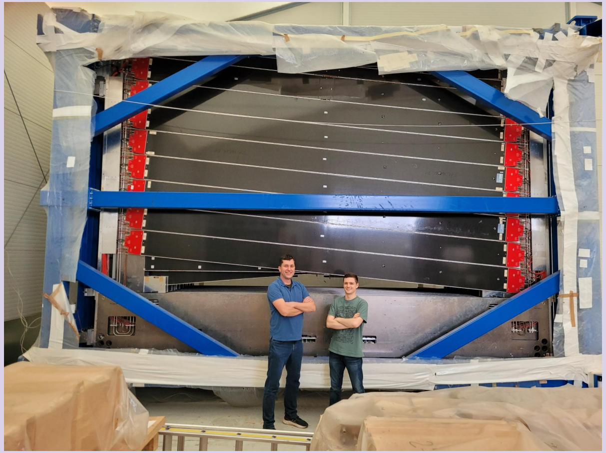
MUST overview

1. The Concept
2. Motivation and Opportunity in CBM
3. Feasibility studies
4. Current Status
5. Timeline
6. Organisation

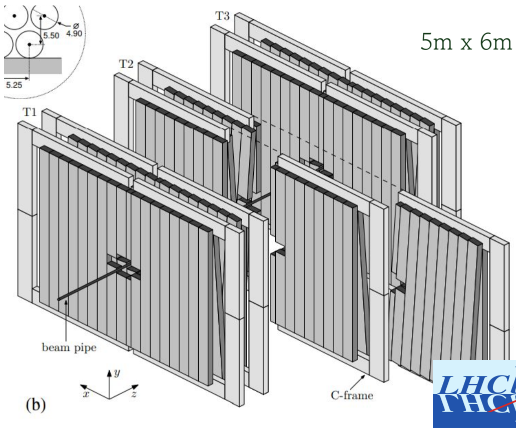


Shreya Roy, Anastasios Belias
On behalf of the MUST group

1. The MUST Concept

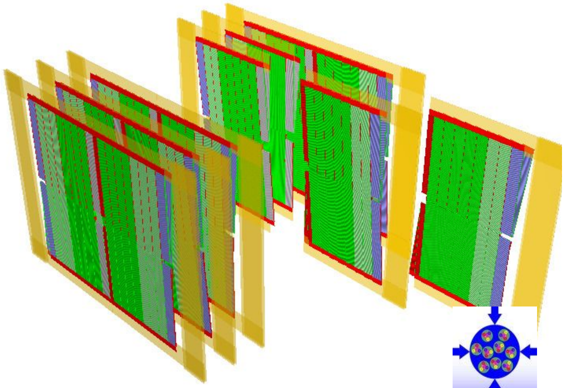
MUon STraws

LHCb Outer Tracker



5m x 6m

Use in CBM Muon Chamber



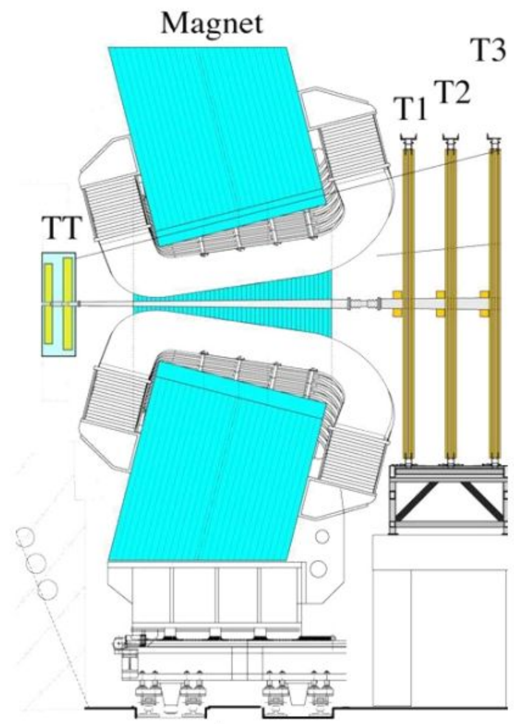
The LHCb Outer Tracker story..

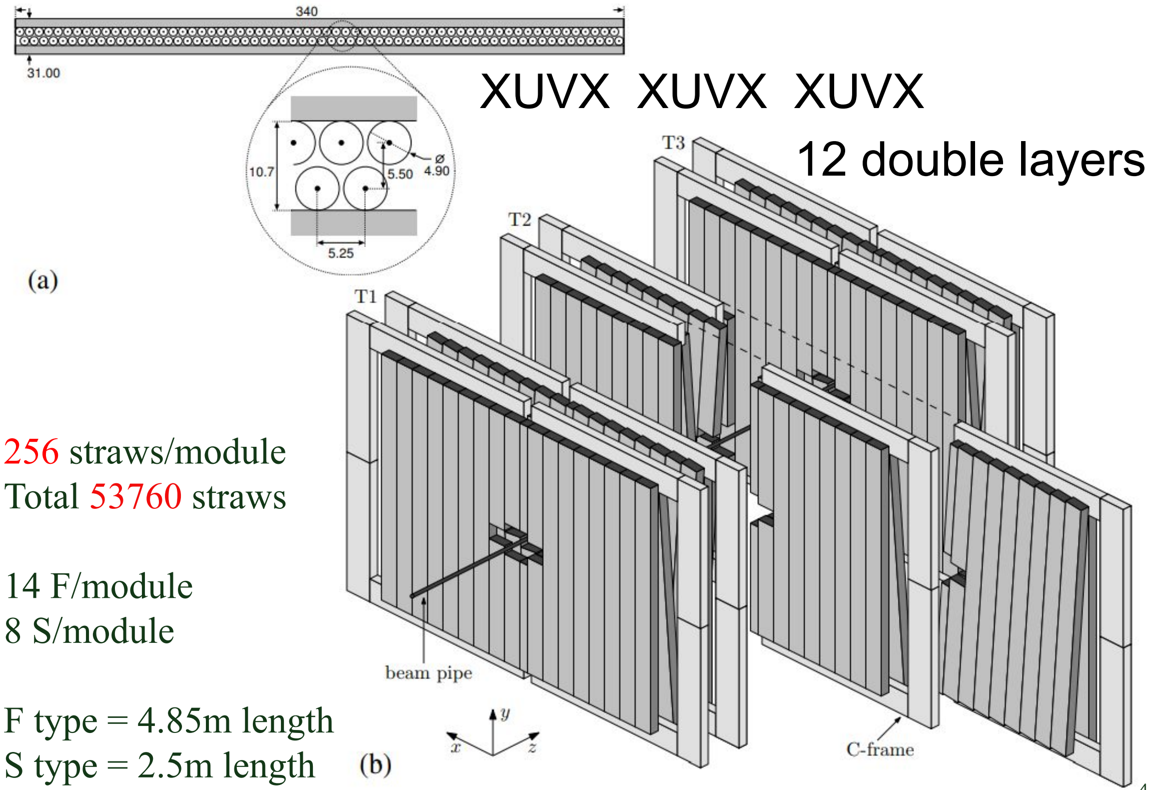
- 2004: start construction
- 2005: end construction
- 2008: installation in LHCb
- Run1 & Run2 (2011-13, 2015-16)
- 2018: end of operation
- 2023: shipment to GSI, Darmstadt

Final parameters

- Cathode: Kapton XC
- Anode: Gold + Tungsten (+1550 V)
- Panel: Rohacel
- Glue: Araldite Epoxy AY103
- Gas: $Ar/CO_2/O_2$: 70/28.5/1.5

