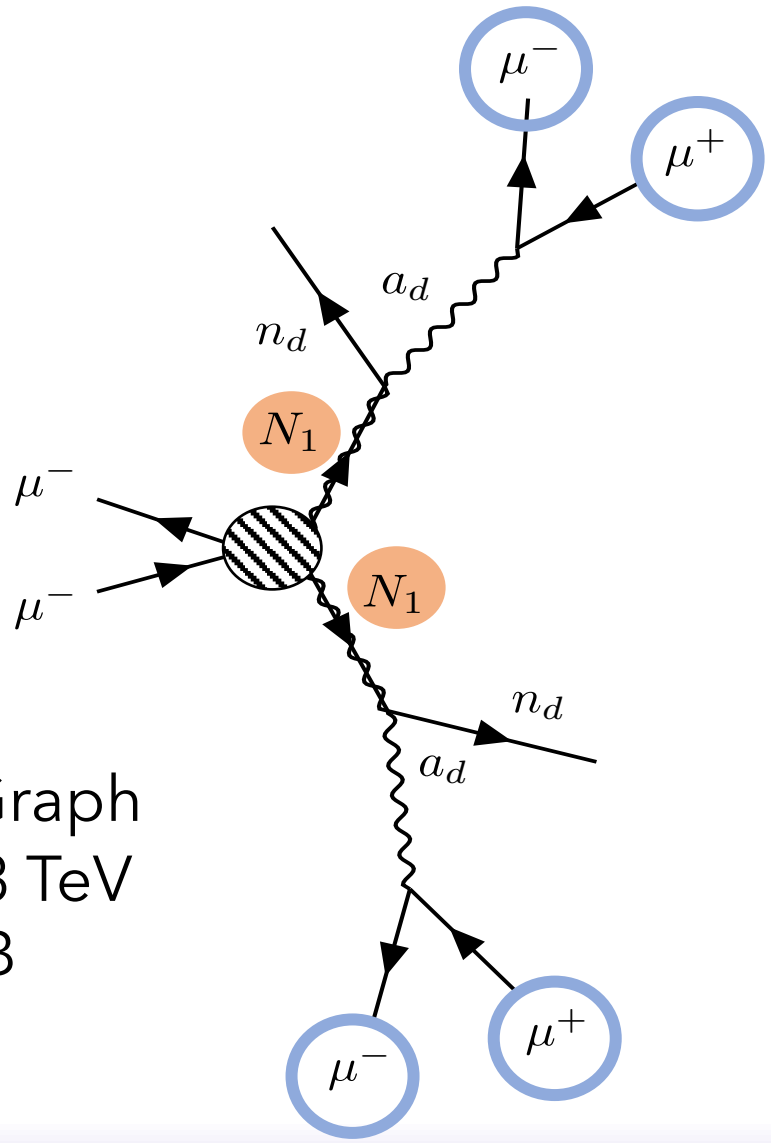
Sensitivity to **dark sector** through the **neutralino** production and **muon pairs** decay at **Muon Collider**

Chiara Aimè[a], Cristina Riccardi[a], Paola Salvini[a], Ilaria Vai[b]

[a] Università di Pavia & INFN Pavia, [b] INFN Pavia & Università di Bergamo

APS – April Meeting 04/20/2021

The physics channel



MadGraph
$\sqrt{s}$ = 3 TeV
no BIB

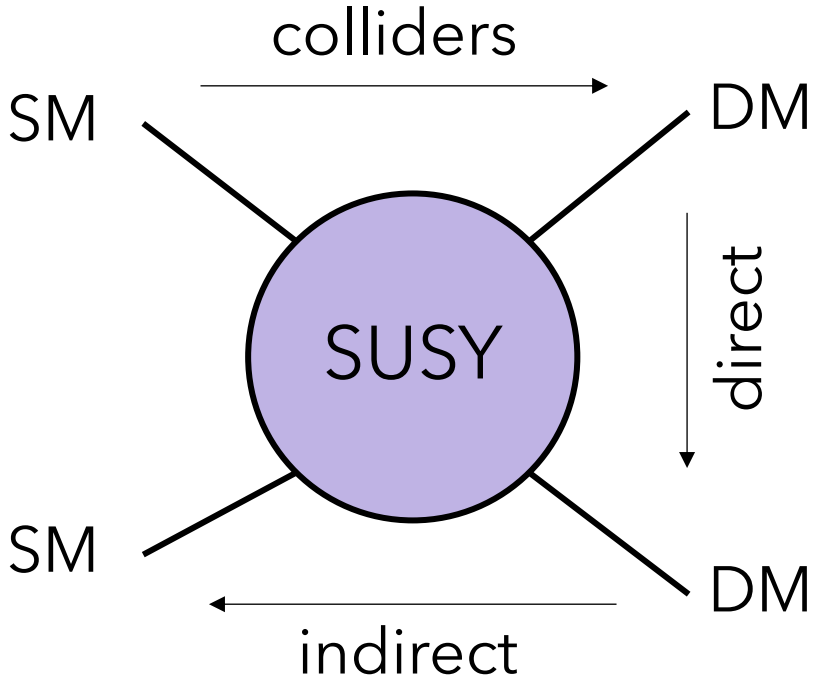
- N_1: lightest neutralino
- n_d: dark neutralino
- a_d: dark photon

Interesting for the study of:

1. Dark SUSY models
2. Muon reconstruction

Previous analysis of the channel performed by the CMS experiment arXiv:1812.00380 [hep-ex]

Dark SUSY



Additional symmetry $U(1)_D$

THEORY PARAMETERS

Symmetry breaking → Dark photon massive (m_{a_d})

Dark photon coupling with SM photons: kinetic mixing parameter ε

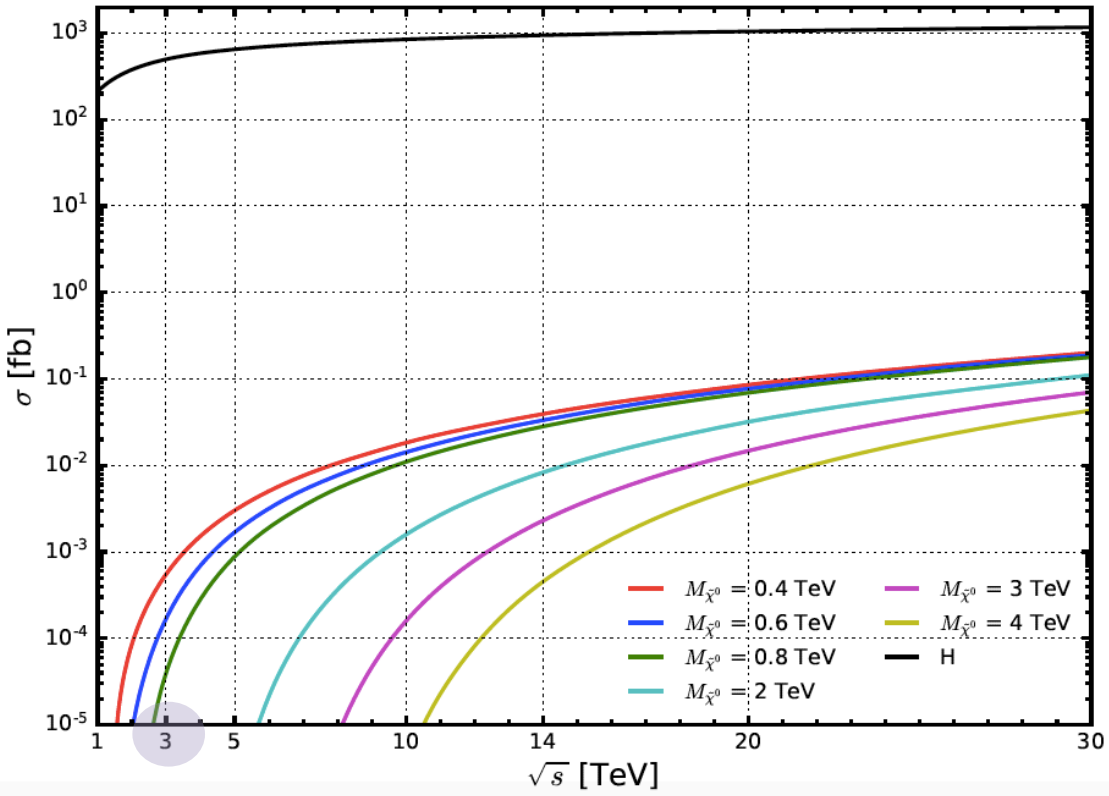
Dark photon decay width (Γ):

$$\Gamma(a_d \longrightarrow l^+l^-) = \frac{1}{3}\,\alpha\varepsilon^2 m_{a_d}\sqrt{1-\frac{4m_l^2}{m_{a_d}^2}}\left(1+\frac{2m_l^2}{m_{a_d}^2}\right)$$

