Detector design for a 10 TeV Muon Collider

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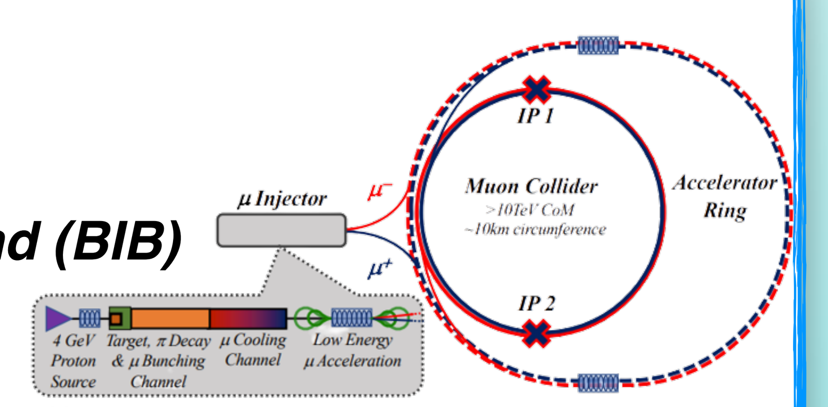
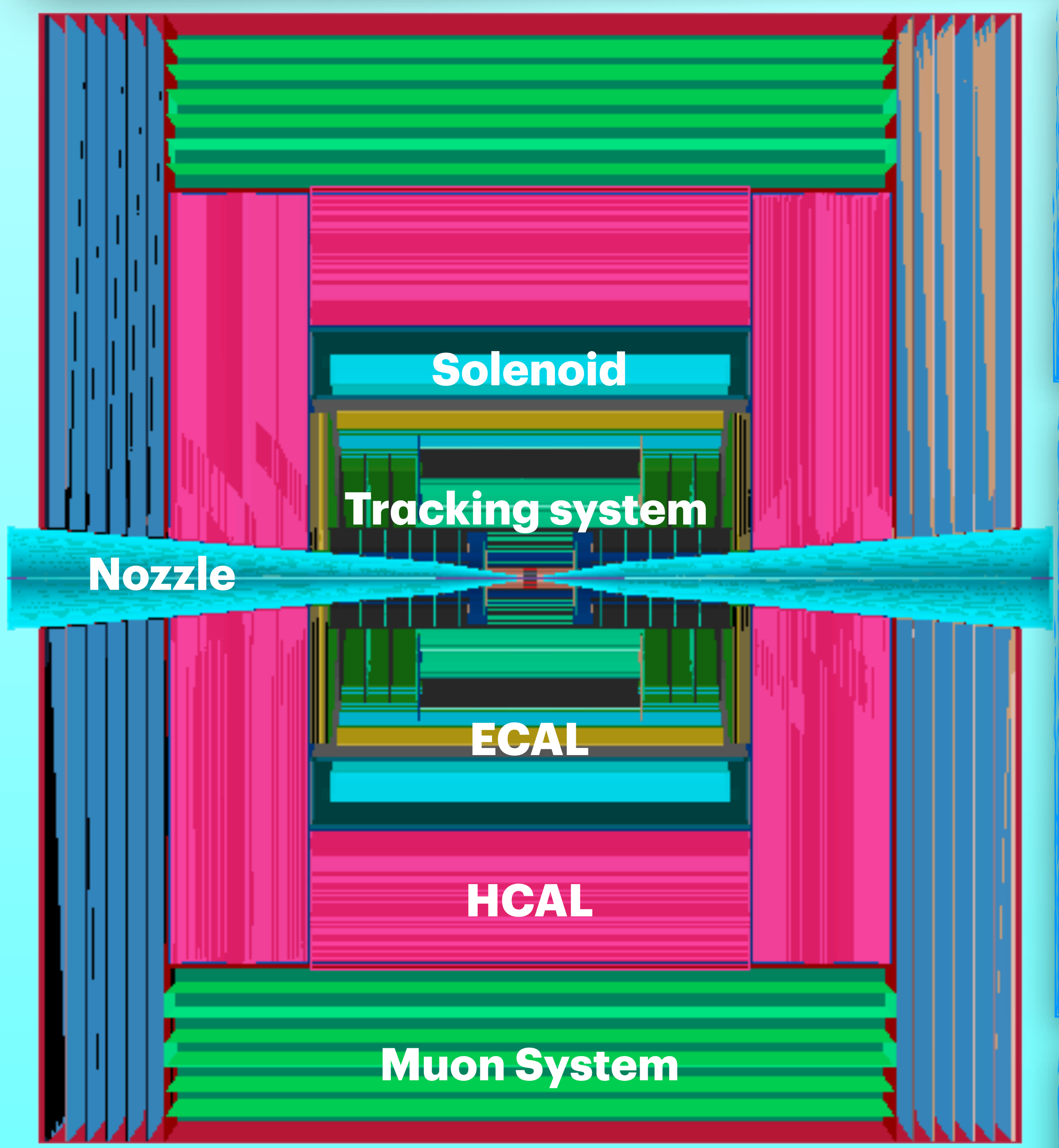
The Muon Collider project