The LHCb Outer Tracker : quick overview





XUVX XUVX XUVX

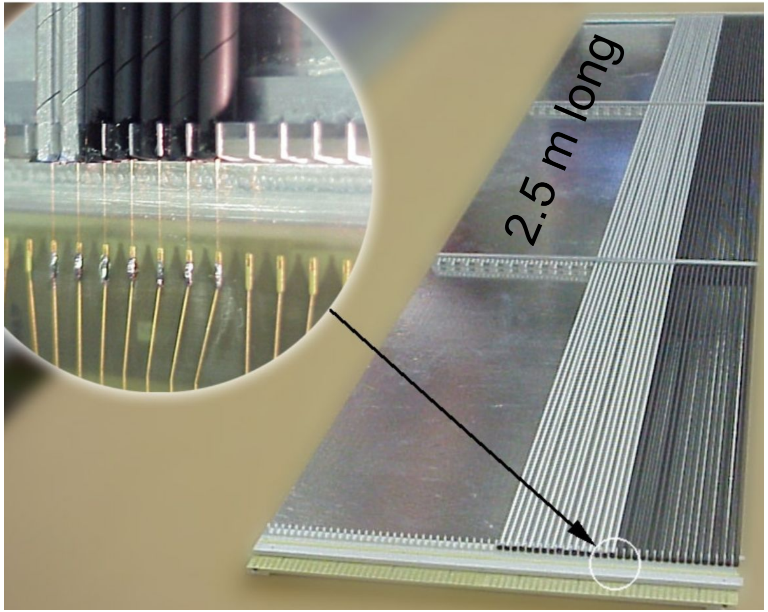
12 double layers

256 straws/module
Total 53760 straws

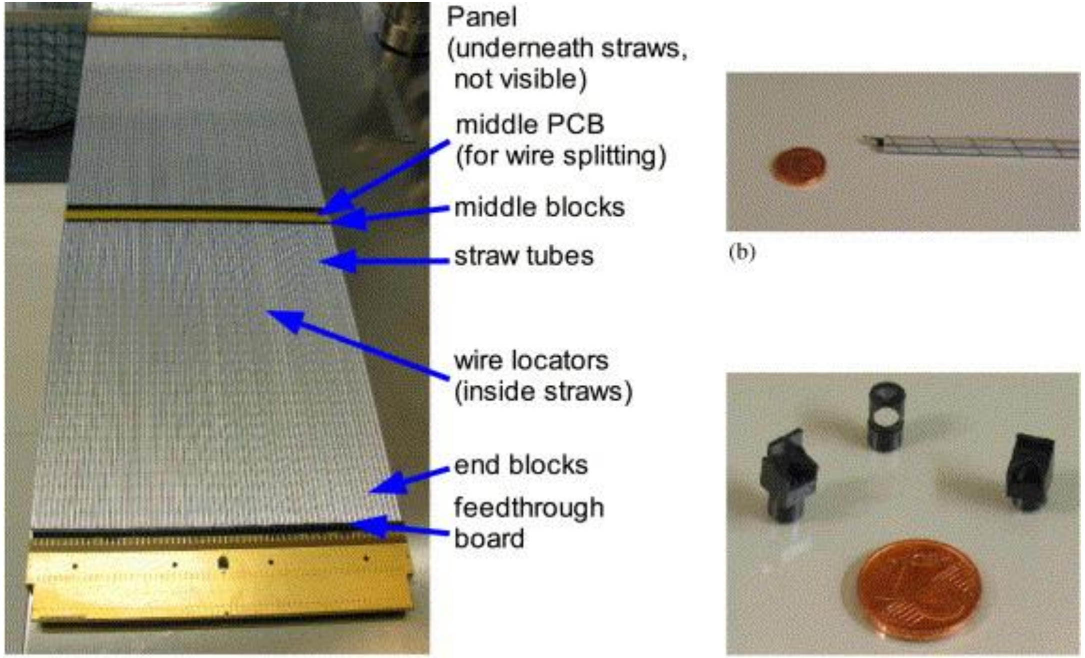
14 F/module
8 S/module

F type = 4.85m length
S type = 2.5m length

Inside of modules : straw tube detectors



LHCb-PROC-2004-002



(a) (b) (c)

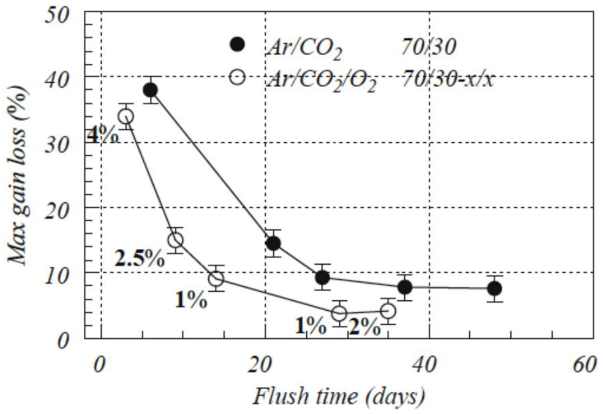
Status of the LHCb OT

LHCb-CONF-2009-019

Aging :

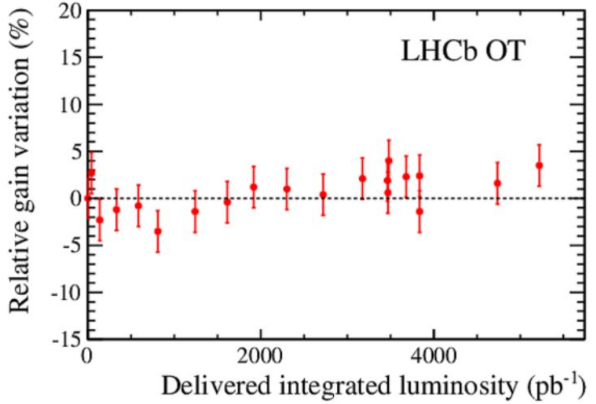
- The culprit : Glue sample shows outgassing
- Solution : adding 1.5% Oxygen and operate in open gas mode

S.Bachmann et al., The straw tube technology for the LHCb OT, Nucl. Instr. and Meth. A 535 (2004) 171.
S.Bachmann et al., Ageing in the LHCb Outer Tracker, Nucl.Instr. and Meth. A 617 (2010) 202.



Performance :

- High hit efficiency (>99%)
- Handled 5 MHz rates/straw
- Good resolution (~200 µm) with BX clock
- No irradiation effects observed (~0.4 C/cm in hottest region)



https://indico.cern.ch/event/1237829/contributions/5609613/attachments/2746316/4778770/OT_Performance-final.pdf

LHCb sends gift to PANDA

2023

The decommissioned outer tracker of CERN's LHCb experiment embarked on a one-week journey to the FAIR facility in Darmstadt, Germany, where it will be used by the PANDA experiment to study how subatomic particles build up matter

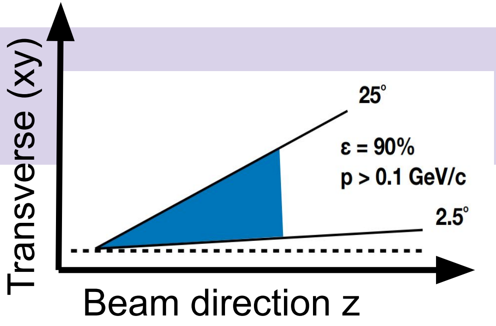
5 OCTOBER, 2023 | By Sanje Fenkart & Carola Pomplun

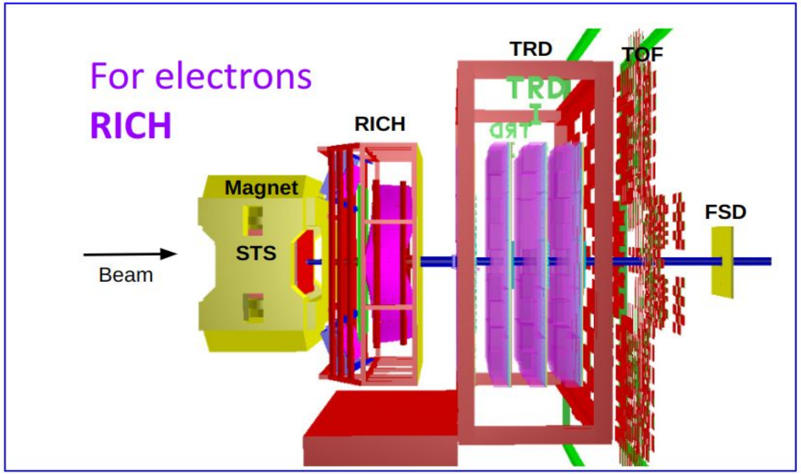
Impressions of the outer tracker's journey from LHC Point 8 at CERN to GSI/FAIR in Darmstadt, where it now awaits its second life.
Credit: Piotr Traczyk