Parameters choice

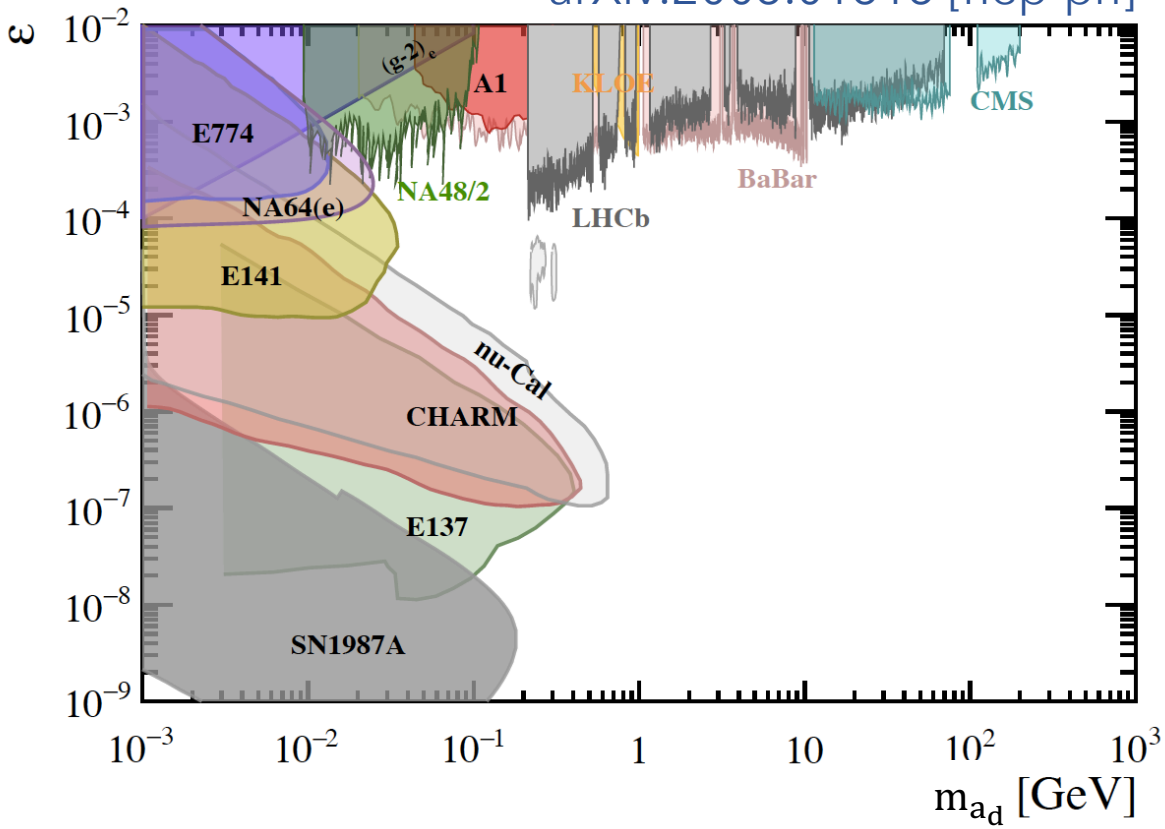
100 GeV < N_1 mass < 700 GeV

arXiv:2005.10289v2 [hep-ph]



25 GeV < a_d mass < 200 GeV

arXiv:2005.01515 [hep-ph]



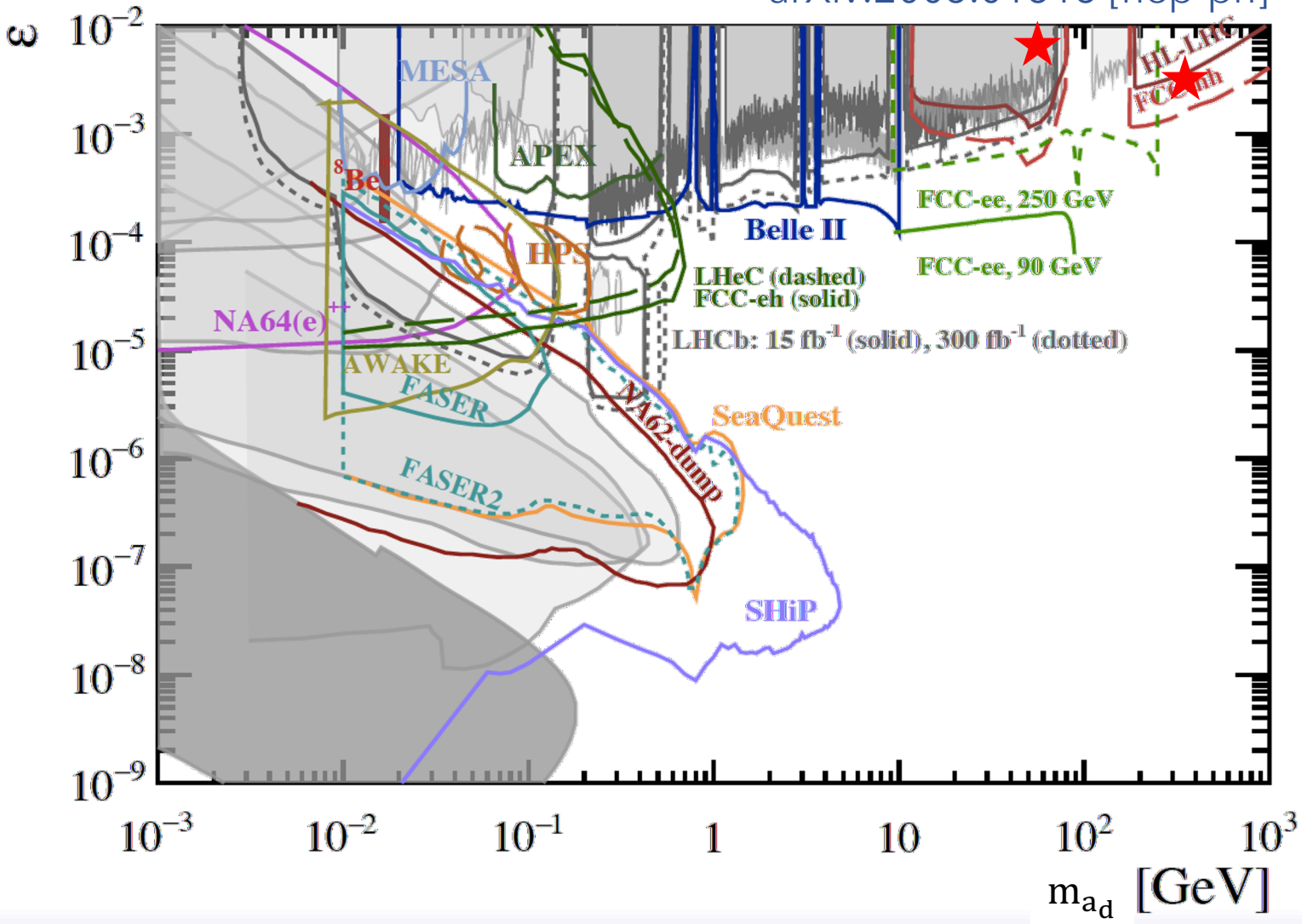
CMS analysis - 0.25 GeV< a_d mass < 8.5 GeV
arXiv:1812.00380 - N_1 mass = 10 GeV

Parameters choice

$\Gamma\ a_d = 10^{-5}$ GeV

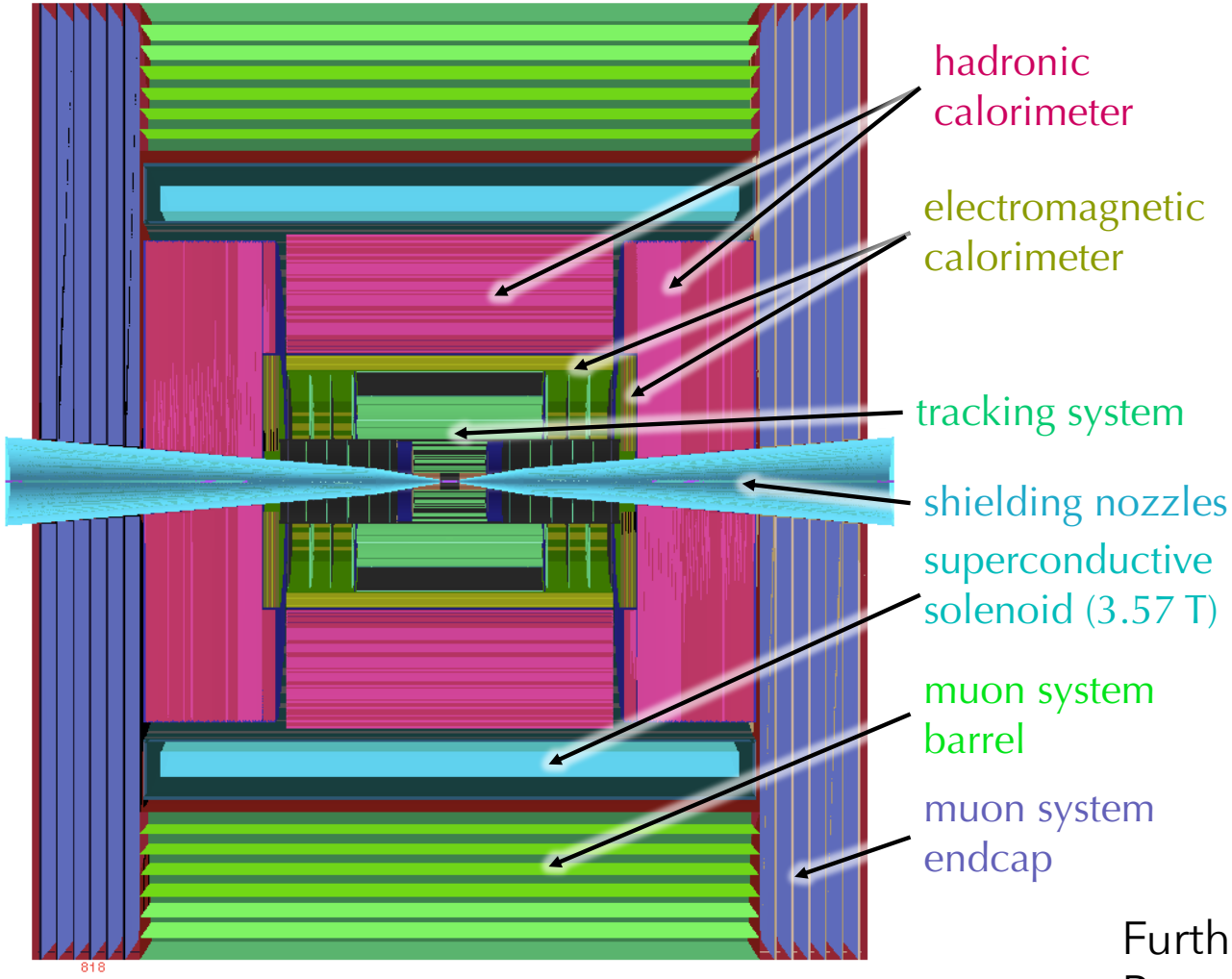
$\varepsilon \sim 10^{-3}$

arXiv:2005.01515 [hep-ph]