- In a **muon collider** facility intense beams of μ^+ and μ^- could collide at **multi TeV** center of mass energy
- **Advantages:** possibility to perform high precision measurement and to reach the energy frontier for discovery
- **Challenges**: muons are unstable particles → decays generate a diffuse background → ***Beam-Induced Background (BIB)***



- BIB particles [1] enter the detector region making the **events reconstruction challenging**.
- **Two Tungsten cone-shaped shields (*Nozzles*)** are inserted in the forward region of the detector to mitigate the BIB effects [2].



Physics cases

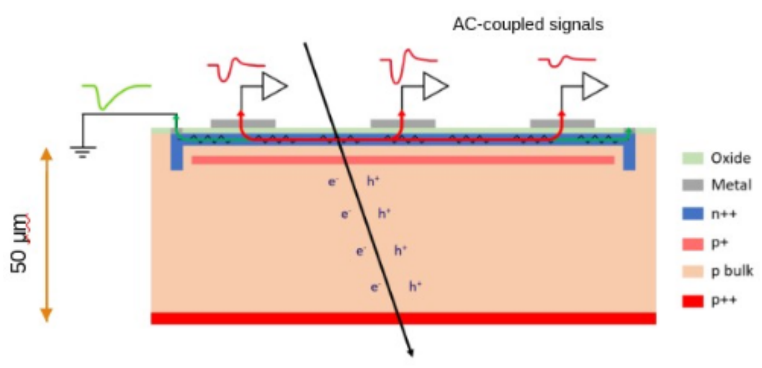
- A 10 TeV Muon Collider can target many different physics cases [3]
  - **High precision physics measurements**, for example Higgs physics
  - Search for **new physics at the energy frontier**, for example search for new particles like Z'
  - Search for **unconventional signatures** like (Disappearing tracks, long-lived particles, WIPMS)

