UNIVERSITÀ DI PAVIA

INFN Istituto Nazionale di Fisica Nucleare

International MUON Collider Collaboration

First Annual Meeting
CERN 11-14 Oct 2022

Muon detectors performance

Chiara Aimè on behalf of the Physics and Detector working group

Summary

1. Hints from theory
2. Detector
   1. now
   2. …and then?
3. A big issue: Beam-Induced Background
4. Overview of reconstruction techniques
5. Very preliminary results without BIB
6. Dealing with BIB: two possible ways
   1. Results with standalone muon reconstruction
   2. Results with ACTS and Pandora
7. Conclusions and perspectives

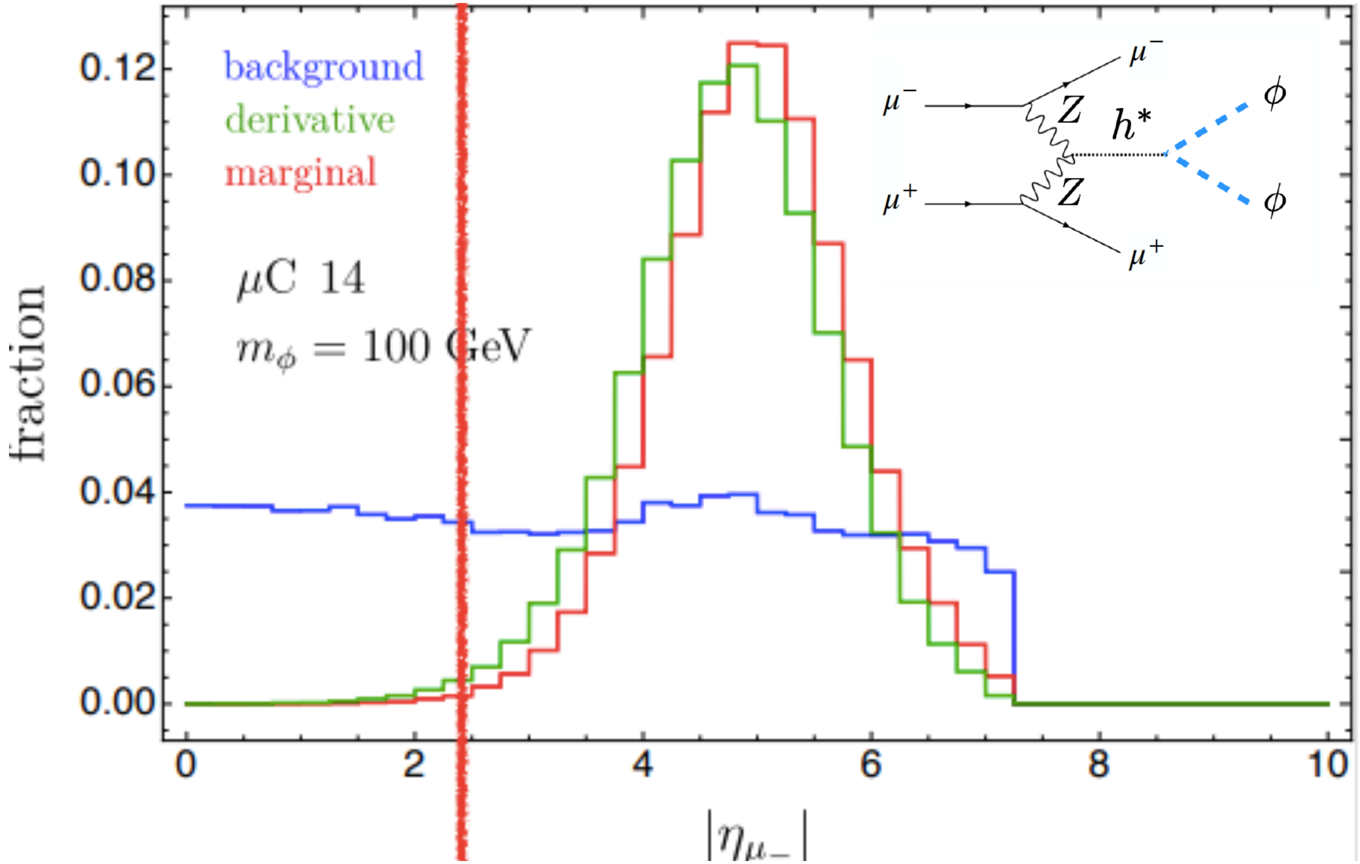
Physics with muons

Goal:

- Higgs' precision physics
- dark matter searches
- …

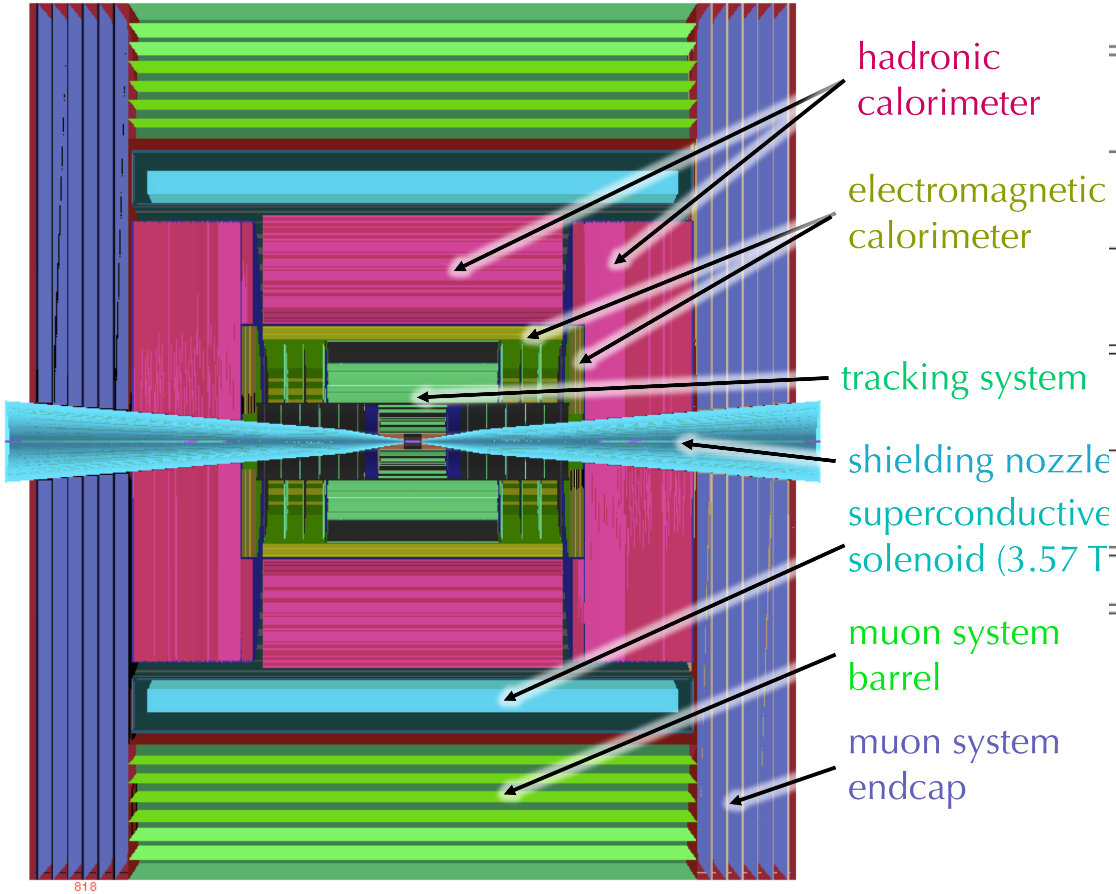
BACK **Maximilian Ruhdorfer**
The physics case of a very forward muon detector