Thanks to B. Mele and F. Piccinini for the helpful discussions

Muon system at Muon Collider



Iron yoke plates instrumented with:

- 7 layers of detectors in the barrel
- 6 layers in the endcap

Detector technology:
Glass RPC cells (30x30 mm^2)

Further information: C. Aimè in Poster Session KP01
Based on CLIC detector: arXiv:1202.5940[physics.ins-det]

Muon reconstruction

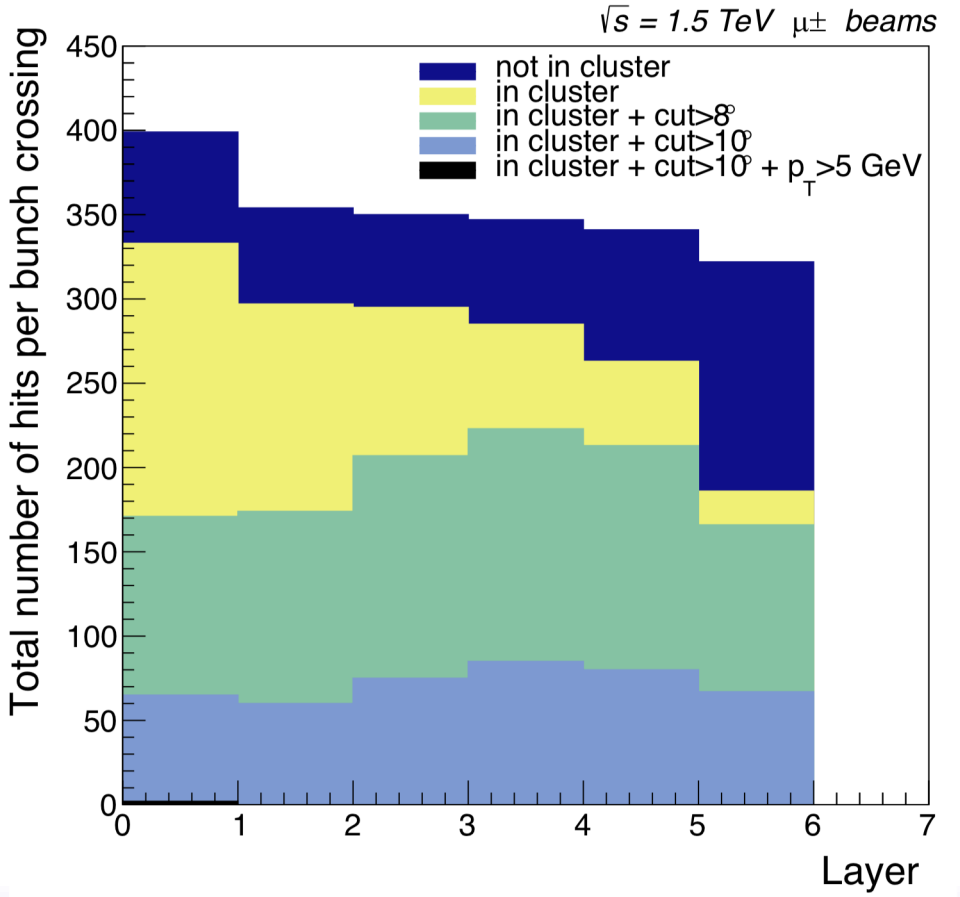
- Simulation: ILCSoft (N. Bartosik in Muon Collider Symposium I)
- Muon reconstruction: PANDORA PFA framework

CLUSTER: combination of hits (one hit per layer) inside a cone and on neighbouring layers

Single muon tracks well reconstructed

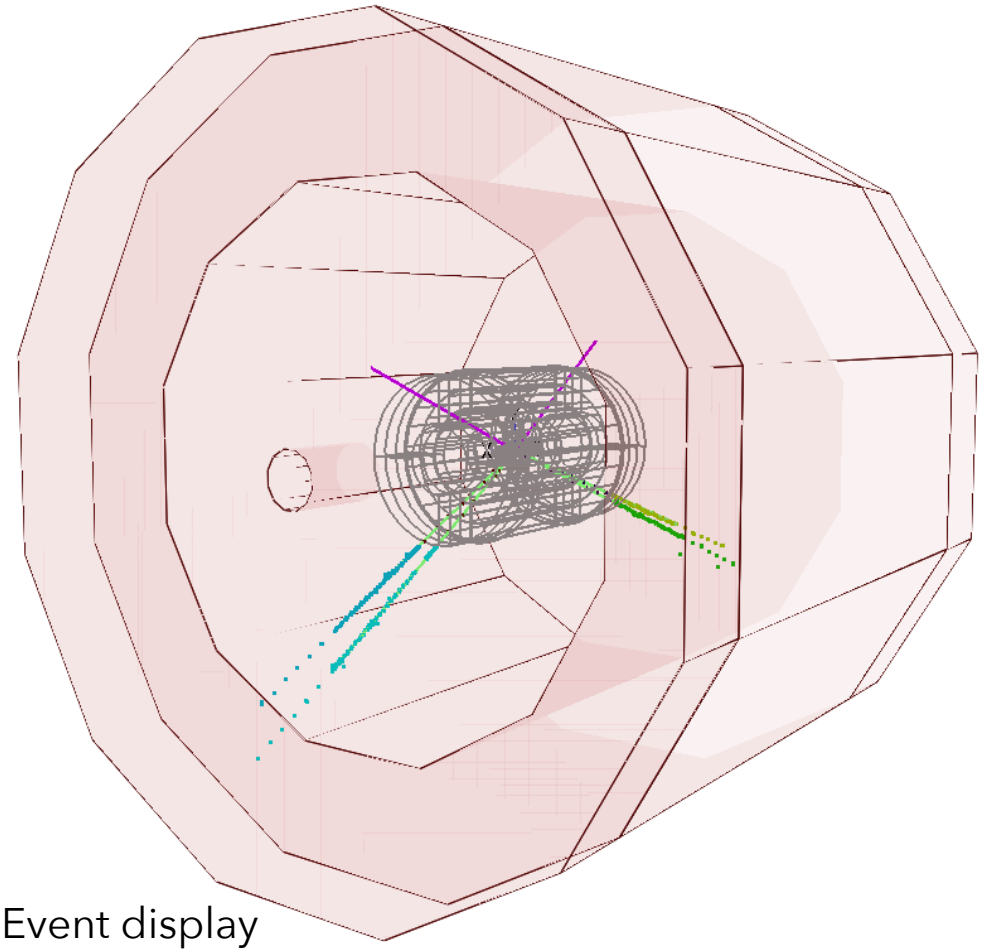
Beam Induced Background hits in the muon system easily rejectable

→ new strategy

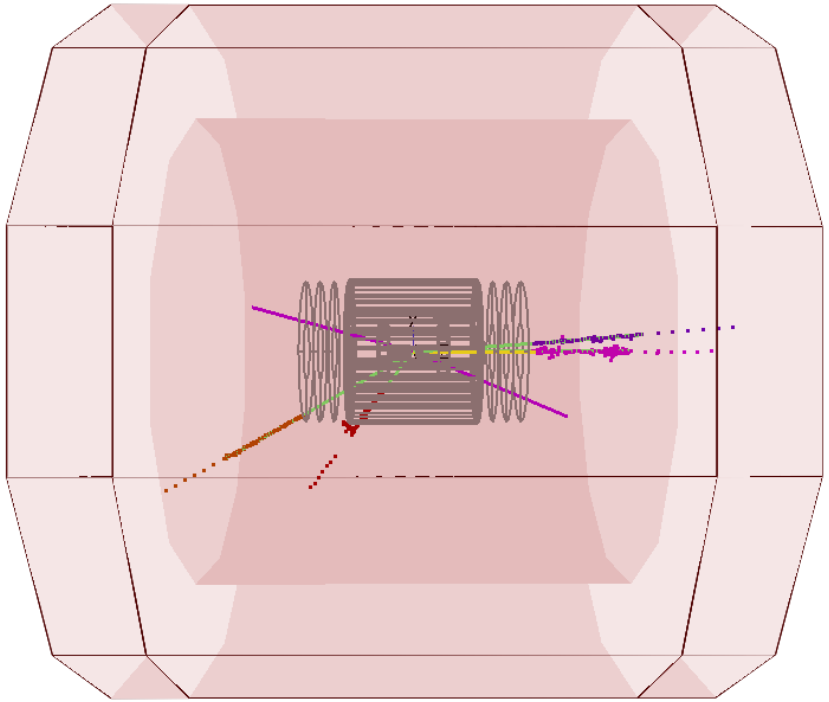


Signature: dimuon pairs

Dimuon = muon pairs from dark photon decay



Event display
(N_1 = 100 GeV a_d = 25 GeV)