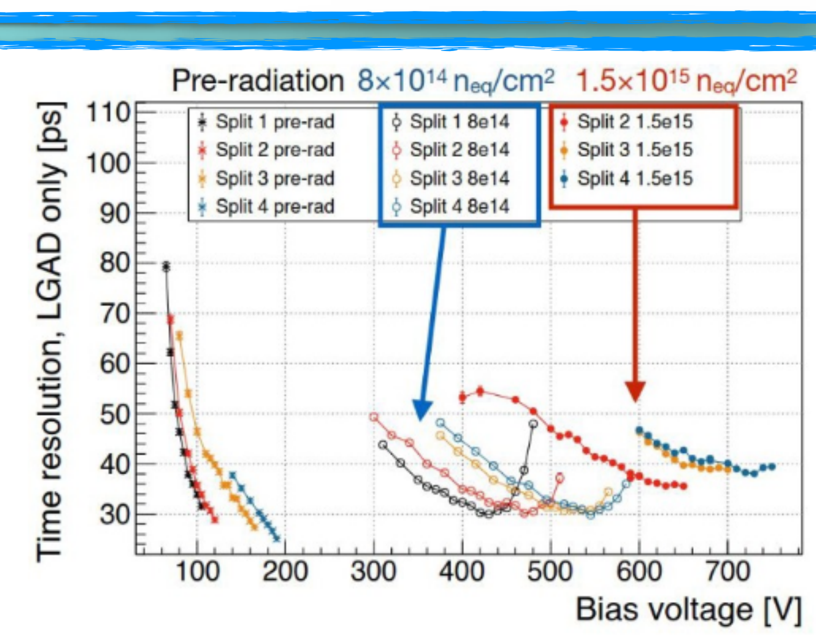
Tracking system

- Several requirements [4]:
  - **Good timing** performance
  - **Radiation hardness**
  - Good **granularity**

Experiment	1 MeV n_{eq} / cm²	GRad
HL-LHC (ATLAS)	1.87 x 10¹⁶	1.268
μC (1.5 TeV)	10¹⁵	0.01
μC (10 TeV)	3 x 10¹⁴	0.02
FCChh	8 x 10¹⁷	27
FCCee	? not big ?	? not big ?

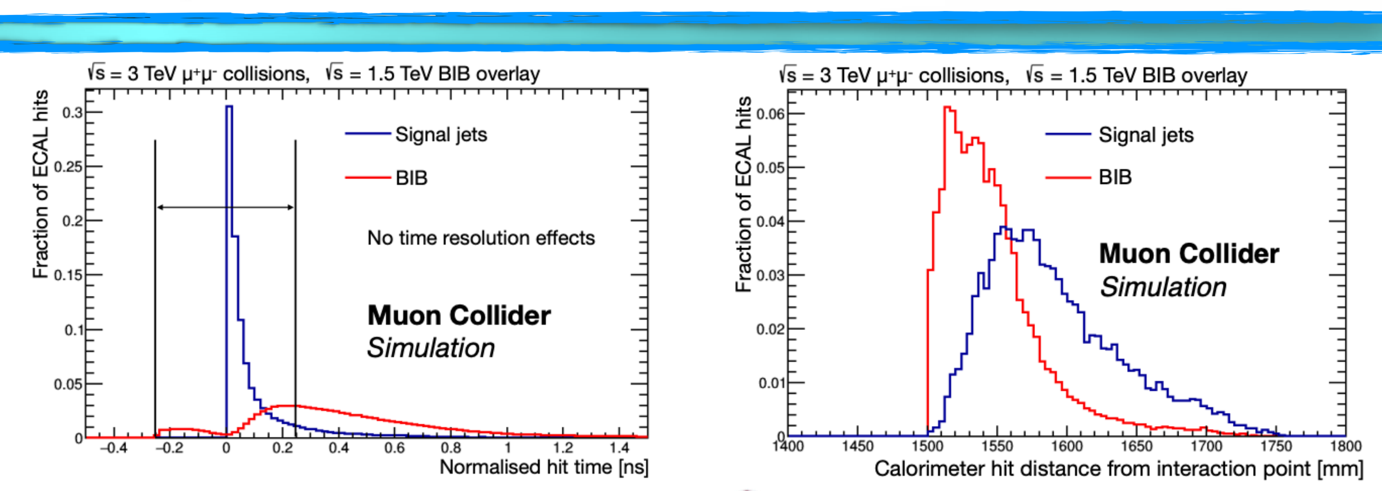
- Several possible candidates:
  - LGADs ($\sigma_t \sim 30$ ps)
  - Monolithic Sensors



