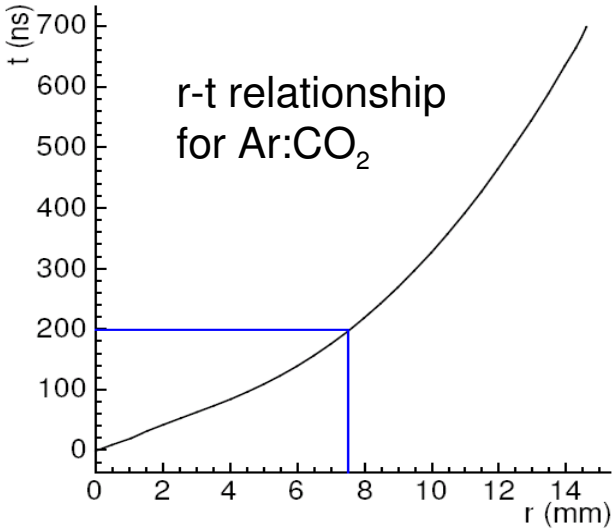
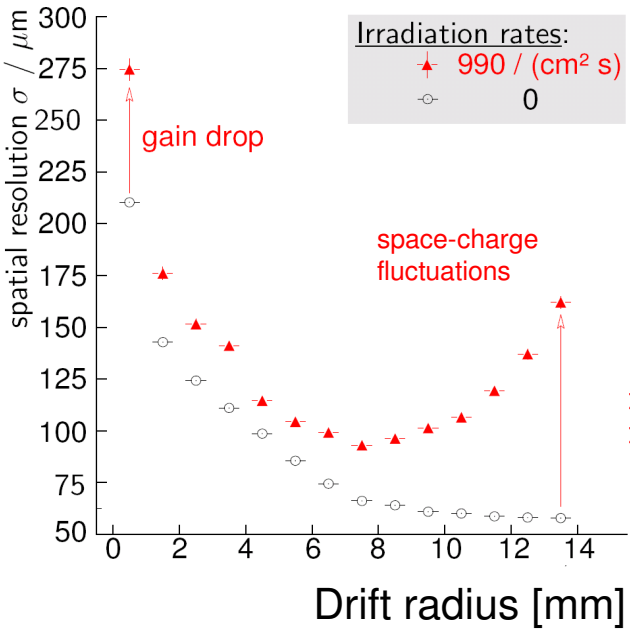
R&D for Super-LHC: smaller diameter MDT high rate tests at the GIF@CERN

Why?

- **Super-LHC:** the LHC upgrade plan foresees a luminosity increase of ~10x;
- If the background scales with the luminosity, at Super-LHC we will have to cope with 10x higher rates ;
- The **ATLAS MDT chambers** suffer at high rates because of:
  - Degradation of the muon detection efficiency due to high occupancy;
  - Degradation of the spatial resolution due to space charge fluctuations.
- To cope with high rates @SLHC we can **reduce** the diameter of the tubes because:
  - Occupancy reduced of x2.3 due to shorter drift time
  - Space charge less critical because we work in a region where the gas behaviour is more linear

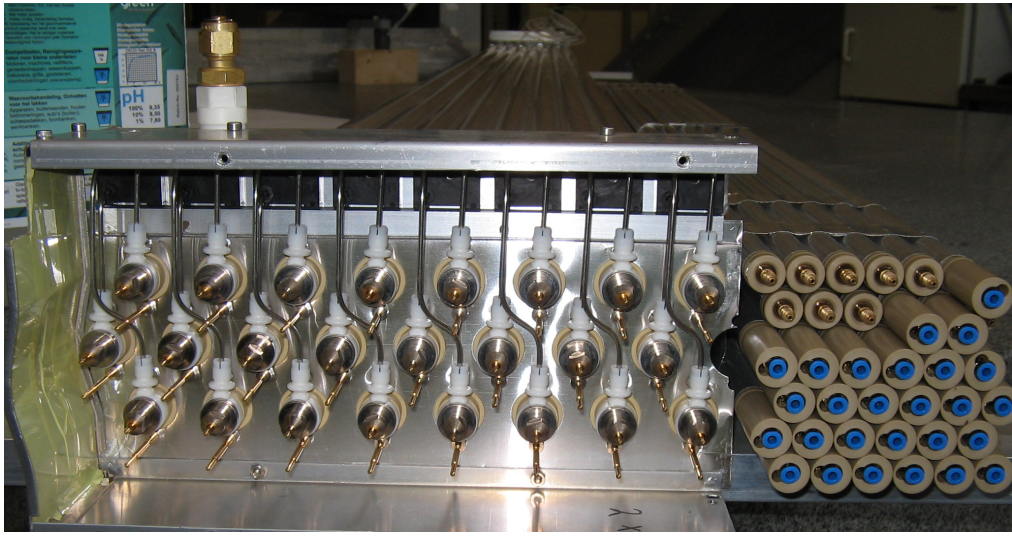
MDT operating limits: 500 Hz/cm2
(ATLAS max rate * safety factor 5)



