

DUNE: preventivi per il 2026

Gruppo di Lecce

Antonio Surdo

26-June-2025

Hardware activities in 2024 / 2025

✓ Realization of Cosmic Ray Tagger (CRT) for ARTIC @ GE

... to provide a trigger and tracking device of cosmic muons for the image reconstruction setup of tracks in LAr

CRT Designed, assembled and tested in Lecce in 2024

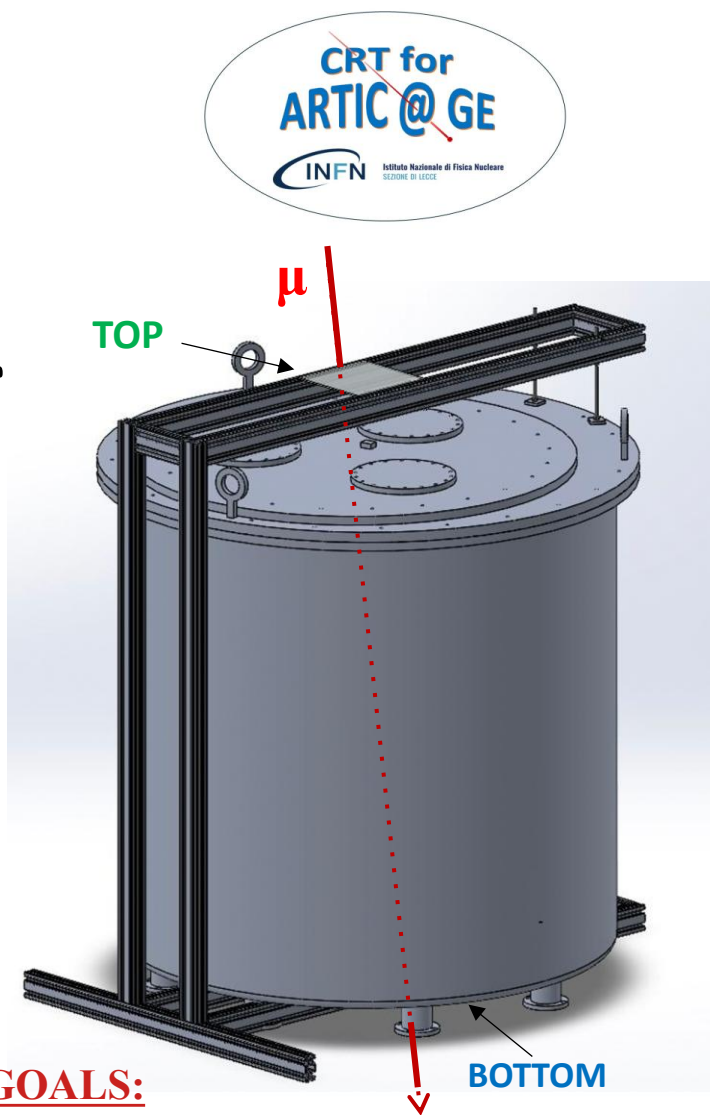
✓ Commissioning at end of July '24 at INFN-Genova

Servizi coinvolti nelle attività: **Elettronica, Meccanica**

Mechanics (A. Miccoli, S. Maggiore, G. Rizzo, R. De Nicola)

Electronics (A. Corvaglia, M. Panareo)

Detector setup (F. Alemanno, C. Pinto)



CRT GOALS:

- Trigger for the LAr acquisition (fourfold coincidence)
- Two-view tracking to help the LAr event reconstruction

CRT setup @ Lecce



17/05/2024



DAQ with TOP-BOTTOM fourfold coincidence

GRAIN WG Meeting - A. Surdo



TOP tray



BOTTOM tray



ARTIC cryostat was previously lifted up to allow the placement of the CRT bottom arm



