Tuning of GFlash for COMPASS calorimeter simulations

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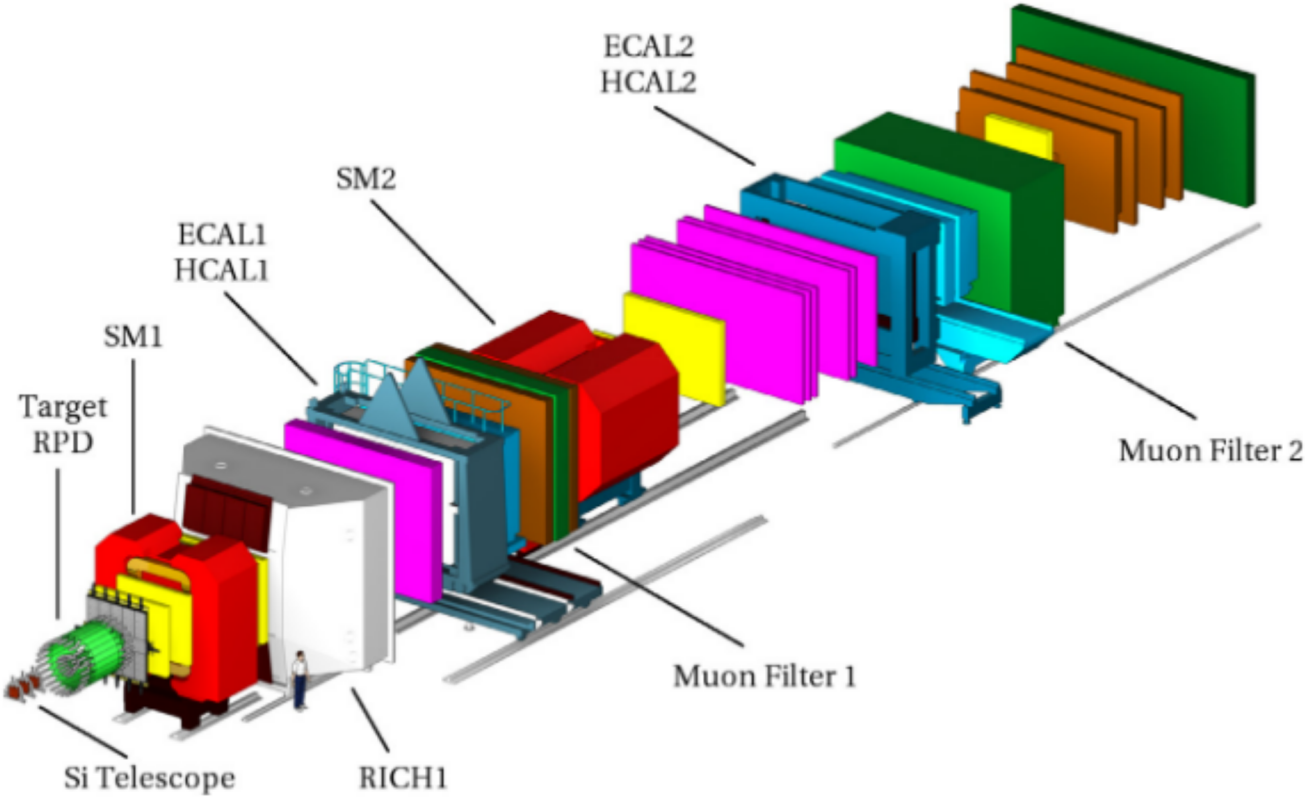
at the DPG in Dresden, HK 2.4
supported by BMBF

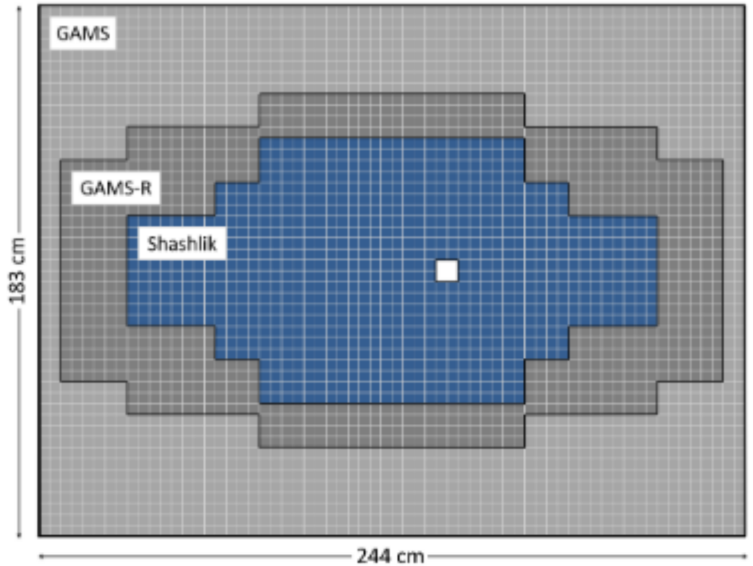
20th March 2023

COMPASS Experiment at CERN



[COMPASS, NIM A779, 69-115 (2015)]