Invisible Higgs decays



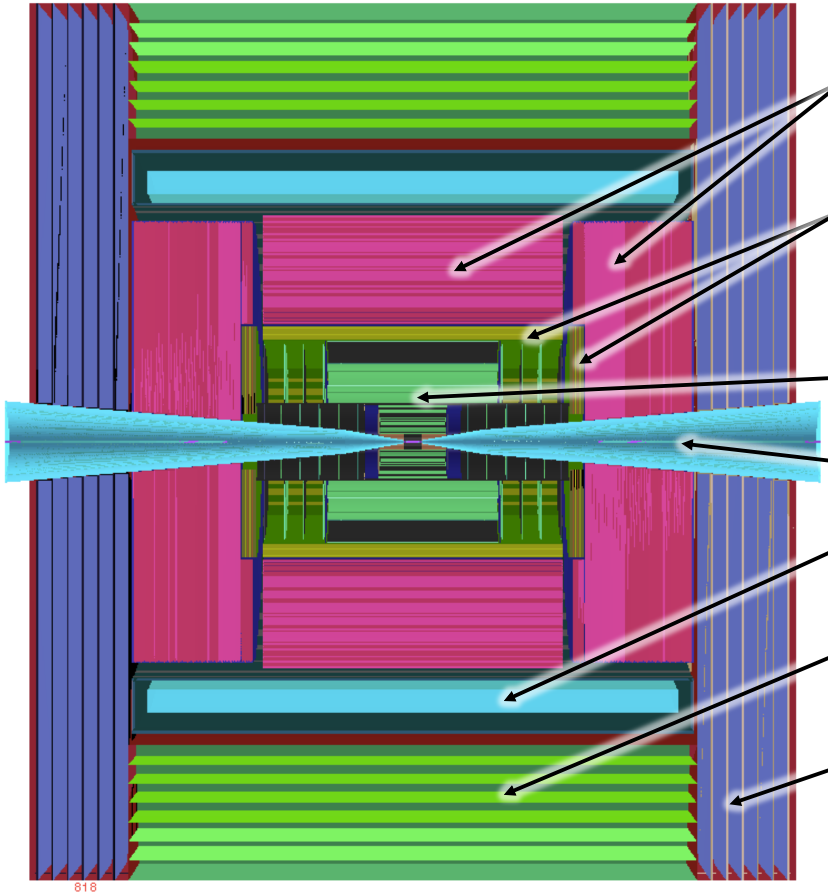
Muon Collider detector

arXiv:2203.07964v1 *Simulated Detector Performance at the Muon Collider*



Subsystem	Region	R dimensions [cm]	|Z| dimensions [cm]	Material
Vertex Detector	Barrel	3.0 – 10.4	65.0	Si
	Endcap	2.5 – 11.2	8.0 – 28.2	Si
Inner Tracker	Barrel	12.7 – 55.4	48.2 – 69.2	Si
	Endcap	40.5 – 55.5	52.4 – 219.0	Si
Outer Tracker	Barrel	81.9 – 148.6	124.9	Si
	Endcap	61.8 – 143.0	131.0 – 219.0	Si
ECAL	Barrel	150.0 – 170.2	221.0	W + Si
	Endcap	31.0 – 170.0	230.7 – 250.9	W + Si
HCAL	Barrel	174.0 – 333.0	221.0	Fe + PS
	Endcap	307.0 – 324.6	235.4 – 412.9	Fe + PS
Solenoid	Barrel	348.3 – 429.0	412.9	Al
Muon Detector	Barrel	446.1 – 645.0	417.9	Fe + RPC
	Endcap	57.5 – 645.0	417.9 – 563.8	Fe + RPC

Muon system



Geometry based on CLIC detector
arXiv:1202.5940 *Physics and Detectors at CLIC: CLIC CDR*

Current design

Iron yoke plates instrumented with:
- 7 layers of detectors in the barrel
- 6 layers in both endcaps

Detector technology: Glass Resistive Plate Chamber (GRPC)

Detector cells: 30x30 mm^2

Magnetic field:
- 1.34 T in barrel
- 0.01 T in endcaps

Technologies for the muon system

Classical gaseous detector

- Double gap Glass RPC
- Double gap HPL RPC

Classical Micro Pattern Gaseous Detectors (MPGD)

- Triple GEM

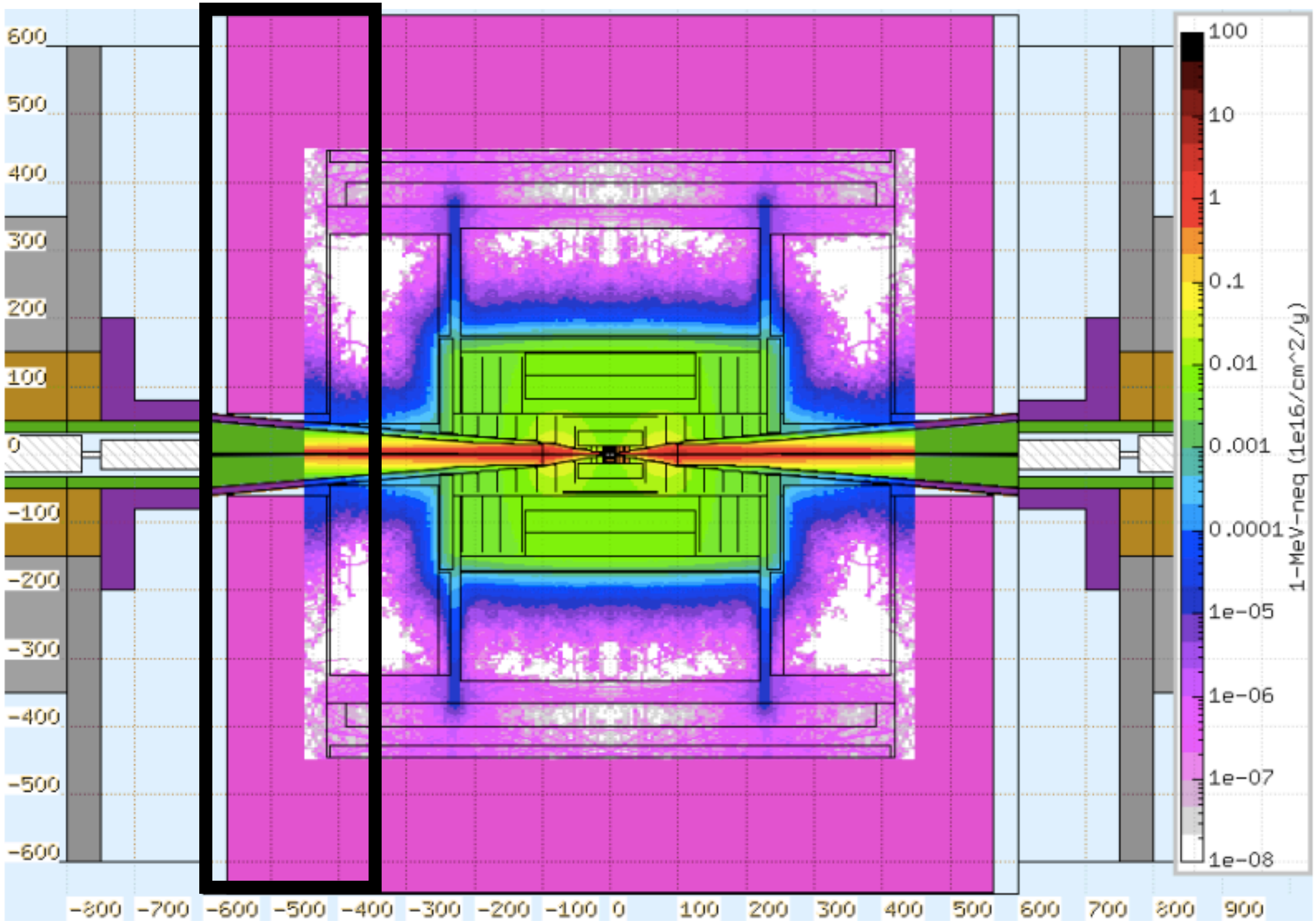
New generation MPGD

- PicoSec

SOON Ilaria Vai *R&D studies on muon detectors*

Beam-induced background

arXiv:2203.07224v1 *Promising Technologies and R&D Directions for the Future Muon Collider Detectors*