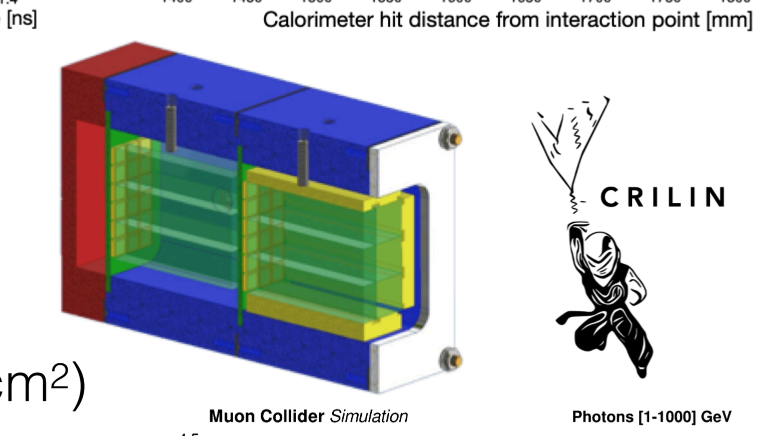


ECAL

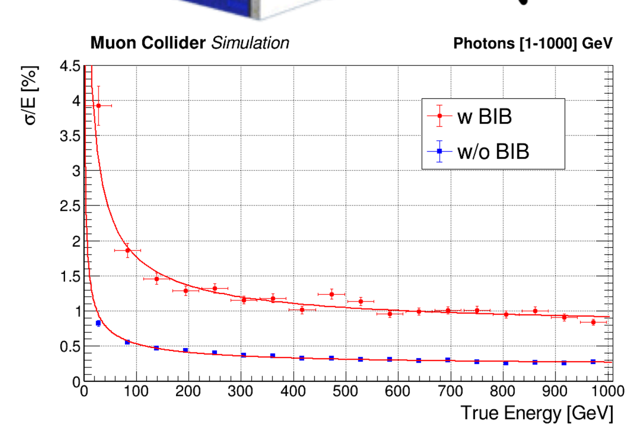
- To reduce the BIB contribution[5]:
  - **Fine granularity**
  - **Good Timing** (<100ps)
  - **Longitudinal segmentation**
  - **Excellent energy resolution**
  - **Radiation hardness**



- New technology proposal: **CRILIN** (Crystal calorimeter with longitudinal information)[6]
  - **Semi-homogeneous calorimeter** with 5 PbF_2 crystal (10x10x40cm²) layers read by SiPM

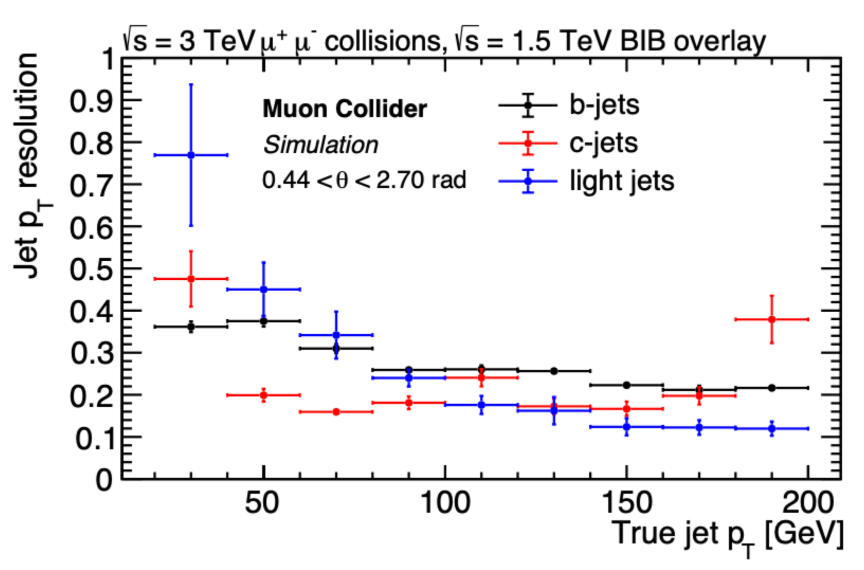


- From experimental tests: σ_t **< 20ps** and good radiation hardness
- From simulation studies: energy resolution ~ **4.8%/√E** w/o BIB, **15%/√E** w/ BIB



