SAND Calibration WG

P.Gauzzi
(Universita' La Sapienza e INFN – Roma)

July 26, 2024

Scope of Calibration WG

- Calibration: from detector signals to physical variables
  - ECAL: energy, time and positions of the particles
  - STT: *r-t* relations, track momentum, dE/dx for PID, ...
  - GRAIN: tracks, time, energy, ...
  - Timing alignment among the subdetectors (for the determination of the interaction time)
- Start to define a strategy for each subdetector:
  - Sources: cosmics, particles from beam, (radioactive sources ?)
  - Choose suitable processes (given the expected fluxes of particles in the detector) (*e.g.* for the ECAL: cosmic μ's as MIPs, MIPs from the beam, electrons and photons ....)
  - Set a calibration procedure (at which level of precision ? How much time expected for a calibration ?)
- Reference people:
  - ECAL: P.Gauzzi
  - GRAIN: A.Surdo
  - Tracker: ……

ECAL calibration

- This week there has been the Preliminary Design Review of the KLOE-to-SAND project by a Fermilab committee
- The reviewers raised the question of the ECAL performance in SAND related to the different calibration procedure w.r.t. to KLOE because of different environment

24. **It is assumed that the performance of the ECAL will be the same as what was measured in KLOE. For this to be true the calibration will need to be equally precise in DUNE, but the experimental environment is quite different. Please provide the studies showing how the calorimeter will be calibrated and that the expected precision can be achieved. It seems likely that large samples of Bhabha events are not going to be available.**

We are well aware of that. In KLOE we exploited the huge Bhabha and e+e- => gamma gamma processes for fast calibration check/correction during the runs, while the basic calibration and cell inter-calibration (but the absolute energy scale) was performed with MIPs (minimum ionizing particles) from cosmic rays. In SAND we are studying the best solution to inter-calibrate ECAL cells using (i) cosmic rays, (ii) punch-through muons, pions and (iii) particles from other processes reconstructed with the tracker. For the absolute energy scale we are going to exploit pi0->gamma gamma, K0S=> 2 pi0 decays, and electrons from neutrino interactions. Reconstruction techniques developed in KLOE and suitable also in SAND will be exploited. Note that a dedicated working group has been set to study the calibration issues (see also the TDR Section on ECAL calibration).

In general we are going to calibrate ECAL using a several step process.

1. Cell-by-cell response equalization and time offset alignment with MIPs;
2. Setting the absolute energy scale, at cluster level, with photons from pi0 decays and electrons from beam events;
3. Timing alignment with other SAND sub-detectors by using muons, pions, and electrons from events with reconstructed vertices in the inner tracker.

We expect on average ~150 neutrino interactions per spill at the maximum beam power. Most of the muons produced in these interactions will also be exploited for calibration purposes. The study with MC simulation is in progress.

P.Gauzzi

ECAL Calibration in SAND

MIPs from cosmic rays: muon flux at surface ~ 0.02 μ/(s cm^2)

- **with an effective cross-section of the ECAL for vertical muons of ~ 5 × 10^5 cm^2**
  ⇒ ~ 10^4 μ/s on ECAL (⇒ 100 Hz of "golden mips" in KLOE)
- **Underground reduction of a factor of about 100**
  ⇒ ~ 100 μ/s on ECAL (without any selection)
- **Rough estimate by rescaling the KLOE numbers ⇒ 1 day (24 hrs): ~ 10 evts/cell**
- **Relaxing the "golden mip" selection: in few days ~ 10^3 evts/cell**

MIPs from beam (rock, magnet and Fe yoke, upstream ECAL modules)

- **~ 1.5 × 10^3 μ/spill (1 spill = 9.6 μs every 1.2 s) without any selection**

Cut	ECAL		Rock muons		Magnet events	
	Events	ε (%)	Events	ε (%)	Events	ε (%)
No cut	2.23	100.0	1447.26	100.000	50.82	100.000
μ in ECAL FV	2.23	100.0	12.73	0.880	18.92	37.229
STT & ECAL hits	1.63	72.9	6.05	0.420	3.443	6.775
NN cut	1.56	95.5	0.10	0.007	0.07	0.136

Table 40: Number of events per spill (9.6 μs, 7.5 × 10^{13} pot) and selection efficiency for the signal from ν_μ CC in the front barrel ECAL and the backgrounds from rock muons and magnet events.

(from DUNE-doc-13262, A Near Detector for DUNE)

Energy scale calibration

- γ's from π^0 decays, invariant mass reconstruction (need a vertex from the STT)

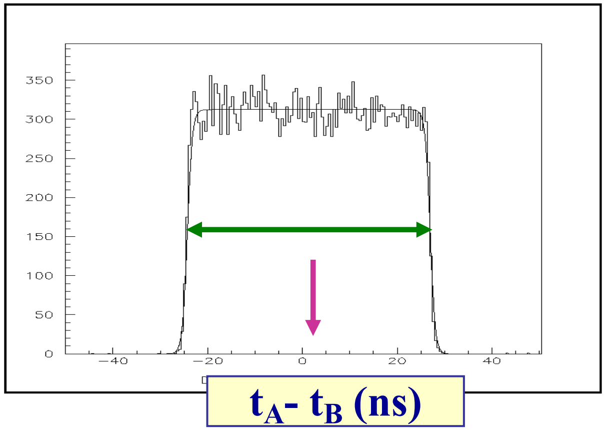
- γ + electrons: ~ 30% of photons from π^0 convert in the STT
  ⇒ ~ 50% of π^0 have at least one $\gamma \to e^+e^-$
  (from DUNE-doc-13262, A Near Detector for DUNE)

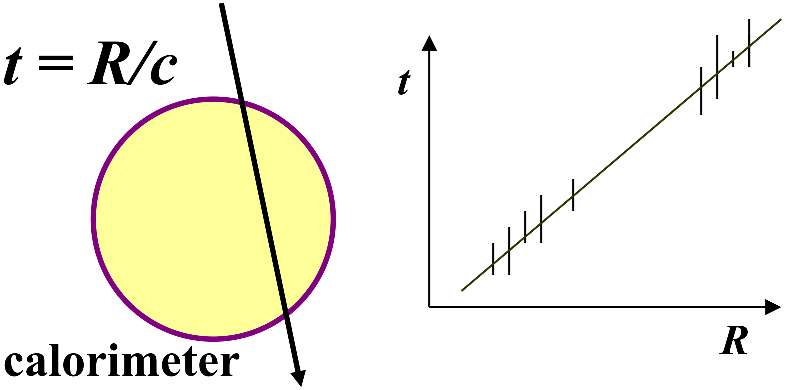
- Exploit $K^0 \to \pi^0\pi^0 \to 4\gamma$?

- High energy electrons from ν_e interactions
  ⇒ need the momentum measurement in the STT

Time Calibration

- Alignment of the t_0's: MIPs from cosmics and other beam particles





- Timing alignment with the rest of SAND: μ, π, and electrons from ν interactions with vertices and momenta reconstructed in the tracker