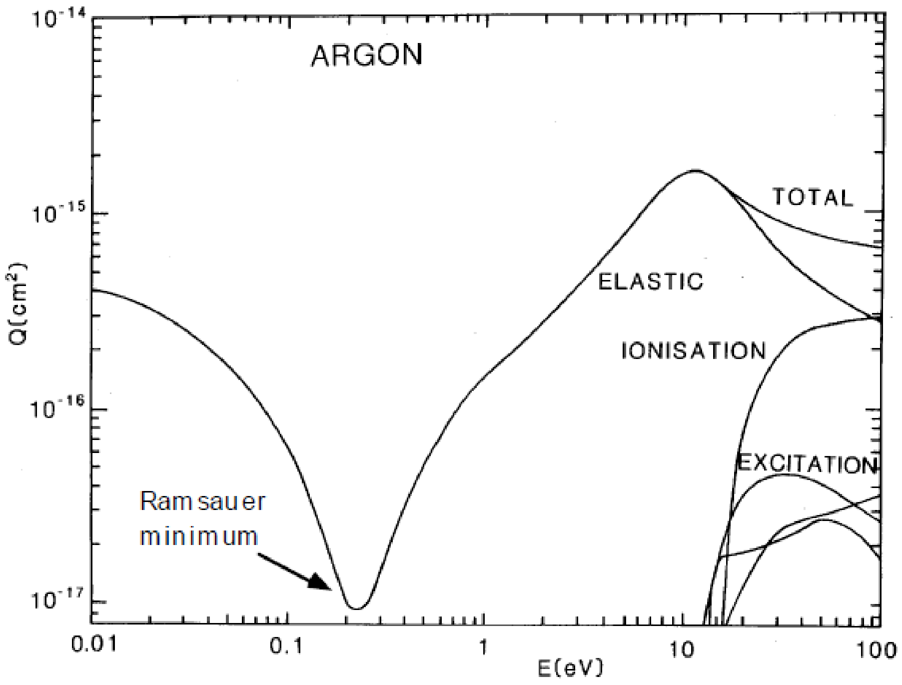


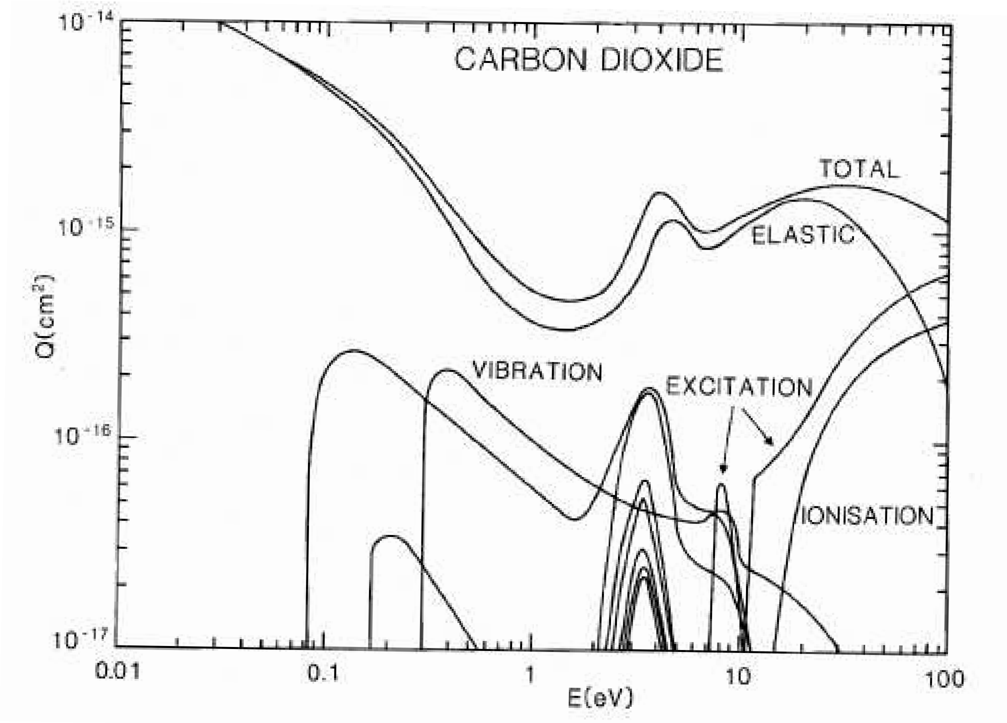
High rate capable drift tubes

- **Outer tube diameter: 15 mm**
- Wall thickness: 0.4 mm
- Wire diameter: 50 µm
- Gas mixture: Ar/CO_2=93/7
- Pressure: 3 bar absolute
- Gas gain: $2\ 10^4$ (**at 2730 V**)
- Maximum drift time: ∼200 ns

- Occupancy reduced by factor 7
- Space charge effects reduced by factor 10