HCAL

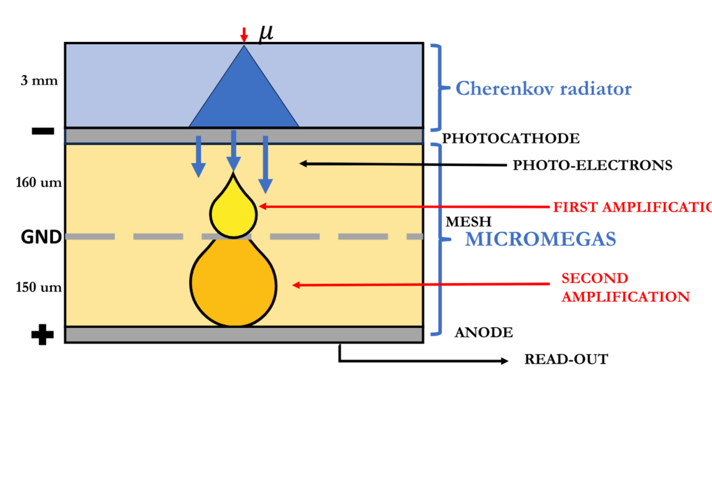
- A **sampling calorimeter** provides excellent reconstruction of jets, and offers good energy resolution.
  - Base design: 60 layers of **steel** and **plastic scintillating** tiles (3x3 cm²) [4]
  - The **solenoid** is placed between ECAL and HCAL. The magnetic field can be closed with HCAL iron.

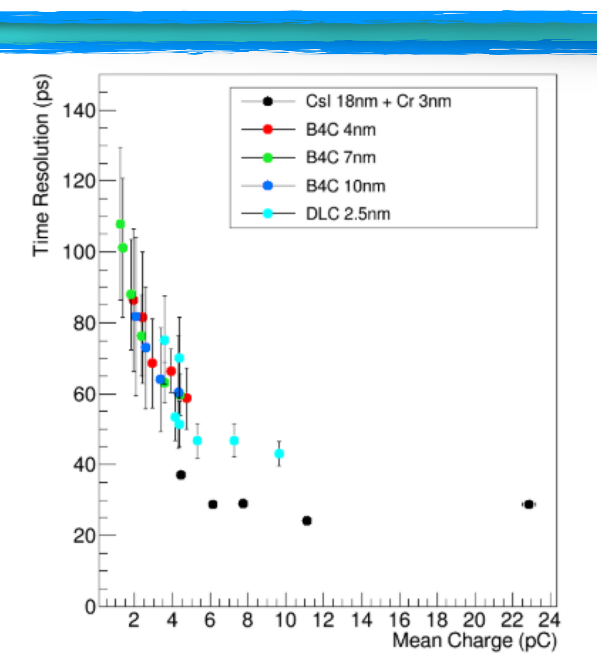


- New proposal: **MPGD**-based HCAL [7]
  - Higher granularity (1x1cm²)
  - Excellent rate capability (up to 10 MHz/cm²)
  - Good energy resolution

Muon system

- Muon reconstruction will benefit from **good timing** performance
- Proposal: **MPGD** (Picosec)
- Ongoing R&D to test scalability





Conclusions

- The unique experimental environment of the Muon Collider imposes stringent requirements in detector design to mitigate the presence of BIB and achieve optimal measurement performance.
- The results obtained with the current preliminary configuration are very promising. Upcoming software developments and advancements in hardware technology will significantly improve the current performance.

References

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For more information