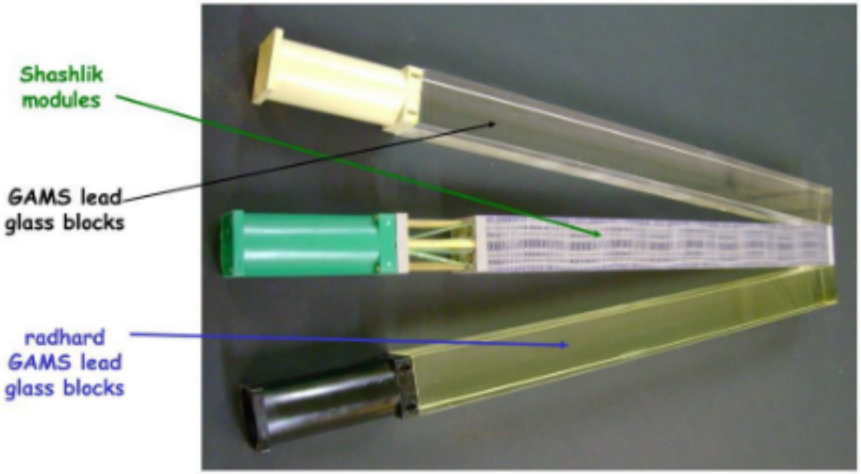
ECAL2 at COMPASS



[Ketzer et al., Prog. Part. Nucl. Phys. 113, 103755 (2020)]

- Homogeneous (lead glass) modules
  - GAMS and GAMS-R
- Inhomogeneous Shashlik modules
  - 155 layers of scintillator / lead slices
  - Pierced with WLS Fibers for readout
  - Pierced with steal rods for stability

Calorimeter Modules at COMPASS



	GAMS	GAMS-R	Shashlik
X_0	27.4 mm	27.4 mm	17.5 mm
R_M	47 mm	47 mm	36 mm
rad. hardness	400 rad	3 krad	0.5 Mrad
rad. dose	400 rad	2 krad	40 krad

rad. dose is for 350 days, 190 GeV hadron beam, $5 \cdot 10^7$/spill

[V. Polyakov, IHEP Protvino, 2010]

Monte Carlo Simulations at COMPASS

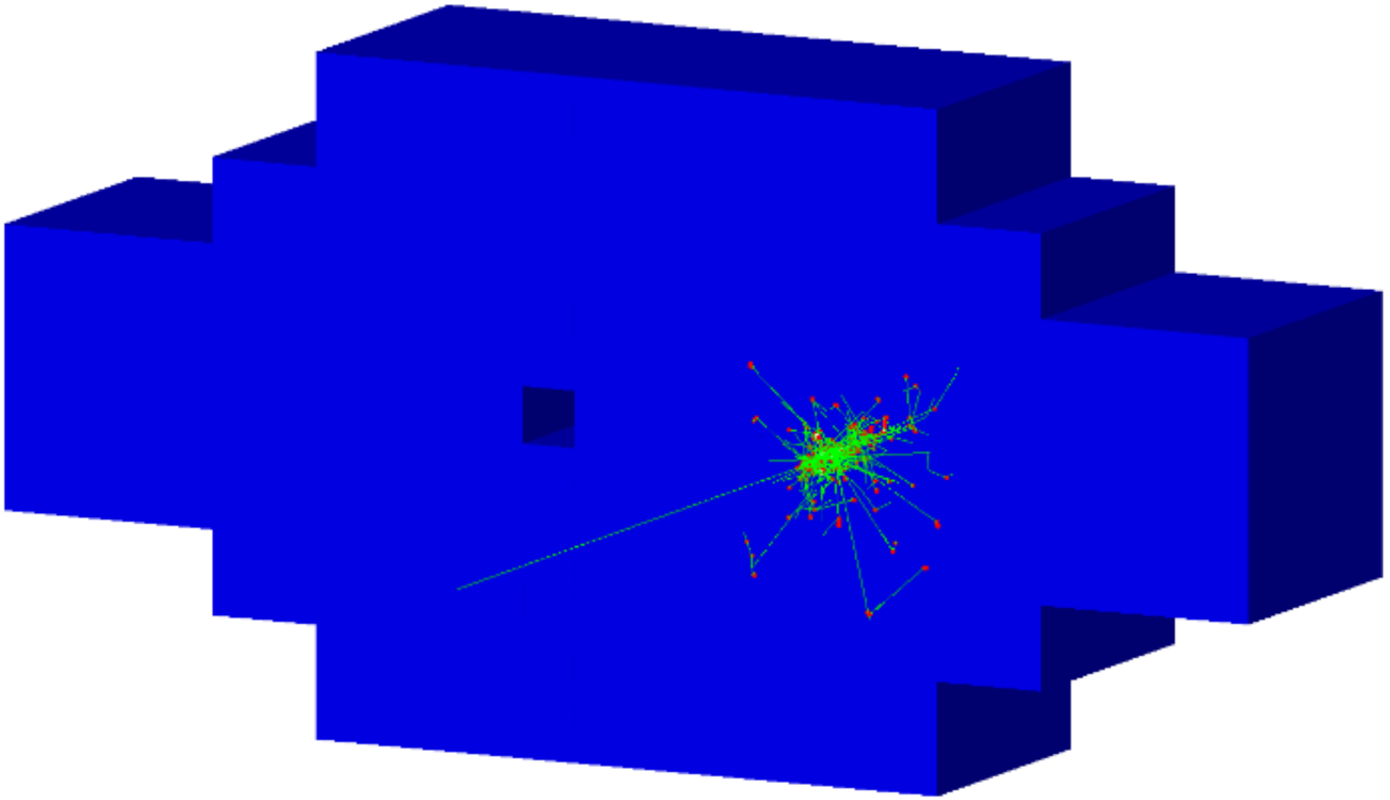
General

- Based on GEANT4
- Every readout plane of every detector is implemented
- Holding structures are included, no optical photon tracking

