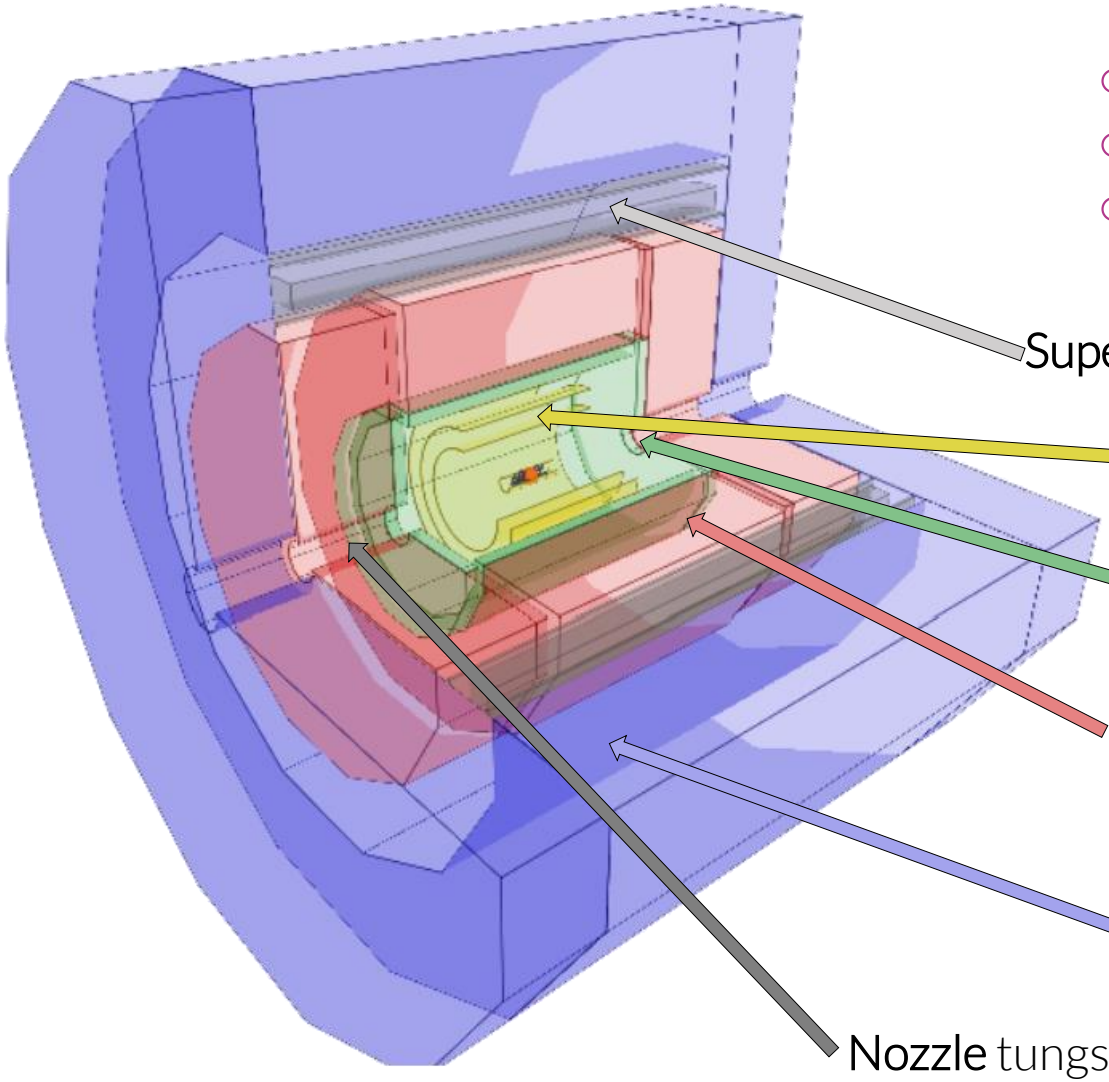
Attività di fisica
Detector a 10 TeV
Full simulation

Chiara Aimè, Nazar Bartosik, Massimo Casarsa, Lorenzo Sestini

Meeting coi referee di RD_MUCOL
4 settembre 2023

Full simulation – Detector @ 3 TeV



- Initially based on CLIC detector
- Design optimised for suppressing the 1.5 TeV BIB
- Used also for 3 TeV studies with full simulation

Superconducting solenoid (3.57 T)