2025 **CBM-PANDA MoU**
- MUST cooperate

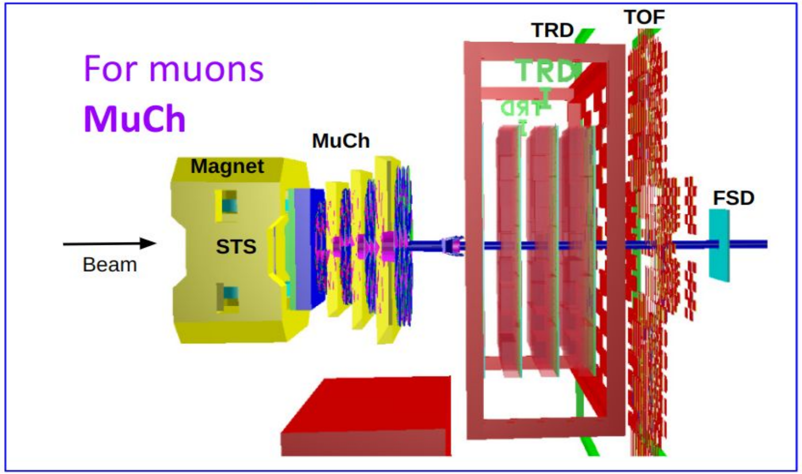
7 October, 2025

The CBM detector setups



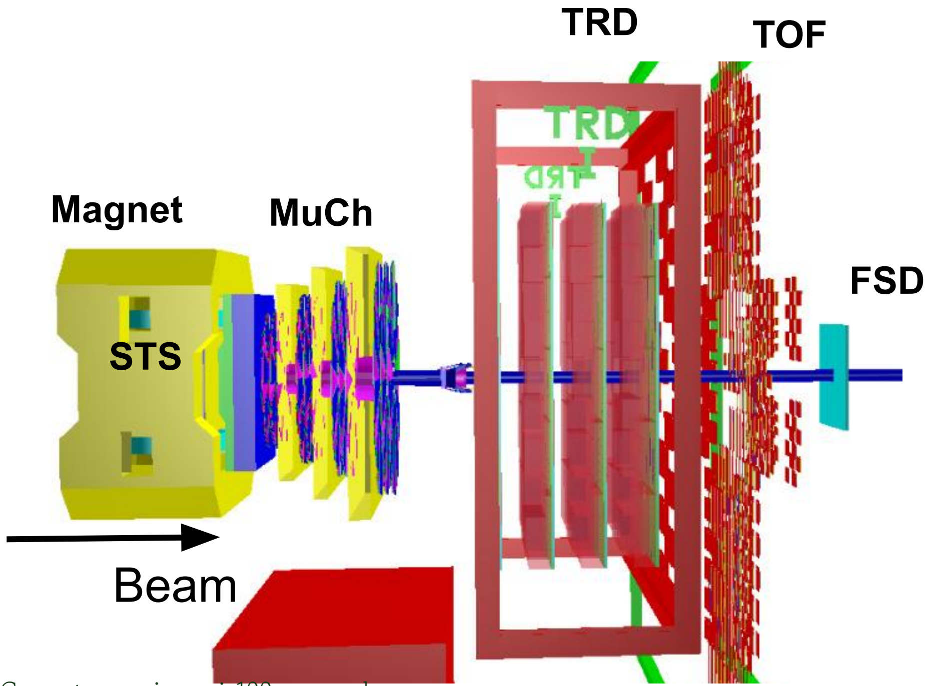


Geometry : sis100_electron



Geometry : sis100_muon_lmvm

2. Motivation and Opportunity in CBM



Geometry version : sis100_muon_lmvm

CBM Physics Context

CBM studies dense baryonic matter.

Key observables:

- Low-mass vector mesons (ρ, ω, ϕ)
- Charmonia via $\mu^+\mu^-$

MUCH is the muon detection system.

Advantage : Hadronic background is highly suppressed. Clean observables!!

MUST fits well in the CBM-MuCh

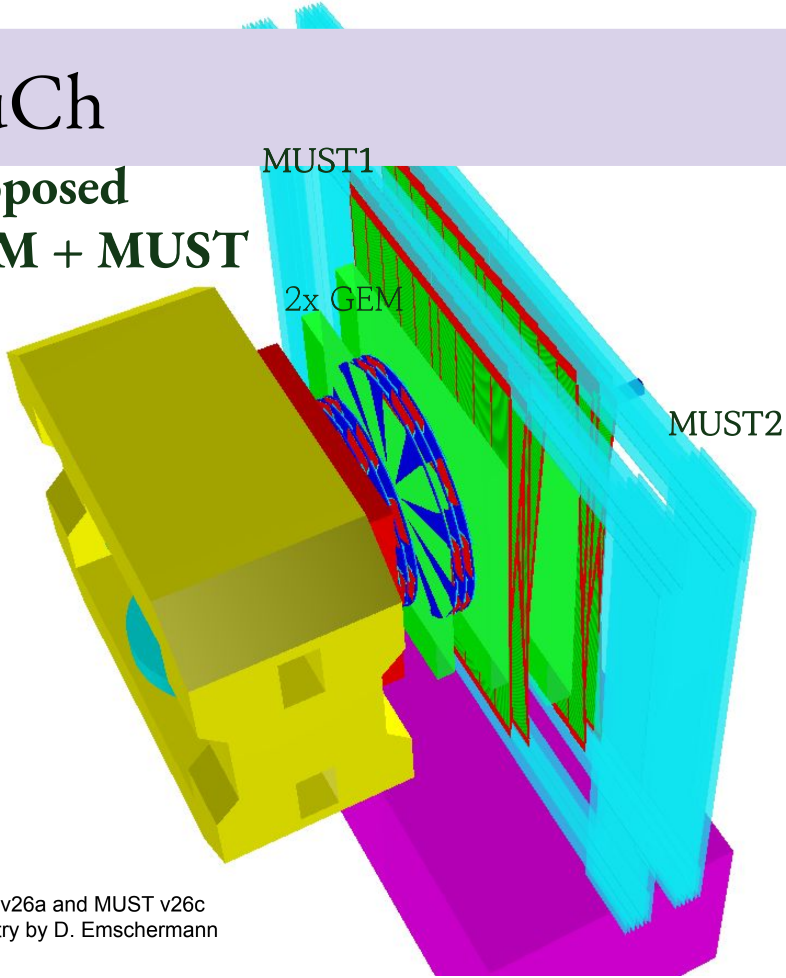
Where MUST sits : Upstream of absorber stack in MUCH station 3 and 4 respectively

Why MUST :

- Optimized geometry to fit between absorbers and cover the MUCH acceptance (St. 3–4).
- Provides the spatial and timing resolution required for muon identification.
- Have handled high rates~MHz in LHCb environment