29/10/2024

DUNE Italian General Meeting - A. Surdo



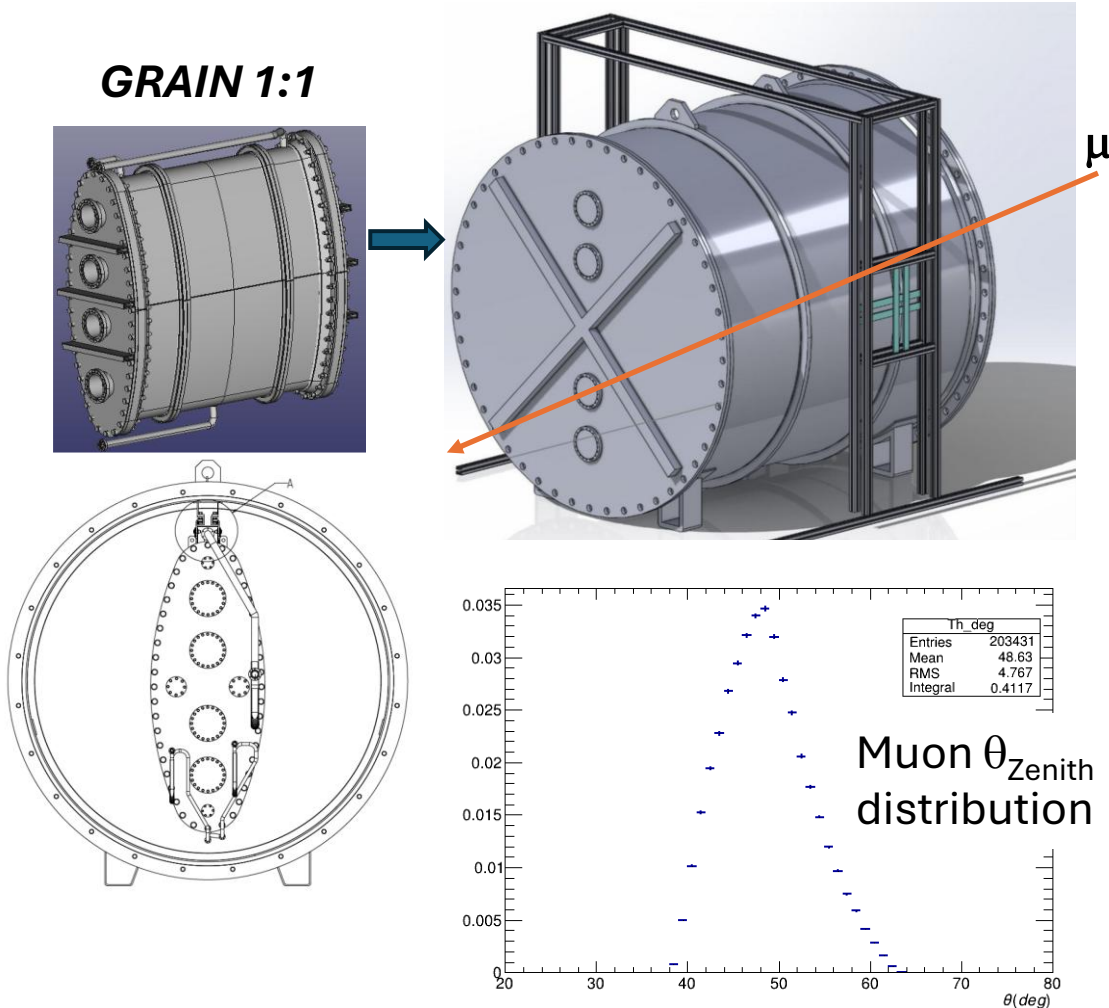
CRT commissioning

- Installed on ARTIC @ Genova in July
- Preliminary stand-alone test: OK
- Ready for ARTIC operations on next months

CRT for GRAIN full-size prototype @ LNL

✓ Simulation and start of design of the new Cosmic Ray Tagger for LNL

GRAIN 1:1



Monte Carlo simulation with

- TOP & BOTTOM size: 68cm x 68cm
- (T-B) Horizontal Distance: 180 cm
- (T-B) Vertical-Distance: 160 cm

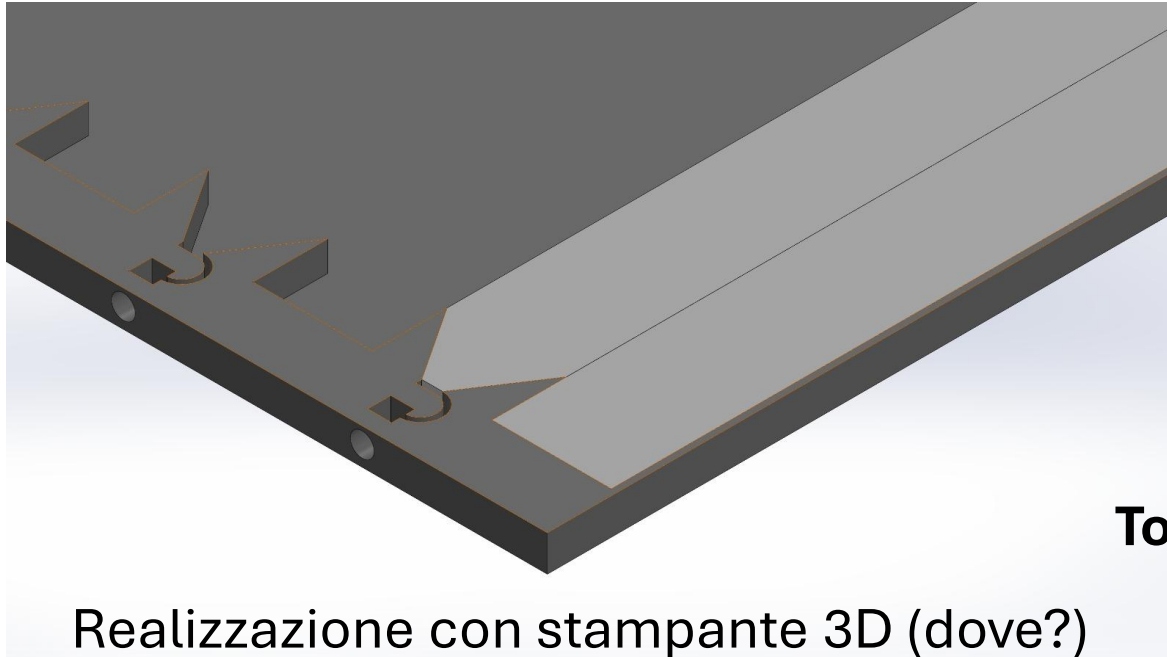
Cosmic muons on vertical surface A (one side):
Rate $\approx 44 \mu / \text{m}^2/\text{s} * A \rightarrow \text{Rate(TOP)} \sim 20 \mu / \text{s}$

From the simulation:

- Geometry acceptance of (T+B): 0.02
- **Expected Muon Rate: $\sim 0.4 \text{ Hz}$ ($\sim 1400 \mu/\text{h}$)**
 $\rightarrow \sim 10^3 \text{ tracks /h}$ (for inefficiency, track reco, ..)

Design of CRT @ LNL in progress

- **Design dei vassoi 70cm x 70cm per le barre di scintillatori (in progress)**



Realizzazione con stampante 3D (dove?)



