A novel grain calorimeter: GRAiNITA

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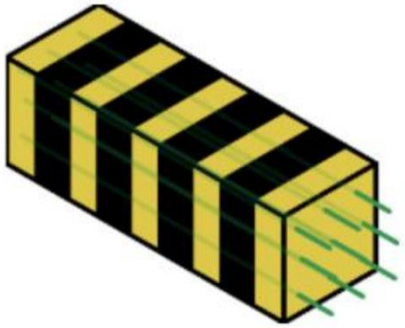
FCC activities @ LPCA

- Feasibility studies
  - Branching fraction of $B^0 \to K^*\tau^+\tau^-(3\pi\nu)$ and the resolution requirements to the tracking system.
  - Exclusive R_b measurement and the requirements to the detectors.
  - CKM profile studies and V_{cb} measurement
- Detetor(GRAiNITA) (collaborate with IJCLab, ISMA and TSNUK)
  - Contribution to the proof of concept of GRAiNITA.
  - Cosmic muon test and testbeam test bench (electronics and data analysis)
  - Proof of pulse shape discrimination (PSD) with the prototype.

Inspired by LiquidO technique for neutrino detector
(A. Cabrera et al. LiquidO Commun Phys 4, 273 (2021))

The concept of GRAiNITA

- Shashlik-like sampling:
  - Energy resolution: (~10%/$\sqrt{E}$)

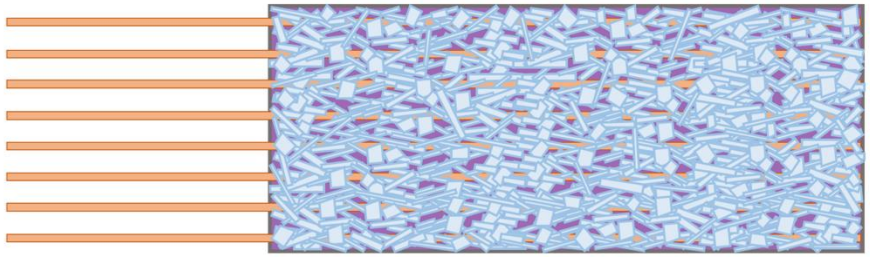


Better resolution

Lower cost
(vs homogeneous)

- GRAiNITA:
  - Mixture of scintillator grains and heavy liquid
  - Extremely fine sampling

  + Energy resolution (~2%/$\sqrt{E}$)



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The concept of GRAiNITA

- The grains (produced by *ISMA)
  - Cadidates:
    - $ZnWO_4$ and BGO (reference)
  - Size:~1 mm
  - $ZnWO_4$: produced via flux method by ISMA
  - BGO: produced via mechanical crushing

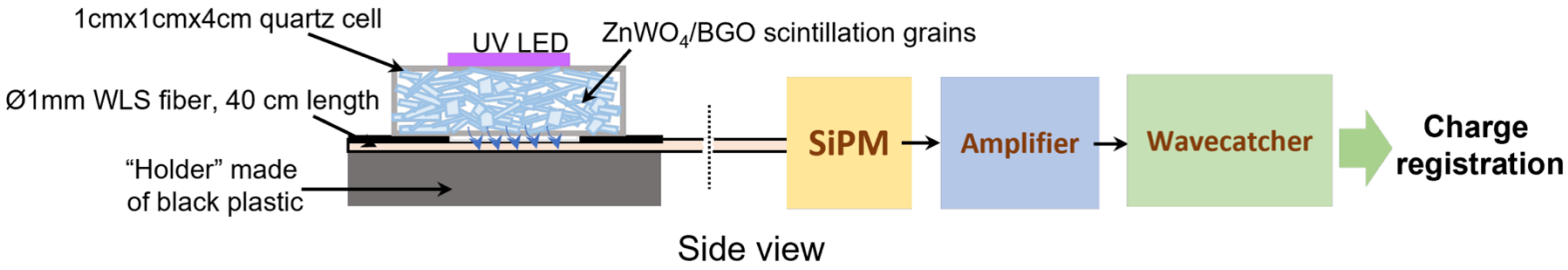
	BGO	$ZnWO_4$
Effective Z	74	61
Density (g/cm^3)	7.13	7.87
Refractive index	2.15	2.0 - 2.3
Light yield (photons/MeV)	~ 9000	~ 9000
Peak emission wavelength (nm)	480	480
Decay time (μs)	0.3	20
Radiation length (cm)	1.12	1.20
Molière radius (cm)	2.26	1.98