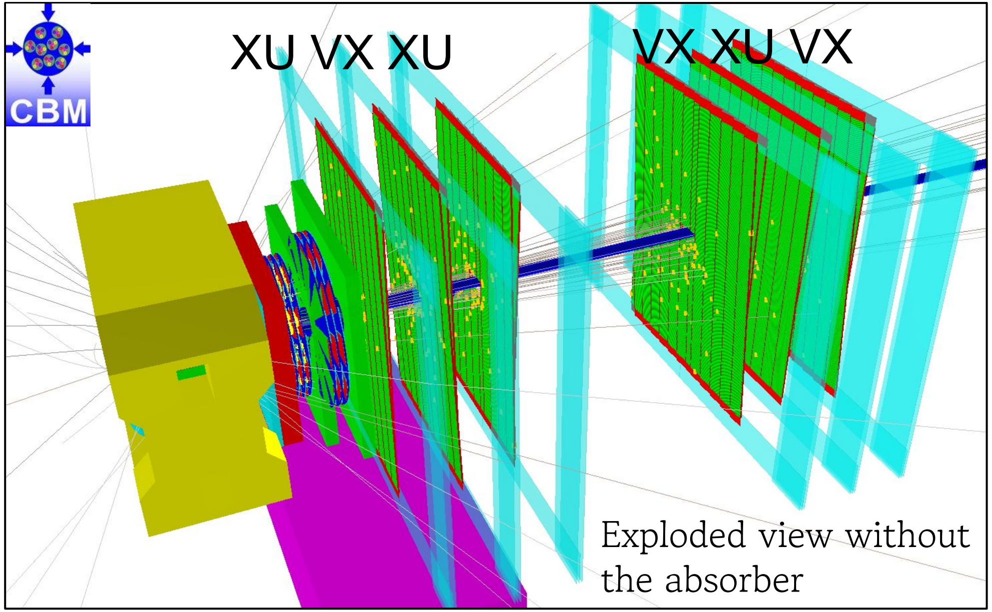
Next step: evaluate the rate capability of the MUST / LHCb OT concept under CBM particle flux conditions

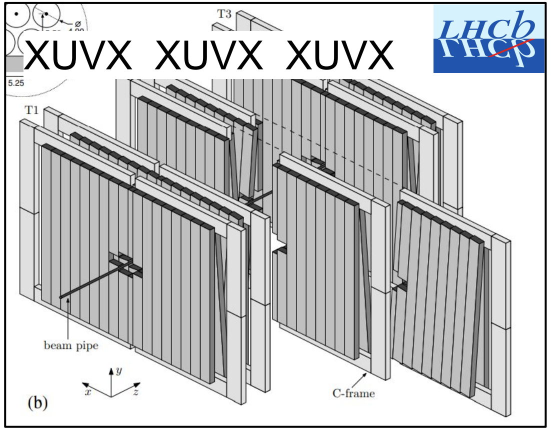
Proposed GEM + MUST



MUCH v26a and MUST v26c geometry by D. Emschermann

3. MUST Feasibility studies



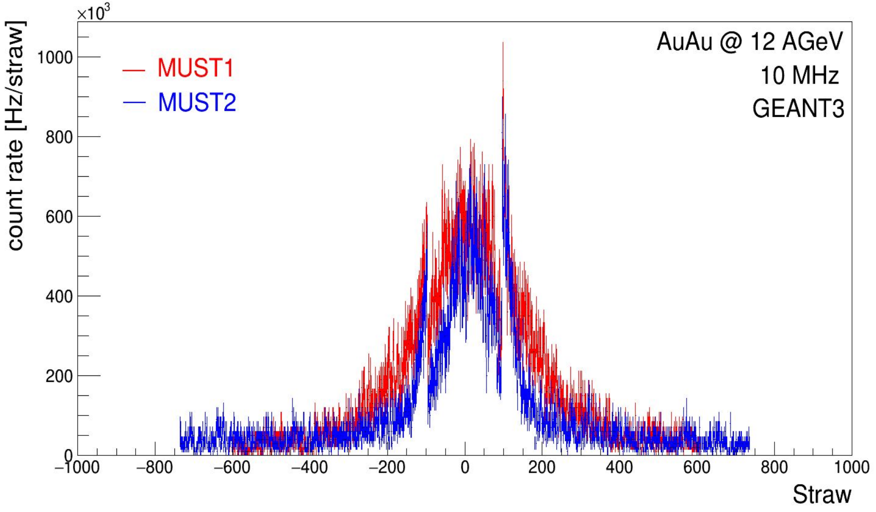


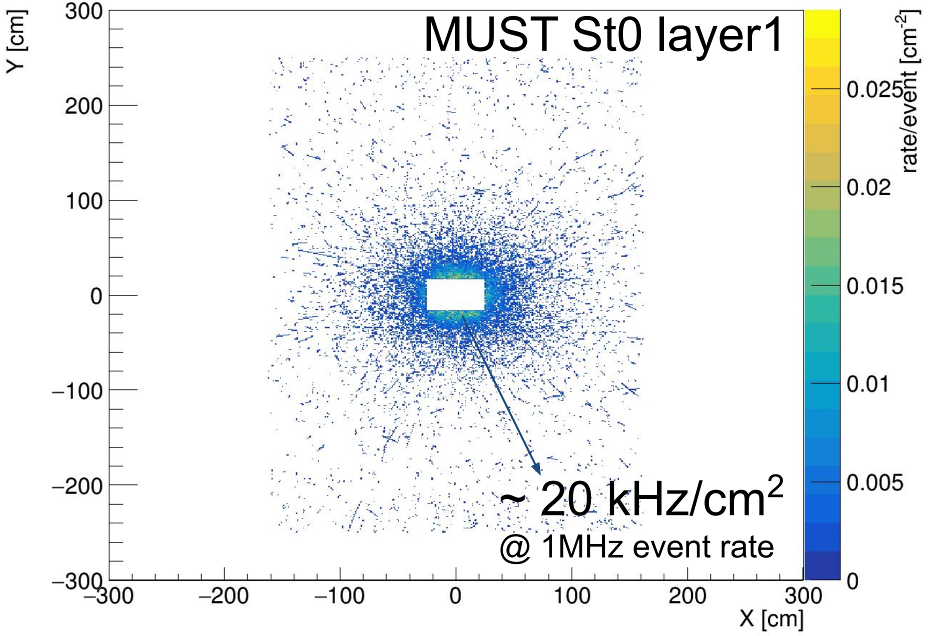
Particle rates

Fairroot : v18.8.0
Fairsoft : nov22p1
Cbmroot master (Feb 2026)