1-MeV-neq **fluence**

$\sqrt{s}$ =1.5 TeV

ring circumference = 2.5 km

injection frequency = 5 Hz

normalised to one year

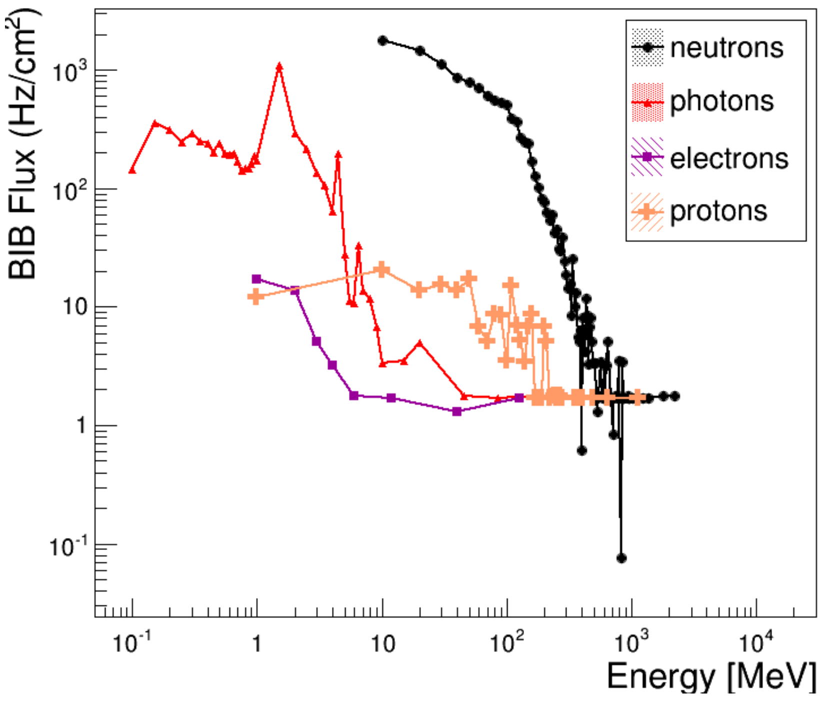
BACK

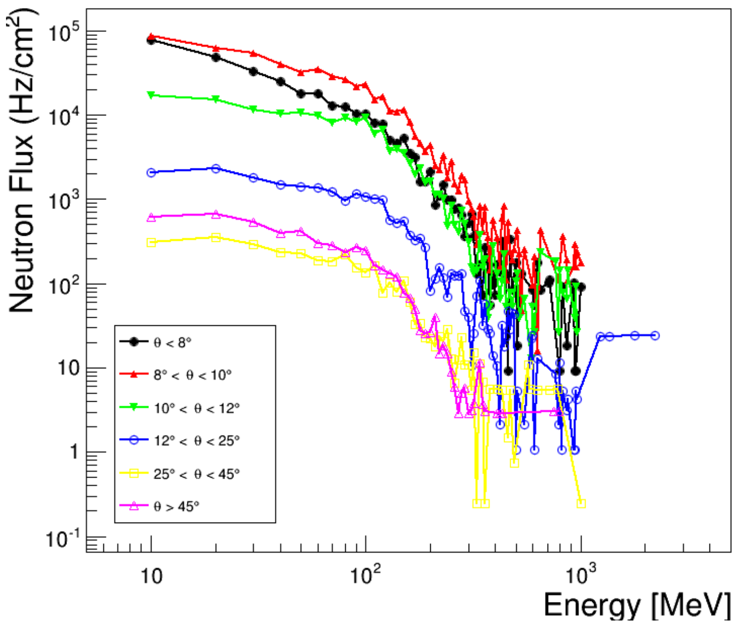
Francesco Collamati *Machine-induced background studies for 1.5 TeV and 3 TeV*

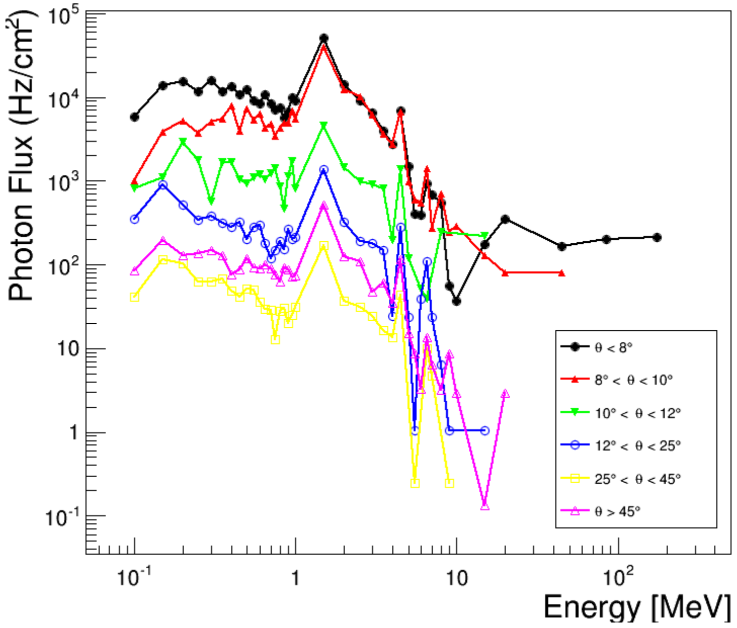
BIB occupancy in the muon system is very low