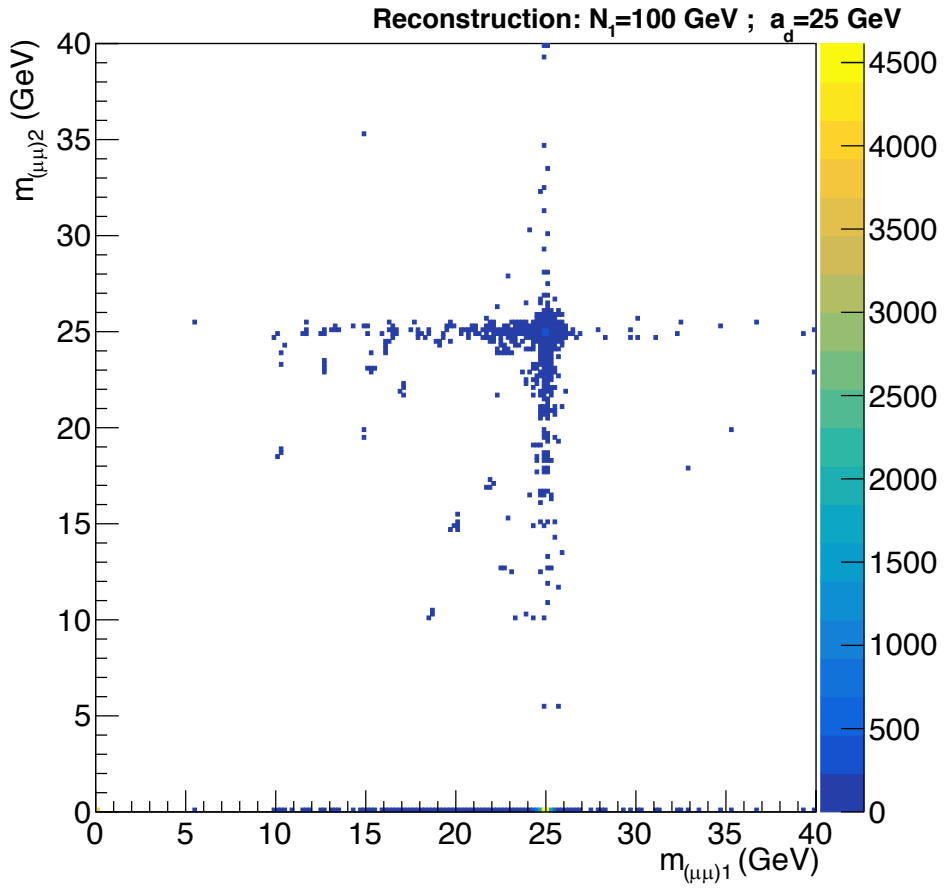


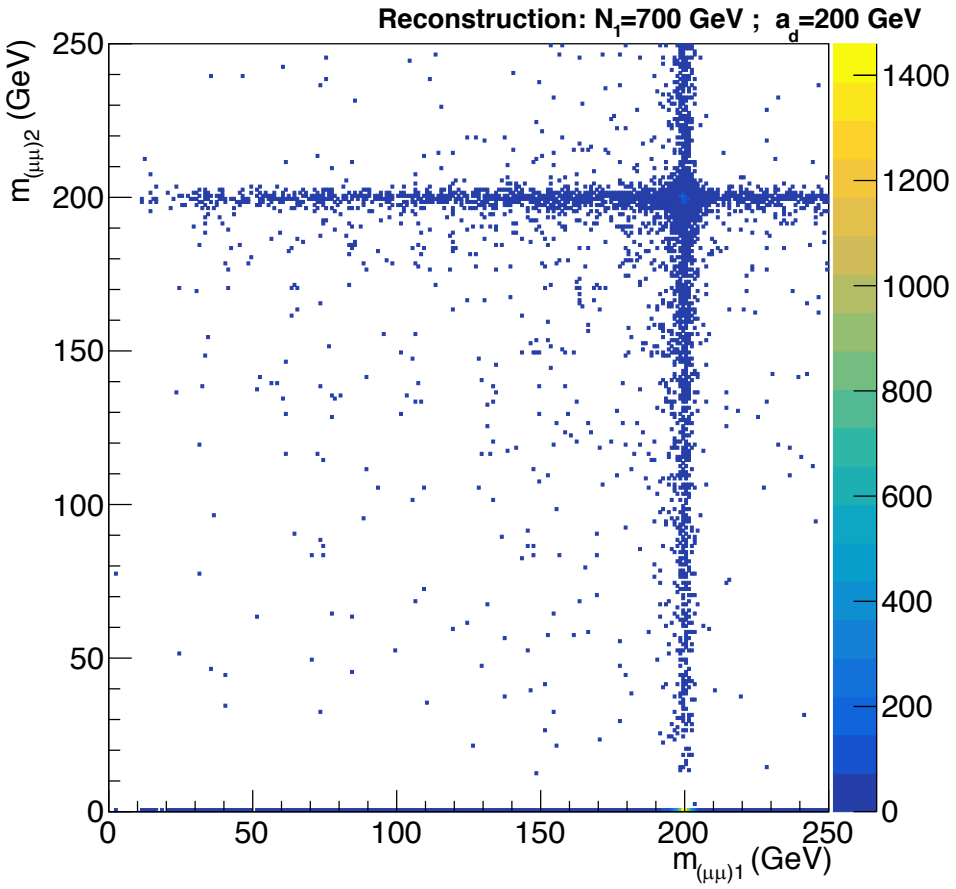
Event display (N_1 = 500 GeV a_d = 50 GeV)