*ISMA: Institute for Scintillation Materials, Kharkiv, Ukraine

The concept of GRAiNITA

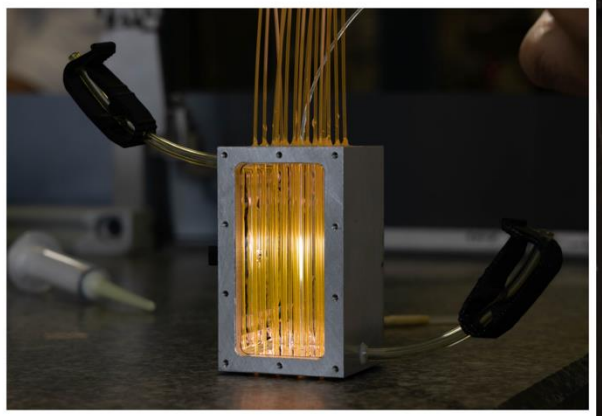
- Wave length shifting fiber (WLS)
  - 4 types of WLS are tested with a UV LED
  - O-2(200) is the preferred choice for the prototype

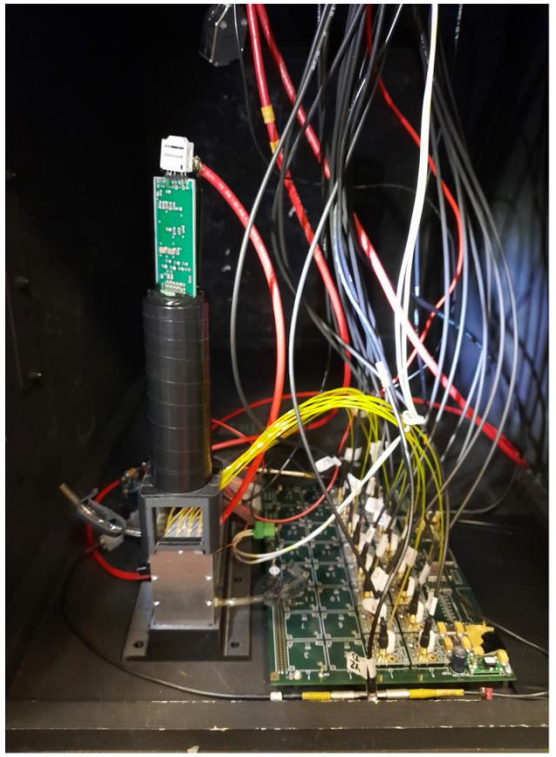
	Relative efficiency (%)	
Fiber type	$ZnWO_4$ grains	BGO grains
O-2(300)	100	100
O-2(200)	104	104
Y-11(200)	44	98
R-3(100)	60	n.a.



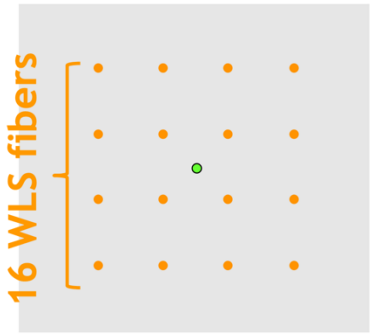
The prototype “Troll”

- Size: 28x28x55 mm^3
  - ~200g $ZnWO_4$
- 16 WLS fibers read-out by SiPM
  - +1 clear fiber (depolished) in the middle to inject blue/green LED for light propagation study
  - Spacing: 7 mm
- The “liquid” for cosmic rays test-bench:
  - Air / water / ethylene glycol