Protipo circuito read-out SiPM

Tot-ch: 96 bars su 4 piani, 2 FERS

- **Design dell'elettronica (PCB custom) per il read-out dei SiPM (DAQ con FERS)**
→ Disponibili Offerte per richiesta sblocco s.j. per PCB e 1 FERS
- **Design della struttura meccanica (in progress)**

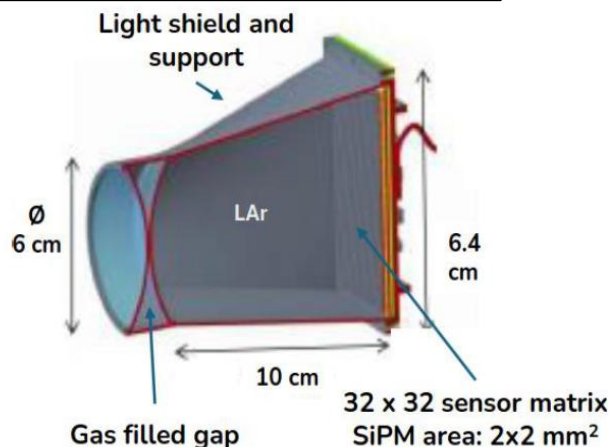
Lecce Software activities in 2024/2025 (1)

Event reco in GRAIN (optical readout in LAr)

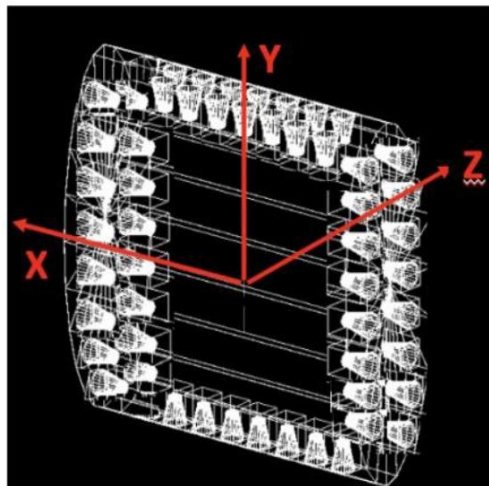
- ✓ Implementation of projective geometry based algorithms for the 3D reconstruction of neutrino events
- ✓ Test on the algorithm performances

Sensor matrix

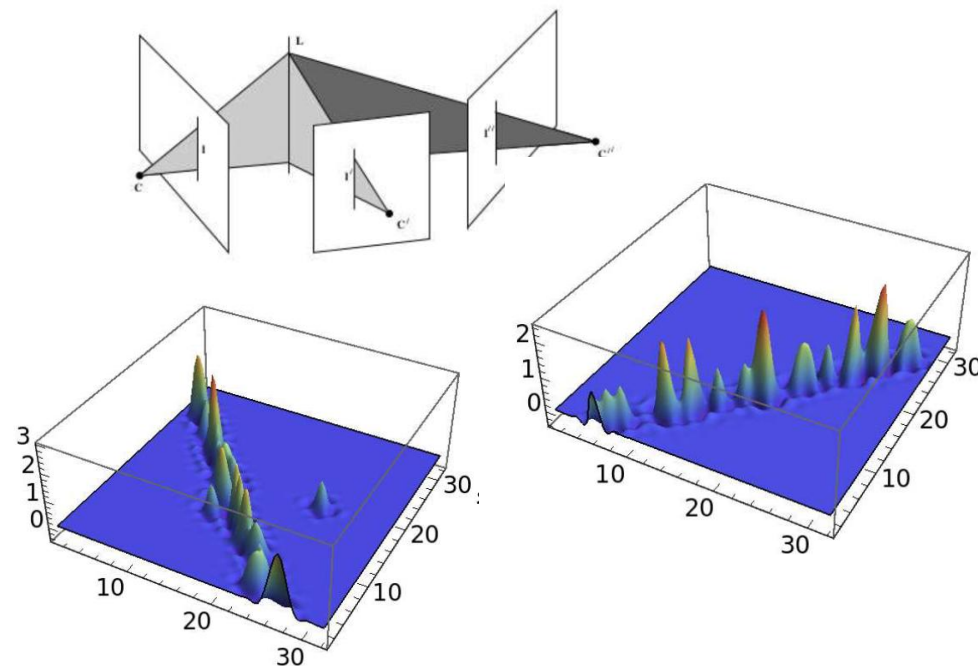
- 32 x 32 SiPMs
- SiPM active area: 2 x 2 mm²
- PDE ~ 0.1-0.2



53 cameras in GRAIN



Triple-View Geometry and image correspondences:
the Trifocal Tensor



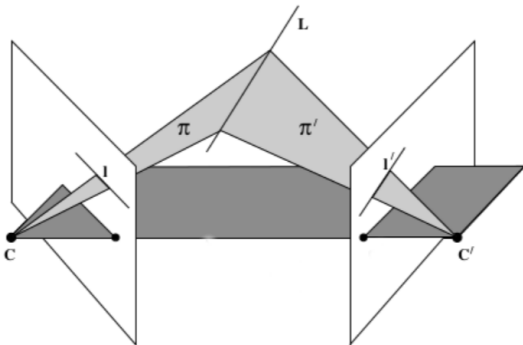
- Projective geometry applied to simulated data (lenses and matrices)
- 3D reconstruction of light spots (vertices) and tracks from couples of camera images

Projective geometry based reconstruction

(from 2D images to 3D track)

- Each α camera is characterized by a 4x3 matrix: $P_\alpha[4][3]$
- 2D track on SiPM array associated with a 3x1 matrix: $L_\alpha[3][1]$
- The plane from the product of two matrixes