Analysis strategy

1. Dark photons decay in the same way → Dimuon masses similar

$$|m_{(\mu\mu)1} - m_{(\mu\mu)2}| < 5 \text{ GeV}$$

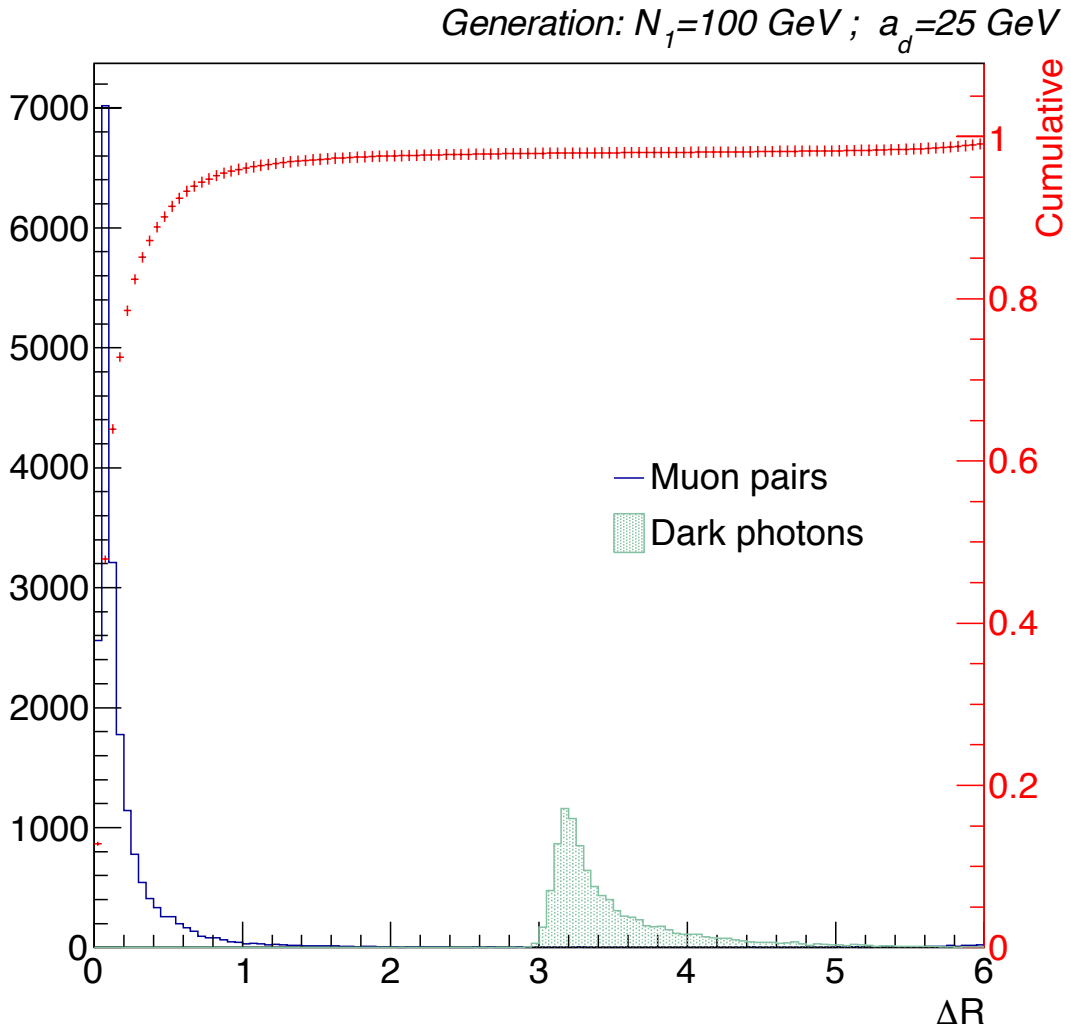


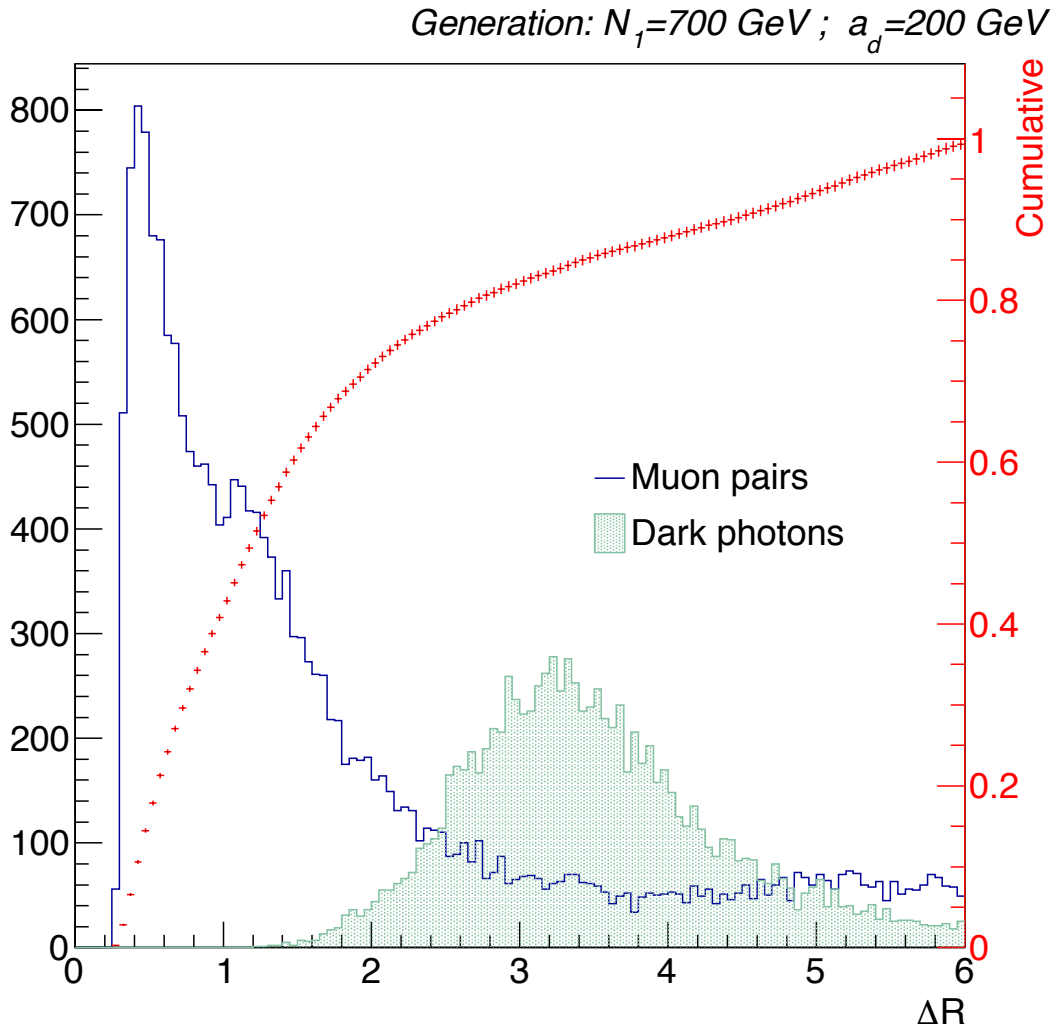


2. Dark photon kinematics quite peculiar

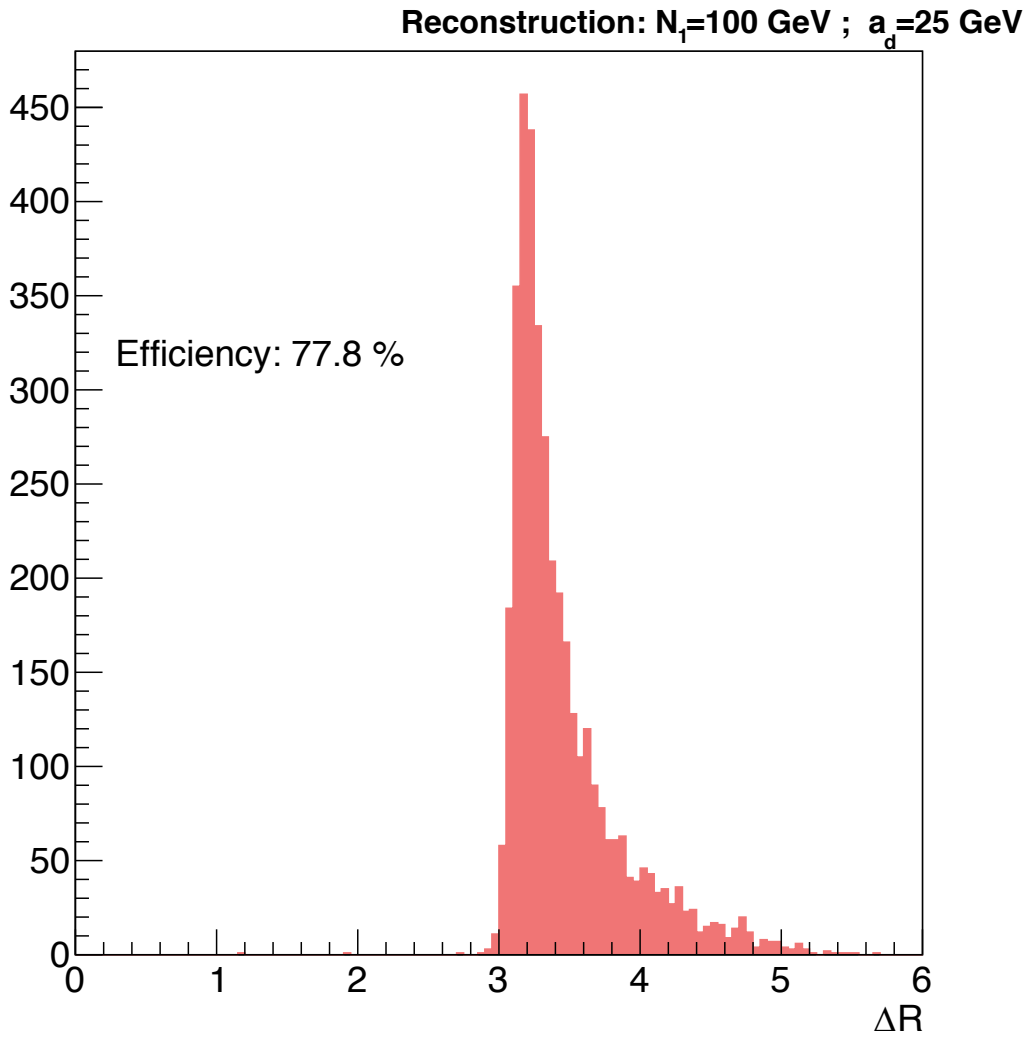
$\Delta R\ (\mu\mu)1\ (\mu\mu)2 > 1$

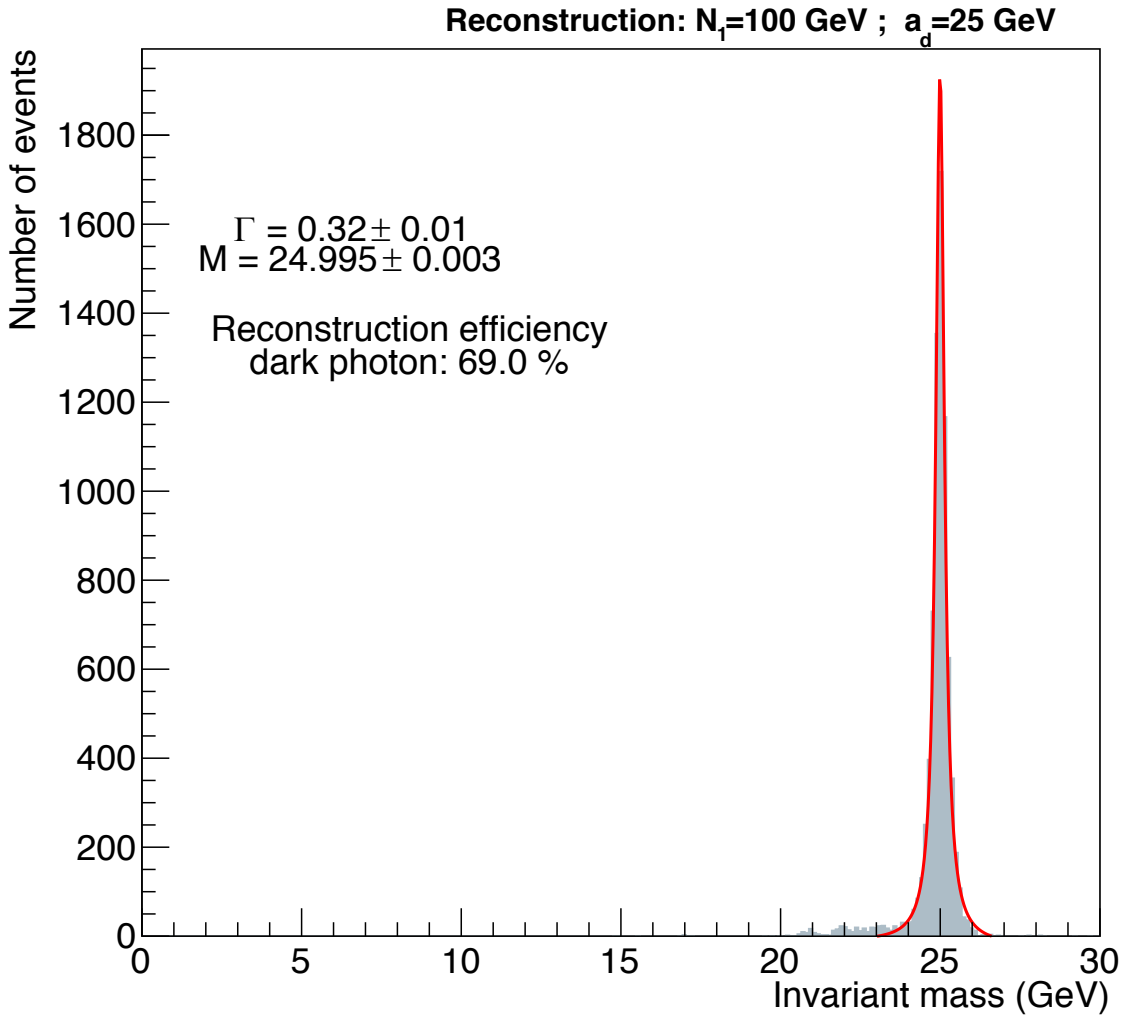
$$\Delta R = \sqrt{(\Delta\eta + \Delta\phi)^2}$$