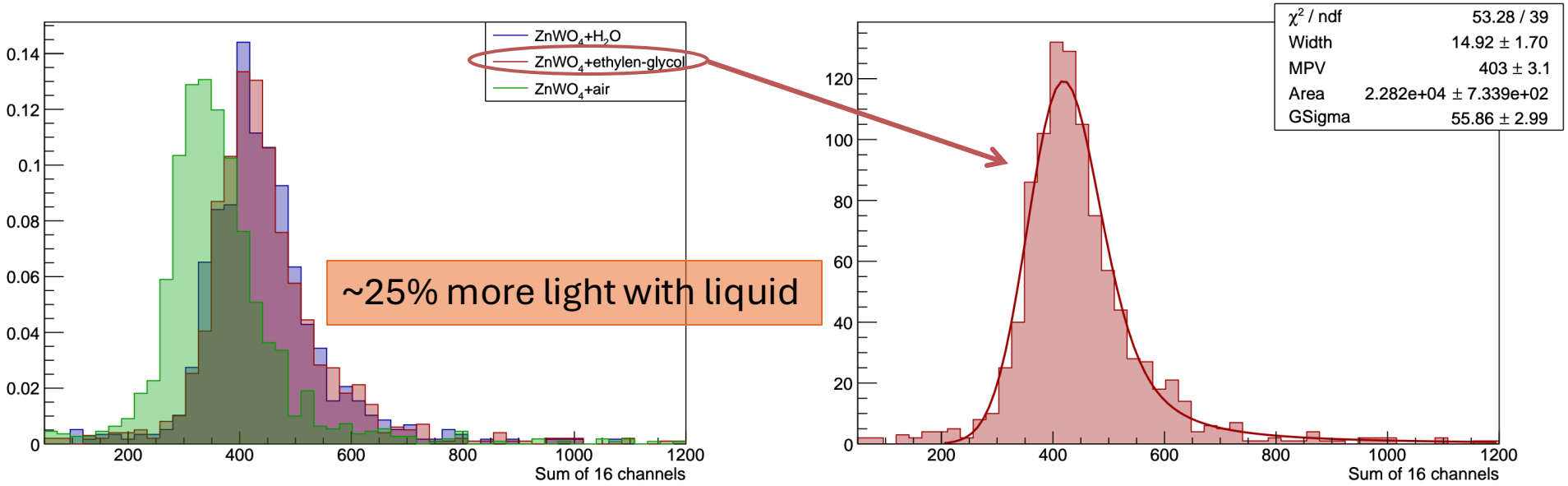




Top view



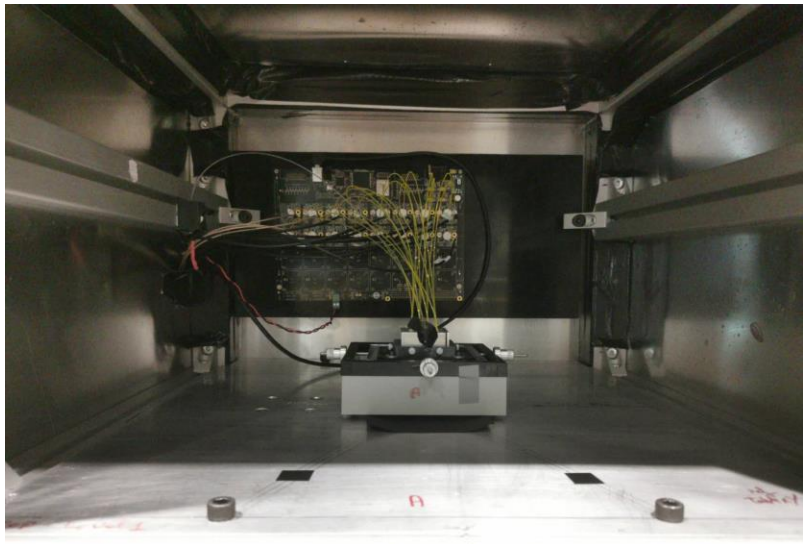
Cosmic ray test result

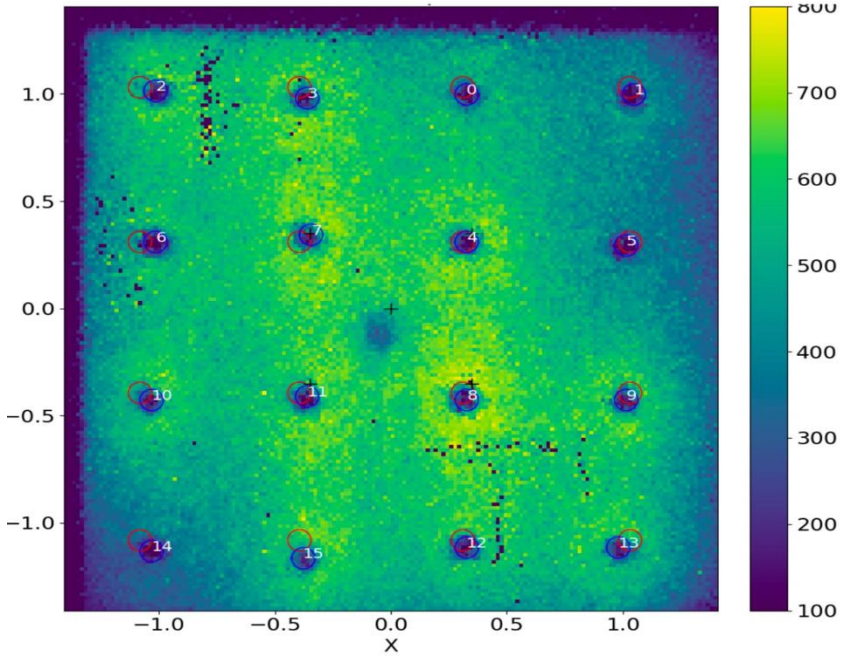


- The signal yield is larger when the medium refractive index is better matched with the grains.
- ~10000 PE/GeV is expected based on the result.
- Opens the road to a statistical fluctuation of $1\%/\sqrt{E}$ due to photon statistics

Testbeam @ CERN

- With the same prototype
  - With water / heavy liquid