Calorimeters

- Simulations in Shashlik modules require much time
- We use GFlash [Weng, CHEP 06, 2006] to shorten the simulation
  - Simulation of shower in effective homogeneous material
  - Simulation according to spatial energy distribution function, no secondary particles
  - Energy deposited with $\mathcal{O}(1000)$ space points
  - Realistic material taken into account during deposition
- Energy collection only in active material

Shower without GFlash



Physics behind GFlash

Spatial energy distribution

$$\mathrm{d}E(\vec{r}) = E f(t)\mathrm{d}t f(r)\mathrm{d}r f(\phi)\mathrm{d}\phi$$

Longitudinal component $f(t)$, shower depth t in units of radiation lengths

- Described by gamma distribution
- Depends on energy of particle and critical energy

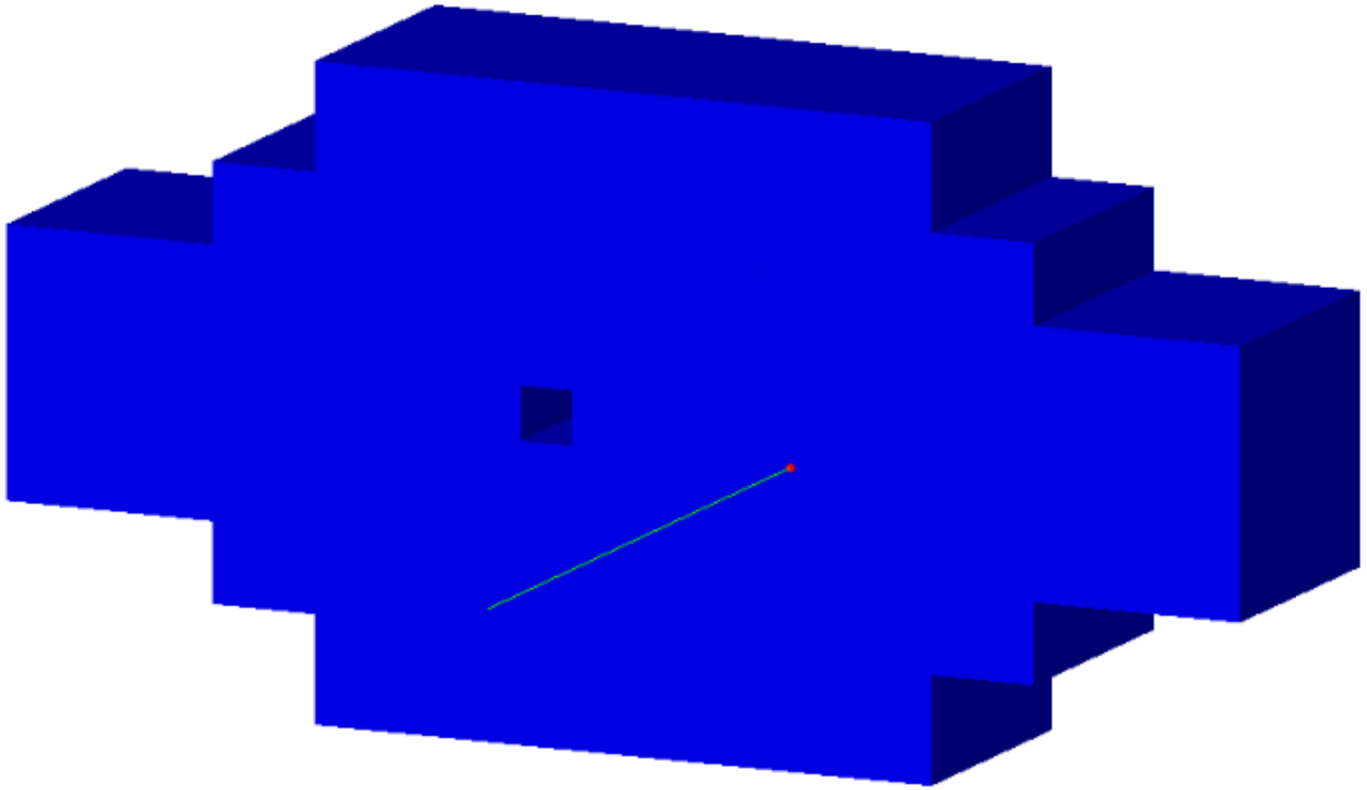
Radial component $f(r)$, shower radius r in units of Molière radii