Input file : Urqmd AuAu 12AGeV mbias, 1000 events, Geant3

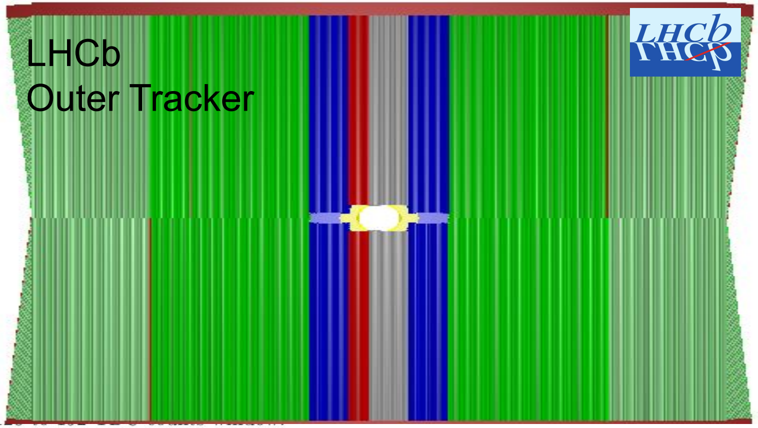
Preliminary results

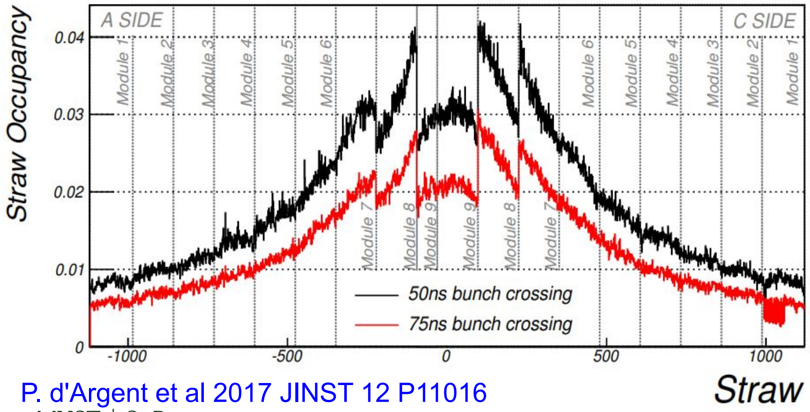




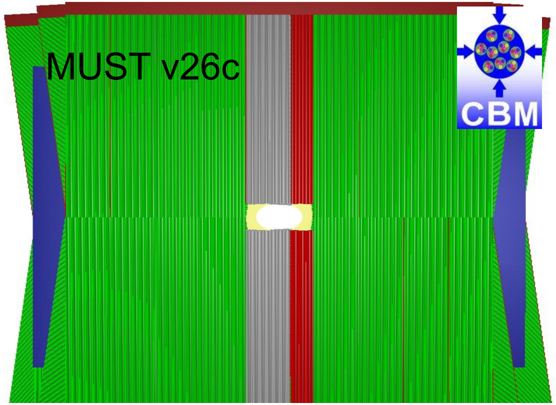
MUST1 = < 1 MHz/straw
MUST2 = < 800 KHz/straw

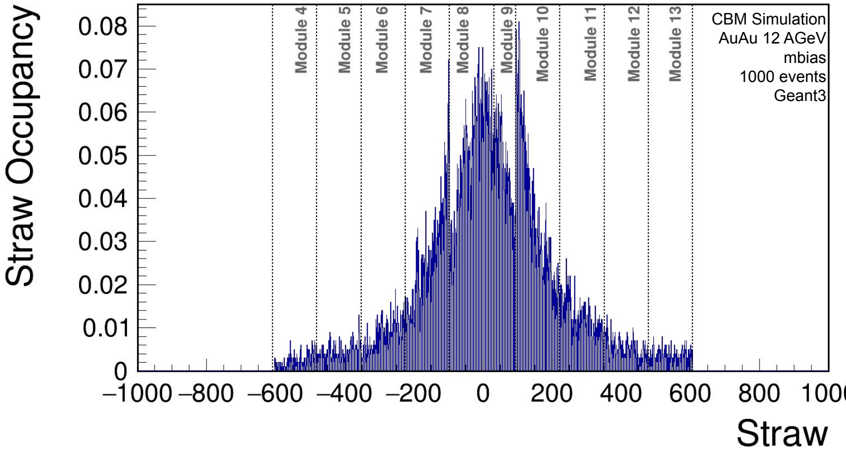
Occupancy





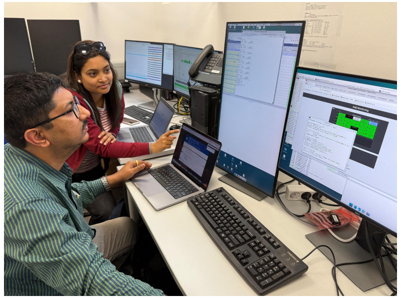
P. d'Argent et al 2017 JINST 12 P11016

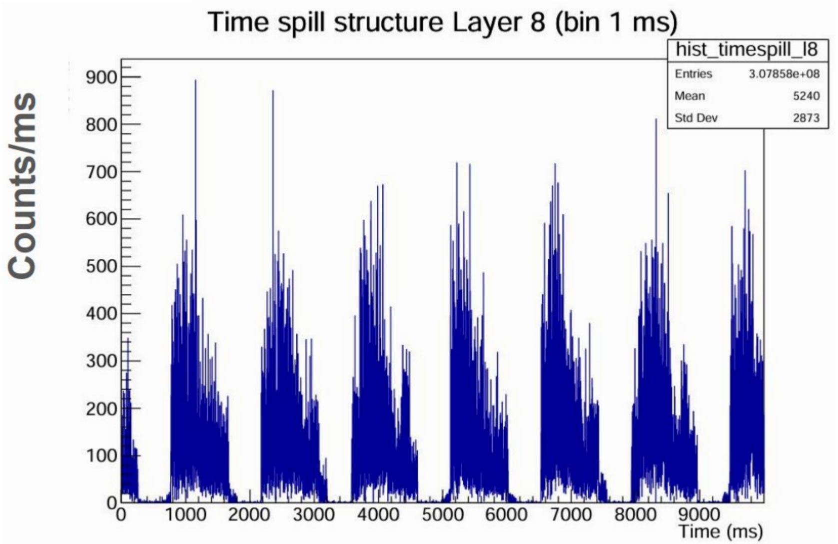


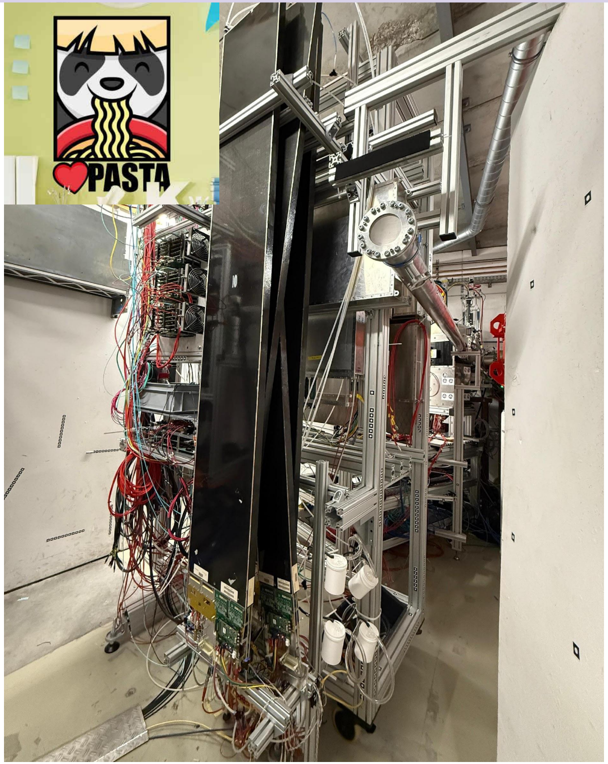


4. Current Status

- **Hardware efforts** : PASTA (PAnda StrAws in mini-CBM), FEE development at GSI (talk by Luca Schramm)