Silicon tracker

Electromagnetic calorimeter
40 layers of tungsten + silicon pads

Hadronic calorimeter
60 layers of steel absorber + plastic scintillating tiles

Muon system Resistive Plate Chambers interleaved with the iron yoke

Nozzle tungsten with a borated polyethylene

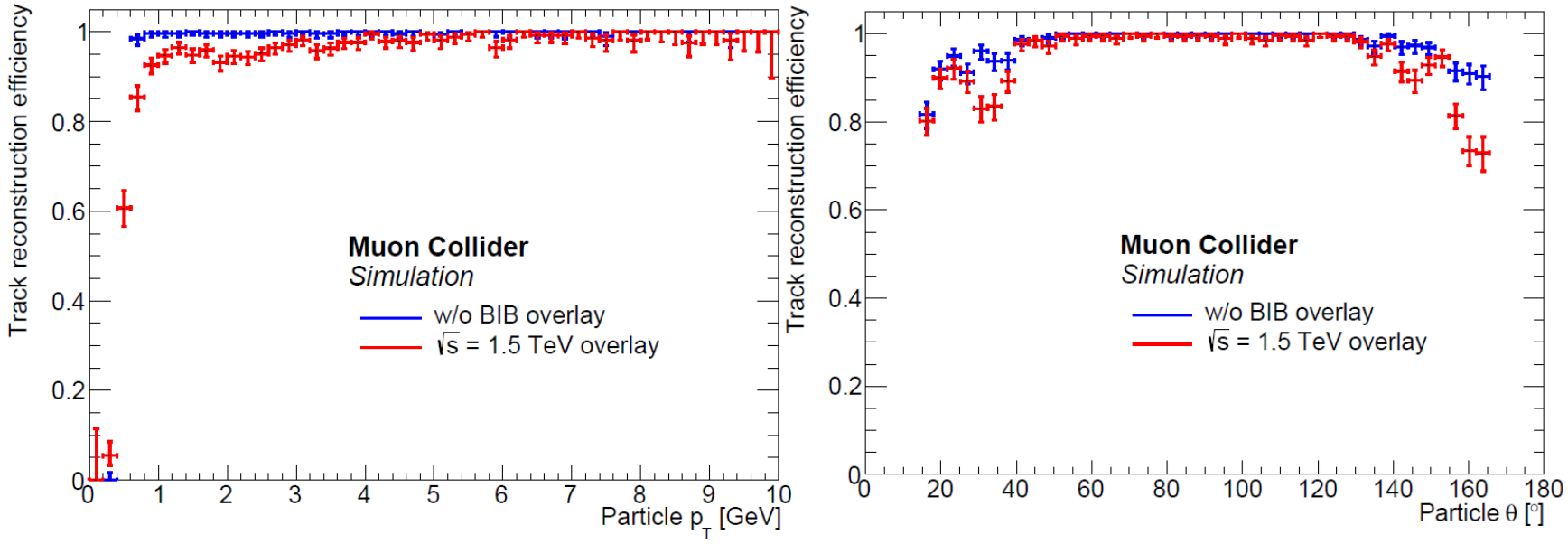
Talk Lorenzo Sestini @ EPS-HEP23 https://indico.desy.de/event/34916/contributions/147113/

Physics objects reconstruction

Challenging events reconstruction with BIB

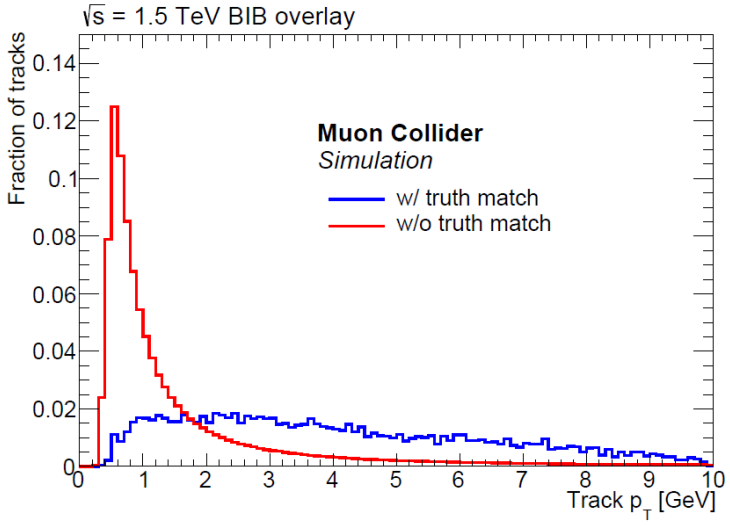
- Reduced efficiency in the forward region and at low p_T for tracking, jets, photon, electron, muons
- Fake tracks, fake jets and fake secondary vertices
- No-optimal energy resolution