Beam-induced background in the muon system

BIB mainly composed of neutrons and photons





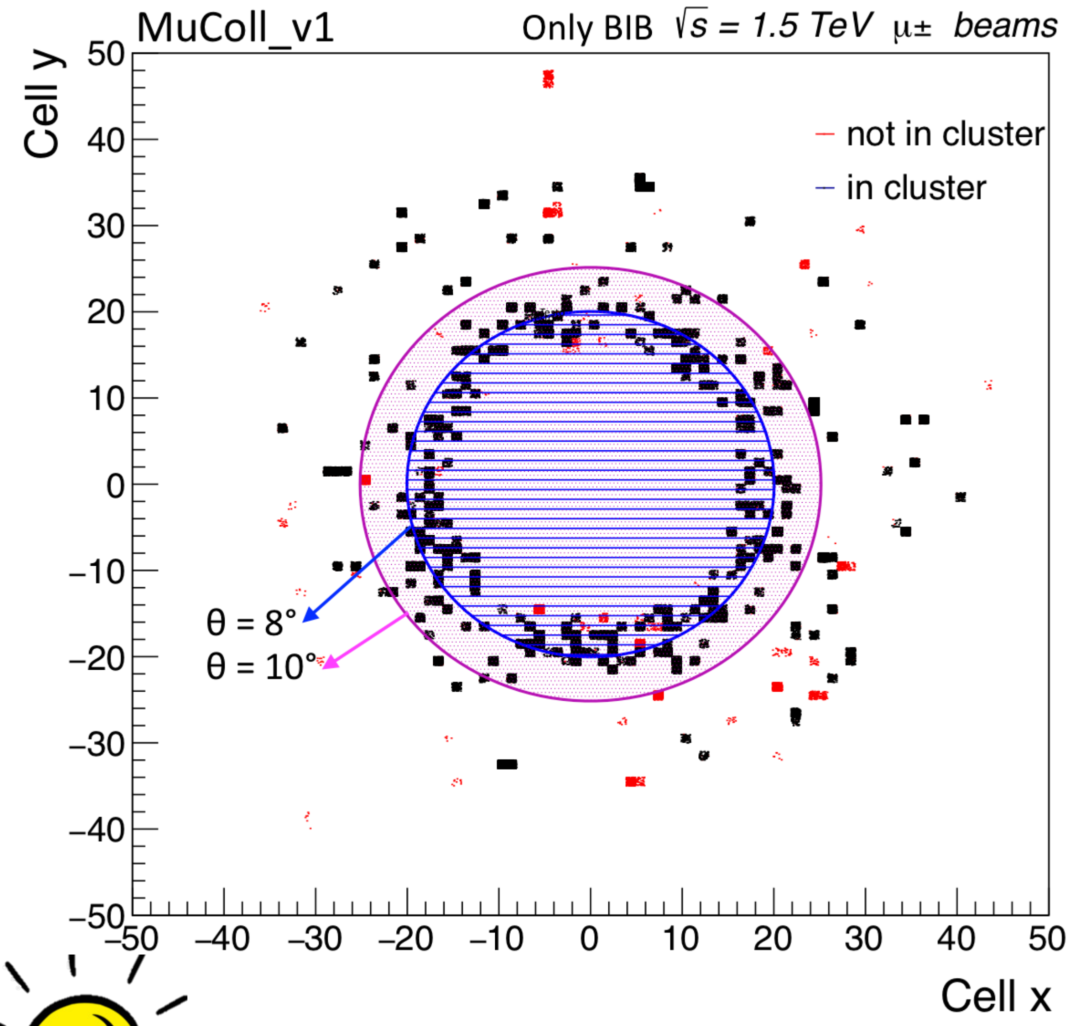


Energy ranges at $\sqrt{s}$ = 1.5 TeV

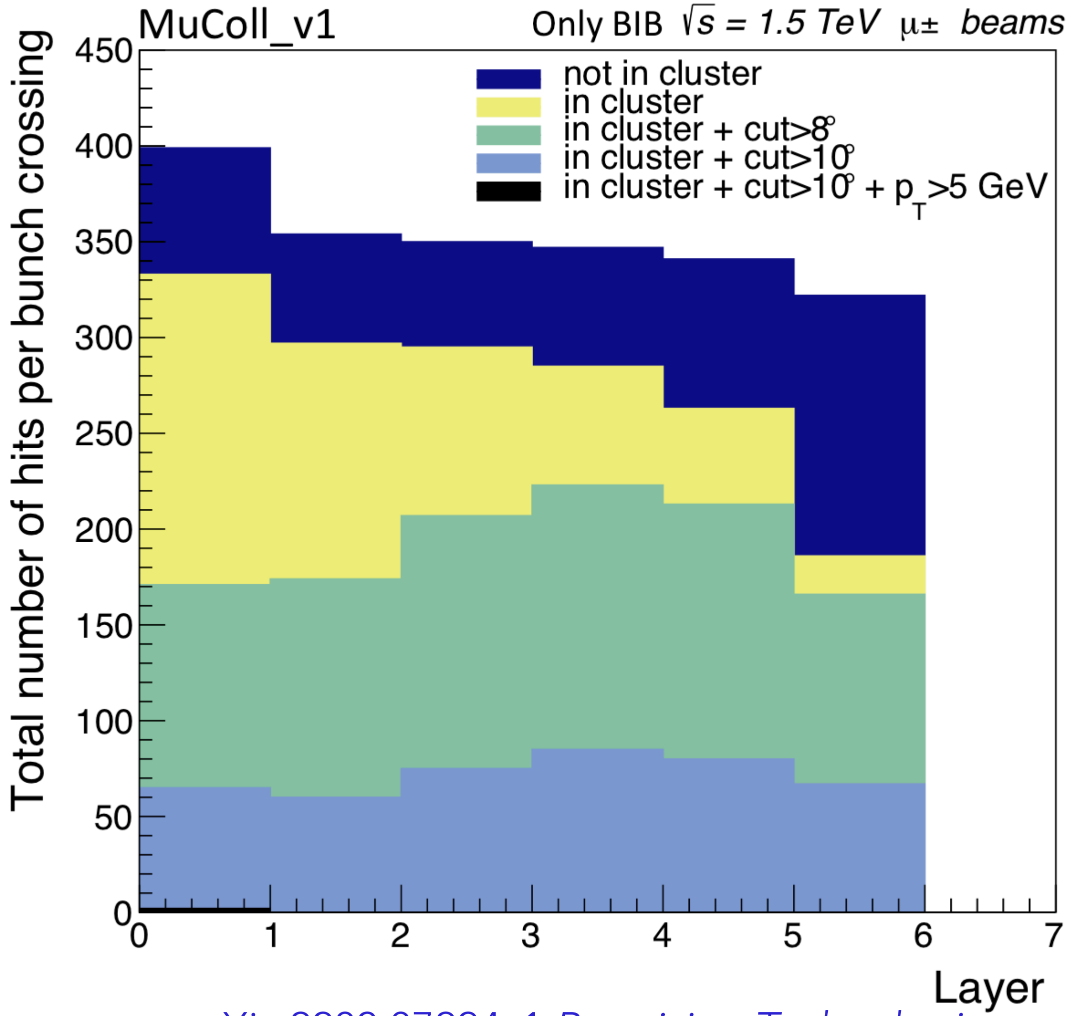
- neutrons: from 10 MeV to 2.5 GeV
- photons: from 100 keV to 200 MeV

SOON Ilaria Vai *R&D studies on muon detectors*

BIB hits concentrated around the beam axis in the endcaps



Geometrical cut + other cuts to reject almost all BIB hits in the muon system



Standalone muon objects to seed the global muon track reconstruction

arXiv:2203.07224v1 *Promising Technologies and R&D Directions for the Future Muon Collider Detectors*

Muon reconstruction

Algorithms for tracks

BACK Karol Krizka *Tracks reconstruction algorithms performance*

1. From electron positron colliders: **Conformal Tracking** (CT)
   - ↳ with BIB: too long
     - ↳ strategies:
       a. Region of Interest (ROI)
       b. double-layer filter
2. From hadron colliders: **Cubature Kalman Filter** (CKF) implemented using A Common Tracking Software (ACTS)

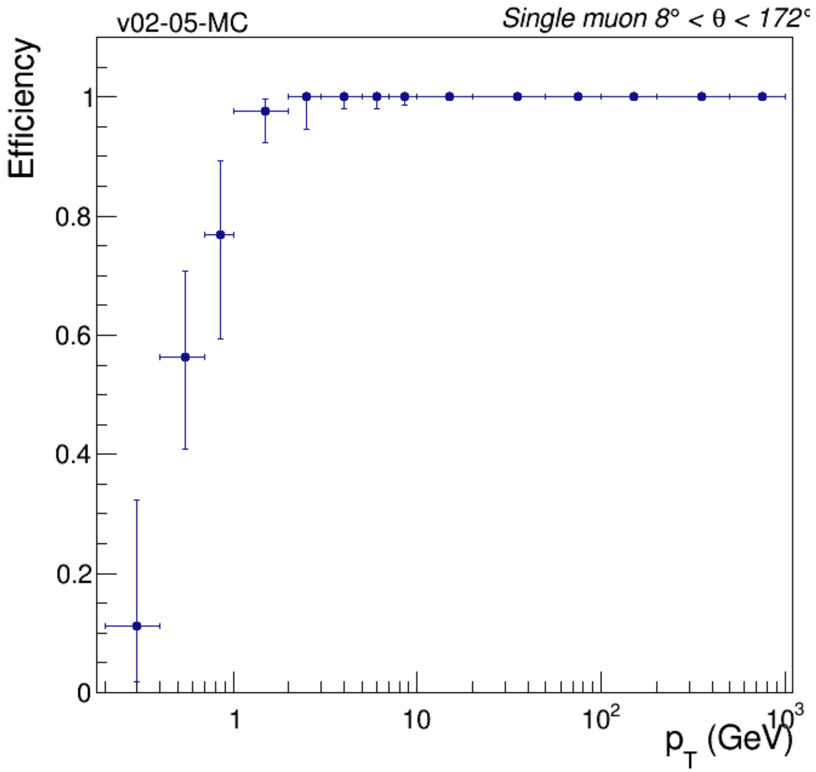
Muon reconstruction

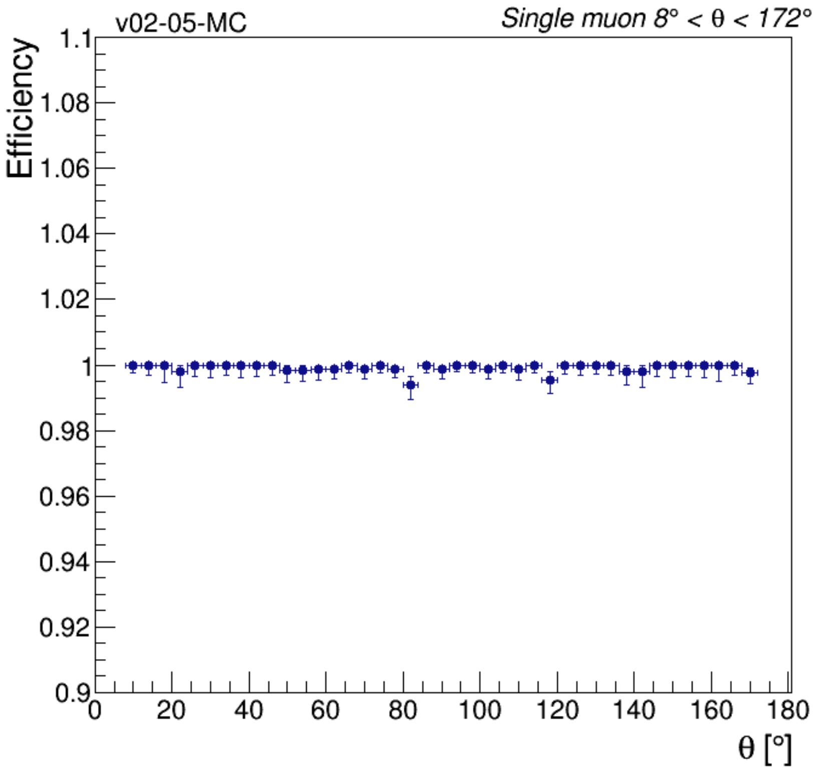
Muons are reconstructed with the **Pandora Particle Flow** algorithm by matching tracks in the inner detector with clusters of hits in the muon system.
Cluster = combination of hits (one hit per layer) inside a cone extending to the neighbouring layers