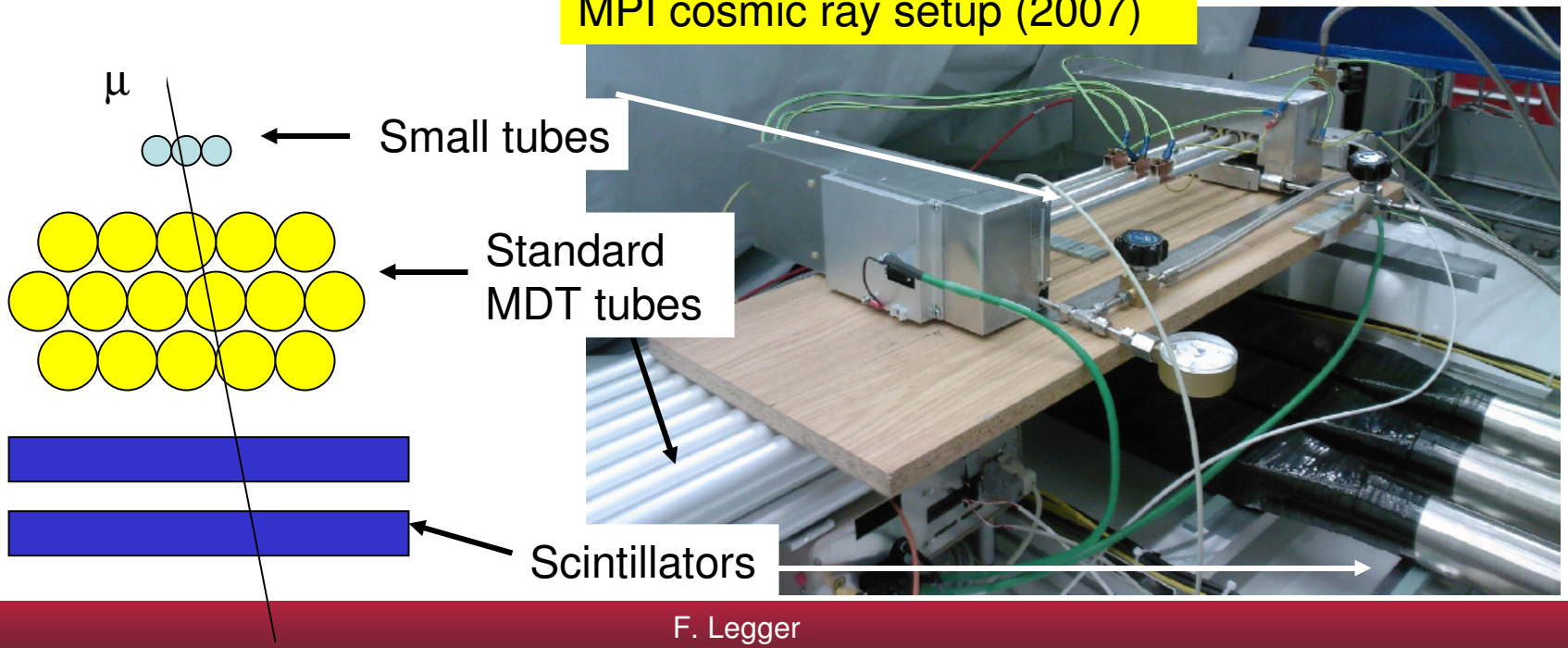


Small tube design

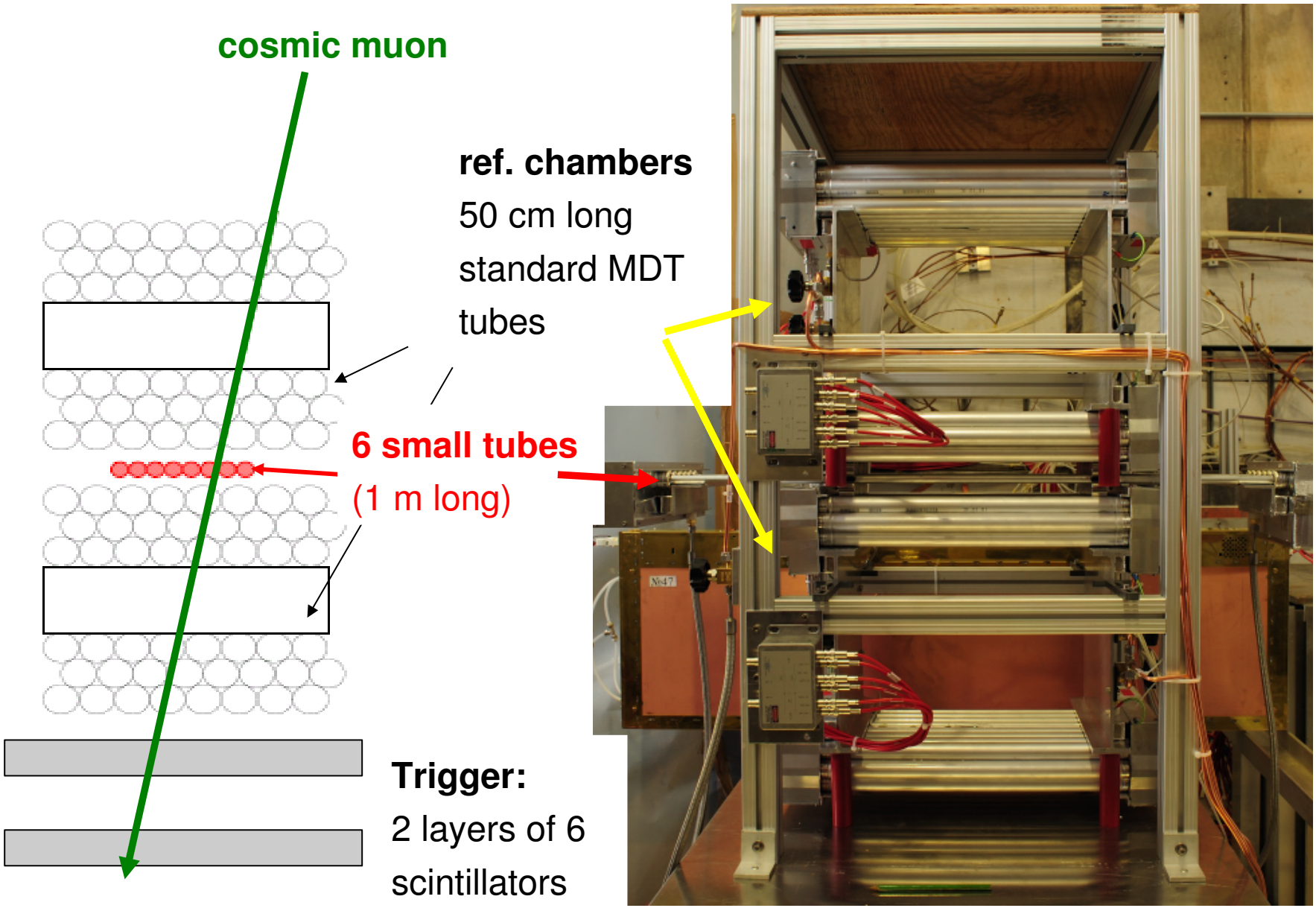
- **4 times more tubes** can be packed in the same space, however limited space available for gas and electronics connections;
- First tests @MPI with **cosmic** rays in 2007;
- Test in **high rate** environment (Gamma Irradiation Facility – GIF) at CERN in spring 2008



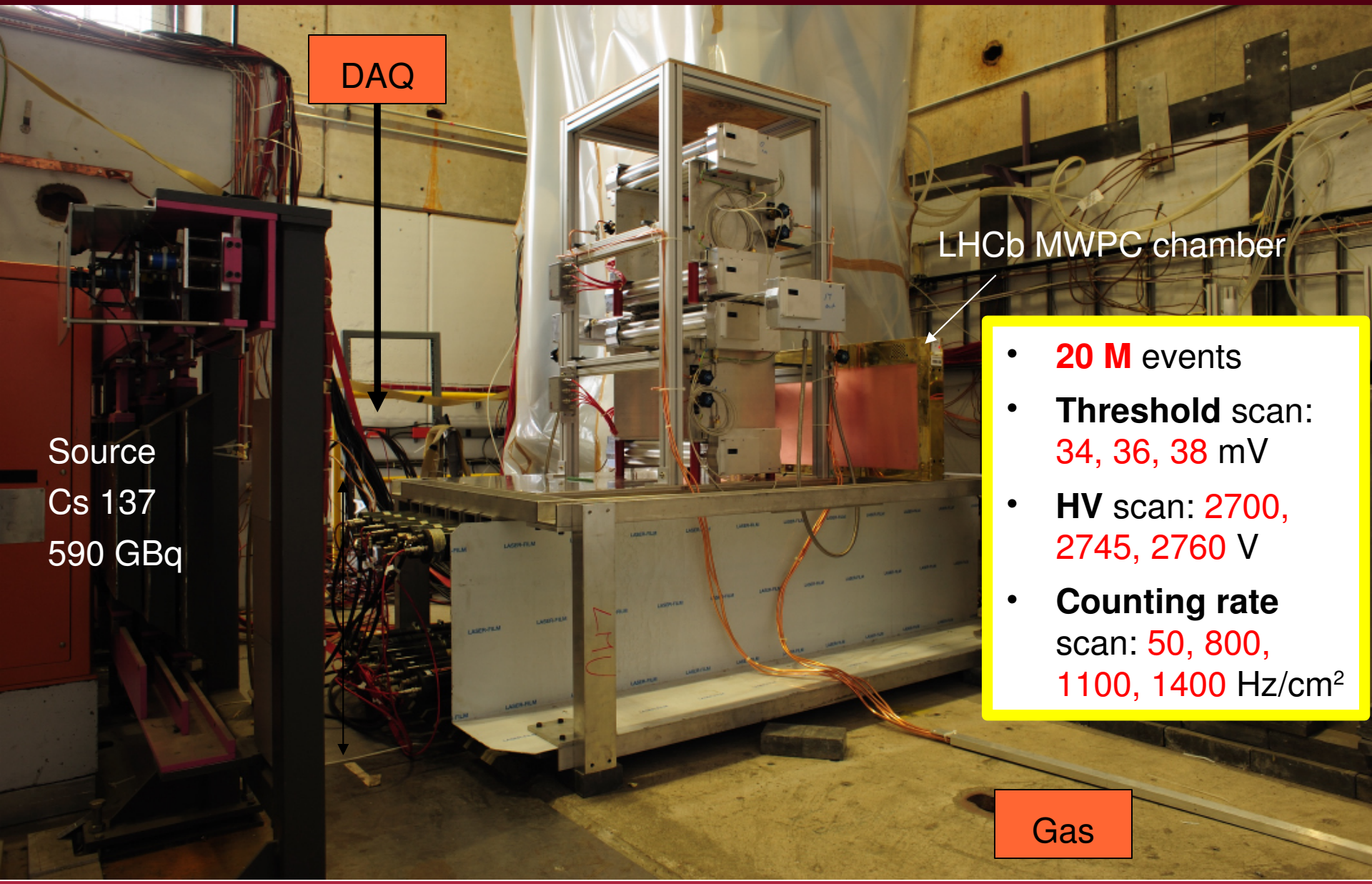
MPI cosmic ray setup (2007)