Tracks reconstructed with CKF implemented in ACTS



Fake tracks ~100, 000 per event

- Low momentum
- Small number of hits



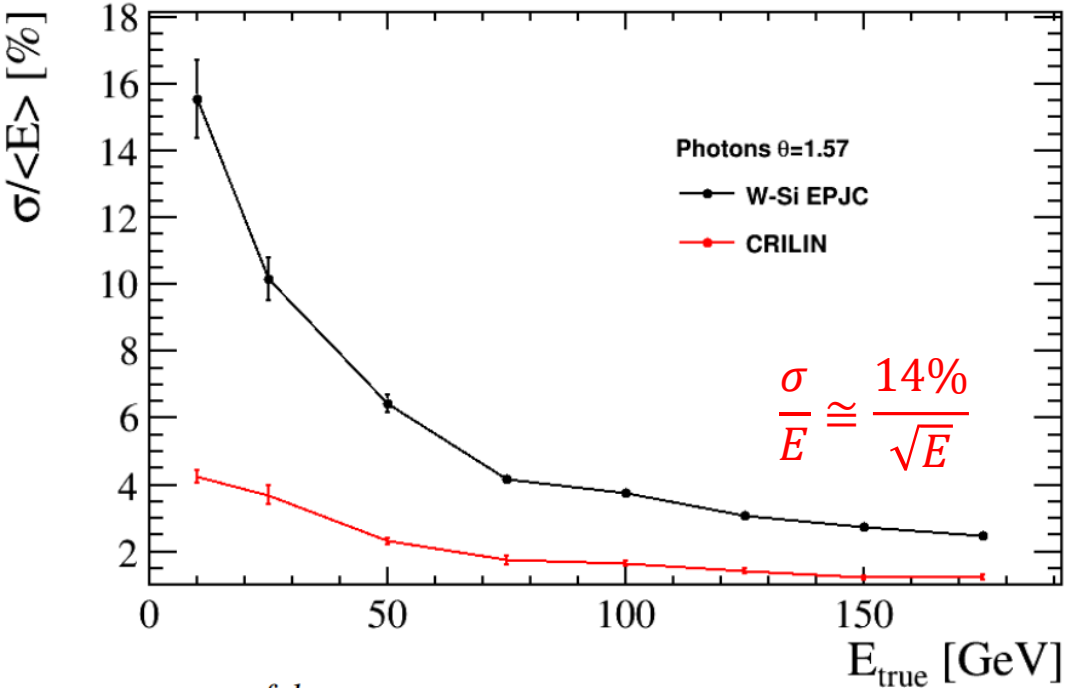
Talk Chiara Aimè @ IMCC 2023 https://indico.cern.ch/event/1250075/contributions/5349959/

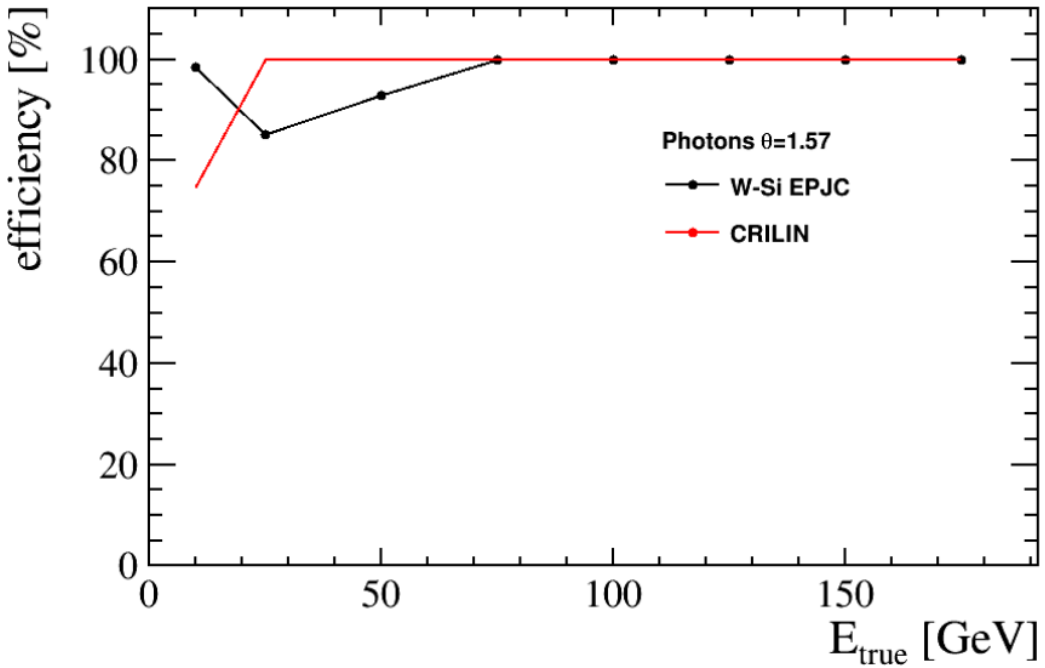
Physics objects reconstruction

Challenging events reconstruction with BIB

- Reduced efficiency in the forward region and at low p_T for tracking, jets, photon, electron, muons