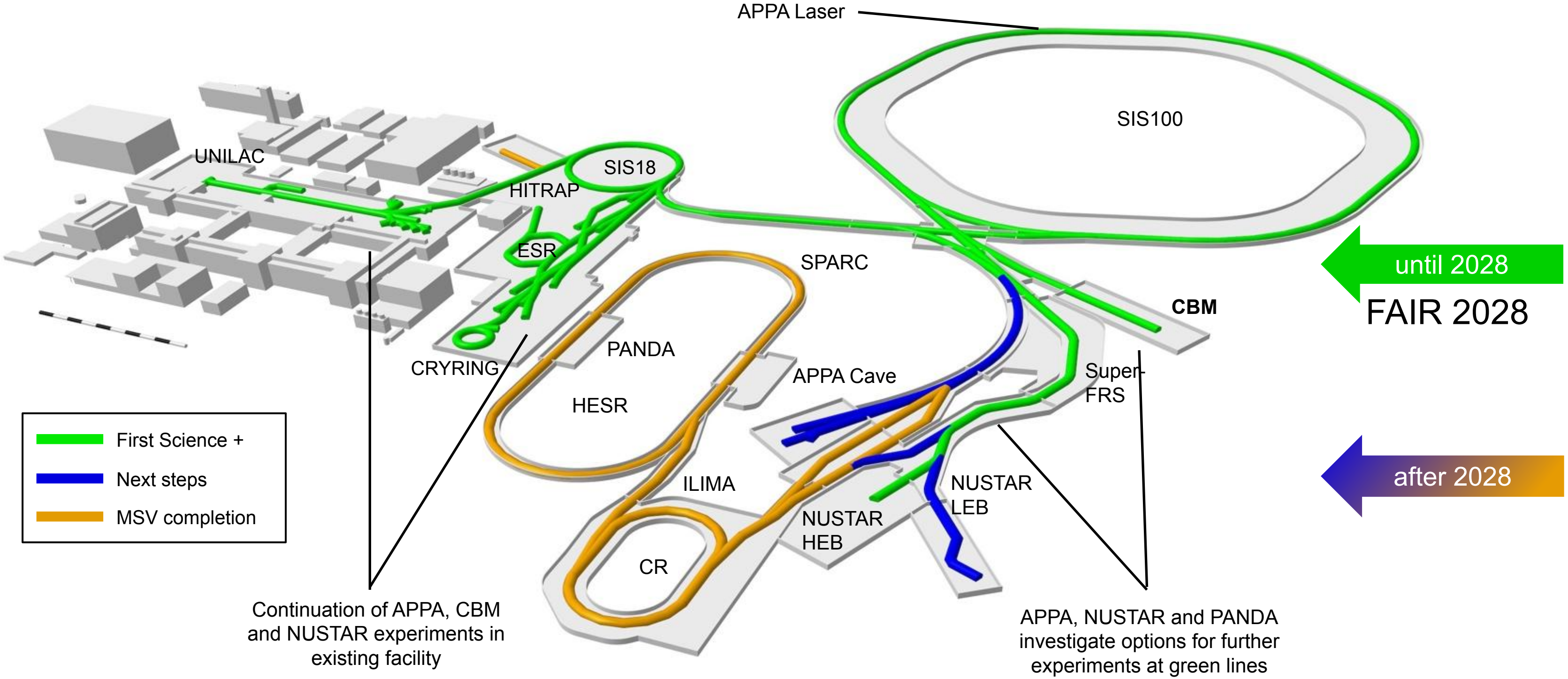




4. Current Status

- **Mechanics** : Support structure design (talk by Stefan Koch)
- **Software status** : Full geometry, digitisation implementation in CBMRoot (talk by Rafal Lalik)
- **MUST group** : 16+ members (2025), 30+ (2026) across 5 institutes.
- **Coordination** : regular software and mechanics meetings
- **Other news** : 2 new PhDs joined the group
- **Manpower from India** : 6 new institutes expected, 6 Phds and postdocs to contribute.

5. Timeline


APPA Laser
SIS100
UNILAC
SIS18
HITRAP
ESR
SPARC
CBM
PANDA
CRYRING
APPA Cave
HESR
Super-
FRS
ILIMA
NUSTAR
LEB
NUSTAR
HEB
CR
First Science +
Next steps
MSV completion
Continuation of APPA, CBM and NUSTAR experiments in existing facility
APPA, NUSTAR and PANDA investigate options for further experiments at green lines
until 2028
FAIR 2028
after 2028

5. Timeline

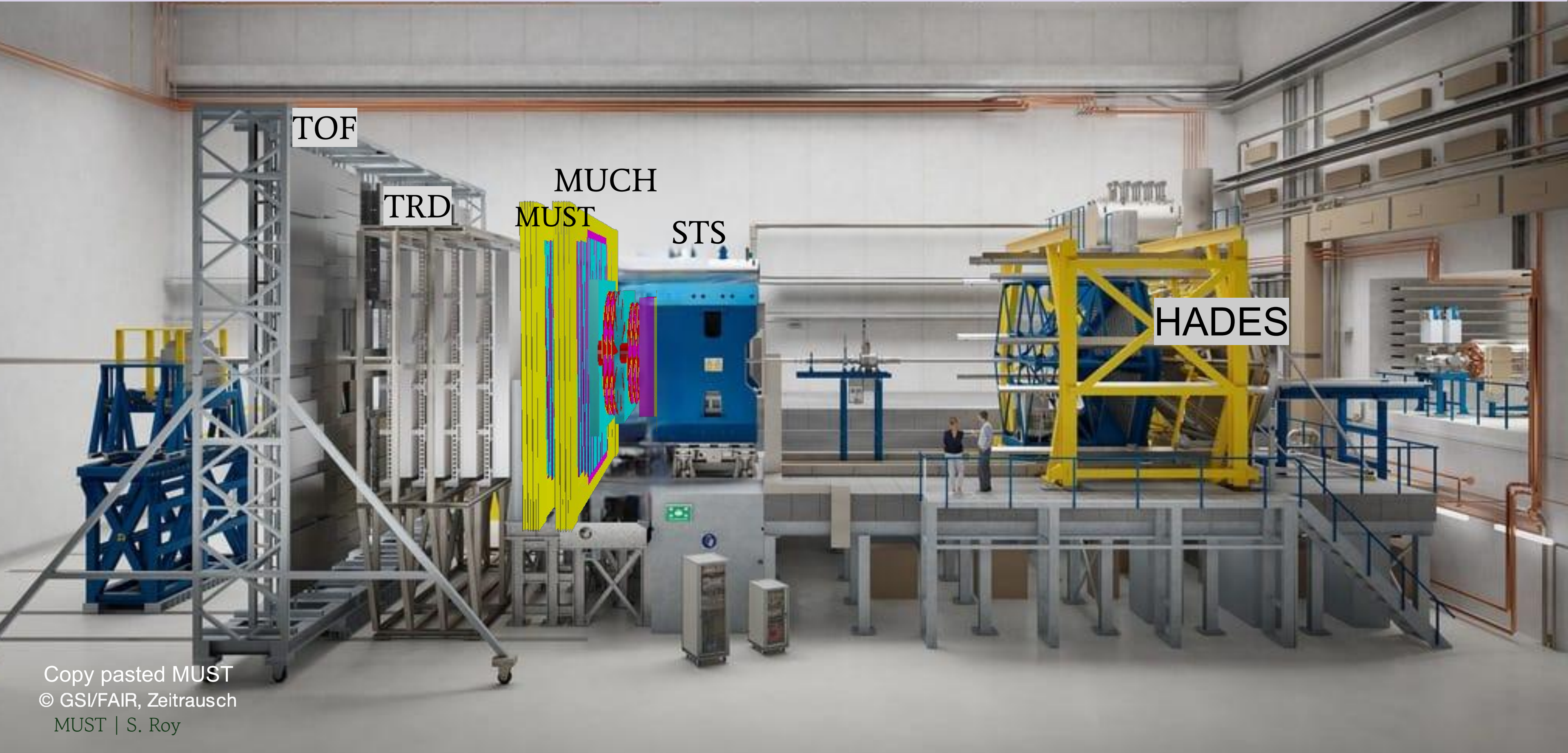
CBM timeline (assuming beams provided to the CBM cave in 2028/29)

- Commissioning with light ions, Ebeam = 8AGeV
- Run1: AuAu 10AGeV, BES, IR=100 kHz, RICH setup
- Run2: proton beams, RICH setup
- Run3: AuAu 10AGeV, BES, IR=100 kHz, RICH setup
- Run4: AuAu 10AGeV, BES, IR=500 kHz, RICH setup
- Run5: AuAu 10AGeV, IR=1 MHz, MUCH setup

MUST timeline

- 2026: Technical designs, software, simulations,
- 2027-28: Hardware testing, electronics & mechanics production,
- 2029: Installation & Commissioning

MUST in the CBM Cave ~ 2030..



Copy pasted MUST

© GSI/FAIR, Zeitrausch

6. Organisation

- Work packages
- Cost estimate
- Manpower
- Funding
- Letter of Intent

The show MUST begin..