The setup for GIF tests

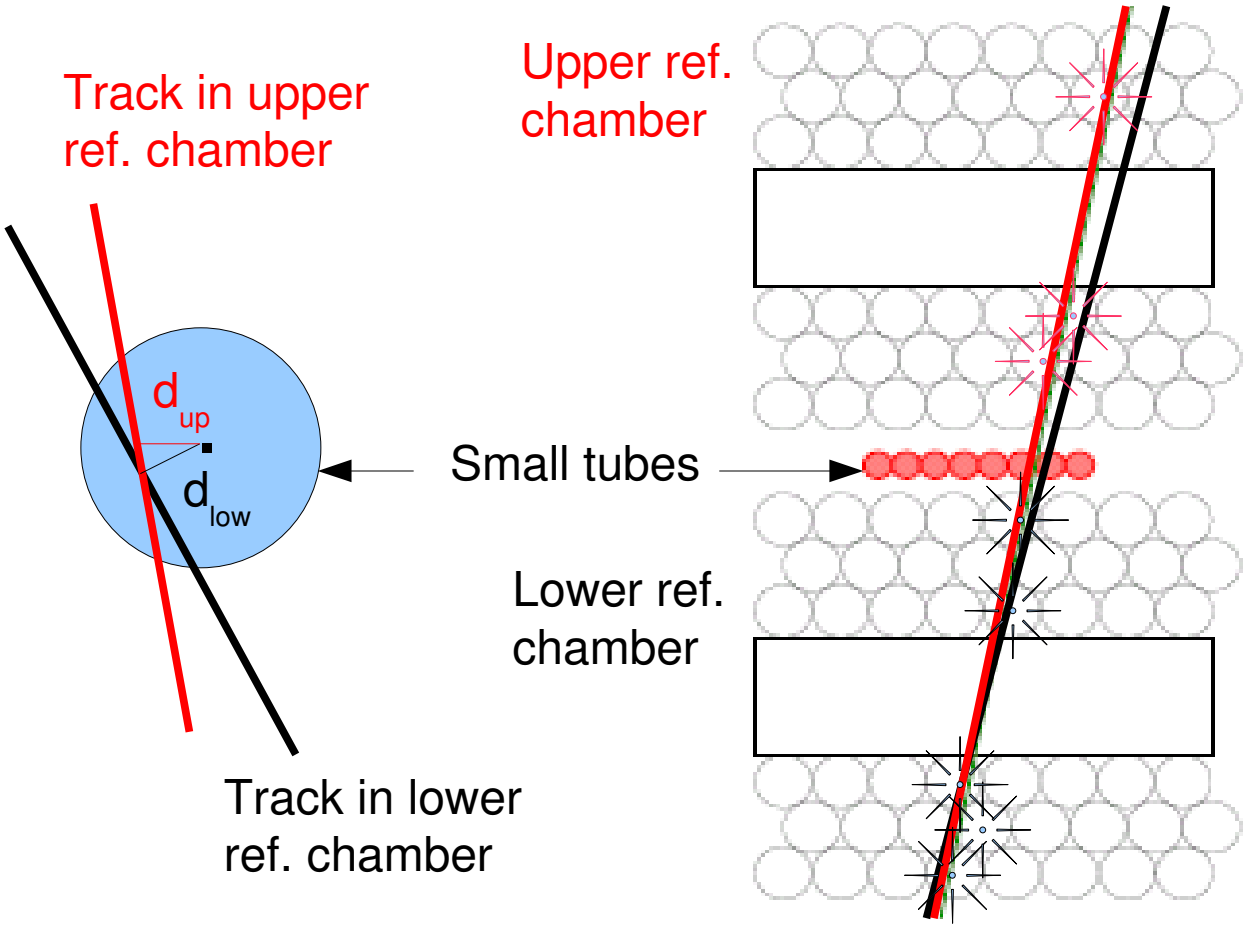


The setup at the GIF



- **20 M** events
- **Threshold** scan: 34, 36, 38 mV
- **HV** scan: 2700, 2745, 2760 V
- **Counting rate** scan: 50, 800, 1100, 1400 Hz/cm^2

GIF data analysis



objectives:

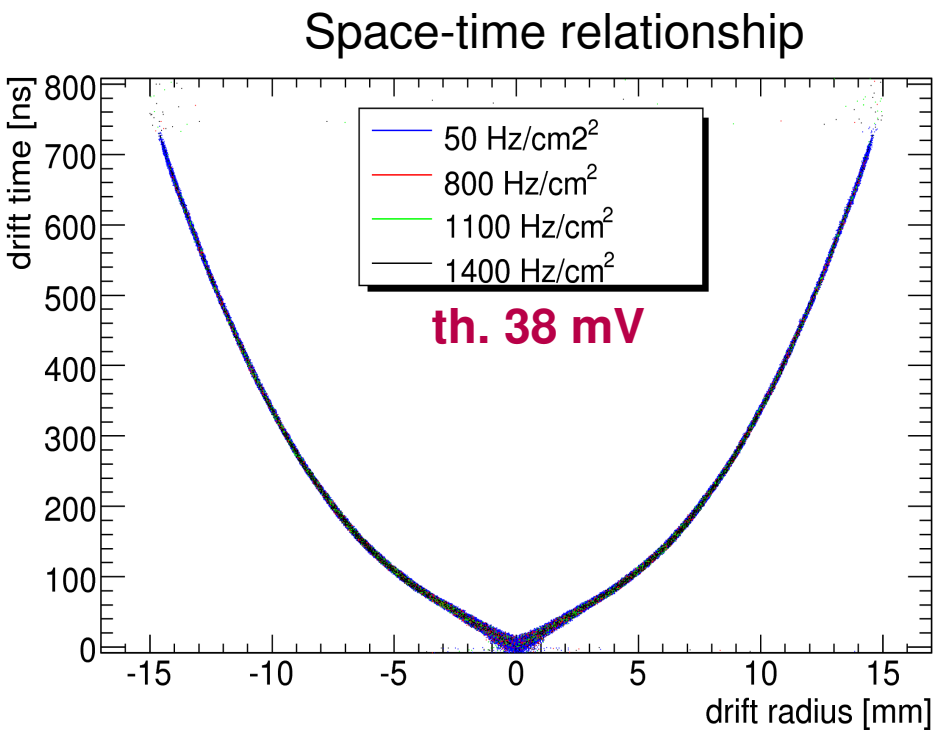
- Drift time spectra
- r-t relationship
- Efficiency
- Resolution

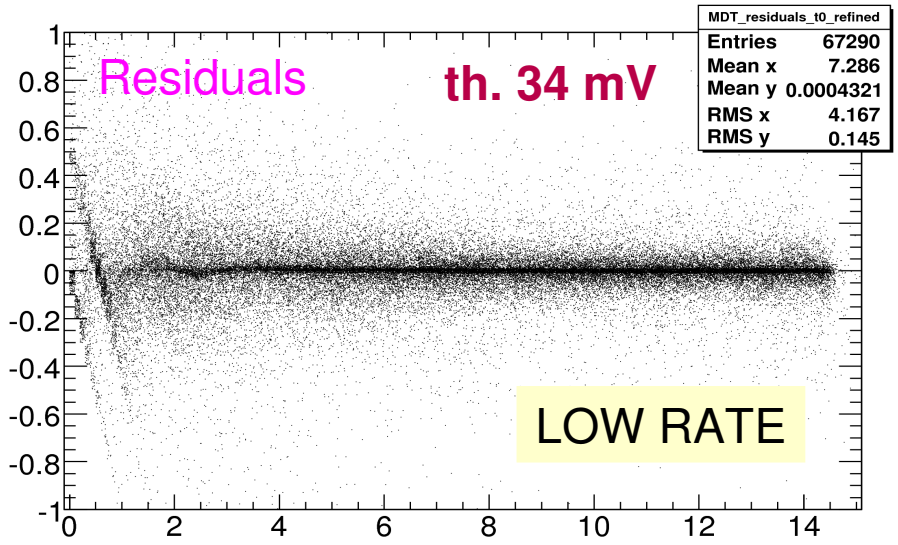
Tracking cuts

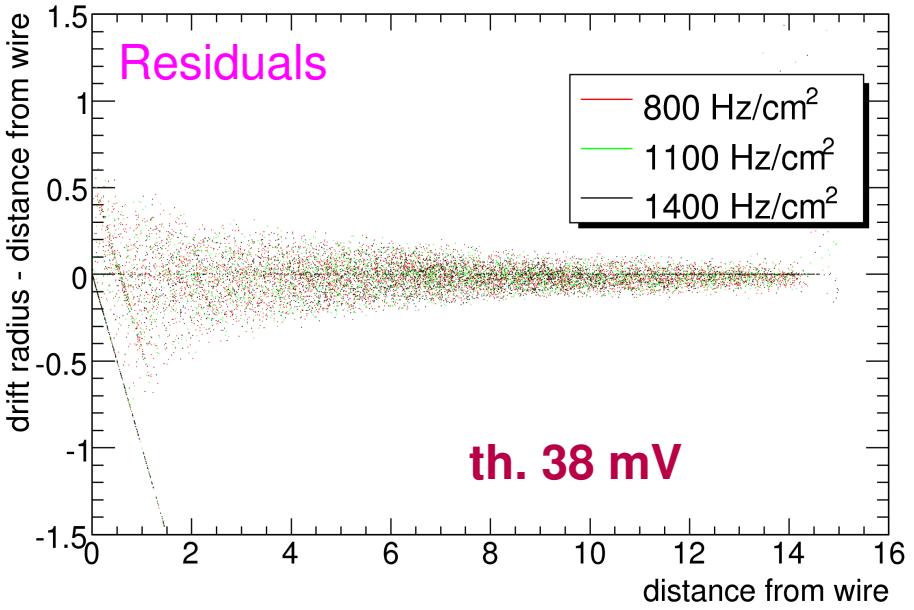
- CL > 0.02
- |slope| < 0.3
- |d(track, wire)| < 8 mm
- |Δ slope| < 0.006

Hit position in small tube from tracks in ref. chambers: average distance of tracks from wire $|d_{low} + d_{up}|/2$