First results without BIB

CT + Pandora

Single muon efficiency

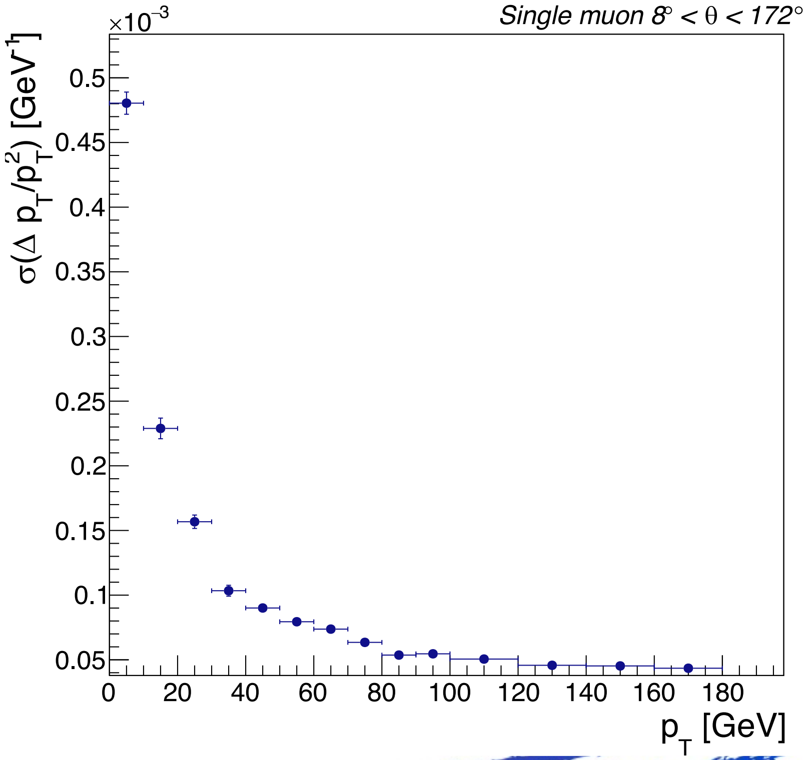




Single muon efficiency ~100% for muons with $p_T > 10$ GeV

Transverse momentum resolution

$\Delta p_T = p_T$ of the generated muon $- p_T$ of the Pandora reconstructed track