The cast

Z. Ahammed, Anastasios Belias, P. P. Bhaduri, Saikat Biswas, , Souvik Chattopadhyay, Supriya Das, Anuska Dey, Anand Kumar Dubey,David Emschermann, Somen Gope, Klaus Gotzen, Radoslaw Karabowicz, Ralf Kliemt, Stefan Koch, Rafal Lalik, Subir Mandal, Shruti Patra, S. K. Prasad, Prithwish Pramanick, Shreya Roy, Joginder Saini, Swastika Sarkar, Luca Schramm, Abhishek Kumar Sharma, Anjali Sharma, Bartosz Sobol, Anna Senger, Vikas Singhal, Florian Uhlig...

backup

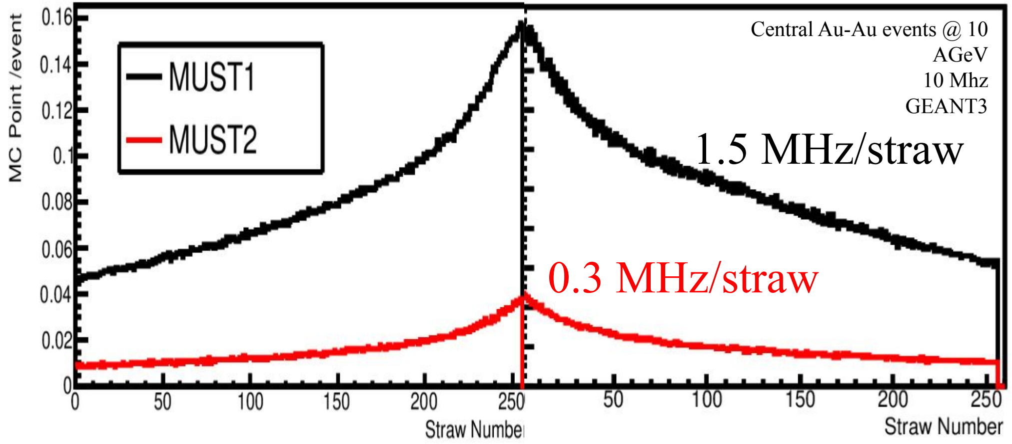
First feasibility test results : Particle rates

FLUKA results : 12 AGeV Au beam or 29 GeV p beam

System	Beam rate (ions/sec)	MUST1 (kHz/cm^2)	MUST2 (kHz/cm^2)
Au+Au	10^9	40	15
p+p	10^9	1	0.5
p+Au	10^{11}	140	50
p+p	10^{11}	100	40

– Preliminary numbers from A. Senger

GEANT3 results : 10 AGeV Au beam



~ A. Sharma & A. K. Sharma

For more detailed results : [click here]

Remark : Maximum particle flux in LHCb OT ~ 5 MHz/straw

LHCb Outer Tracker overview

Slide from Tassos

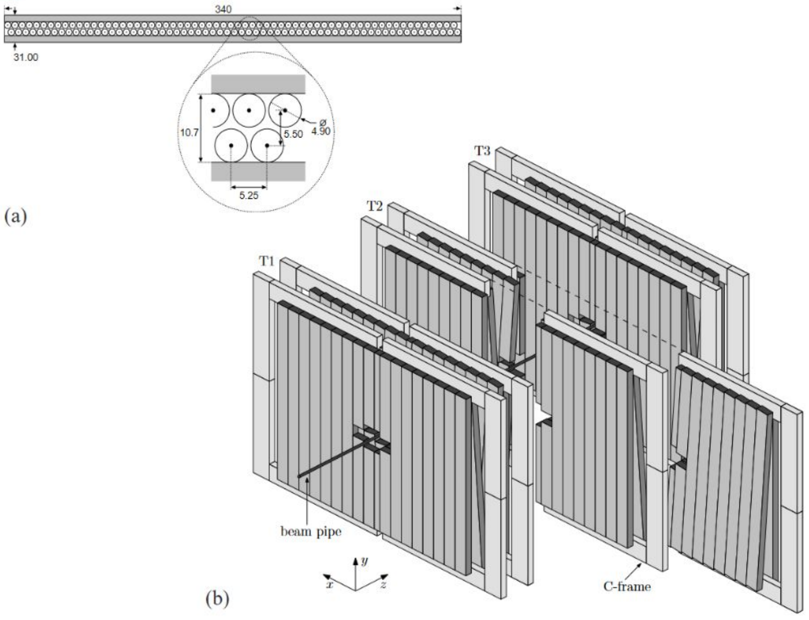
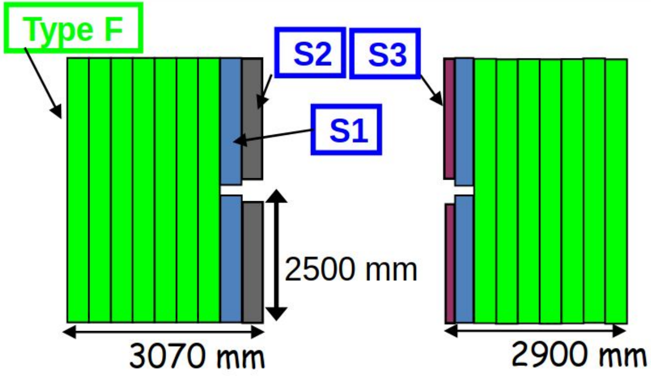


Figure 1. (a) Module cross section. (b) Arrangement of OT straw-tube modules in layers and stations.

N Tuning 2014 JINST 9 C01040



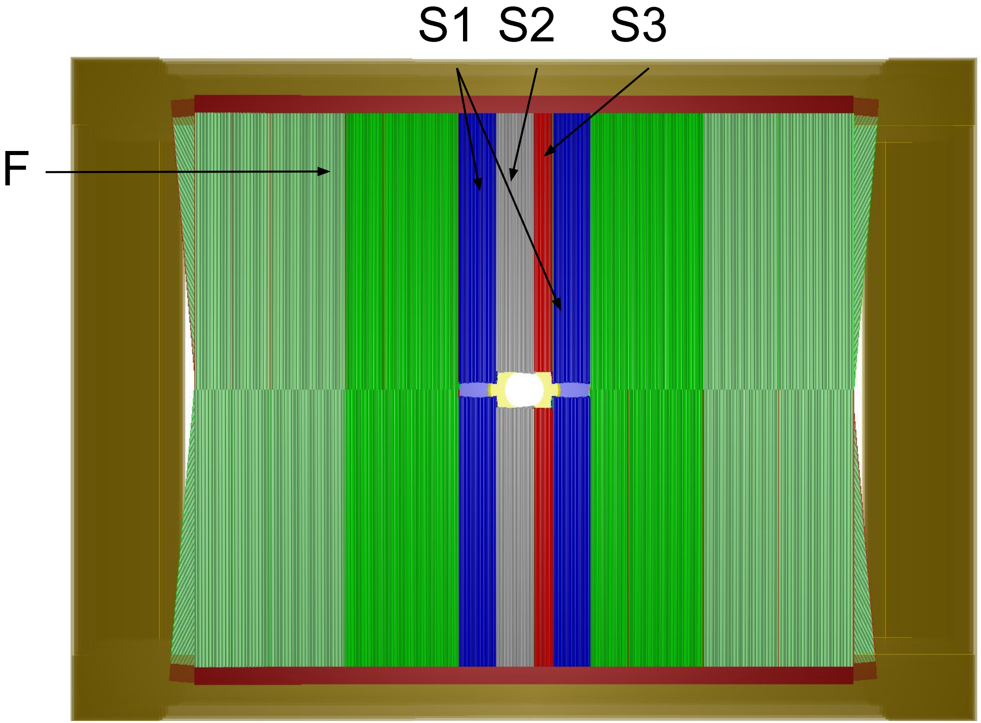
LHCb Outer Tracker consists of 3 stations T1, T2, T3

- Station contains
  - 4 layers of modules with orientation $0^0,+5^0,-5^0,0^0$
  - attached to 4 support frames (C-frames), two per side of the beam pipe
- Layer contains modules of straw tubes:
  - 14 type F ; cover 5 m (2 x 2.5 m) without gap
  - 4 type S ; cover < 5 m (2 x 2.3-2.4 m) with gap around beam pipe