Photons reconstructed with Crilin detector





fake
- Crilin ~0
- W-Si ~60

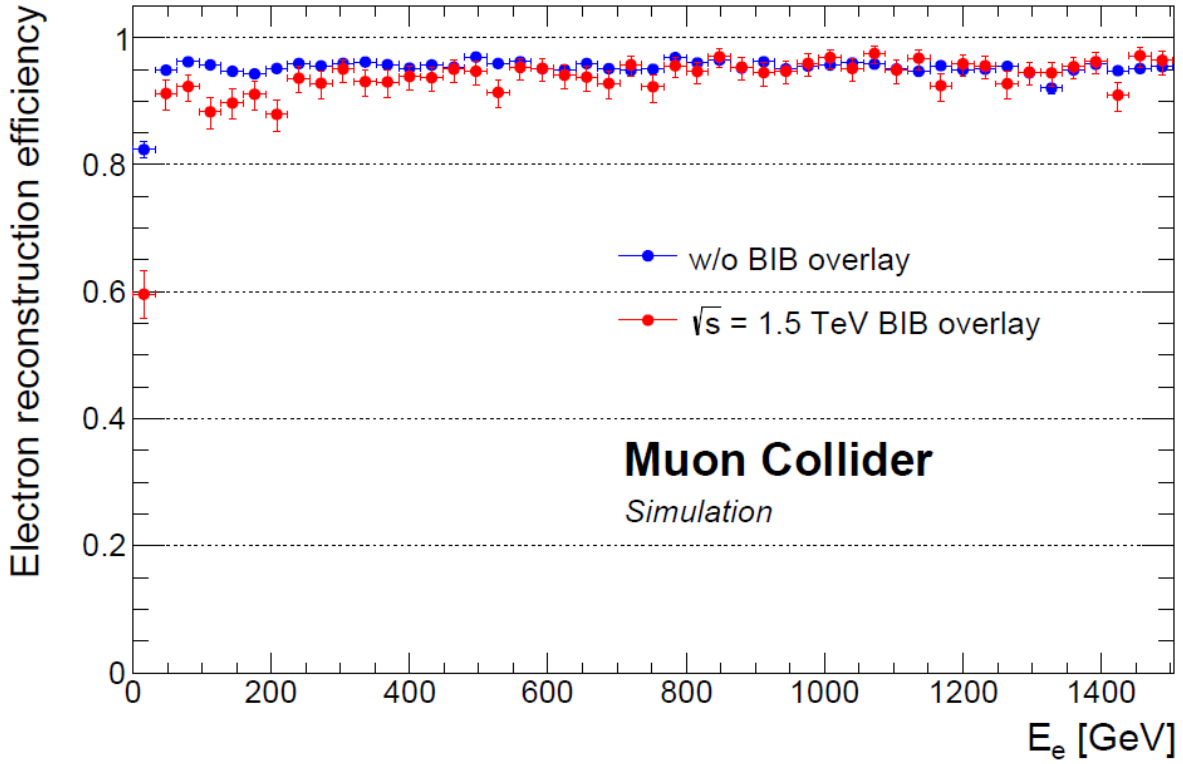
Talk Lorenzo Sestini @Detector Performance and MDI meeting https://indico.cern.ch/event/1274190/contributions/5351484/

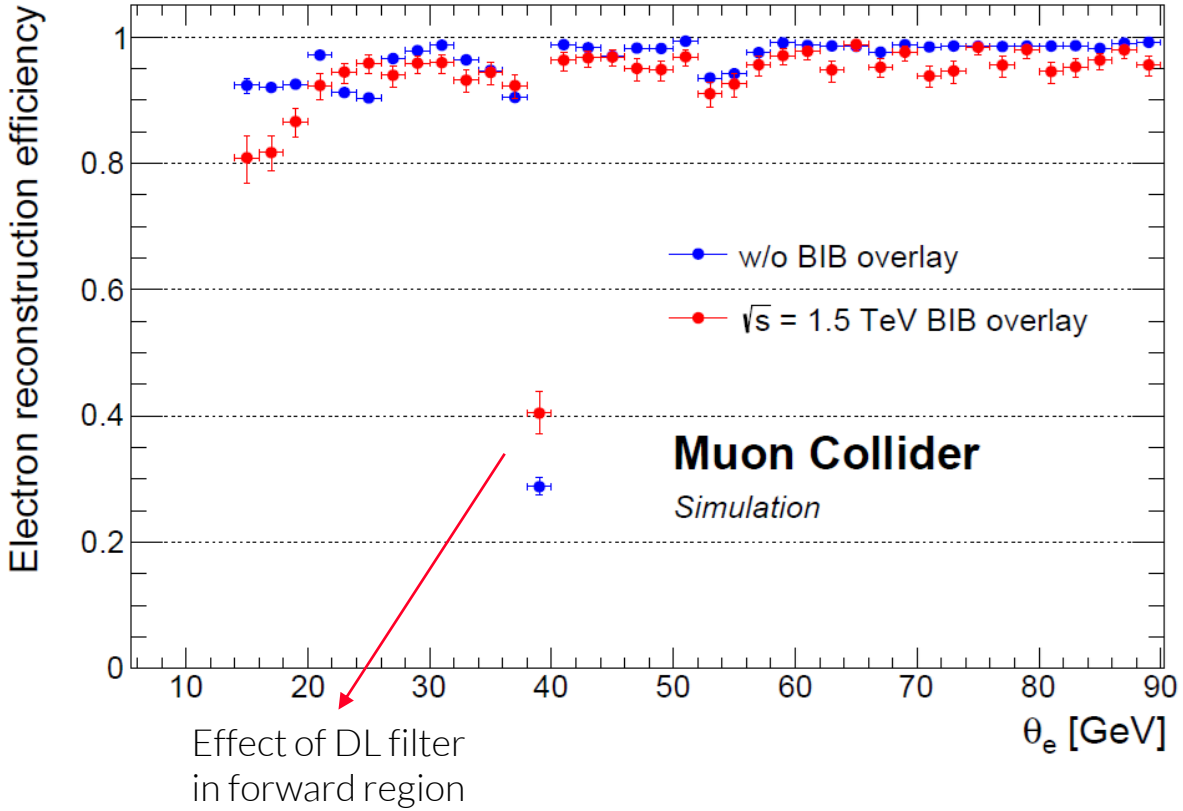
Physics objects reconstruction

Challenging events reconstruction with BIB

- Reduced efficiency in the forward region and at low p_T for tracking, jets, photon, electron, muons