Tracking in Ref. Chambers

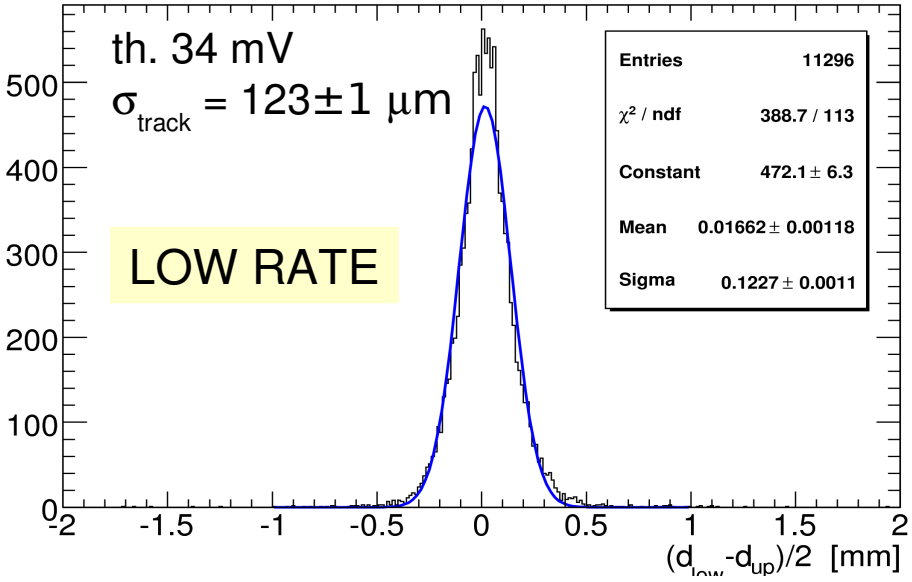


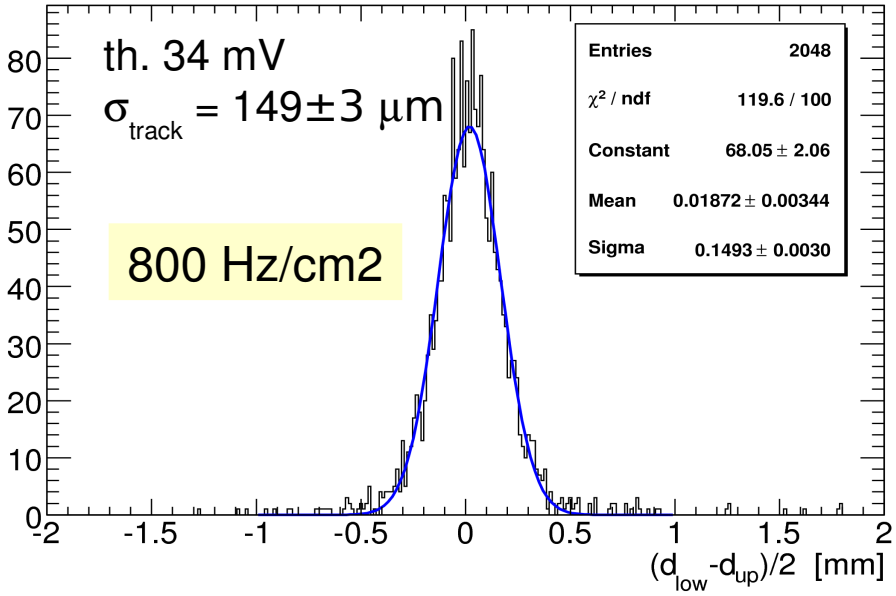


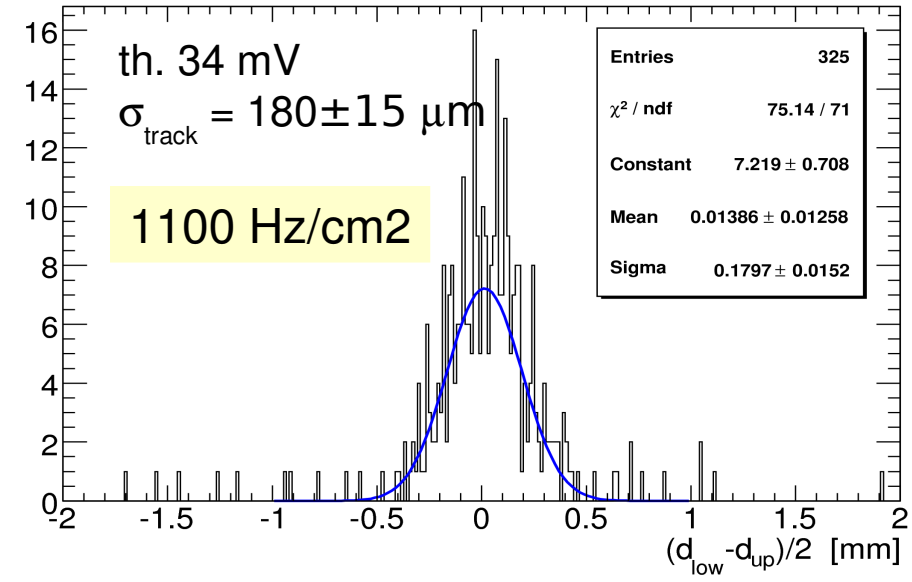


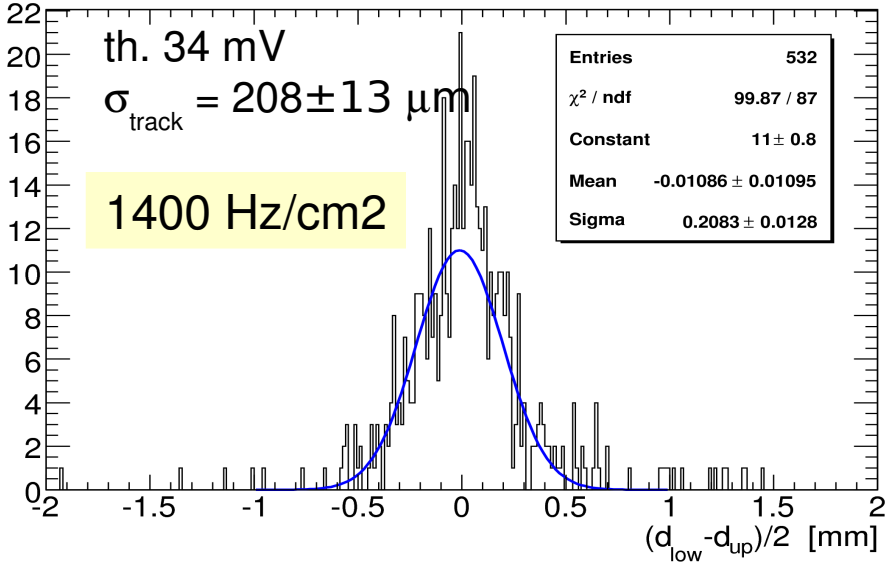
- Space-time relationship does not change significantly with the hit rate
- Very clean muon selection, as a drawback statistics goes down significantly with the rate