- Muon and pion runs were taken in 48h.
- Data analysis is ongoing, more details can be found in Marie-Helene's talk

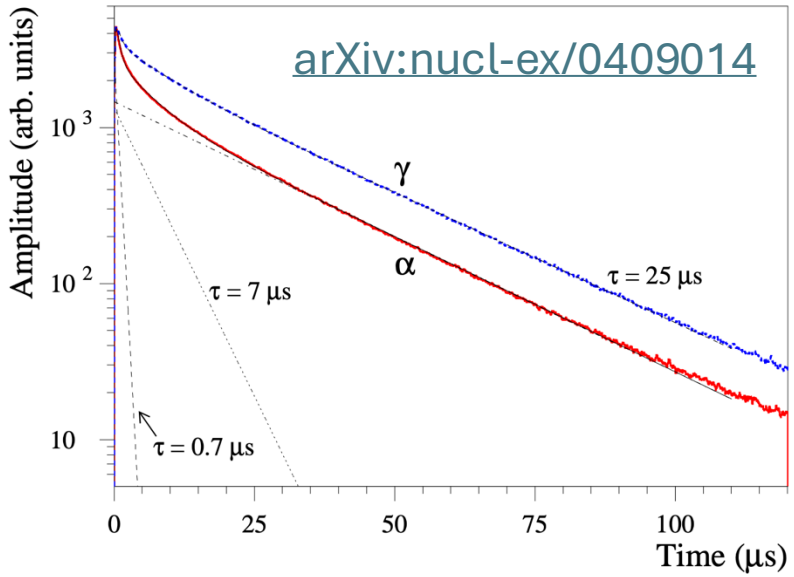


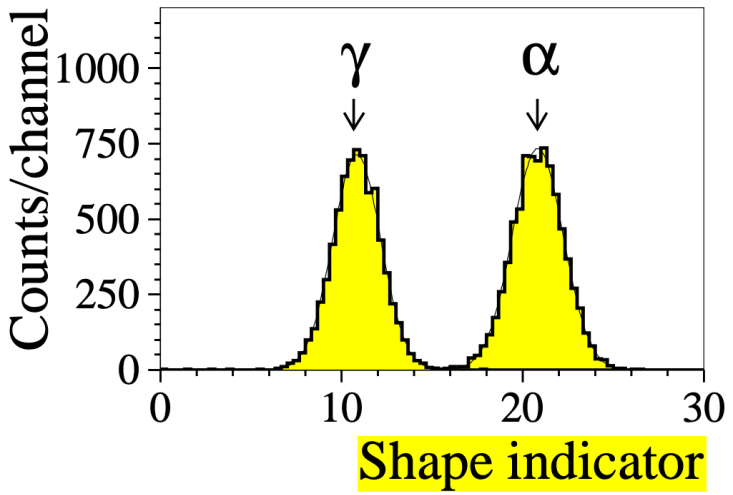


Track density map

Possible improvement of hadron showers

- Pulse Shape Discrimination (PSD)
  - Using the decay time shape difference (fractions of fast and slow components) to separate the hadronic and electromagnetic scintillation light.