Electrons reconstructed ΔR [cluster (E>5 MeV) & track (CT+DL)]<0.1





Physics studies: Higgs boson

- c.o.m. energy: 3 TeV
- 1 interaction point
- luminosity: 1 ab^{-1} over 5 years

Estimated the statistical sensitivity on $\sigma_H \times BR$

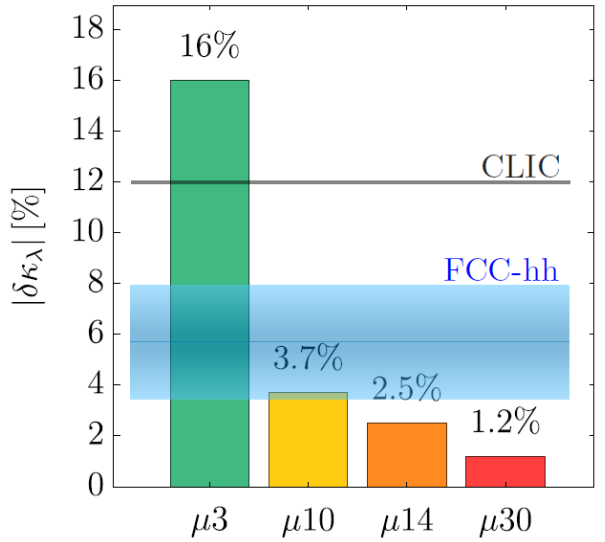
Global fit assuming $\Gamma_H = \Gamma_H^{SM}$

To estimate the uncertainties on couplings

H→ WW*	2.9%
H→ ZZ*	17%
H→ bb	0.75%
H→ μμ	38%
H→ γγ	8.9%
HH→ 4b	30%
λ_3	20%

One channel
Not optimized tagging

Coupling	HL-LHC	HL-LHC + 125 GeV MuC 5 / 20 fb^{-1}	HL-LHC + 3 TeV MuC 1/2 ab^{-1}	HL-LHC + 10 TeV MuC 10 ab^{-1}	HL-LHC + 10 TeV MuC + FCC-ee
κ_W [%]	1.7	1.3 / 0.9	0.4 / 0.3	0.1	0.1
κ_Z [%]	1.5	1.3 / 1.0	0.9 / 0.7	0.4	0.1
κ_g [%]	2.3	1.7 / 1.4	1.2 / 1.0	0.7	0.6
κ_γ [%]	1.9	1.6 / 1.5	1.3 / 1.2	0.8	0.8
$\kappa_{Z\gamma}$ [%]	10	10 / 10	9.3 / 8.6	7.2	7.1
κ_c [%]	-	12 / 5.9	6.2 / 4.4	2.3	1.1
κ_b [%]	3.6	1.6 / 1.0	0.8 / 0.7	0.4	0.4
κ_μ [%]	4.6	0.6 / 0.3	4.2 / 4.0	3.4	3.2
κ_τ [%]	1.9	1.4 / 1.2	1.2 / 1.0	0.6	0.4
$\kappa_t^\dagger$ [%]	3.3	3.2 / 3.1	3.1 / 3.1	3.1	3.1
$\Gamma_H^\ddagger$ [%]	5.3	2.7 / 1.7	1.3 / 1.0	0.5	0.4



Paper «Towards a muon collider» accepted by EPJC

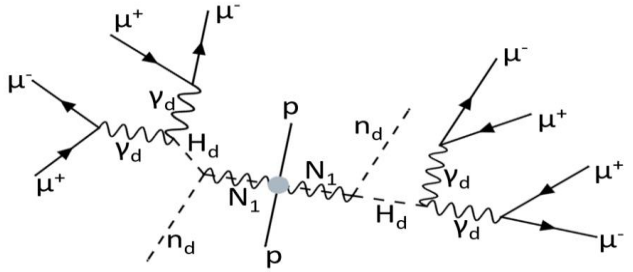
Talk Massimo Casarsa @ EPS-HEP23 https://indico.desy.de/event/34916/contributions/147292/
Talk Laura Buonincontri @IMCC 2023 https://indico.cern.ch/event/1250075/contributions/5349960/