Tracking resolution

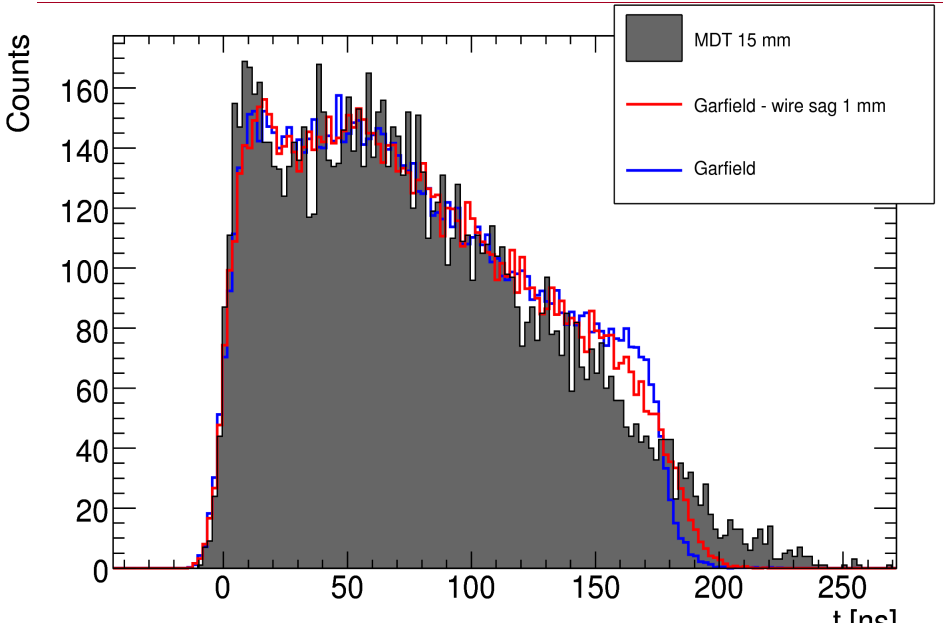




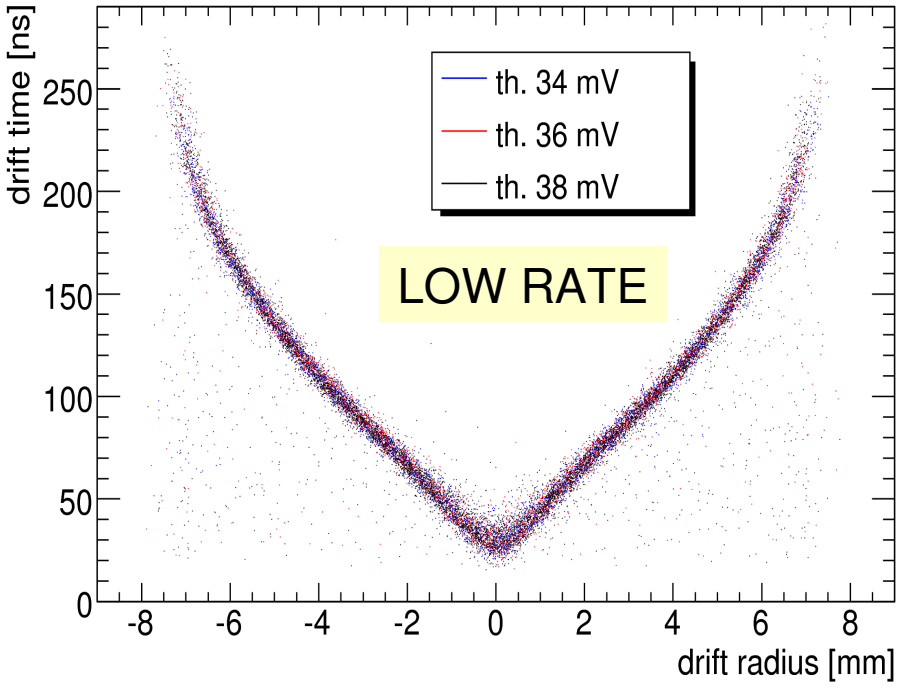


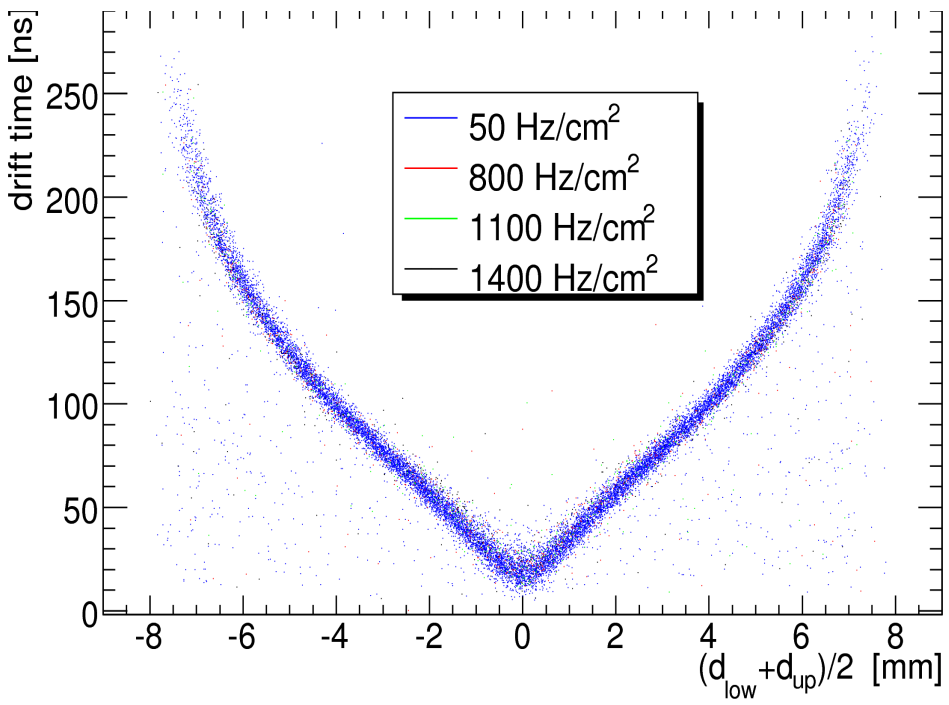


Small tubes



- Drift time spectrum trailing edge: wire sag
- To be taken into account in future designs



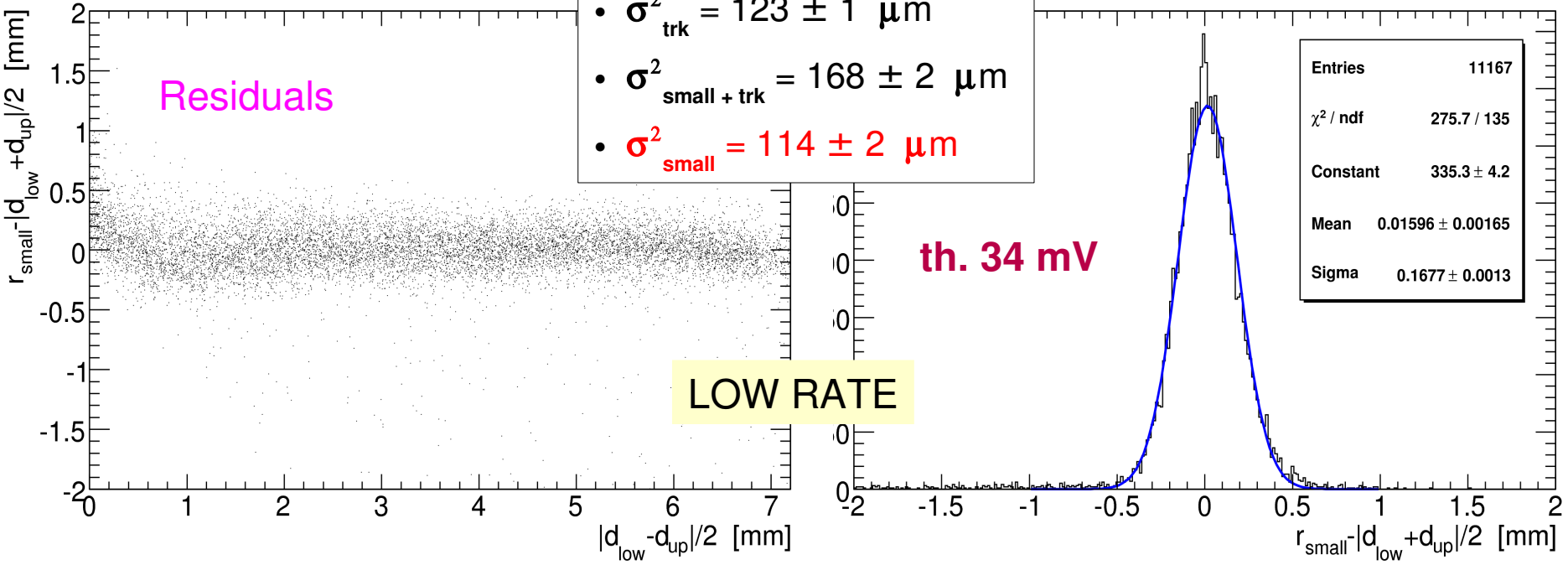


Spatial resolution small tubes

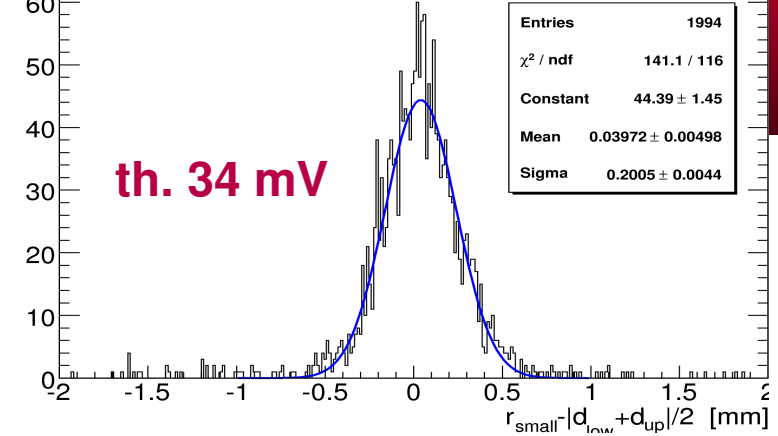
- **Tracking resolution σ^2_{trk}** from fit of **$(d_{low} - d_{up})/2$** since $(d_{low} - d_{up})/2$ has the same variance $(\sigma^2_{low}+\sigma^2_{up})/2$ as $(d_{low}+d_{up})/2$
- **Tracking + small tube resolution $\sigma^2_{small + trk}$** from fit of **$r-(d_{low} - d_{up})/2$**
- **Small tube resolution σ^2_{small}** from: **$\sigma^2_{small + trk} = \sigma^2_{trk} + \sigma^2_{small}$**

Tracking cuts:
- CL > 0.02
- |slope| < 0.3
- |d(track, wire)| < 8 mm
- |Δ slope| < 0.006

- σ^2_{trk} = 123 ± 1 μm
- $\sigma^2_{small + trk}$ = 168 ± 2 μm
- σ^2_{small} = 114 ± 2 μm

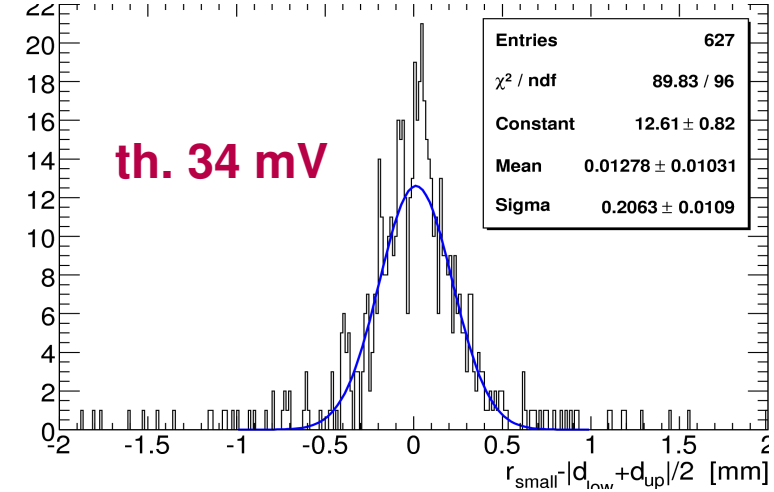


Spatial resolution



- $\sigma^2_{trk} = 149 \pm 3\ \mu m$
- $\sigma^2_{small + trk} = 200 \pm 4\ \mu m$
- $\sigma^2_{small} = 134 \pm 5\ \mu m$