$$P_\alpha^T[3][4] L_\alpha[3][1] = \pi_\alpha [4][1]$$



example

0	0	100	6000
0	-100	0	- 51200
1	0	0	649

$$m_\alpha \quad -1 \quad q_\alpha$$

track parameters

$$a_\alpha \quad b_\alpha \quad c_\alpha \quad d_\alpha$$

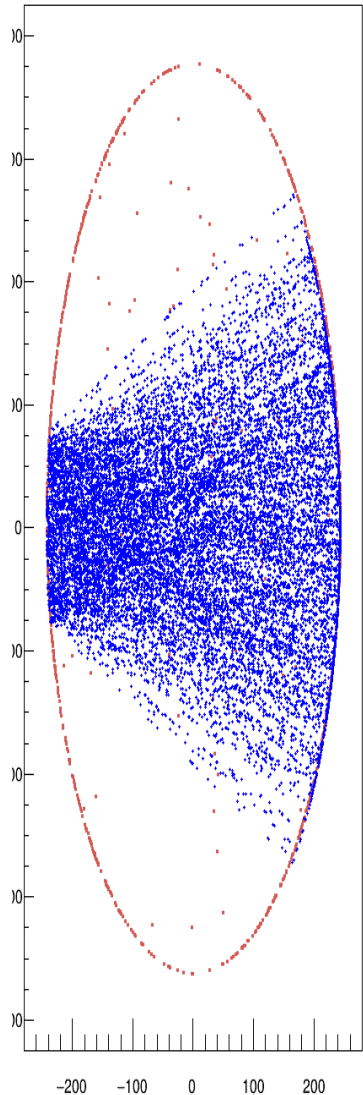
plane parameters

Track in space found from the intersection of two planes
In this analysis only pairs of orthogonal lens-cameras

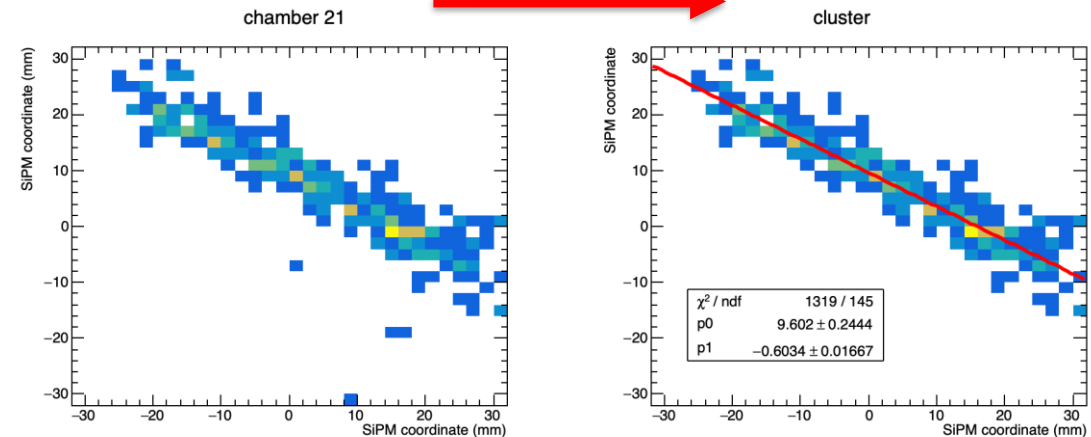
Projective geometry: single track reconstruction

Simulated sample

- 1000 muons with $E = 1 \text{ GeV}$
- first point on an area $30 \times 30 \text{ cm}^2$
- angle w.r.t. Z axis: $\theta < 45^\circ$



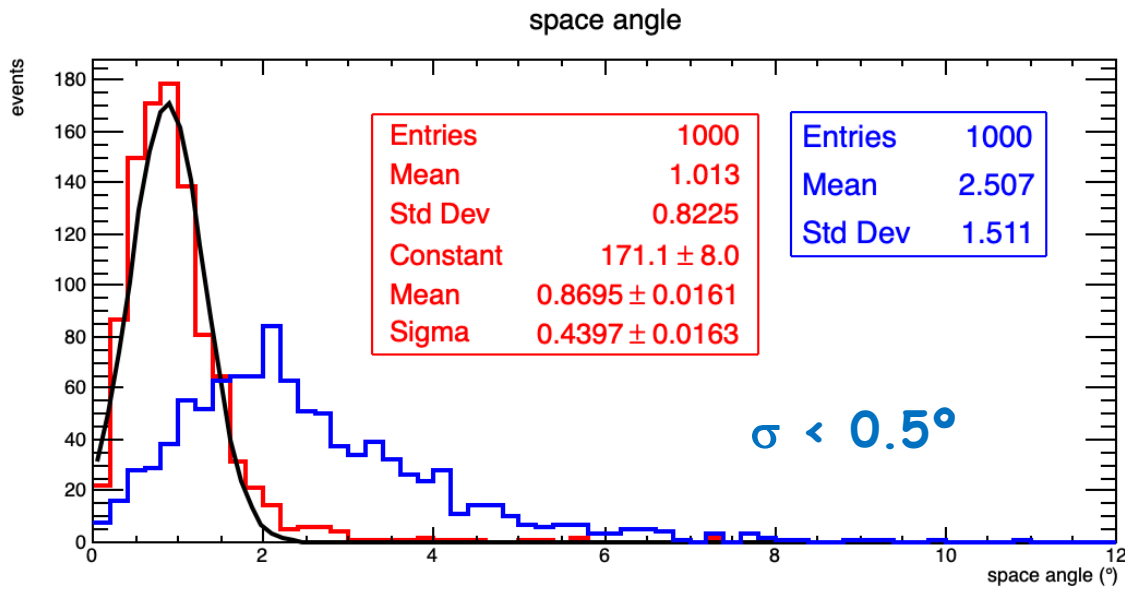
DBSCAN



- Pixel selection by DBSCAN algorithm on each SiPM array
- Linear fit of the selected pixels
- 3D reconstruction using couples of orthogonal cameras