- Described by core and tail
- Depends on longitudinal position

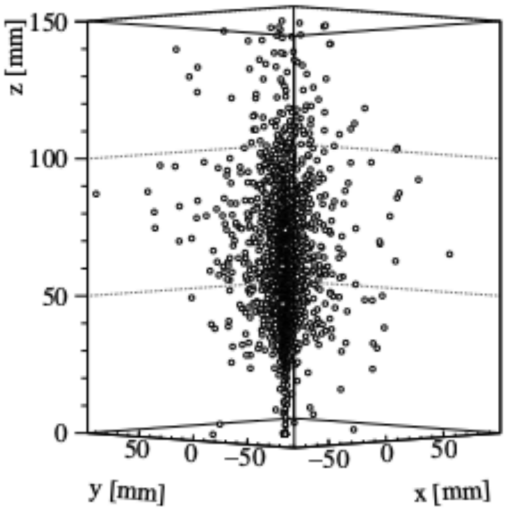
Azimuthal component $f(\phi)$

- Assumed to be uniformly distributed

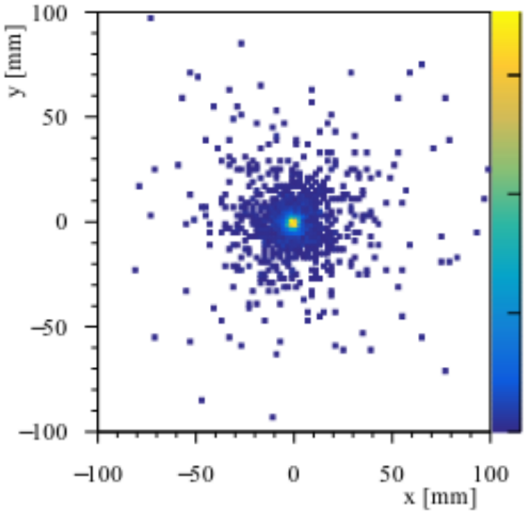
Shower with GFlash



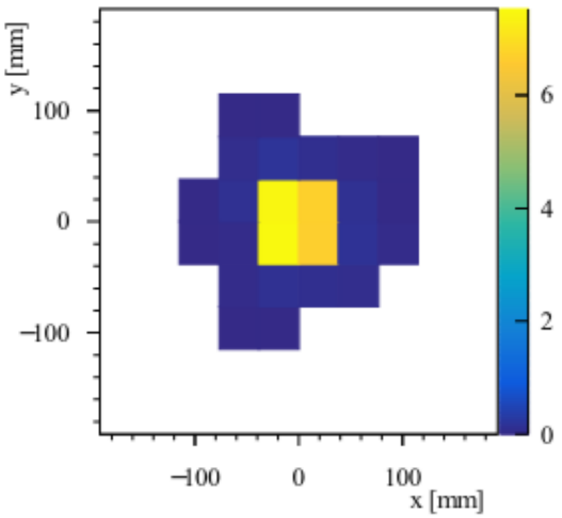
Full GFlash Shower, 30 GeV Electron



GFlash space points



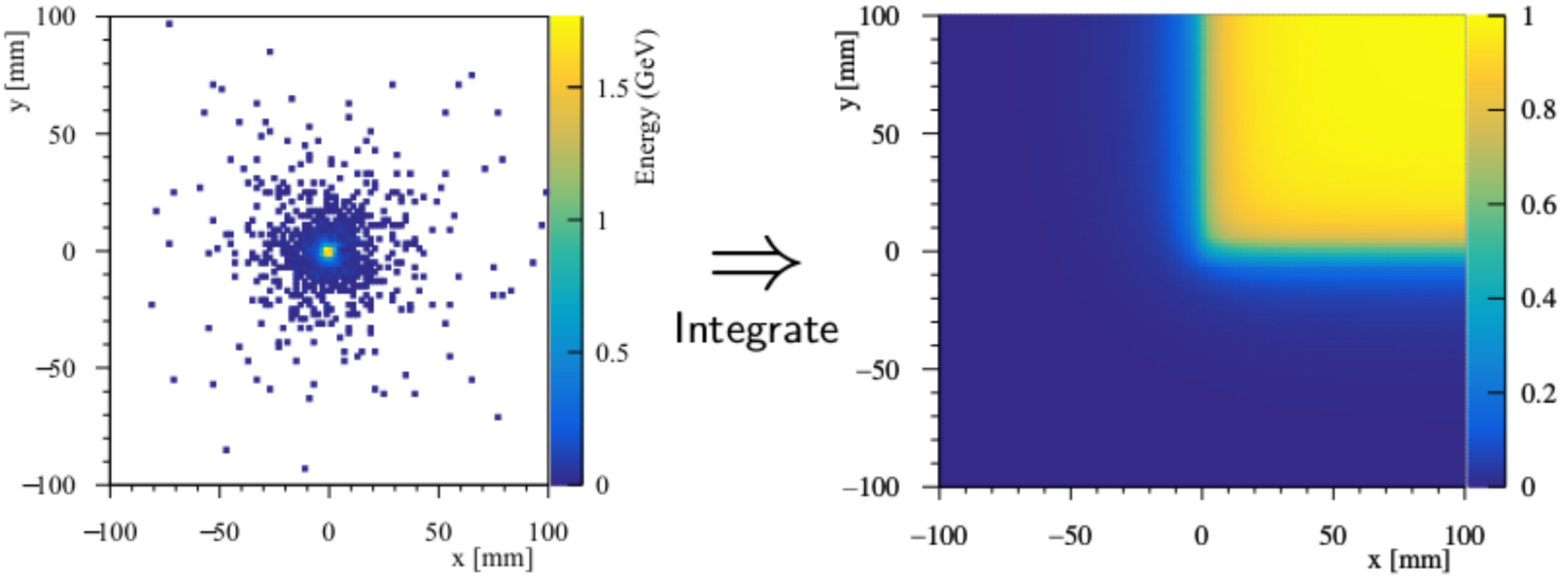
Projection to xy-plane



Projection to cell-plane

Shower Reconstruction

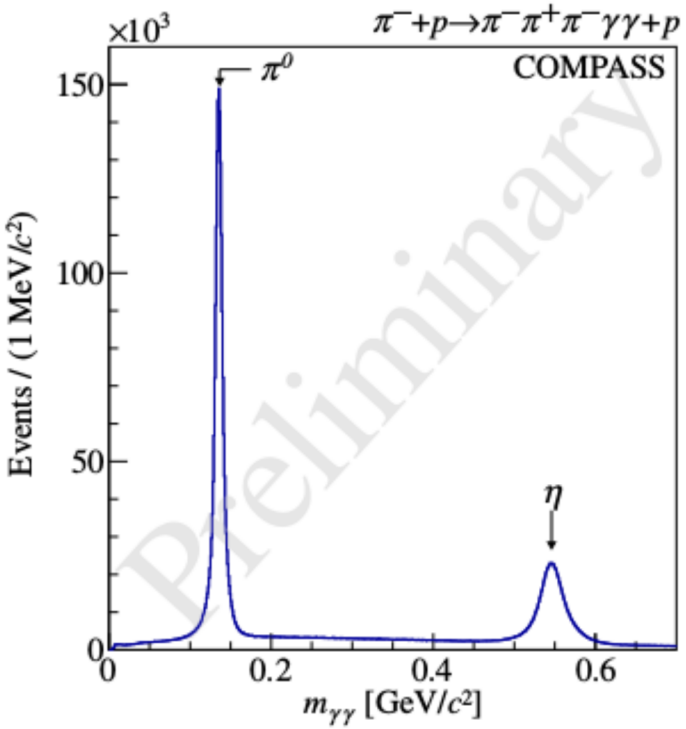