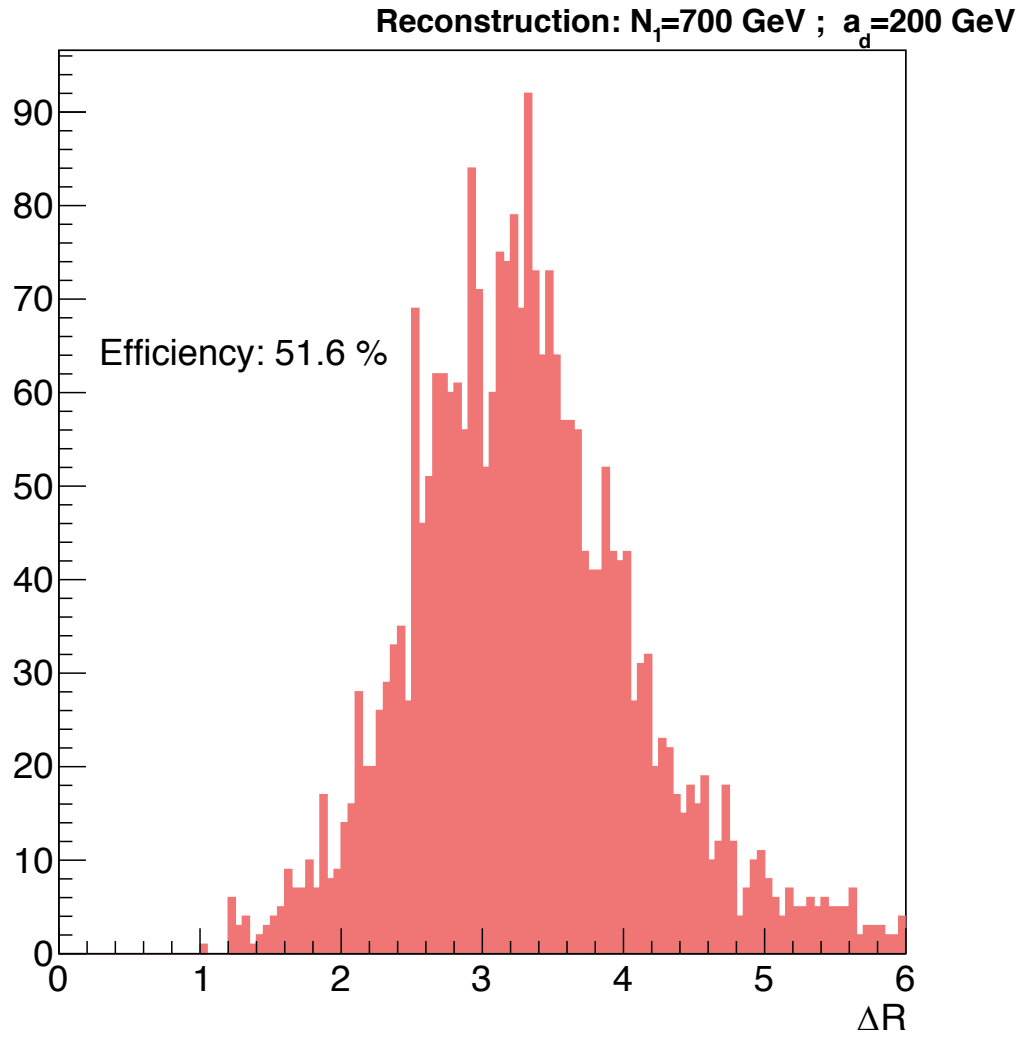


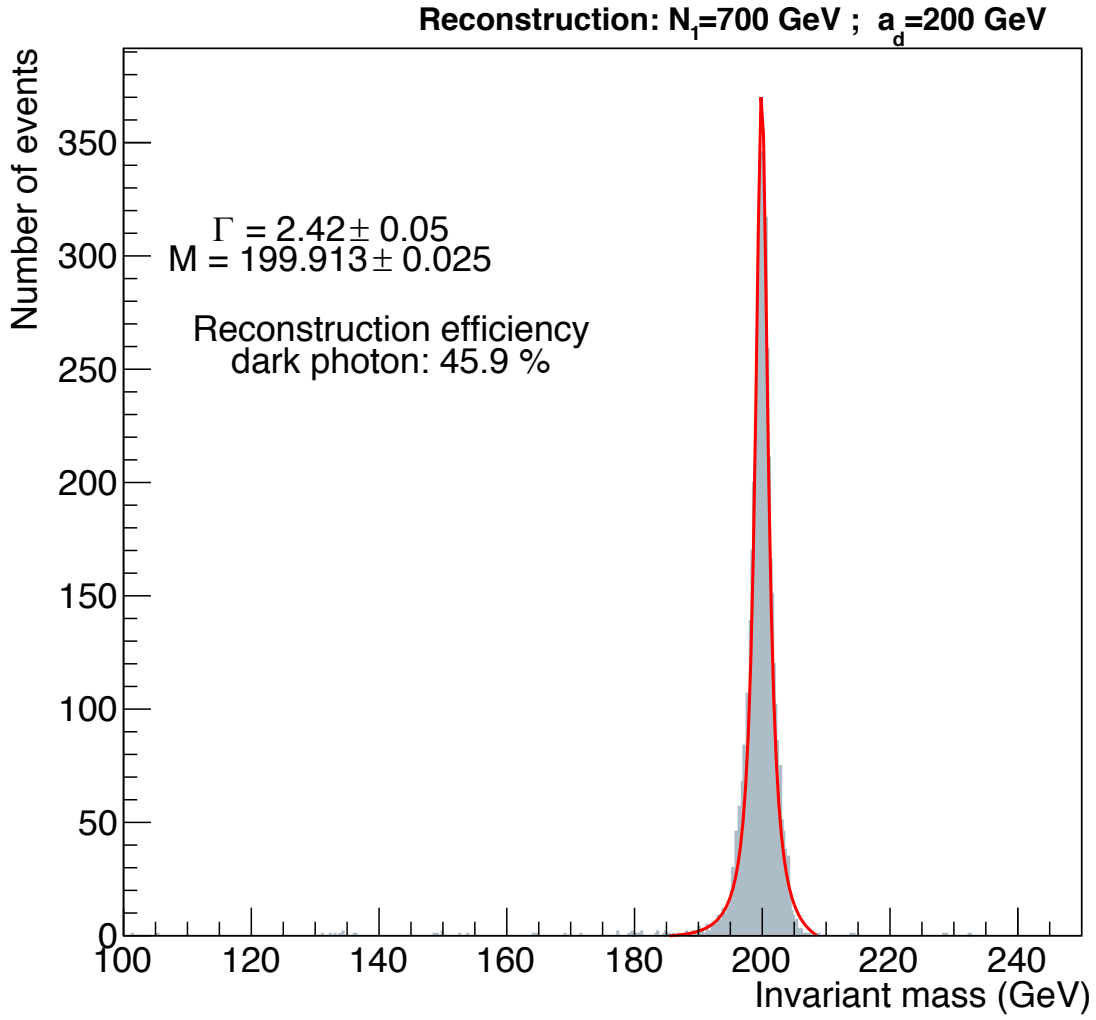
$$\left|m_{(\mu\mu)1} - m_{(\mu\mu)2}\right| < 5 \text{ GeV} \quad \& \quad \Delta R\,(\mu\mu)1\,(\mu\mu)2 > 1$$