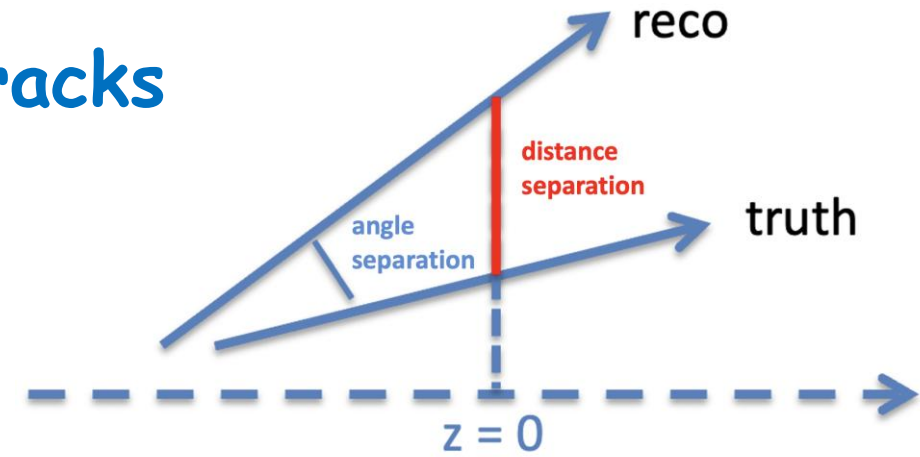
Projective geometry: results for single tracks

Space-angle separation ($^{\circ}$)

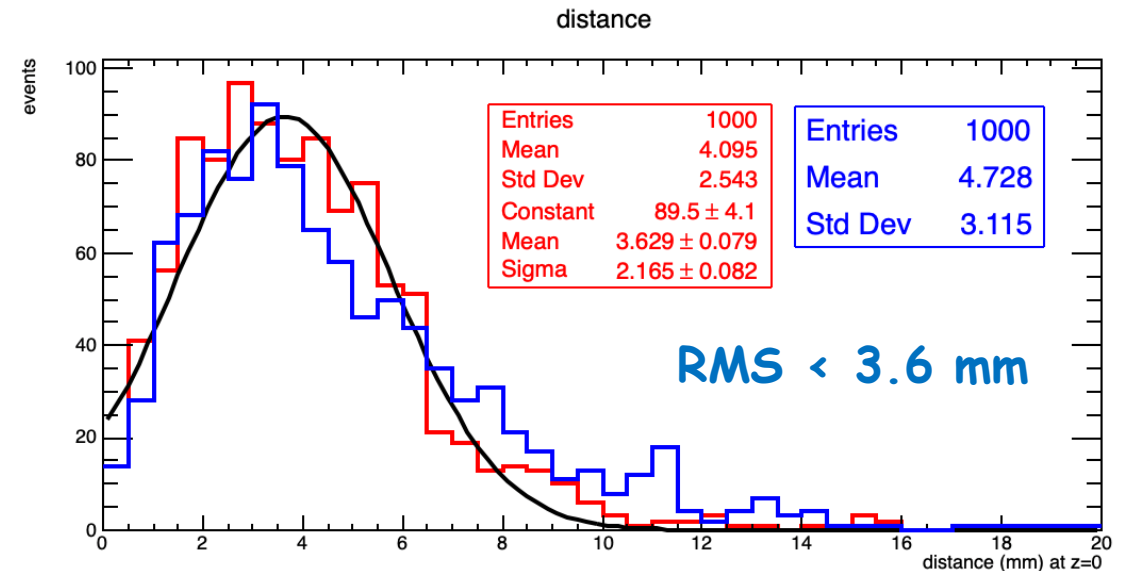


w/o dbscan

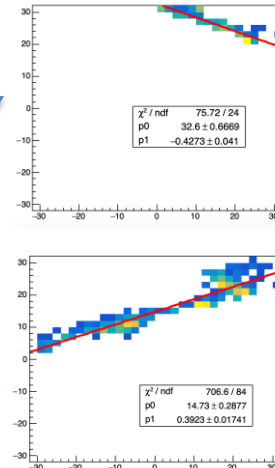
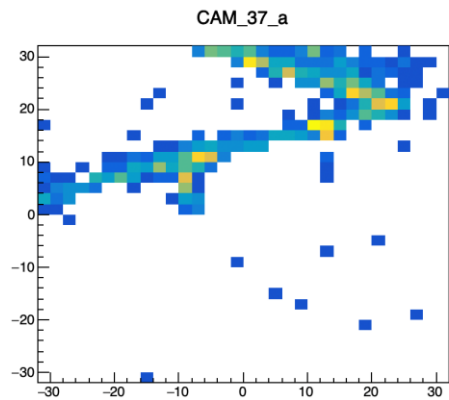
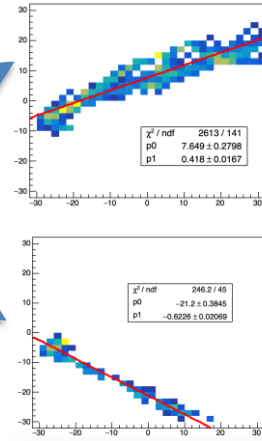
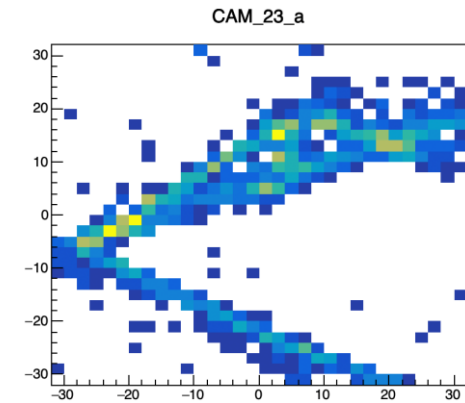
w/ dbscan



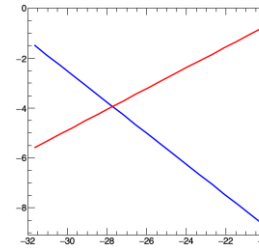
Separation (mm) at $z=0$



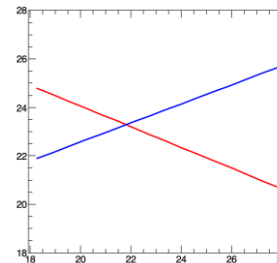
Projective geometry: vertex reconstruction with <three-tracks neutrino events (work in progress)