Describe shower by two dimensional arctan function



$$F(x,y) = \frac{1}{2\pi}\sum_{i=1}^{3} a_i \left(\arctan\left(\frac{x}{b_i}\right) + \arctan\left(\frac{y}{b_i}\right) + \arctan\left(\frac{x\cdot y}{b_i\sqrt{b_i^2+x^2+y^2}}\right)\right) + \frac{1}{4}$$

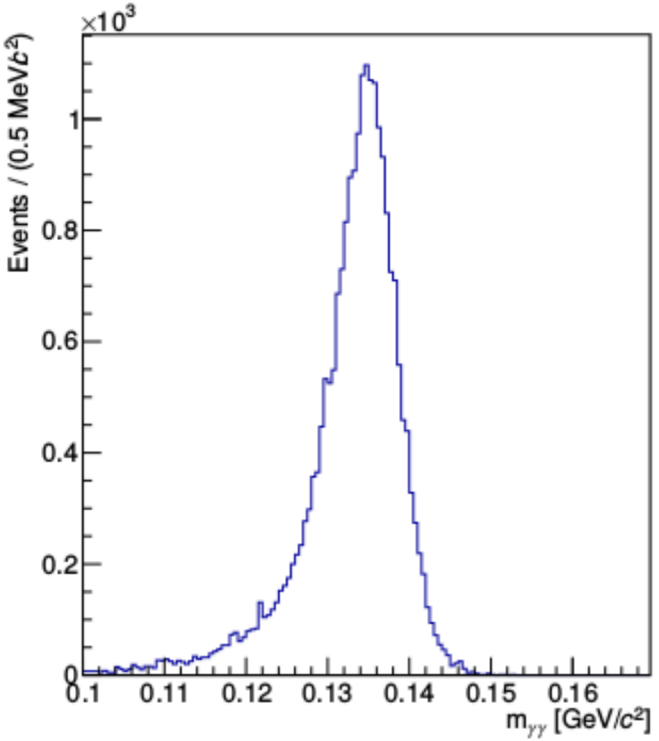
Why tune GFlash

Diffractive 2008 / 2009 COMPASS data

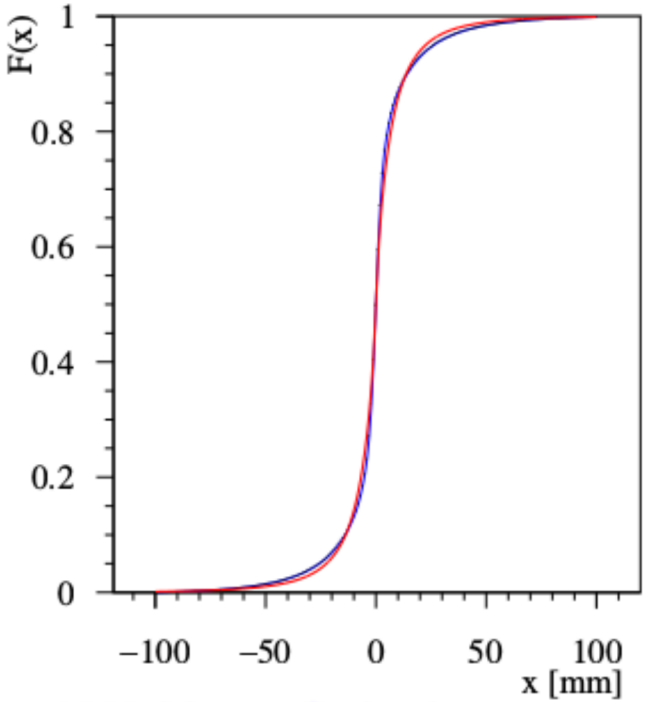


[wwwcompass.cern.ch/compass/results/2022/february_evtsel_3Pi2G/Event_Selection_3Pi2G_06_04.pdf]