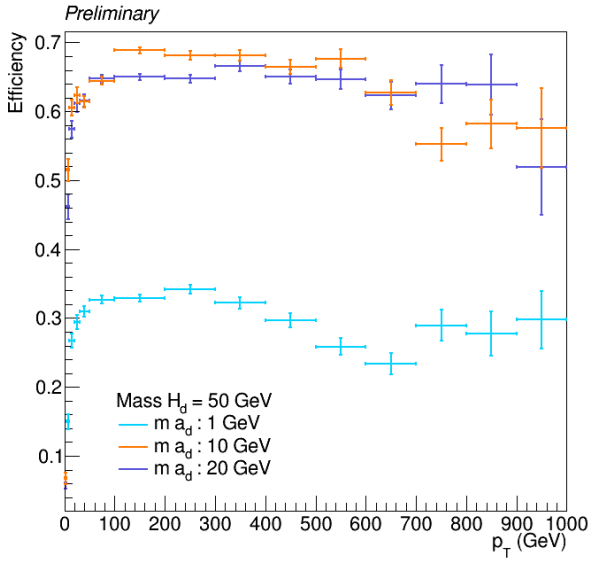
Physics studies: BSM

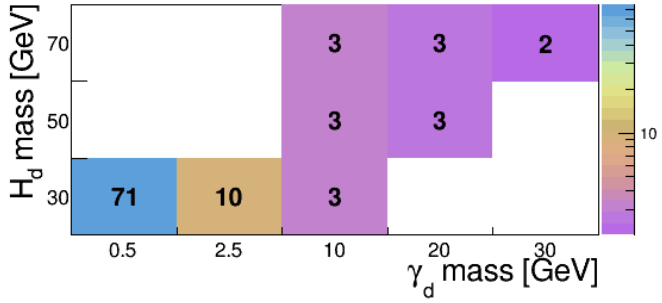
No BIB

Hidden sector: dark -SUSY

A MSSM lightest neutralino decays in two dark photons through a dark Higgs boson (8 final state muons)

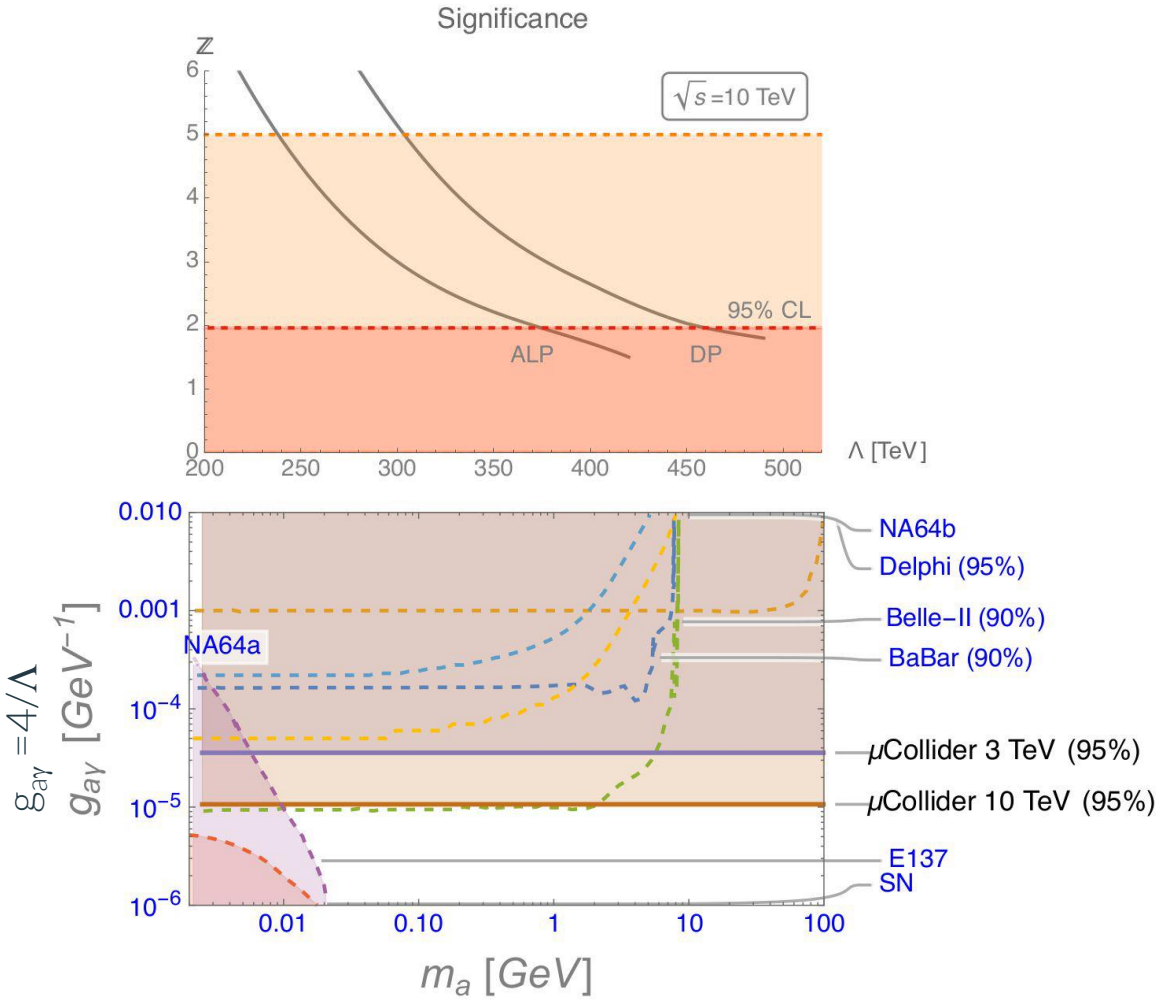






Talk Chiara Aimè @ EPS-HEP23
https://indico.desy.de/event/34916/contributions/147686/