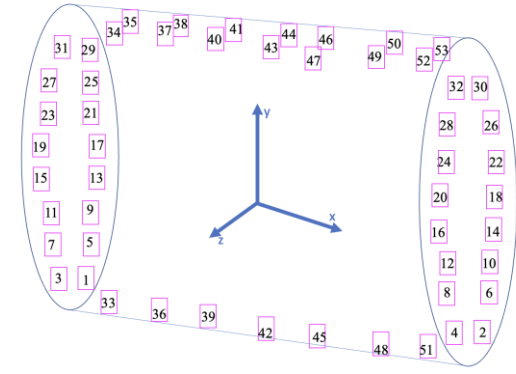
this example
 $\nu \rightarrow \mu^- p \pi^+$



Hor -27.7 mm
Ver -3.9 mm



Hor 22.5 mm
Ver 23.6 mm



- Local vertices are obtained
from two-tracks intersections

Vertex by means of 3D unfolding

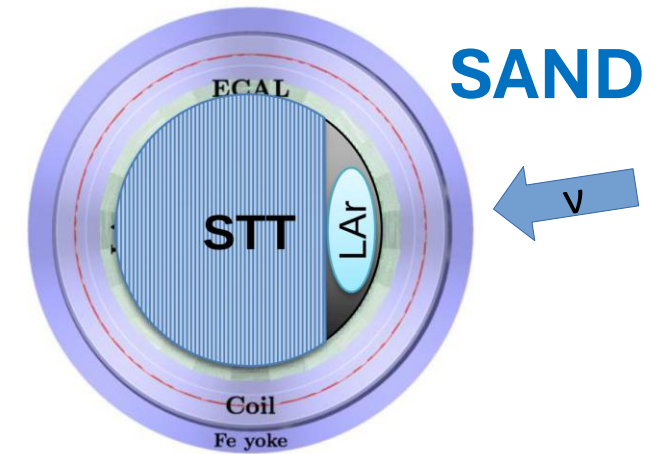
Reco :	-273.5	+162.6	+1.0
True :	-292.3	+183.6	-4.3

Separation: 28.7 mm

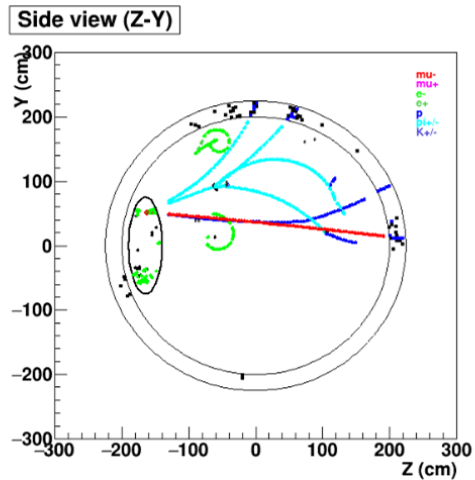
Lecce Software activities: ν event reco in SAND (2)

Full reconstruction of ν interaction events (in progress):

- ν interaction vertex in SAND
- Id and track reconstruction of particles produced in the interaction
- Reconstruction of energy, flavor and interaction type of neutrinos

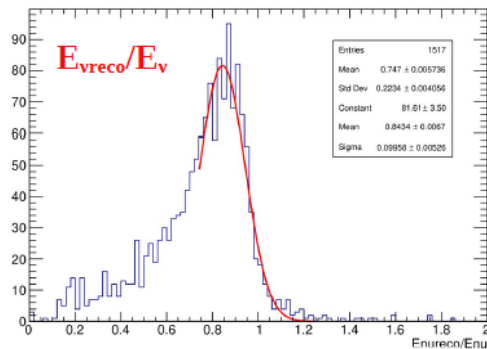


ν_μ interaction in GRAIN

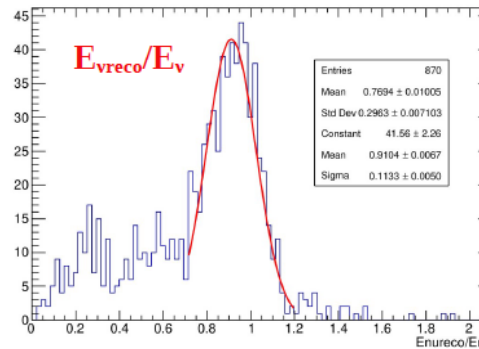


- Characterization of ν interactions in SAND
- Present status of E_ν reco in *SandReco* program (using MC info)

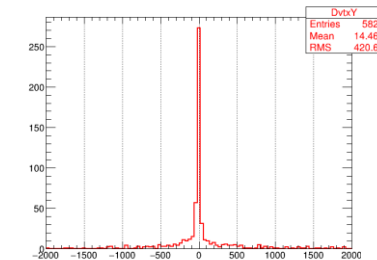
ν_μ -CC interactions in GRAIN



ν_μ -CC interactions in STT

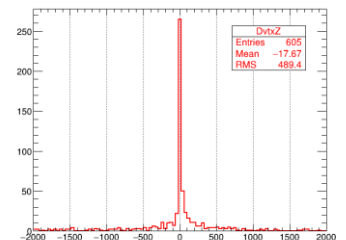


- Vertex reco from full simulation:



Y coord error

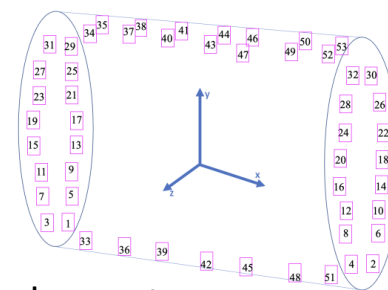
Z coord error



Lecce Software activities: energy calibration for GRAIN

Tools and procedures useful for calibration

- ✓ Calibration obtained from selected processes in GRAIN, using directly the experimentally collected events (in prototype or on the ν beam)



lens setup

“Standard candle” processes:

- MIP

- muon decay electrons

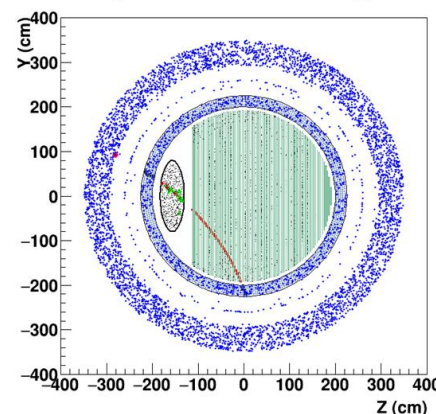
- stopping muons

- π^0

- ✓ Ad hoc calibration sources (?):

- LED or Radioactive source

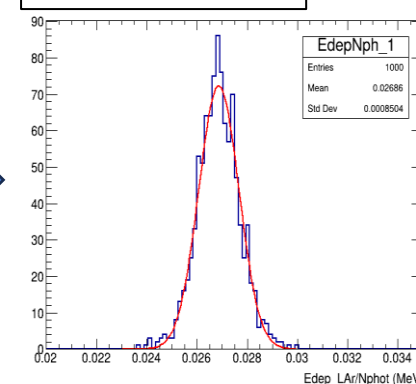
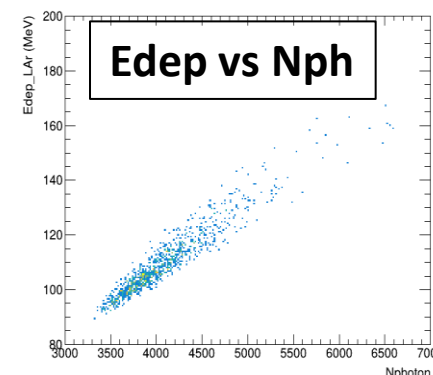
Muon from ν interaction in the yoke and crossing GRAIN