Monte Carlo data

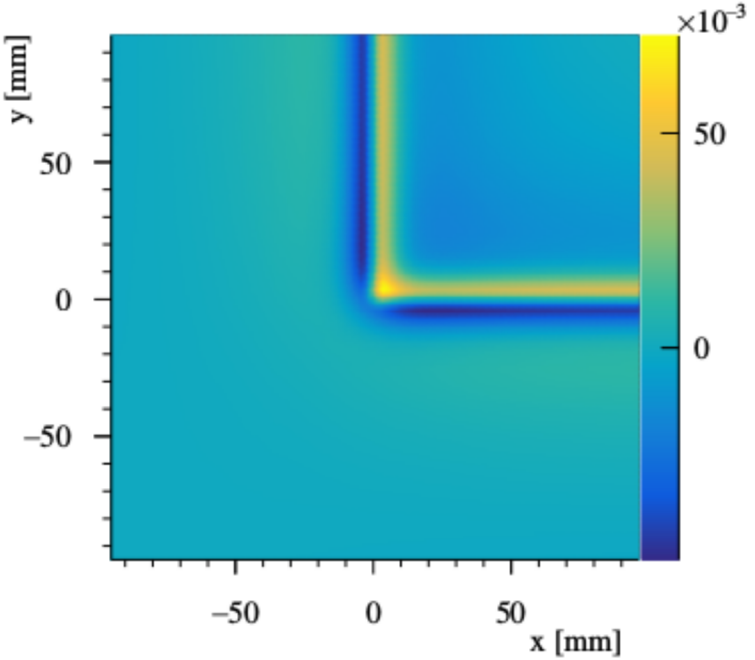


Tuning of GFlash – Shashlik Default



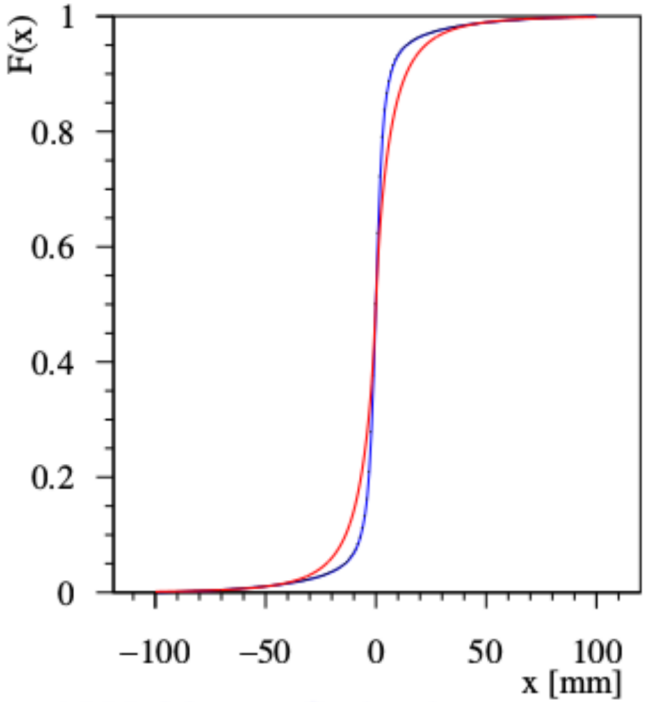
1000 Monte Carlo showers averaged

Real measured shower shape



Monte Carlo – measured

Tuning of GFlash – Radial Tail x50



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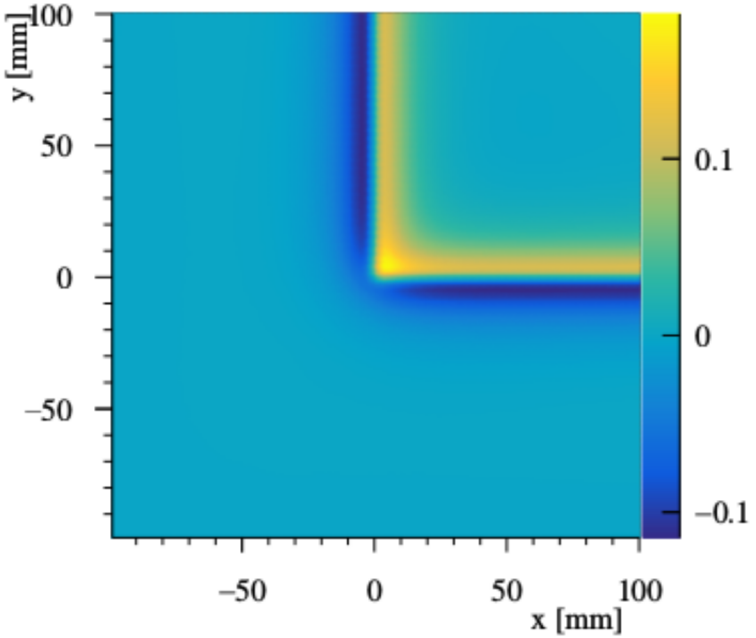
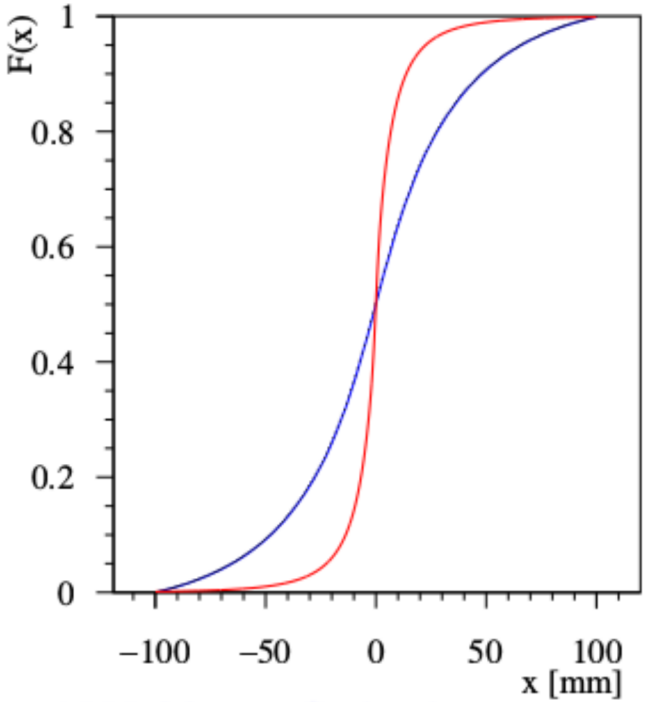