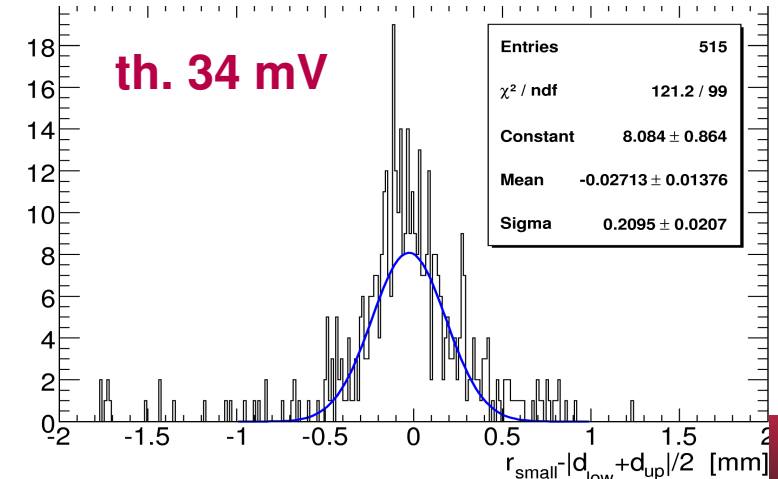
800 Hz/cm2



- $\sigma^2_{trk} = 164 \pm 7\ \mu m$
- $\sigma^2_{small + trk} = 206 \pm 11\ \mu m$
- $\sigma^2_{small} = 125 \pm 13\ \mu m$

1100 Hz/cm2

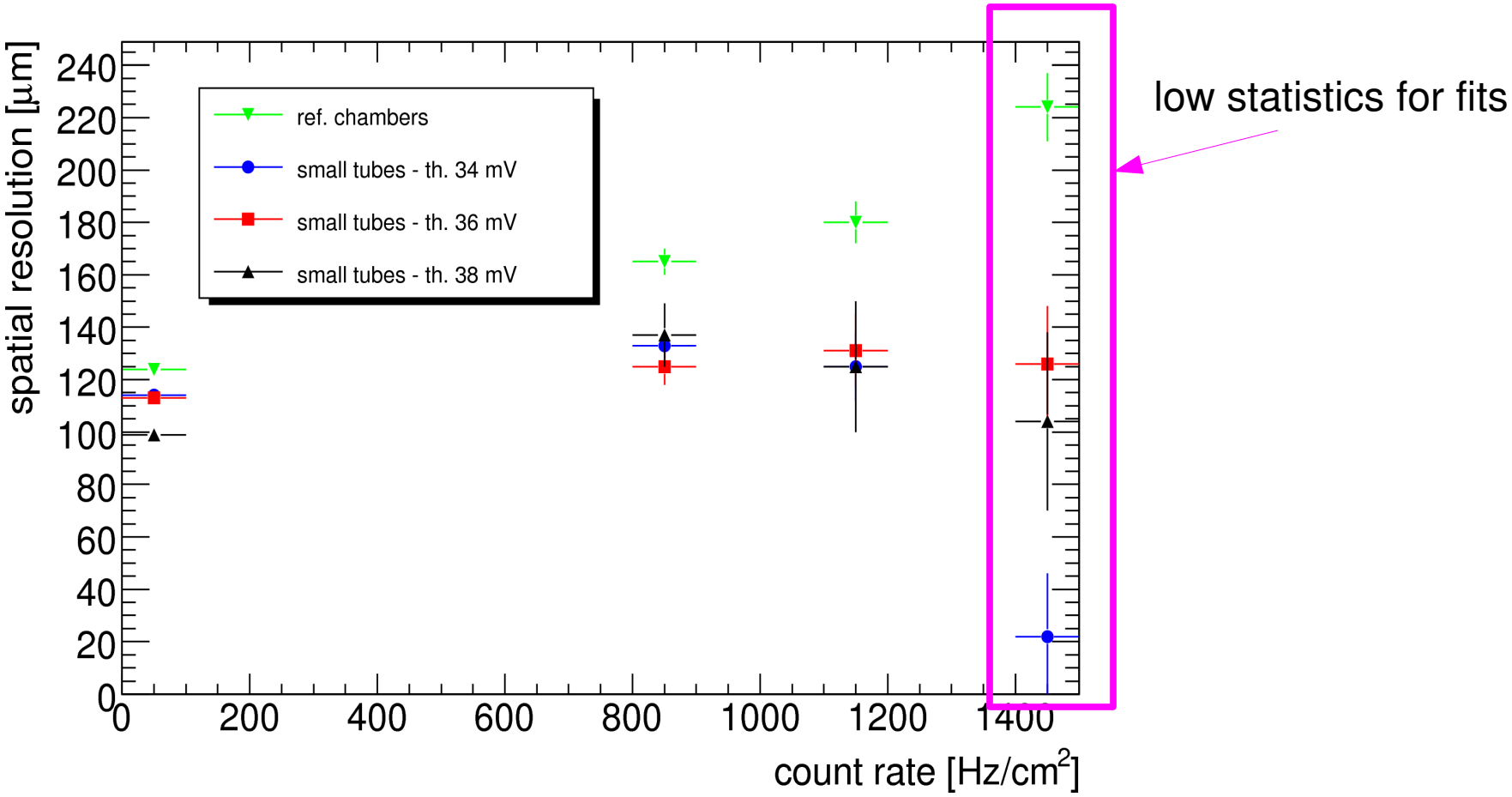
- CL > 0.02
- |slope| < 0.3
- |d(track, wire)| < 8 mm
- |Δ slope| < 0.006



- $\sigma^2_{trk} = 208 \pm 13\ \mu m$
- $\sigma^2_{small + trk} = 209 \pm 21\ \mu m$
- $\sigma^2_{small} = 22 \pm 24\ \mu m$

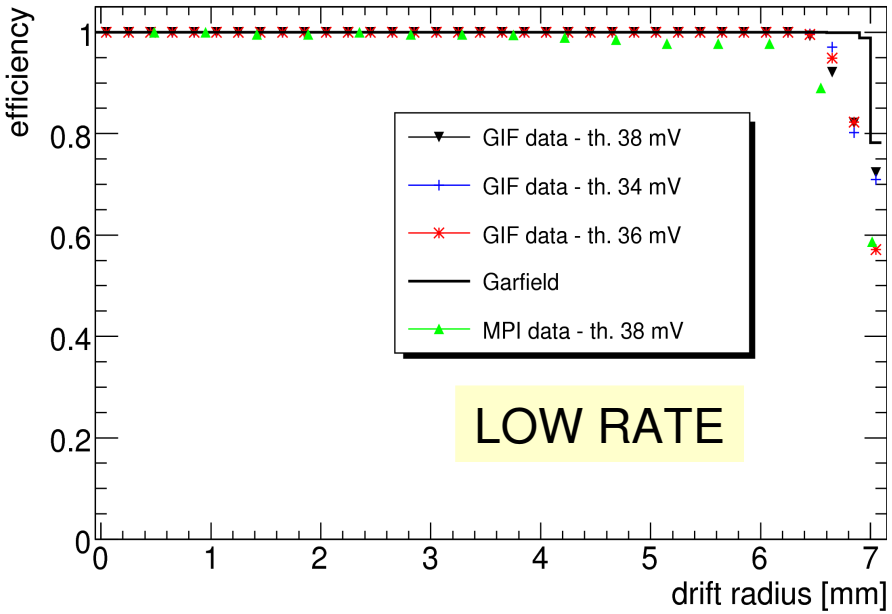
1400 Hz/cm2

Small tubes resolution

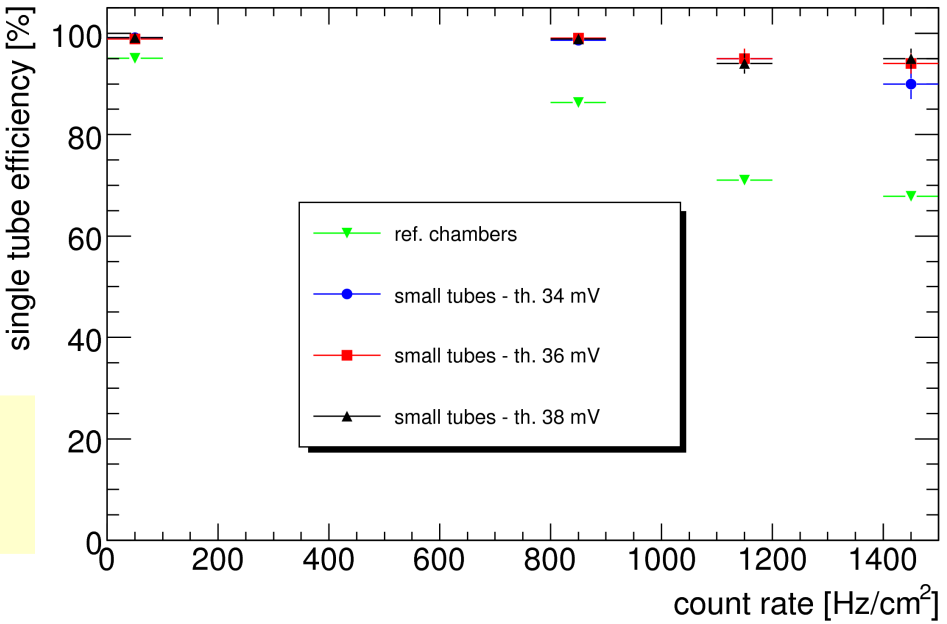


- Spatial resolution grows linearly for big tubes
- For small tubes, the spatial resolution does not change significantly with the hit rate