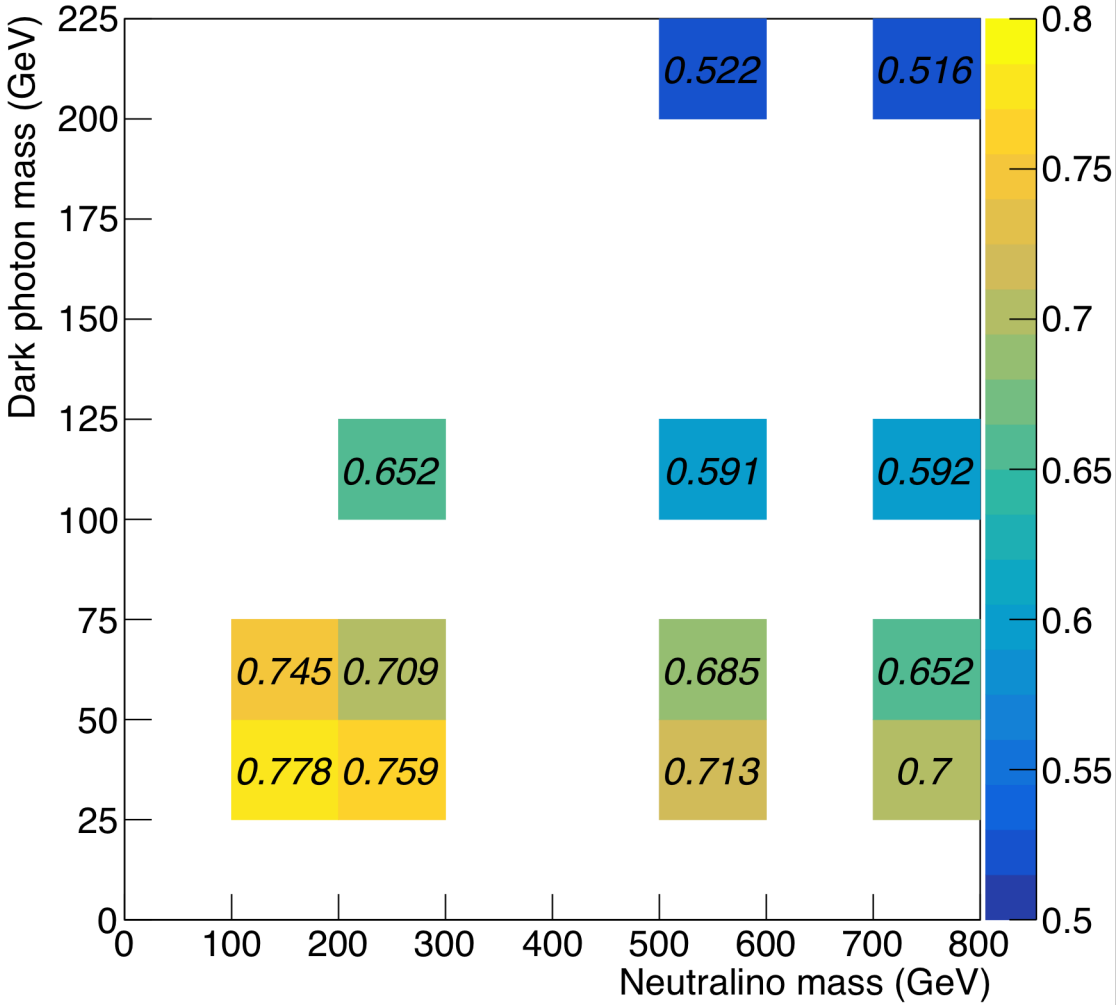
$$\left|m_{(\mu\mu)1} - m_{(\mu\mu)2}\right| < 5 \text{ GeV} \quad \& \quad \Delta R\,(\mu\mu)1\,(\mu\mu)2 > 1$$



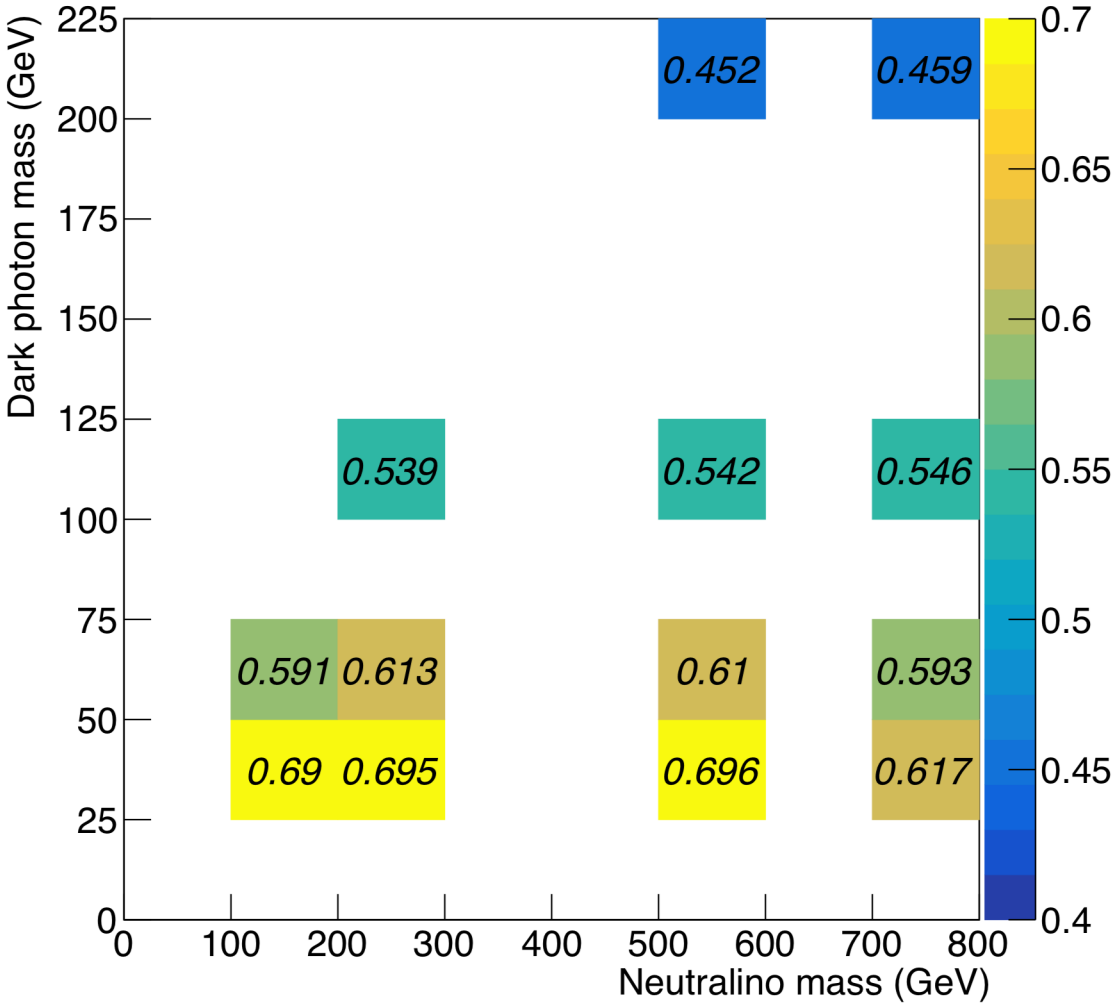


Results: reconstruction efficiency

$|m_{(\mu\mu)1} - m_{(\mu\mu)2}|$ <5 GeV & $\Delta R\ (\mu\mu)1\ (\mu\mu)2 > 1$



$|m_{(\mu\mu)1} - m_{(\mu\mu)2}|$ <5 GeV & $\Delta R\ (\mu\mu)1\ (\mu\mu)2 > 1$
& invariant mass distribution fit



Conclusions and plans

This preliminary analysis shows that:

- a Muon Collider has a great potential for probing dark SUSY channels in parameters regions not yet studied
- the muon reconstruction algorithm has a good efficiency