Monochromatic single photon



Massimo Casarsa et al. DOI: 10.1103/PhysRevD.105.075008

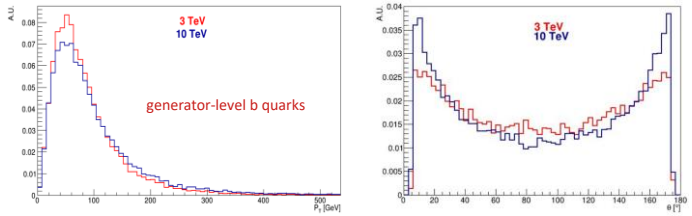
Detector for 10 TeV collisions

design driven by

physics program

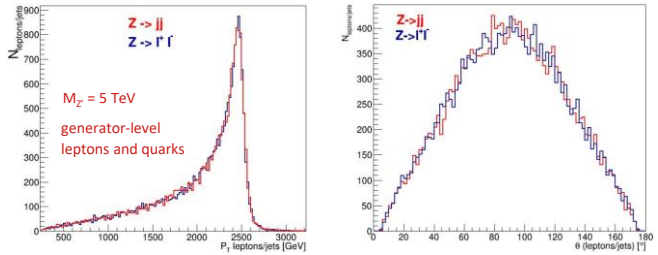
- High-precision measurements of SM processes with relatively light SM particles and forward-boosted physical objects:

$\mu\mu \rightarrow H\nu\nu \rightarrow bb\nu\nu$



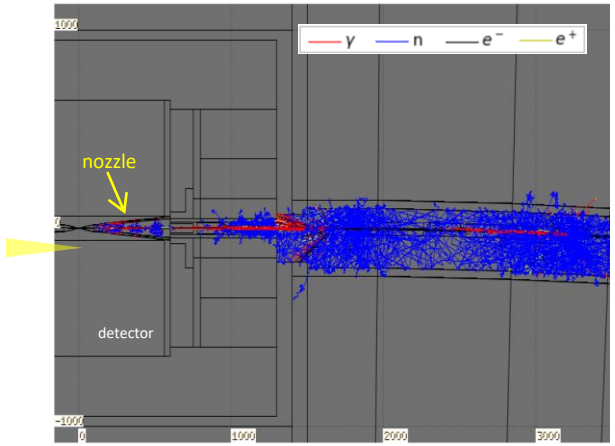
- search for BSM physics involving new, possibly heavy, states and very energetic and mostly central physical objects:

$\mu\mu \rightarrow Z'X \rightarrow qq/\ell\ell X$



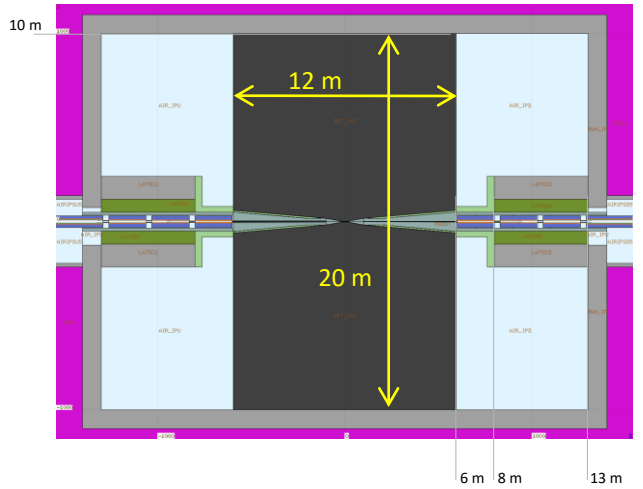
background mitigation

- Using appropriate shielding (nozzles) within the detector volume to reduce the BIB will likely be inevitable
- The nozzle material and shape will ultimately determine the composition and level of the BIB in the detector.



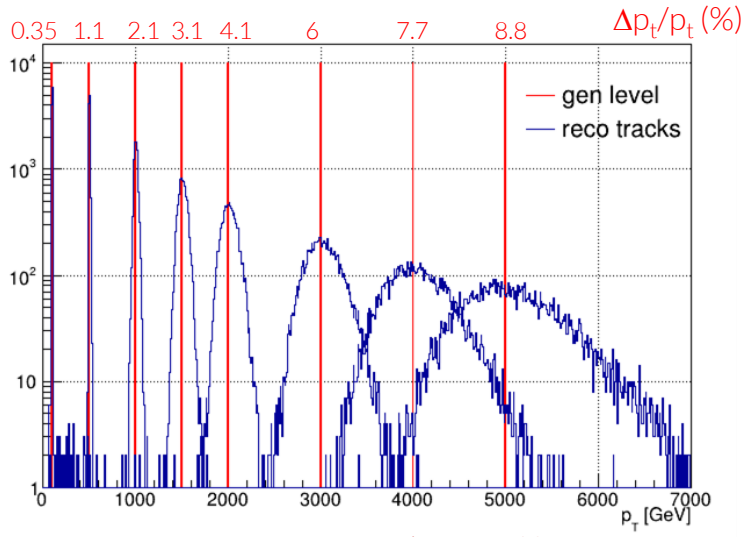
boundary conditions

- The final focusing magnets are placed at ±6 m (L*) from the IP;
- collision hall size.