Simulated muon beams crossing GRAIN

→ Calibration constant

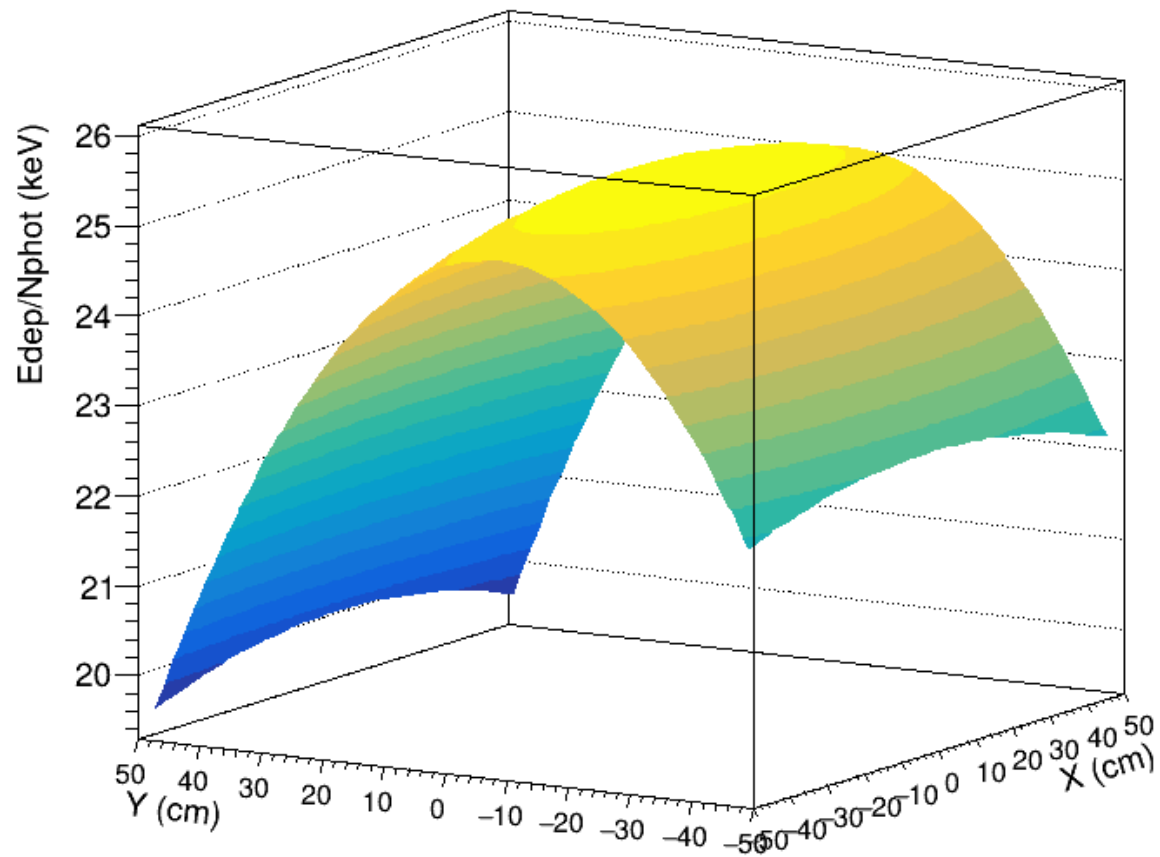
Edep/Nphot



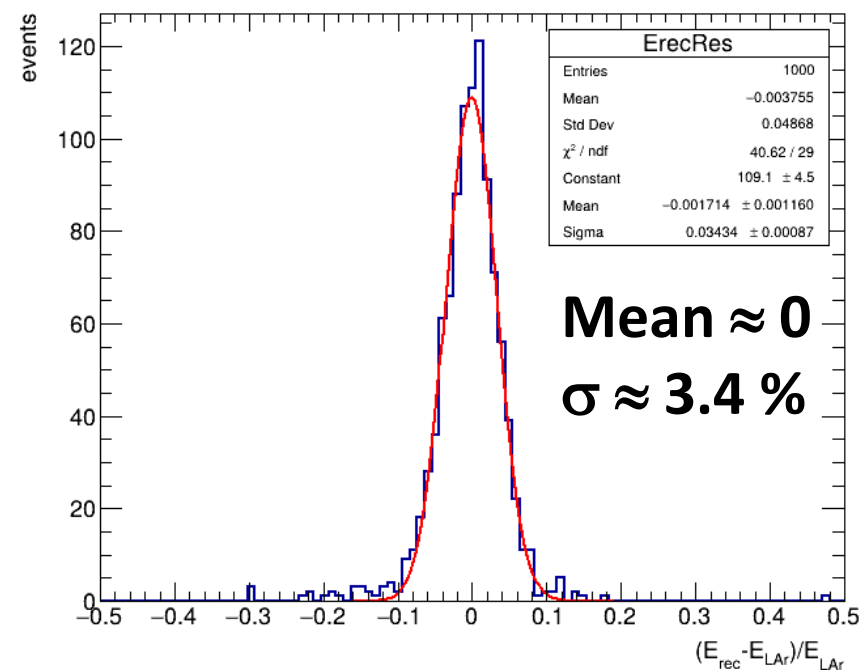
The "constant" is parametrized to account for dependence of collected photons on the average position of deposited energy

Calibration function in the plane X-Y of GRAIN

$$F_{cal} = a \cdot x^2 + b \cdot y^2 + c \cdot x \cdot y + d \cdot x + e \cdot y + f$$



Reconstruction of deposited energy in GRAIN using the Calibration Function, for an independent μ -beam sample



Results for a sample of ν -induced μ 's: in progress...

2025/2026: attività previste

CRT a Genova e LNL

- costruzione del CRT per il prototipo 1:1 di GRAIN a LNL
- test e successiva installazione del CRT a LNL
- supporto per integrazione CRT nella DAQ di ARTIC@GE

SAND software

- sviluppo algoritmi di ricostruzione «full» degli eventi in SAND
- integrazione nel software del complesso ND (SAND + TMS + ND-LAr)

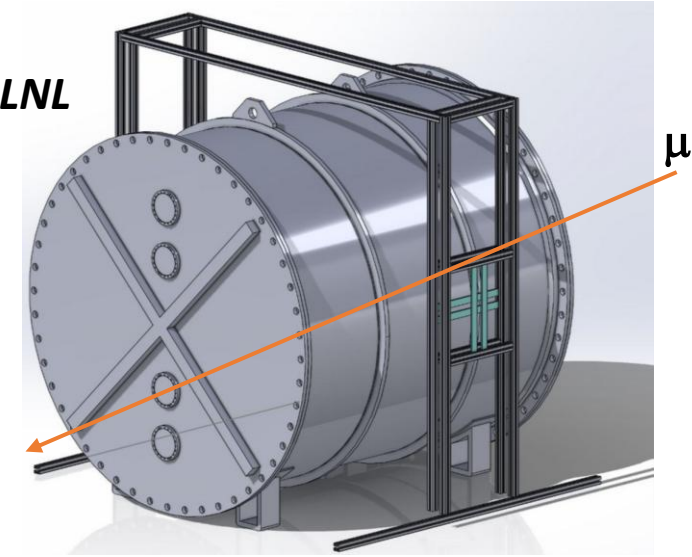
Geometria proiettiva

- ulteriori sviluppi su algoritmi per l'imaging 3D
- verifica degli algoritmi
- inserimento algoritmi nel software ufficiale della collaborazione

Calibrazione GRAIN

- sviluppo della procedura di calibrazioni mediante i muoni (da eventi di ν o cosmici)
- verifica dell'attendibilità della procedura sugli eventi da neutrino
- selezione dei muoni da interazioni esterne dei ν_μ , utili per le calibrazioni

CRT @ LNL



Costruzione, test e commissioning del CRT entro primavera 2026

DUNE - Lecce



	ANAGRAFICA	FTE
Alemanno Francesca	Assegnista - Unisalento	0.8
Bernardini Paolo	Ordinario - Unisalento	0.0
De Matteis Giovanni	Assegnista - Unisalento	1.0
Leaci Antonio	Ordinario - Unisalento	0.6
Martina Luigi	Associato - Unisalento	0.2
Miccoli Alessandro	Tecnologo - INFN	0.2
Montanino Daniele	Associato - Unisalento	0.1
Panareo Marco	Associato - Unisalento	0.2
Surdo Antonio	Primo ricercatore - INFN	0.6
TOTALE FTE		3.7

Personale tecnico

Assiro R.	
Corvaglia A.	
Maggiore S.	
De Nicola R.	
(Rizzo G.)	

Servizi coinvolti nelle attività: **Elettronica, Meccanica**

Richieste finanziarie per 2026

Apparati	- acquisto (eventuale) di ulteriori SiPM per CRT@LNL (s.j.)	5.0 k€
Consumo	- utensileria, resine per stampante 3D, materiale vario	5.0 k€
	- metabolismo	6.0 k€
Missioni	6.0 k€ = 4 persone al meeting al CERN	
	5.0 k€ = 2 persone al meeting a FNAL (USA)	
	5.0 k€ = 2 persone al meeting a Sanford	
	2.0 k€ = 2 trasferte a GE per manutenzione CRT	
	4.0 k€ = 4 trasferte a LNL per installazione CRT	
	8.0 k€ = Missioni al CERN per ProtoDUNE (2 mesi)	30.0 k€
Trasporti	- trasporto materiale a LNL per CRT	2.0 k€