Single tube efficiency



- Very high efficiency (~1) up to 5 mm from the wall
- Improvement from 2007 measurement, because of better alignment of the setup



- Big tubes efficiency drops at high rates
- Good performances of small tubes

Outlook

- **R&D for small drift tubes for the ATLAS MDT chambers at the Super-LHC is on-going and promising:**
  - Successful measurements at high rates
    - Lessons learned
      - Wire sag
    - Objectives achieved
      - drift time spectrum (<200 ns length)
      - space-time relationship
      - Spatial resolution (100-130 μm)
      - efficiency (100-90%)
  - Design of a 8-layer chamber for next tests in progress

Spare slides

GIF counting rates (I)

SOURCE	Threshold (mV)	Nb. evts	Hit rate (Hz/cm$^{2)}$
att. inf.	38	3772021	54.6174
att. Inf.	36	1099982	68.9975
att. inf.	34	1256475	71.7997
att. 1 (shielding)	38	3772021	1032.94
att. 1 (shielding)	36	1199981	1129.75
att. 1 (shielding)	34	1256475	1169.96
att. 2 (shielding)	38	1387269	806.269
att. 2 (shielding)	36	1060907	807.611
att. 2 (shielding)	34	1199979	863.51
att. 1 (NO shielding)	38	2481841	1427.56
att. 1 (NO shielding)	36	1182973	1462.7
att. 1 (NO shielding)	34	1399971	1559.61

<- (small tubes)

To get the counting rate/tube multiply by 150 cm^2

GIF counting rates (II)

SOURCE	Threshold (mV)	Nb. evts	Hit rate (Hz/cm$^{2)}$
att. 1 HV 2745 V	38	1545879	1277
att. 1 HV 2700 V	38	1499971	1224.25
att. inf. HV 2745 V	38	1099981	68.02
att. inf. HV 2700 V	38	1007010	68.0713
att. inf. Atlas sett.	38	1199987	68.3454
att. 1 Atlas sett.	38	1199981	1457.01
att. inf./1 ToT scan	44	10000	
att. inf./1 ToT scan	42	10000	
att. inf./1 ToT scan	40	10000	
att. inf./1 ToT scan	38	10000	
att. inf./1 ToT scan	36	10000	
att. inf./1 ToT scan	34	10000	

<- (small tubes)

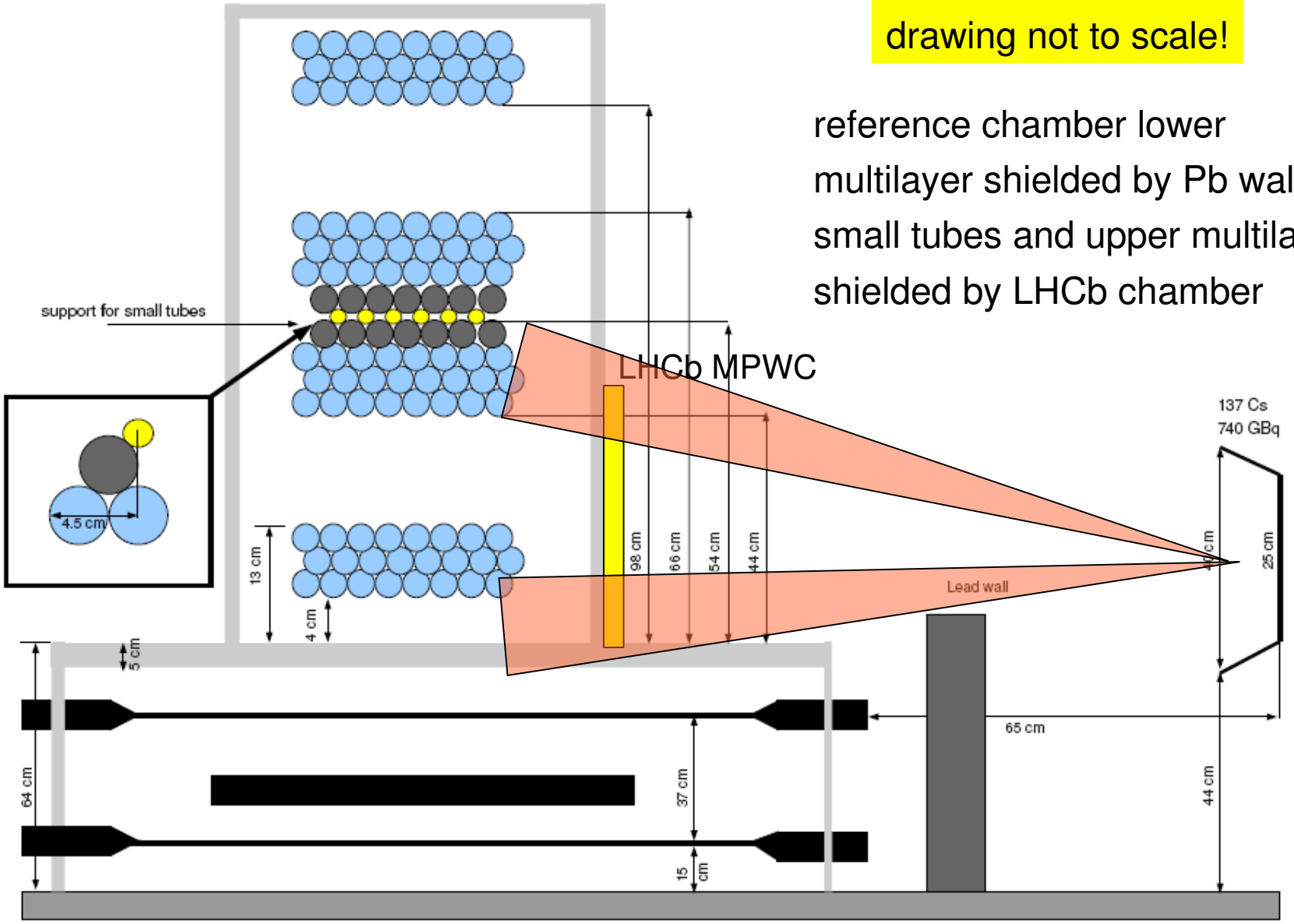
To get the counting rate/tube multiply by 150 cm^2

GIF tests: shielding

drawing not to scale!

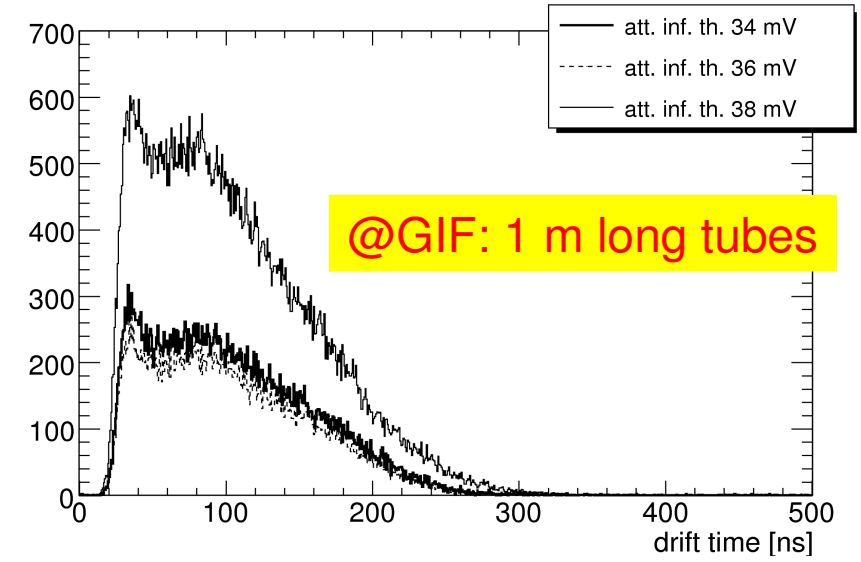
reference chamber lower multilayer shielded by Pb wall