Monte Carlo – measured

Tuning of GFlash – Radial Core x50



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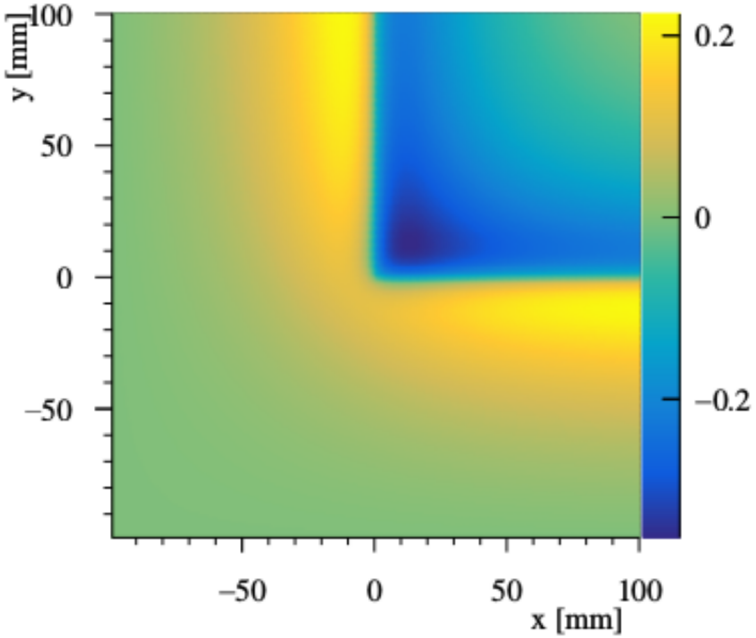
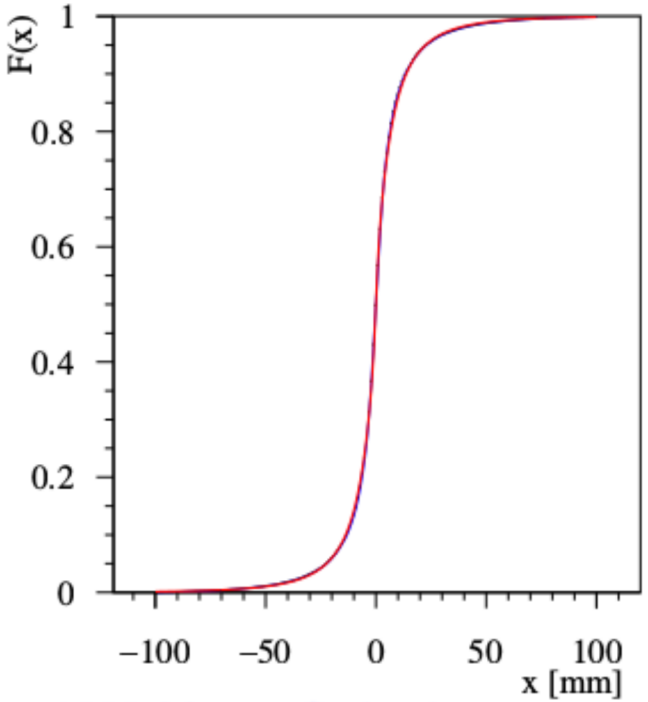