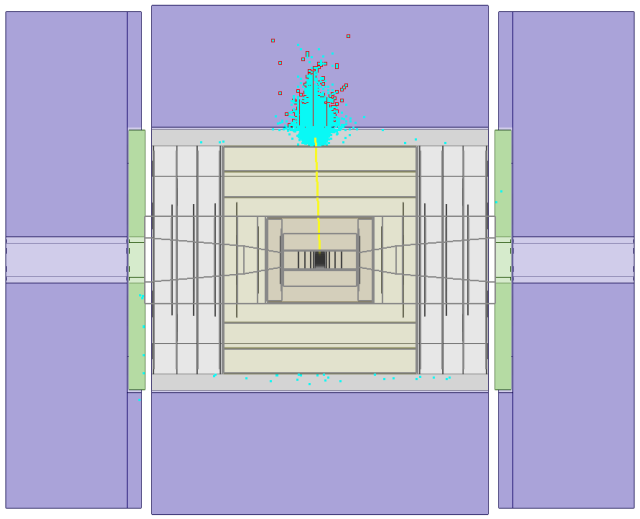


Detector for 10 TeV collisions

- Main challenges to be addressed:
  - forward/backward acceptance for SM processes;
  - momentum and charge measurement for very high-energy muons;
  - high-energy shower containment in electromagnetic and hadronic calorimeters.



muon gun samples at θ = 90°


5 TeV photon

- As a first step, we intend to determine the optimal configuration of the magnet system, which will shape the layout of the detector (and may affect the IR setup), and then build the detector around it.
- Two different approaches at LHC:
  - large central solenoid (CMS);
  - smaller central solenoid + external toroid (ATLAS).

A meeting with detector-magnet experts will be held at CERN on October 5th to review all possible options

Training on detector design and physics performance tools

July 5th-6th, 2023 @CERN
46 participants

July 5th	Software Status
1:30 PM	Introduction to the MuCol project and tutorial goals - Donatella Lucchesi (Universita e INFN, Padova (IT))
1:45 PM	Description of the actual detector - Davide Zuliani (Universita e INFN, Padova (IT))
2:05 PM	Introduction to the software - Karol Krizka (University of Birmingham (GB))
2:30 PM	Hands on: Event generation examples - Donatella Lucchesi (Universita e INFN, Padova (IT)) Nazar Bartosik (Universita e INFN Torino (IT))
3:00 PM	--- Coffee Break ---
3:30 PM	Hands on: detector simulation - Lorenzo Sestini (Universita e INFN, Padova (IT))
4:15 PM	Hands on: event reconstruction - Laura Buonincontri (Universita e INFN, Padova (IT))
5:00 PM	Hands on: event analysis - Chiara Aime' (Pavia University and INFN (IT))

July 6th	Hands on
9:00 AM	Beam Induced background description - Nazar Bartosik (Universita e INFN Torino (IT))
9:20 AM	Hands on: Beam Induced Background overlay to physics event - Nazar Bartosik (Universita e INFN Torino (IT))
9:55 AM	Hands on: Modify the detector geometry - Lorenzo Sestini (Universita e INFN, Padova (IT))
10:30 AM	--- Coffee Break ---
11:00 AM	Open hands on: from beginners to advanced

We succeed in

- using the new software release (see Lorenzo's presentation)
- update the documentation https://mcdwiki.docs.cern.ch/tutorials/cern2023/

BACKUP

Higgs studies

H→ WW* semileptonic
- 2 jets — k_t R=0.5 ; p_t>20 GeV ; $|\eta|$ <2.5
- 1 muon — p_t>10 GeV ; 10°<θ<170°
- 2 BDT

μC 2.9% - CLIC 0.7%

H→ γγ (no BIB)
- 2 photons — p_t>10 GeV ; E>15GeV ; $p_{t,max}$>40 GeV
- inv. mass>40 GeV
- 1 BDT

μC 8.9% - CLIC 10%

H→ ZZ* semileptonic
- 2 jets — k_t R=0.5 ; p_t>15 GeV ; 30°<θ<150°
- 2 muons — opp.charge ; p_t>10 GeV ; 10°<θ<170° ; iso>0.5
- 1 BDT

μC 17% - CLIC 3.9%

H→ bb FAST vs FULL
- 2 jets — k_t R=0.5 ; p_t>40 GeV ; $|\eta|$ <2.5
- b-tagging
- toy MC

μC 0.75% - CLIC 0.3%

H→ μμ (no BIB)
- 2 muons — opp.charge ; p_t>5 GeV ; 10°<θ<170°
- $p_{t,1} + p_{t,2}$ >50 GeV
- muon pair — p_t>30 GeV ; 105 GeV<inv. mass<145 GeV
- 2 BDT

μC 38% - CLIC 25%

HH→ 4b hadronic
- 4 jets — k_t R=0.5 ; p_t>20 GeV
- jet pairs — minimize $\sqrt{(m_{ij} - m_H)^2 + (m_{kl} - m_H)^2}$
- b-tagging
- ANN + toy MC

μC 33% - CLIC 29%

Higgs production

Vector Boson Fusion≫Higgsstrahlung
- 500k H @3TeV
- 10000k H @10TeV
- 30k HH @10 TeV

λ_4 ≈10% @ 10 TeV (lum > 10 ab^{-1})