small tubes and upper multilayer shielded by LHCb chamber

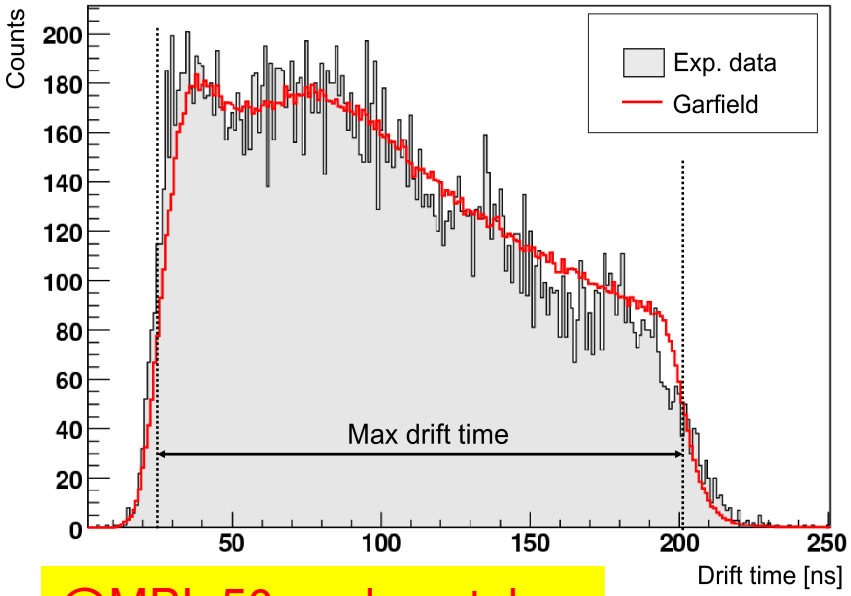


drift time spectrum

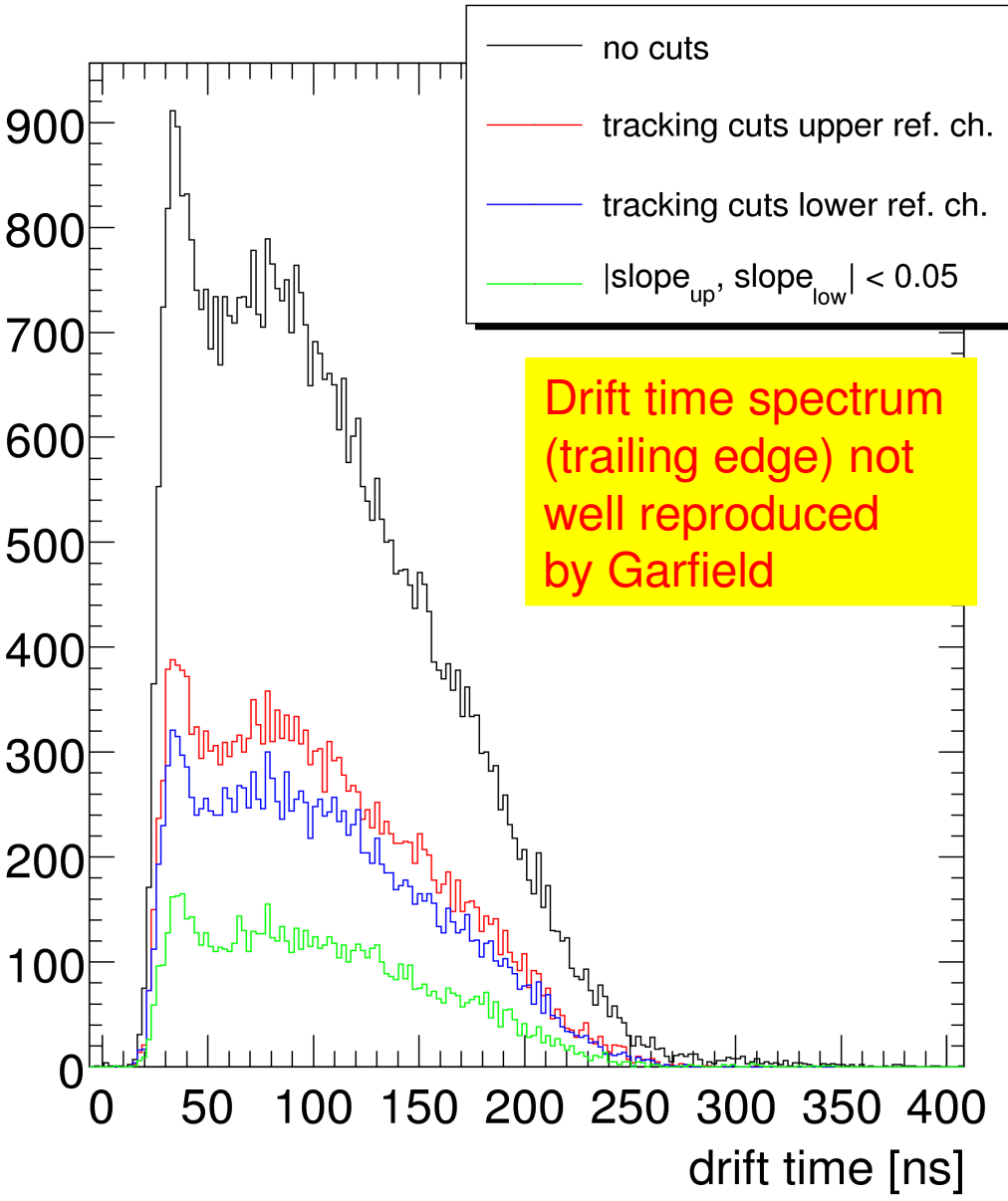
LOW RATE



@GIF: 1 m long tubes



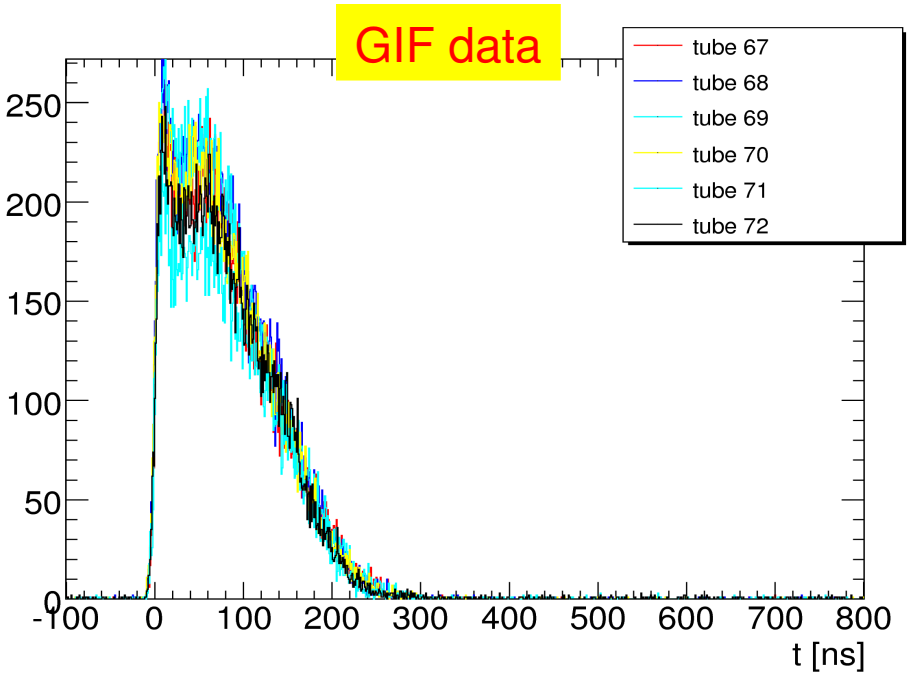
@MPI: 50 cm long tubes

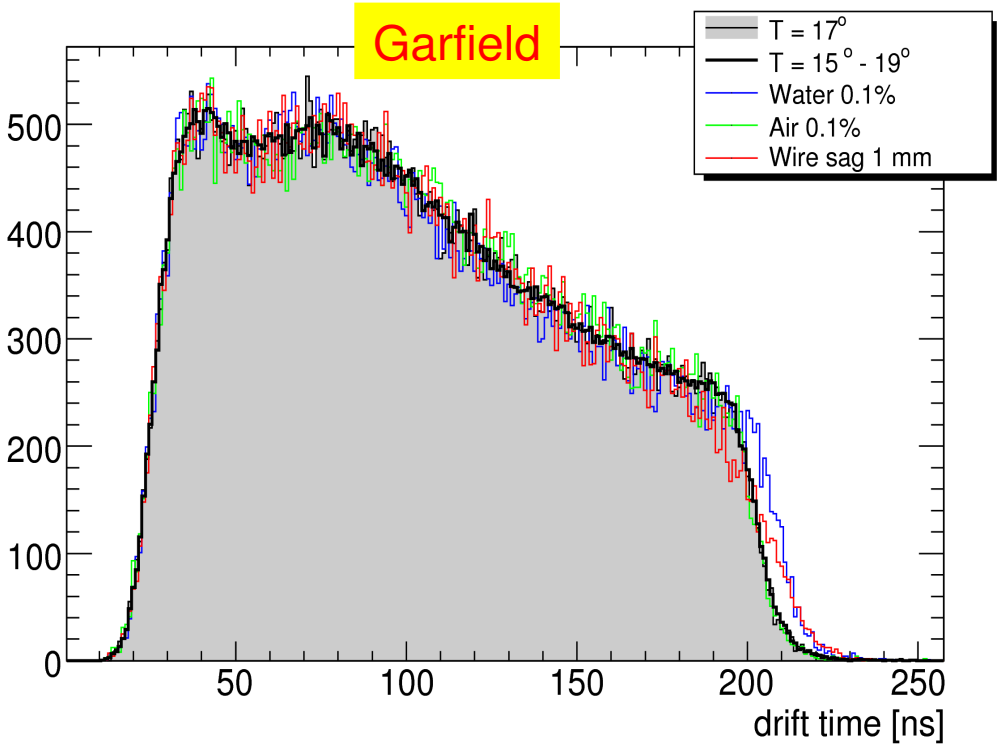


Drift time spectrum (trailing edge) not well reproduced by Garfield

drift time spectrum

LOW RATE





- Trailing edge better explained by wire sag