MUST geometry v26a

Recreate LHCb Outer Tracker module arrangement in CbmRoot

Problem !
Acceptance
around the CBM
beam pipe

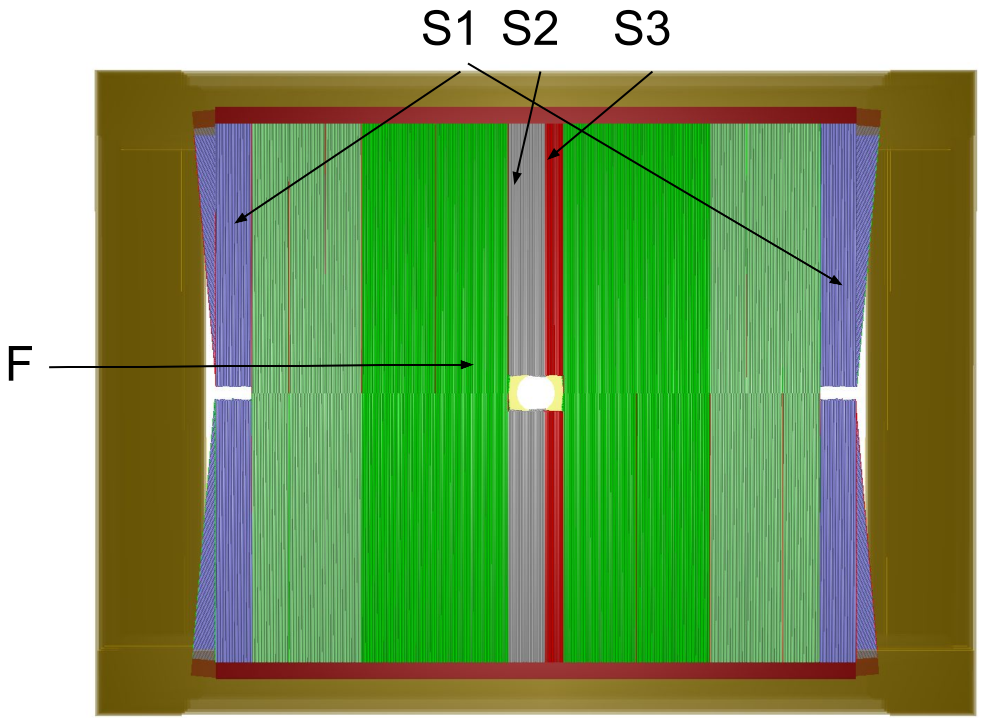


~D. Emschermann

MUST geometry v26b

Swap S1 modules (blue) from inside with F modules (green) from outside

Solution :
Replace the S1 module with F type module



~D. Emschermann

1. Gy to C/cm

1 cm of straw ~ 0.33 mg of Ar/CO_2

1.47 C/kg = 1.47 x 0.33 x 10^{-6} C/cm x Gain (5 x 10^4)

= 0.024 C/cm (MUST1 near beam)

Density Ar = 1.6 kg/m^3

Density CO_2 = 1.9 kg/m^3

Volume of straw tube gas in 1cm length = 0.196cm^3

https://www.convert-me.com/en/convert/radiation/rrgray/rrgray-to-rrcperkg.html?u=rrgray&v=50

2. Accumulated charge in 1 month of CBM

Irradiation tests with straws were performed upto 2C/cm ~ 10 years of LHCb (detector gain 4×10^4)
In LHCb Run 1 and 2 total charge accumulated = 0.4C/cm in the hottest region (detector gain 5×10^4).
In CBM, the charge accumulated (detector gain 5×10^4) = Q (C/cm)

$$Q = n_{primary} \cdot e \cdot Gain \cdot n^{MUST1}_{flux} \cdot t \cdot straw_{\varnothing}$$

$$Q = 50 \cdot e \cdot 5\times10^4 \cdot 50kHz \cdot 1\ month \cdot 0.5\ cm$$

Q = 0.026 C/cm in the hottest region!

2C/cm is 125 months/ 10 years of operation in CBM environment.

Ageing tests in LHCb

The S-module was irradiated with 9 keV X-rays for 60 days, with an intensity of about 500 kHz/cm, corresponding to an accumulated charge of about 1 C/cm. No significant irradiation damage was observed.

The F-module has been irradiated for 1200 hours, with a source profile as shown in Fig. 4, resulting in a total accumulated charge of 0.3 C/cm at the point of highest intensity of 70nA/cm. A negligible gain loss of 5% ± 2% was observed

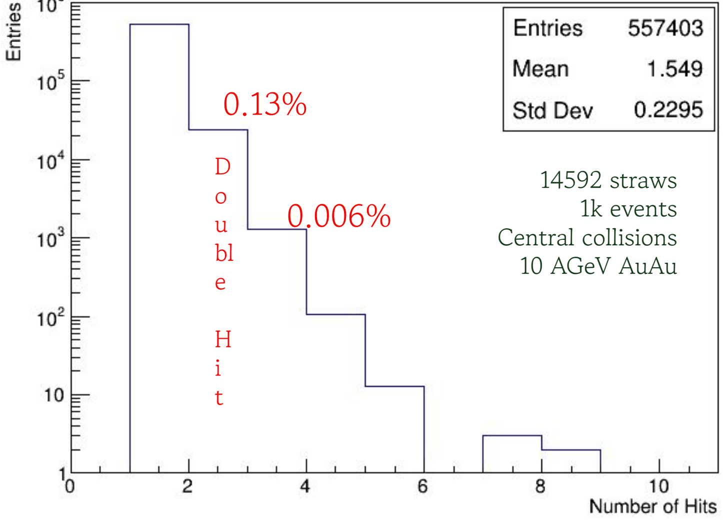
Nucl.Instrum.Meth.A 656 (2011) 45-50

3. Double hit occupancy

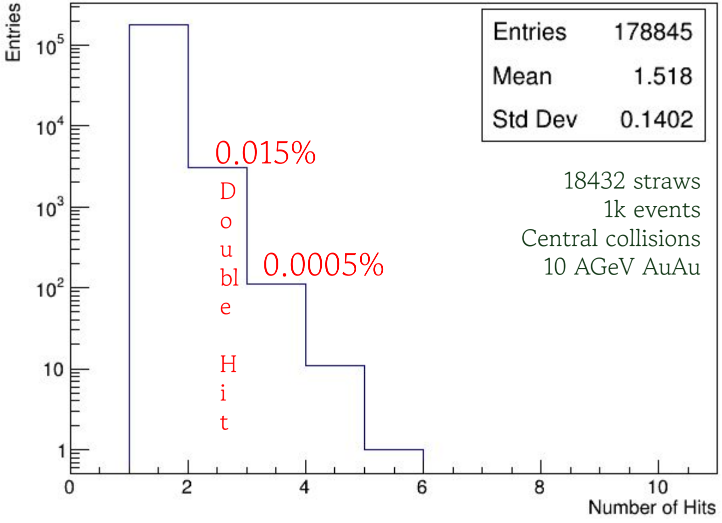
Very low but need to check

$$\%\ \text{probability of n hits} = \frac{\text{Entries}}{N_{straws} \times n_{events}}$$

MUST 1



MUST 2



4. Spatial resolution without drift time

The spatial resolution of OT straws are 180μ , which the LHCb was able to achieve because of known bunch crossing time and the capability of the electronics to read the straw tube signal drift time, plus alignment.

In CBM there is neither bunch crossing info nor drift time measurement will be possible. Therefore, the MUST subsystem will have a spatial resolution that is proportional to the diameter of the straw 5 mm, more precisely using the well known formula $\sigma = d/\sqrt{12} = 5/\sqrt{12} = 1.44$ mm

Again, because of the staggered orientation of the straws (monolayers), the hit position resolution will improve by factor of two ~ 0.7 mm

In MuCh , 1 deg pad segmentation (1 & 2) was the requirement.