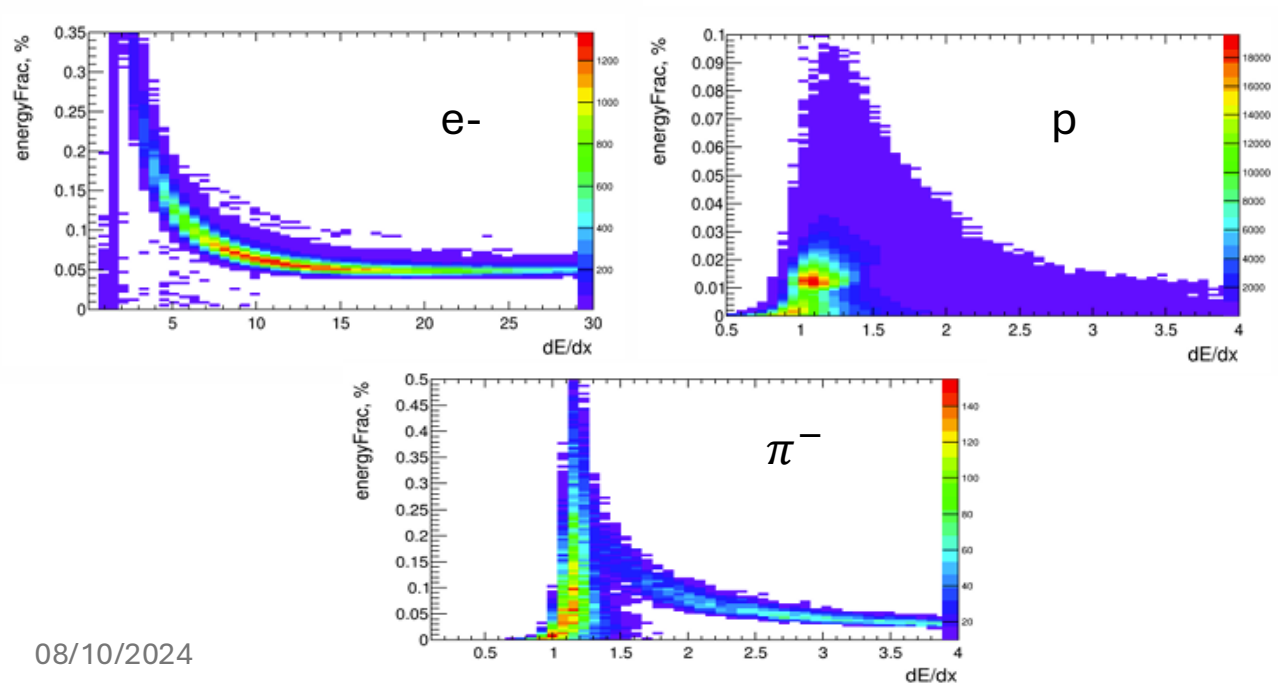


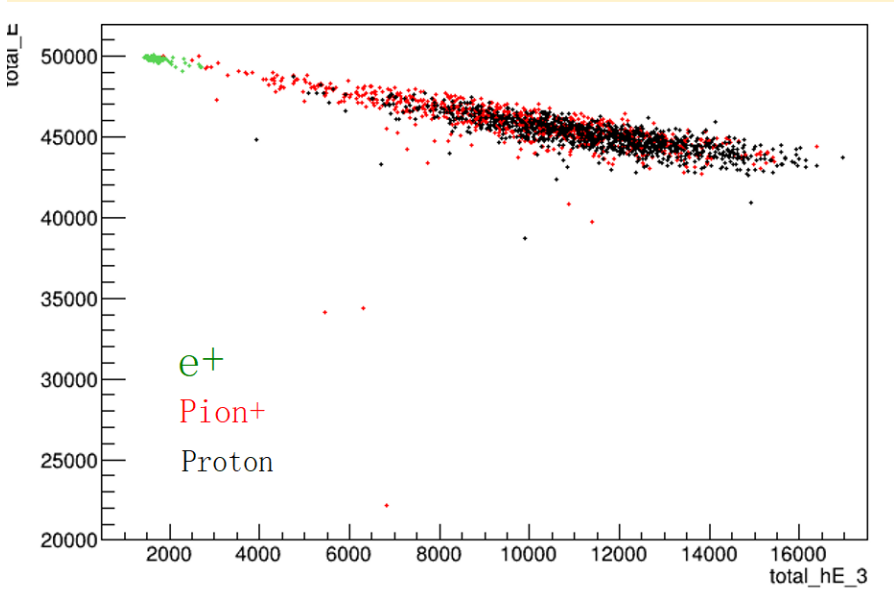


An example with ZnWO4 crystal

Towards applying PSD on GRAiNITA

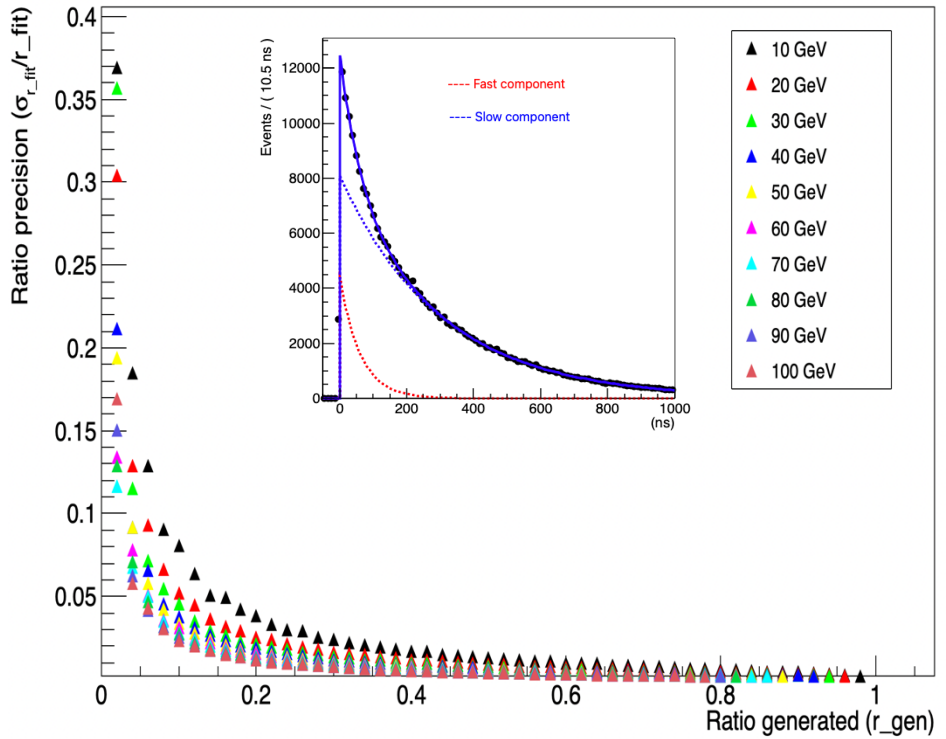
- Simple simulation with different kinds of input particles
  - To check the correlations between deposit energy corresponding to the low momenta high dE/dx particles and the initial energy for different particles





Towards applying PSD on GRAiNITA

- Is it precise enough to measure the fraction and decay time constants with 10k PE/GeV?
  - Checked with simple toys
  - The fraction of fast components are varied from 2% to 98%
- When having ~10% of fast component, the σ_f / f is less than 10%, precise enough to identify the decay time shape difference
- Next step: complete G4 simulation with the adequate optical model ongoing



Conclusions

- The light yield of GRAiNITA prototype, measured with cosmic rays, indicates the energy resolution of 1% at 1GeV can be achieved
  - Next to start assessing the constant term in the energy resolution
  - The non-uniformities can be determined with the data collected during the testbeam
- The capability to use PSD with GRAiNITA is under study
  - First steps with simple toys and simulations are promising
  - A low energy test beam with materials is planned to get the optical properties
  - A better simulation with actual optical model is ongoing