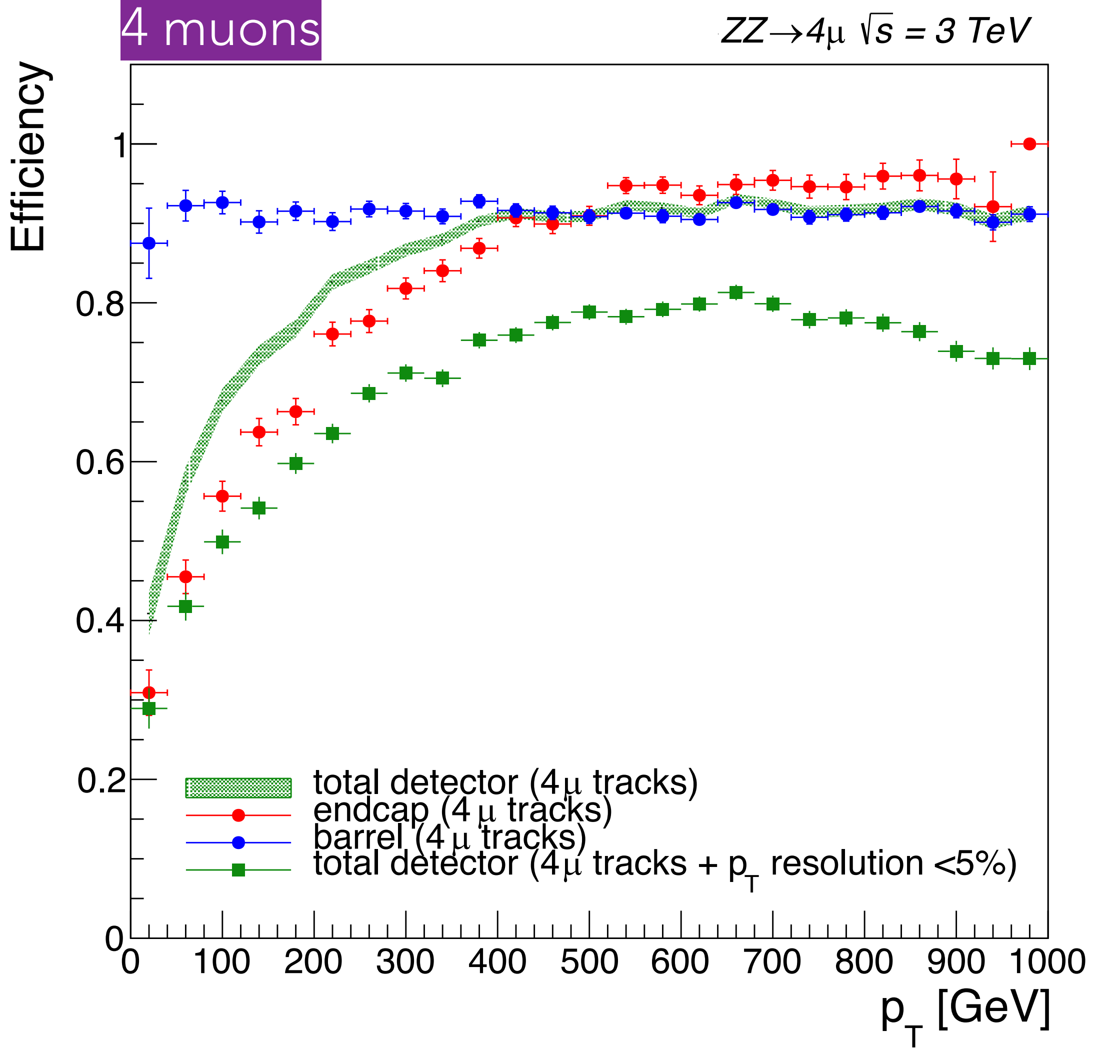


First results without BIB

CT + Pandora

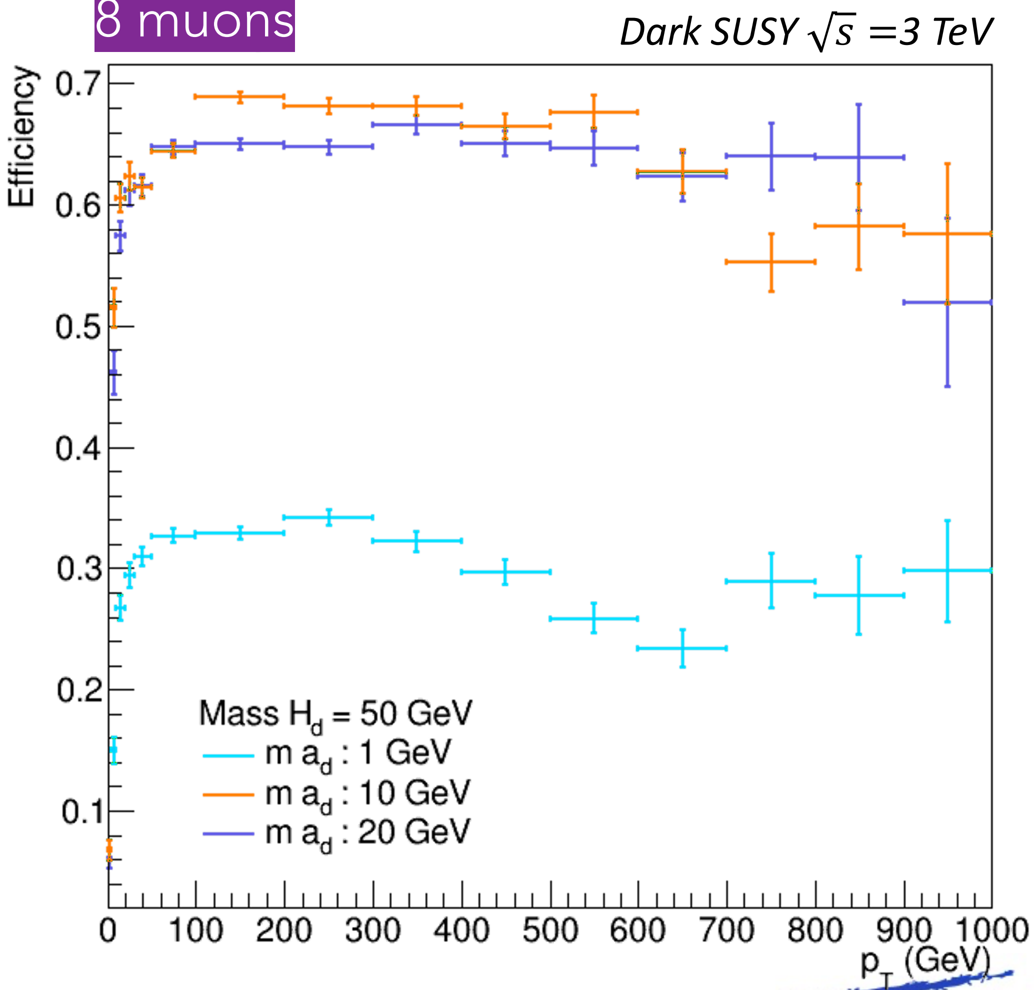
Physics channels efficiency

4 muons



DOI: 10.22323/1.398.0644

8 muons



Dealing with BIB

Muon reconstruction is quite straightforward without BIB.

But with BIB new strategies have to be adopted

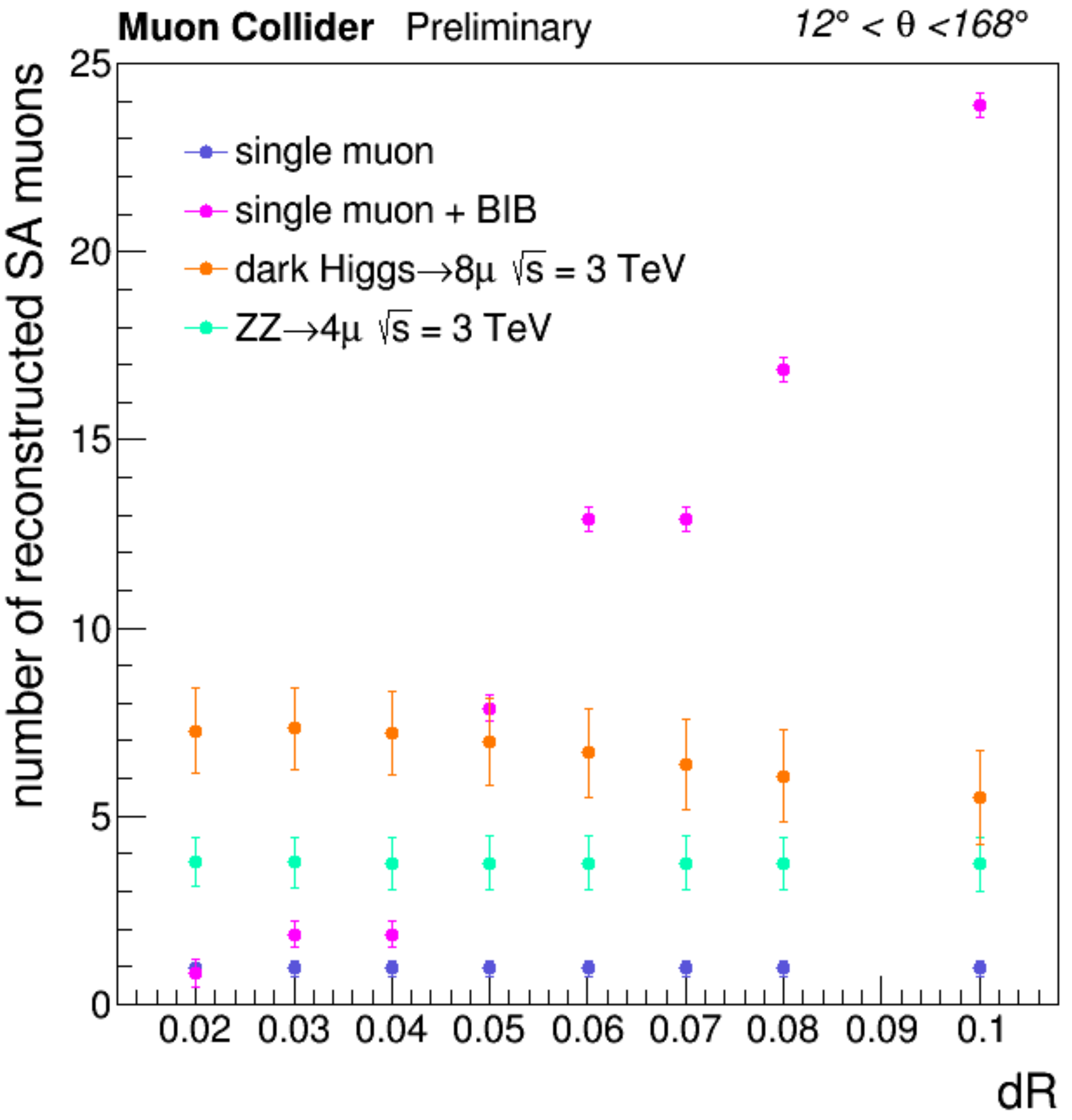
Standalone muon reconstruction
exploiting the low BIB occupancy in the muon system to identify a ROI for CT

ACTS
overcome CT limits

1. Standalone muon reconstruction

CT (ROI)