- More linear rt-relation
- 4 times higher channel density possible

Range of electron energy during drift: 0.1 – few eV

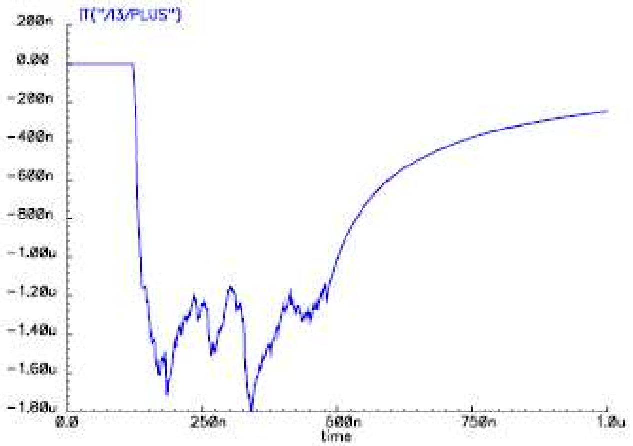




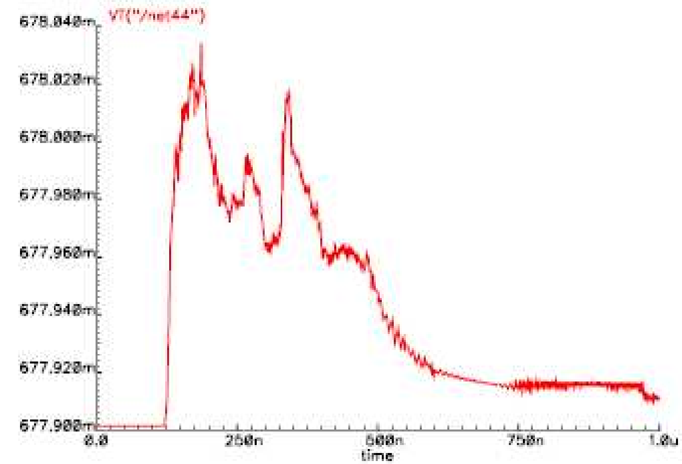
- Elastic scattering
- High electron velocity
- . . . but low drift velocity

- Inelastic scattering
- Low electron velocity
- . . . higher drift velocity in mixtures