Monte Carlo – measured

Tuning of GFlash – Best Approach



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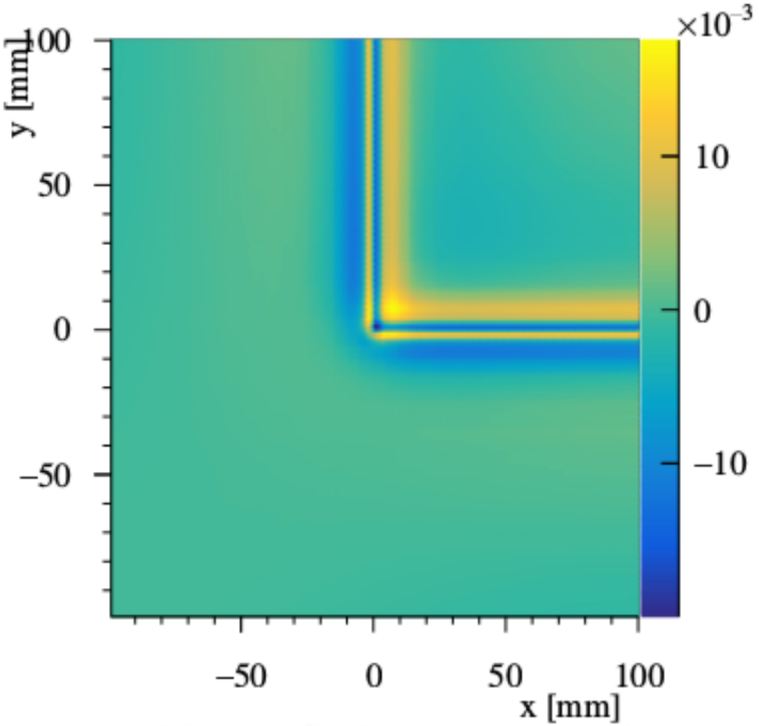
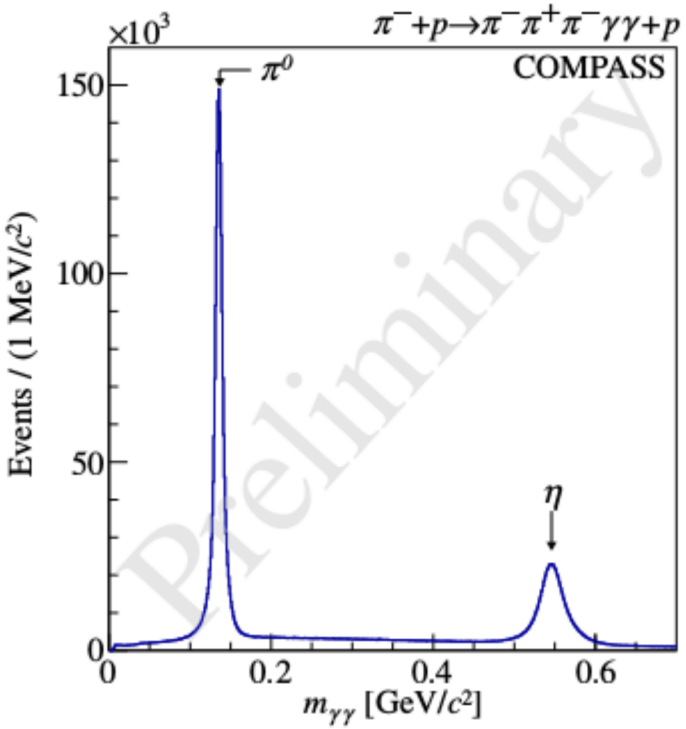


Monte Carlo – measured

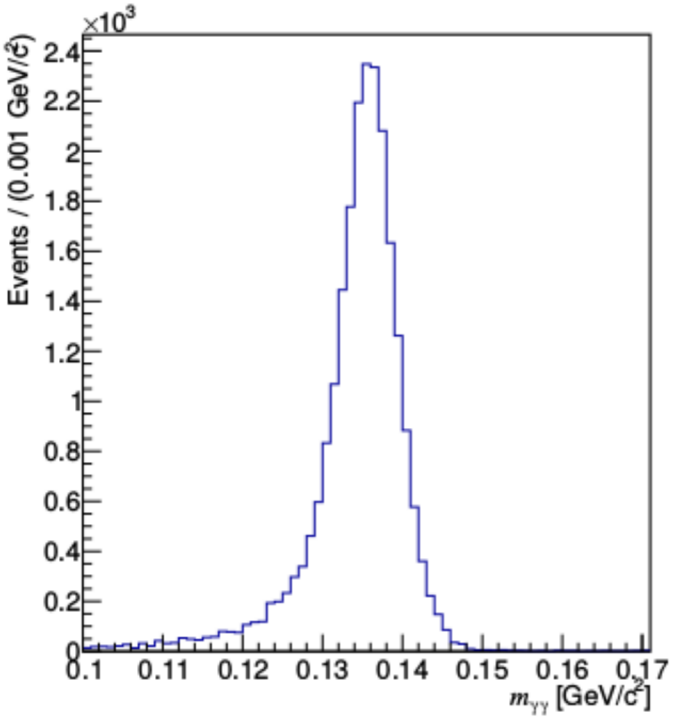
π^0 Mass with updated GFlash Parameters

Diffractive 2008 / 2009 COMPASS data



[wwwcompass.cern.ch/compass/results/2022/february_evtsel_3Pi2G/Event_Selection_3Pi2G_06_04.pdf]

Improved GFlash parameter set



Summary and Outlook

Summary

- Complicated COMPASS calorimeter modules built with GEANT4
- GFlash for COMPASS calorimeters yields a large time gain while taking material into account during energy deposition
- Tuning of radial GFlash parameters changes the shower shape a lot
- Improved on GFlash tuning parameters

Outlook

- Fine tune the GFlash parameters even more to get rid of the π^0 asymmetry completely

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Thanks for your attention!

Backup

Shower without GFlash