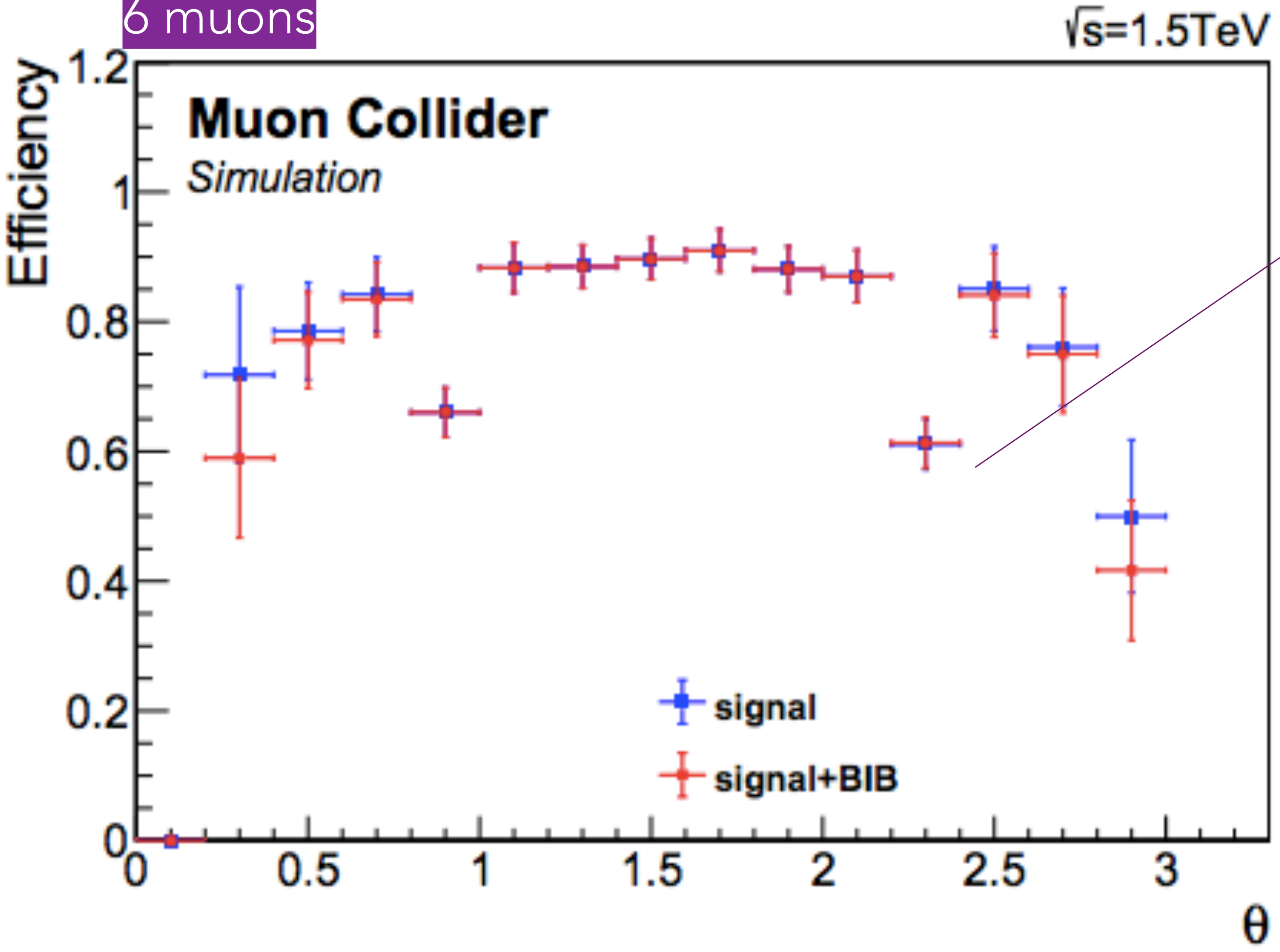
a. muon hits clustered inside a cone with angular aperture ΔR (selected value = 0.02)
b. standalone muon track created if there are hits at least in 5 layers
c. reconstructed hits in all tracker subsystems filtered (ROI)
d. Conformal tracking algorithm applied



Limits

arXiv:2203.07964v1 *Simulated Detector Performance at the Muon Collider*

6 muons



$\theta < 15°$ and $\theta > 165°$ CT limit

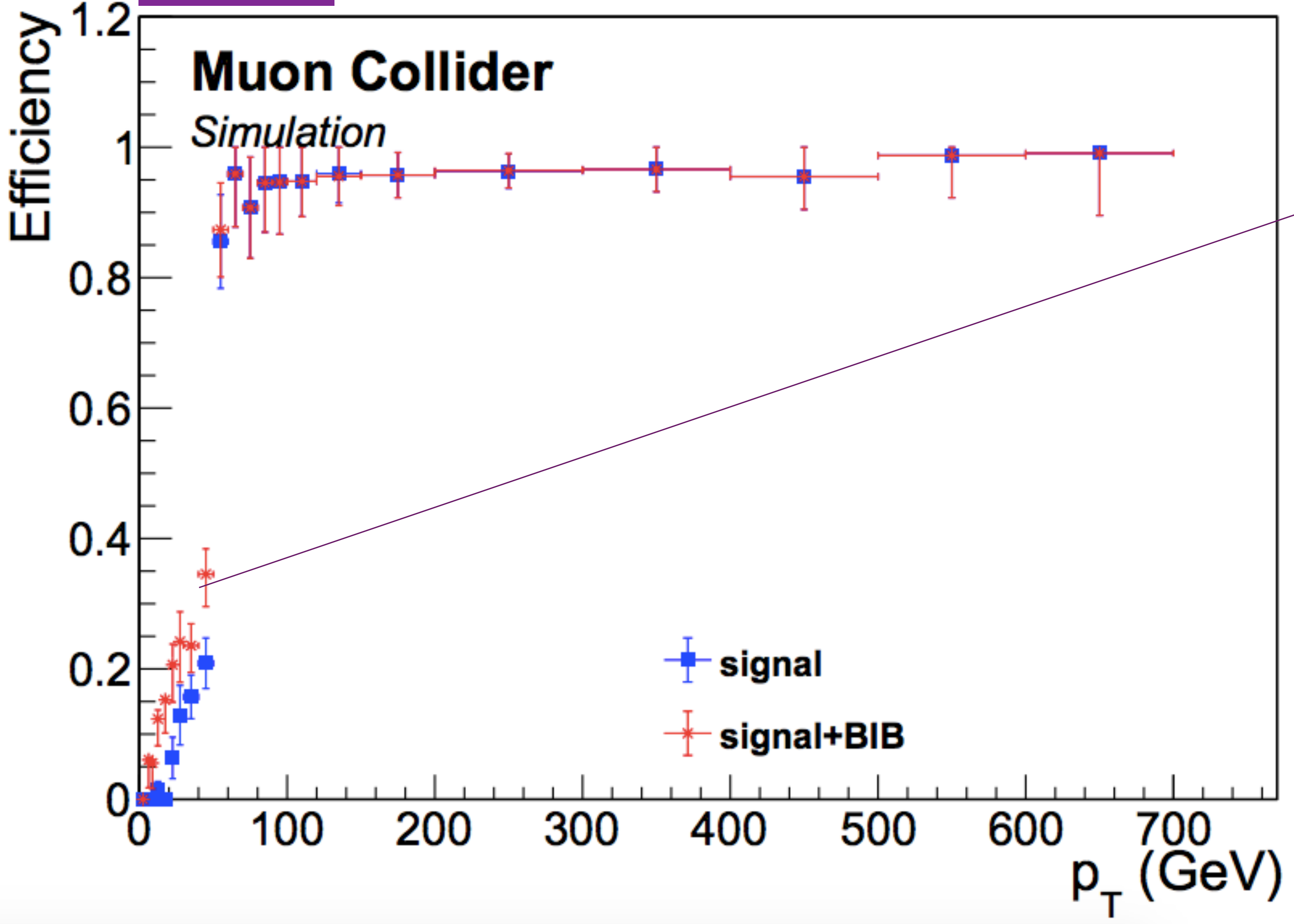
$\theta \sim 32°$ and $\theta \sim 132°$

a specific approach for track with hits both in endcap and barrel is required

Limits

arXiv:2203.07964v1 Simulated Detector Performance at the Muon Collider

6 muons



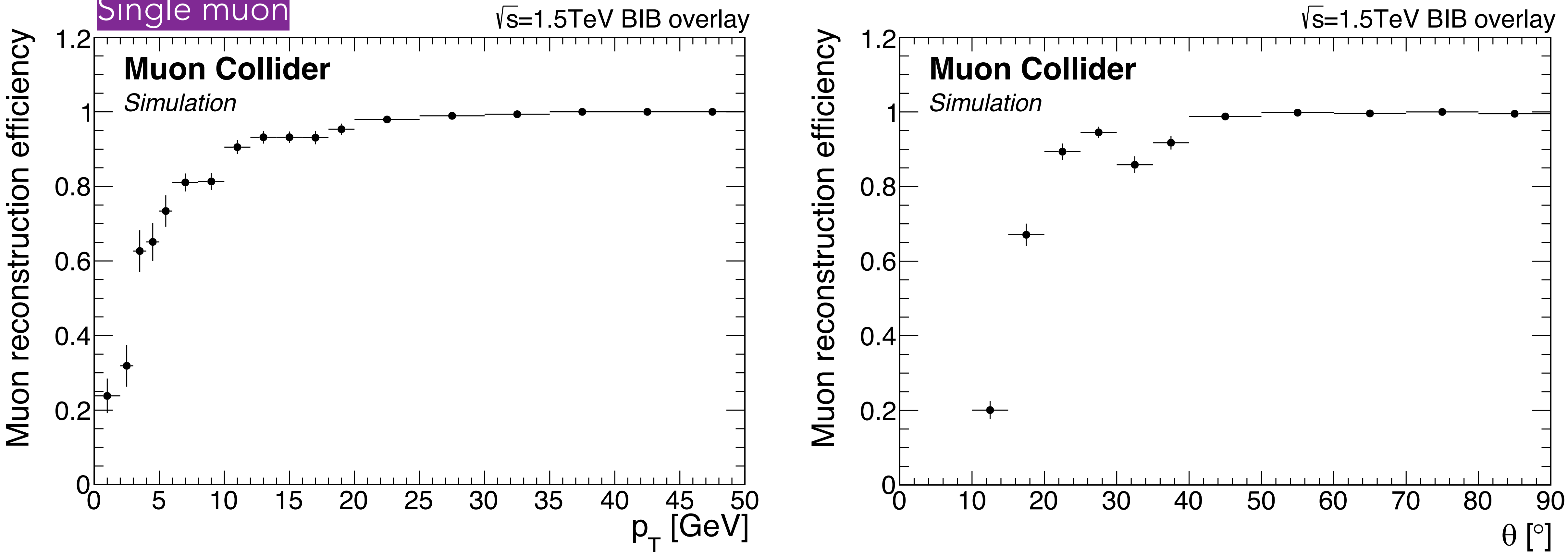
Low p_T

- inefficiencies in reconstruction in the region between barrel and endcap
- parameter tuning for high curvature tracks