The work is in progress. Plans are to

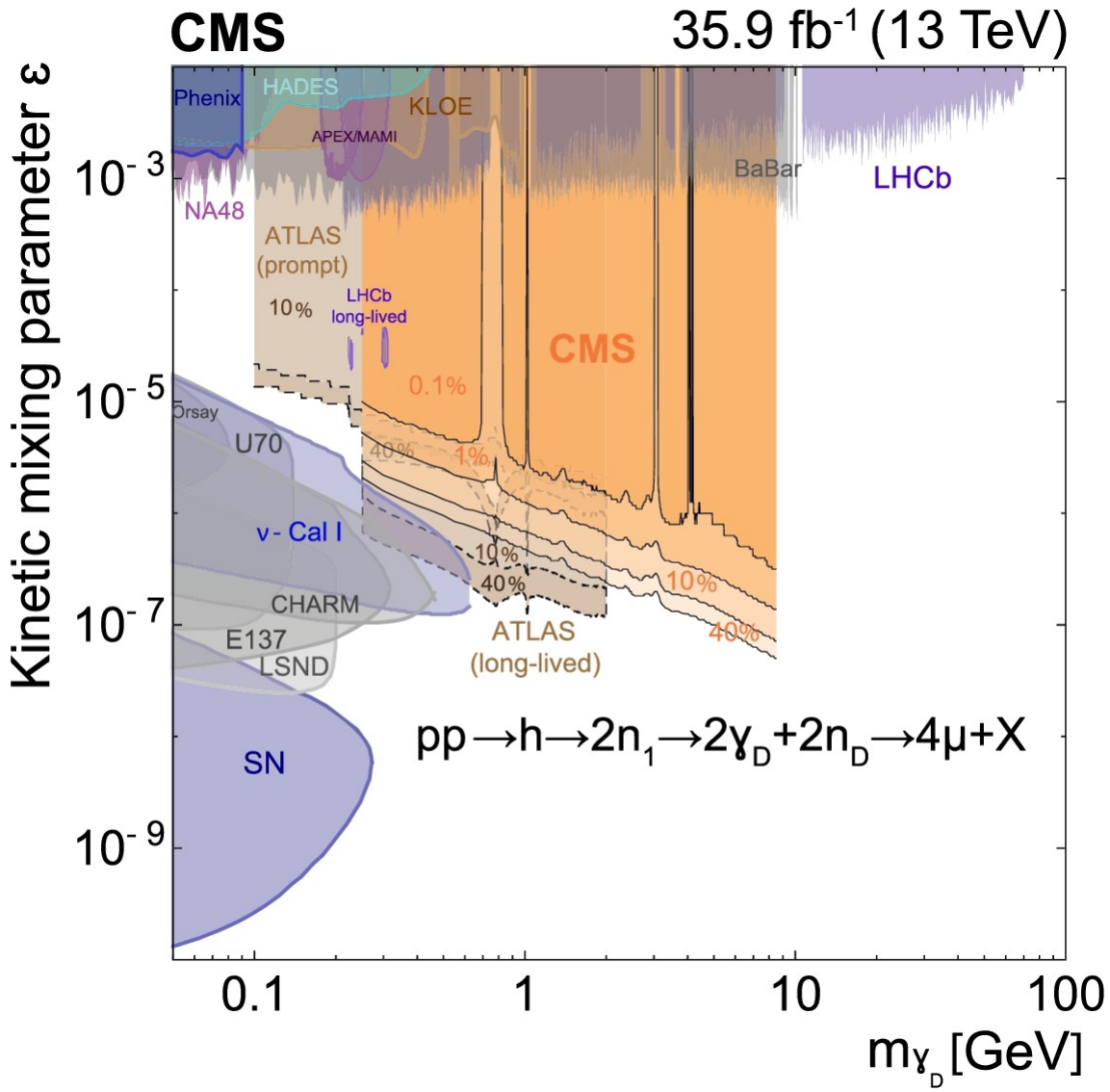
- extend the parameter regions
- try to develop a new reconstruction strategy
- …

Backup slides

CMS analysis

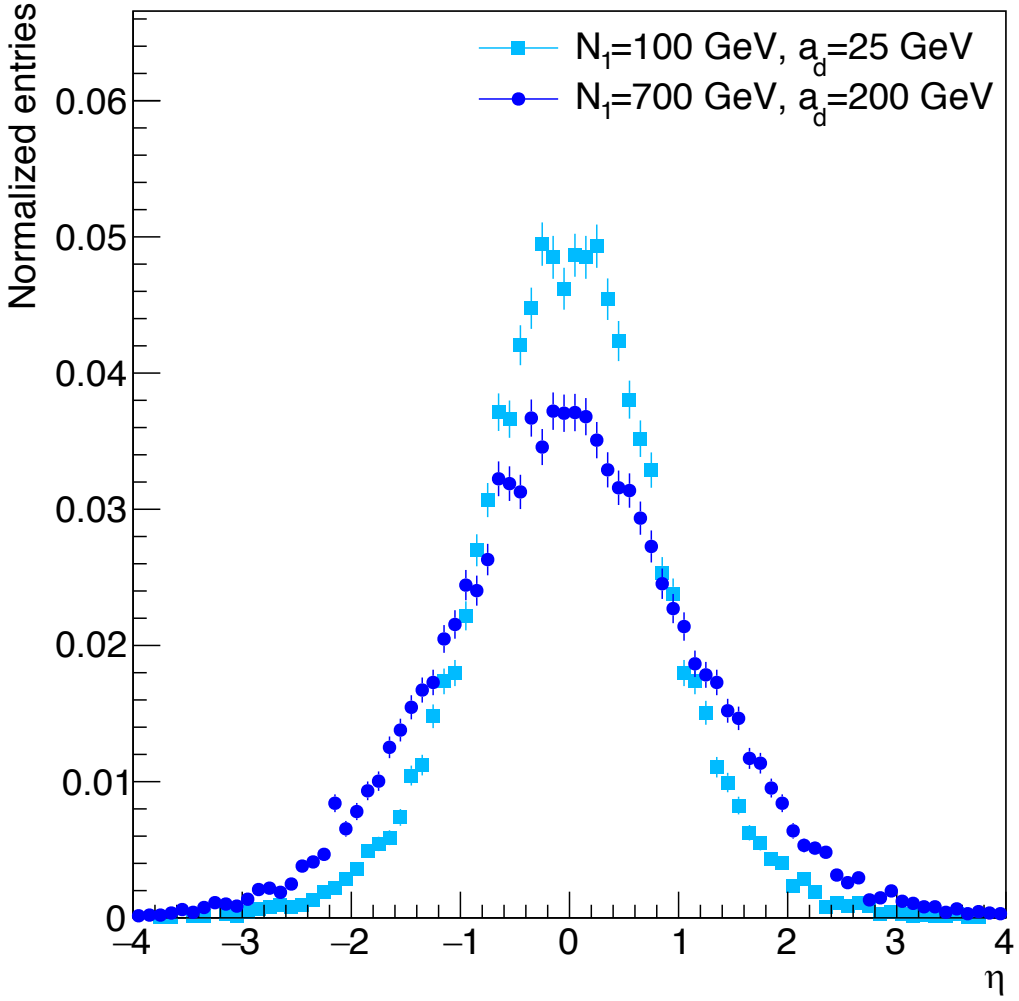
PARAMETERS

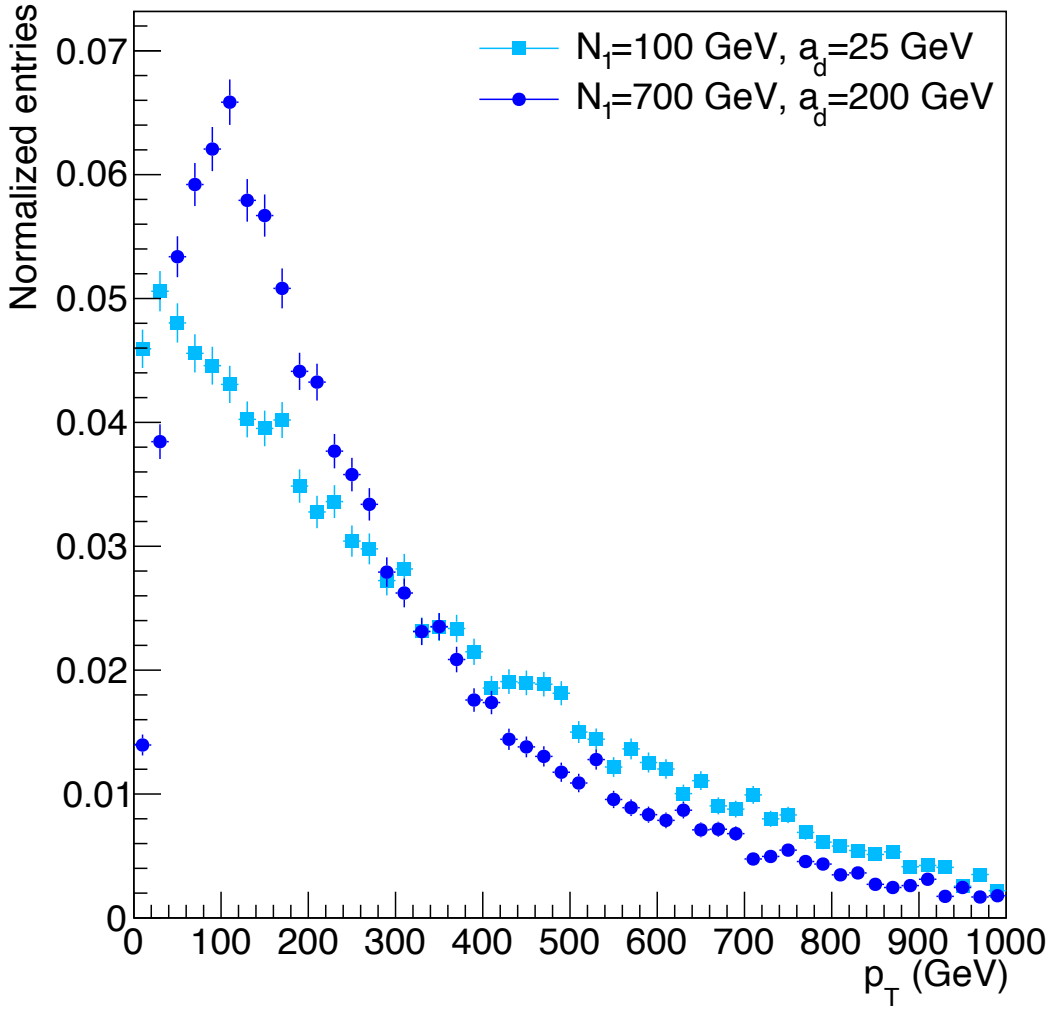
- 0.25 GeV< a_d mass < 8.5 GeV
- N_1 mass = 10 GeV
- n_d mass = 1 GeV



Reference: arXiv:1812.00380 [hep-ex]

Kinematics


Normalized entries
0.06
0.05
0.04
0.03
0.02
0.01
0
–4
–3
–2
–1
0
1
2
3
4
η
N1=100 GeV, ad=25 GeV
N1=700 GeV, ad=200 GeV


Normalized entries
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
100
200
300
400
500
600
700
800
900
1000
pT (GeV)
N1=100 GeV, ad=25 GeV
N1=700 GeV, ad=200 GeV