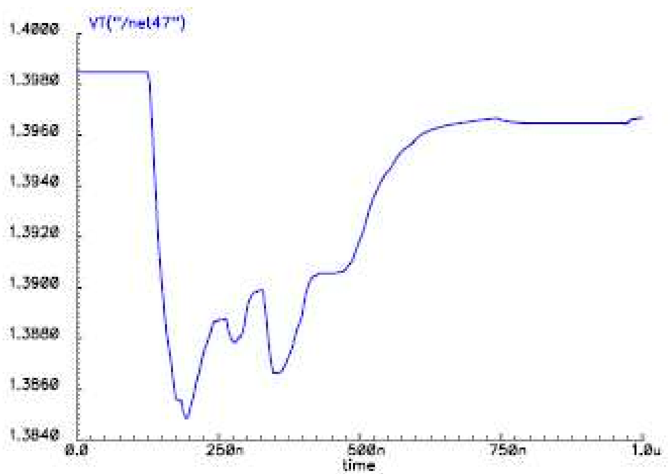
Signal on wire



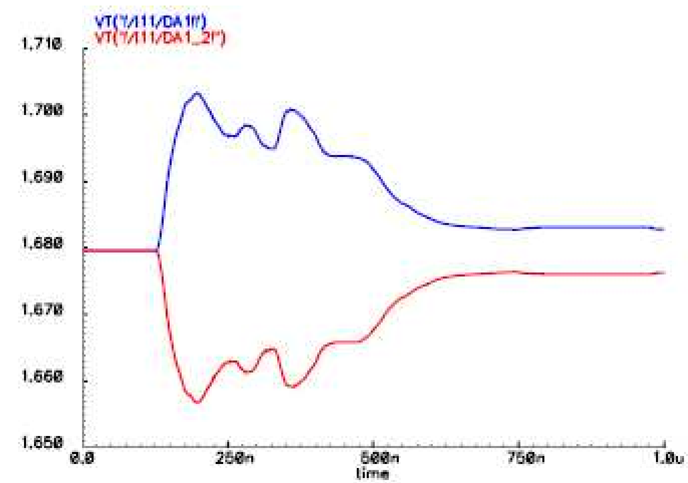
Preamplifier input



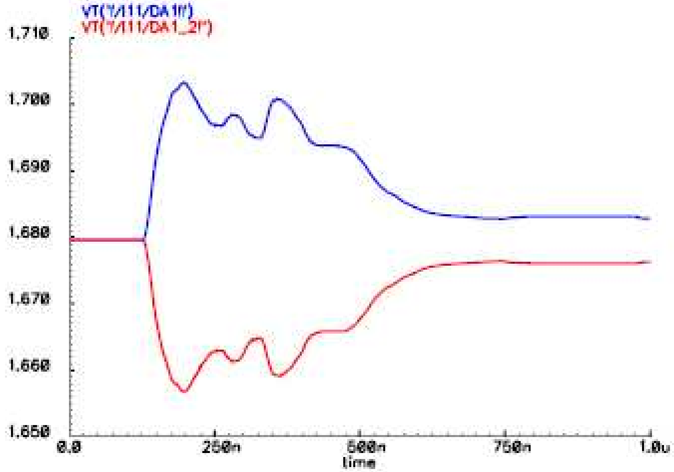
Preamplifier output



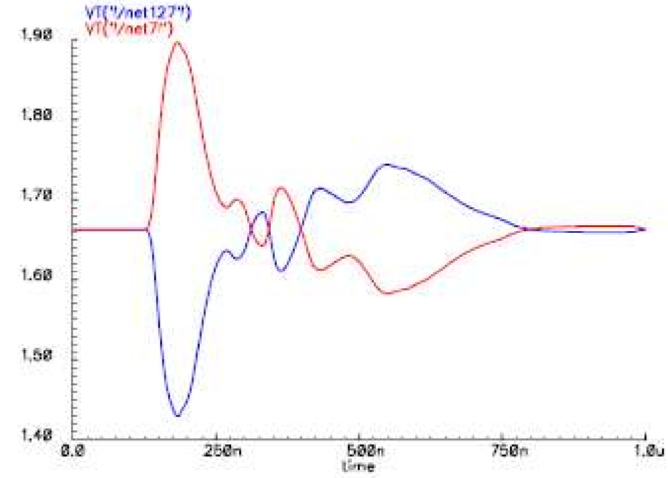
1st shaper stage



2nd shaper stage

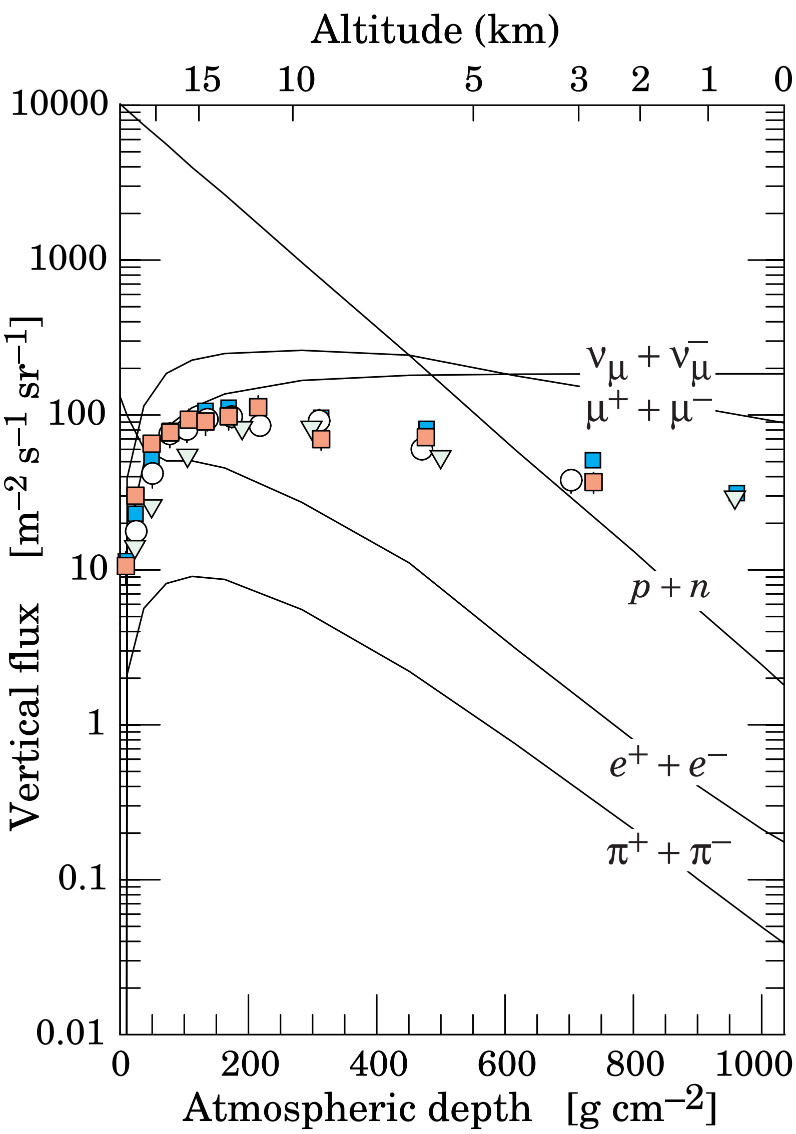


3rd shaper stage



C. Posch, E. Hazen, J. Oliver, *MDT-ASD, CMOS front-end for ATLAS MDT, rev. version 2.1*, ATL-MUON-2002-003, CERN (2007)

- **Cosmic radiation** incident on earth
  - **Primary particles** (p, He, e^-, C, O, Fe. . .) accelerated by **astrophysical sources** (including the sun)
  - **Secondary particles** (Li, Be, B, $\bar{p}$, e^+. . .) produced by **interaction of primaries with interstellar gas**
- **Interaction** with nuclei **in atmosphere creates** particle **cascades**
  - Electrons and hadrons stopped in upper atmosphere
  - **Main component at ground level: muons**
    - Flux ($p > 1$ GeV): 130 m^2 s^{-1}
    - Average energy: 4 GeV
    - Energy spectrum: $I(E) \sim E^{-2.7}$



K. Nakamura et al. (Particle Data Group), J.Phys. G **37** (Cosmic rays (rev.)), 075021 (2010)