2. ACTS

ACTS + Pandora

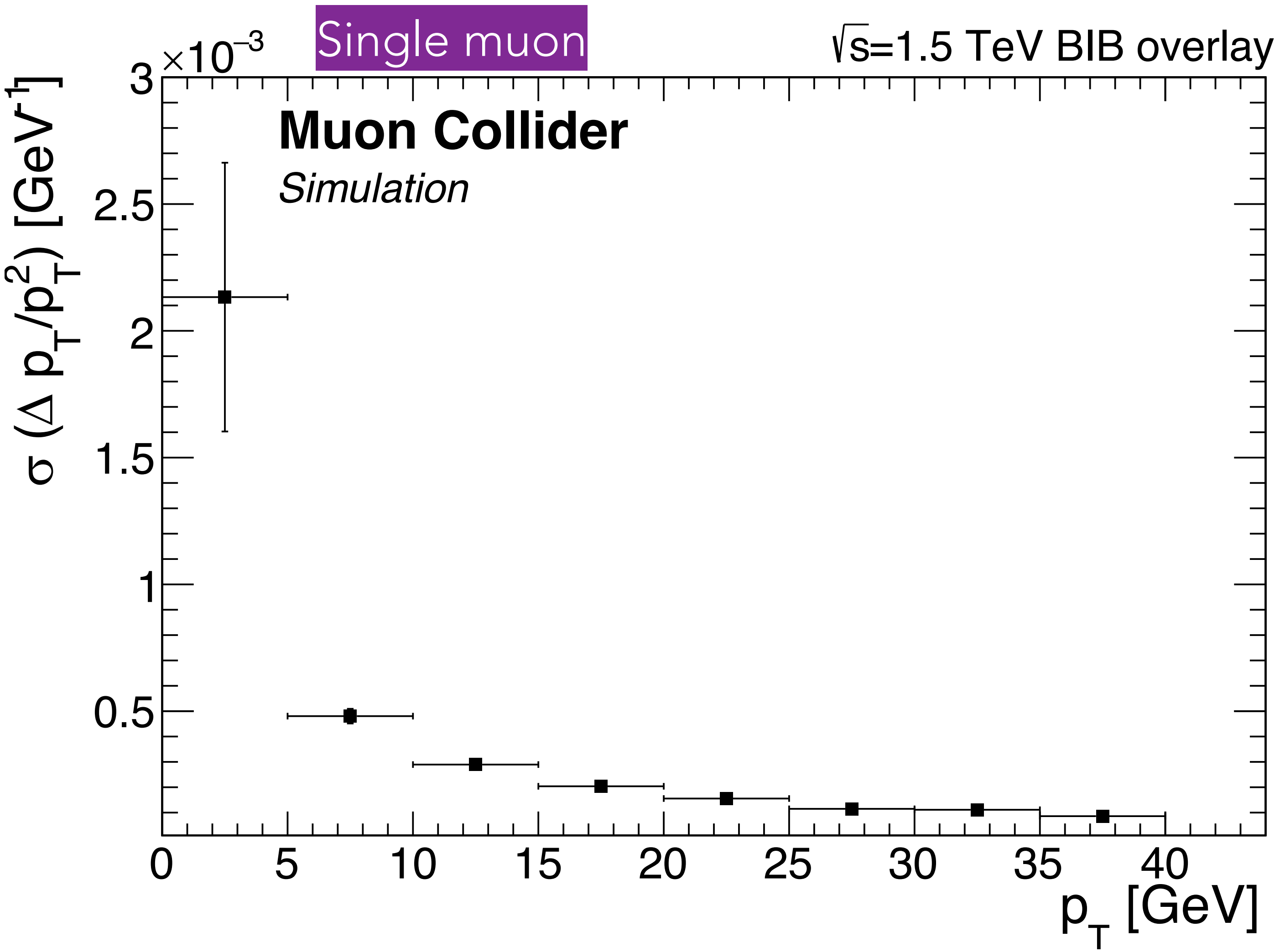
Single muon



Efficiency >99% for p_T >10 GeV and >98% for $8° < \theta < 172°$

2. ACTS

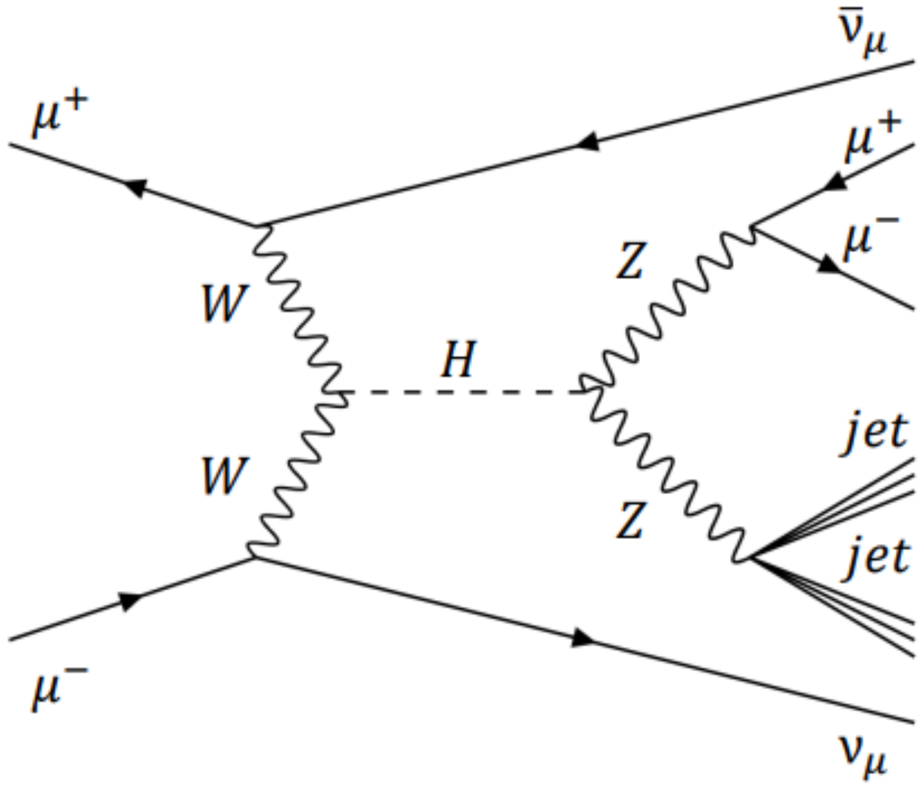
ACTS + Pandora



Resolution less then 10^{-4} GeV^{-1} for p_T >30 GeV

Limits

Physics channel



https://indico.cern.ch/event/1197844/
Study of H->ZZ at 3 TeV CoM energy*

Requirement	Signal events (4000)	ε_s^{abs}	ε_s^{rel}	Background events (9996)	ε_b^{abs}	ε_b^{rel}
$\mu^+\mu^-$ detected	1804	0.451	0.451	2824	0.283	0.283
$p_t(\mu) > 10$ GeV	1584	0.396	0.878	2685	0.269	0.951

Conclusions

What we learned so far

BIB occupancy in the muon system is very low

Muon reconstruction is straightforward without BIB

ACTS + Pandora is perfectly efficient in case of single muons with BIB

Out-in approach seems more efficient for multimuon channels

Thanks for your attention