MEMPHYNO

Simulation studies for the prototype of MEMPHYS detector & Present status of MEMPHYS MC

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Jean-Eric Campagne, Nikos Vassilopoulos / LAL

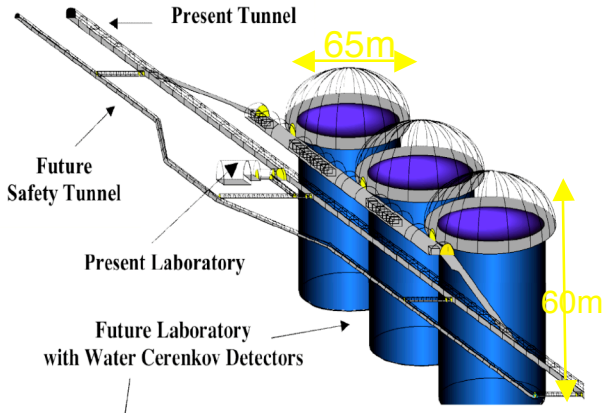
MEMPHYS : Megaton Mass PHYSics

a brief reminder

- water Cherenkov ("cheap and stable")
- total fiducial mass: 440 kt
- 3 cylindrical modules 65X65 m
  - size limited by light attenuation length (λ~80m) and pressure on PMTs
  - readout : ~3 x 81k 12" PMTs, 30% geom. cover (# PEs = 40%cov. with 20" PMTs)
- PMT R&D + detailed study on excavation @Fréjus existing & ongoing

- possible installation site:

  LSM @Fréjus



http://www.apc.univ-paris7.fr/APC_CS/Experiences/MEMPHYS/

arXiv: hep-ex/0607026

Contacts: J.E. Campagne and M. Mezzetto

physics goals :

- proton decay searches
- superNovae core collapse and diffuse neutrinos
- precision measurement of neutrino oscillations with beams and solar neutrinos

MEMPHYS MC

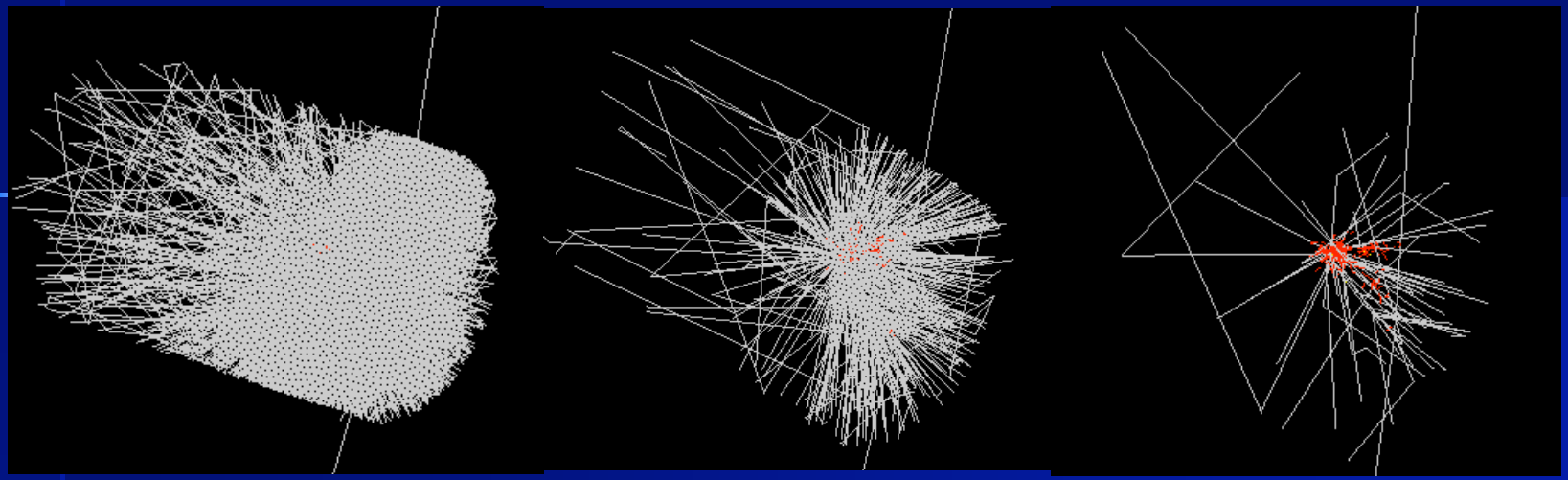
Present status

Jean-Eric Campagne / LAL

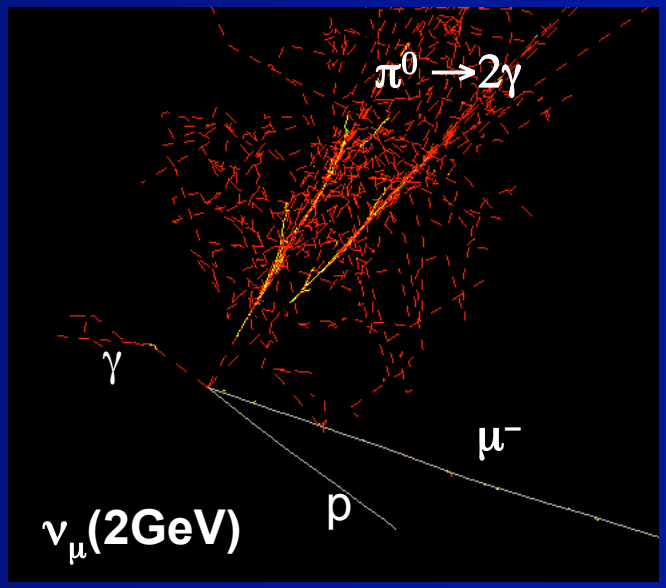
- Event Generator:
  - NUANCE for ν beam, ν Atmospheric & Proton Decay
- Simulation:
  - Version 0:
    - adapted from Geant 4 code used by M. Fechner et al. for T2K-WC-2km. The simulation was x-checked using SK & K2K data. Water & PMT & Black sheet optical parameters.
  - Current version 7:
    - Interface with the OpenScientist v16r0 framework (G. Barrand@LAL) provided using distribution kits including Geant4 & CLHEP & AIDA-IO implementation to RIO (also HDF5, XML)
    - 3 modes of running in the same framework:
      - Interactive Viewing, Batch processing, AIDA_ROOT analysis

- Current version 7 (Cont'ed):
  - Event info from MC
  - Primary + non-Optical photons track infos
  - Hits: each PM maintain a list of arrival time of optical photons detected (i.e photo-cathod efficiency)
- Future developments:
  - Code review to improve the geometry implementation, clean up the patches used to adapt the code from T2K-WC to MEMPHYS use case
  - Implement the electronics simulation: work in collaboration with B. Genolini (IPNO) in the context of PMm2.
  - Implement a Data Model to be able to do "replay" event-display

2km WC Geometry

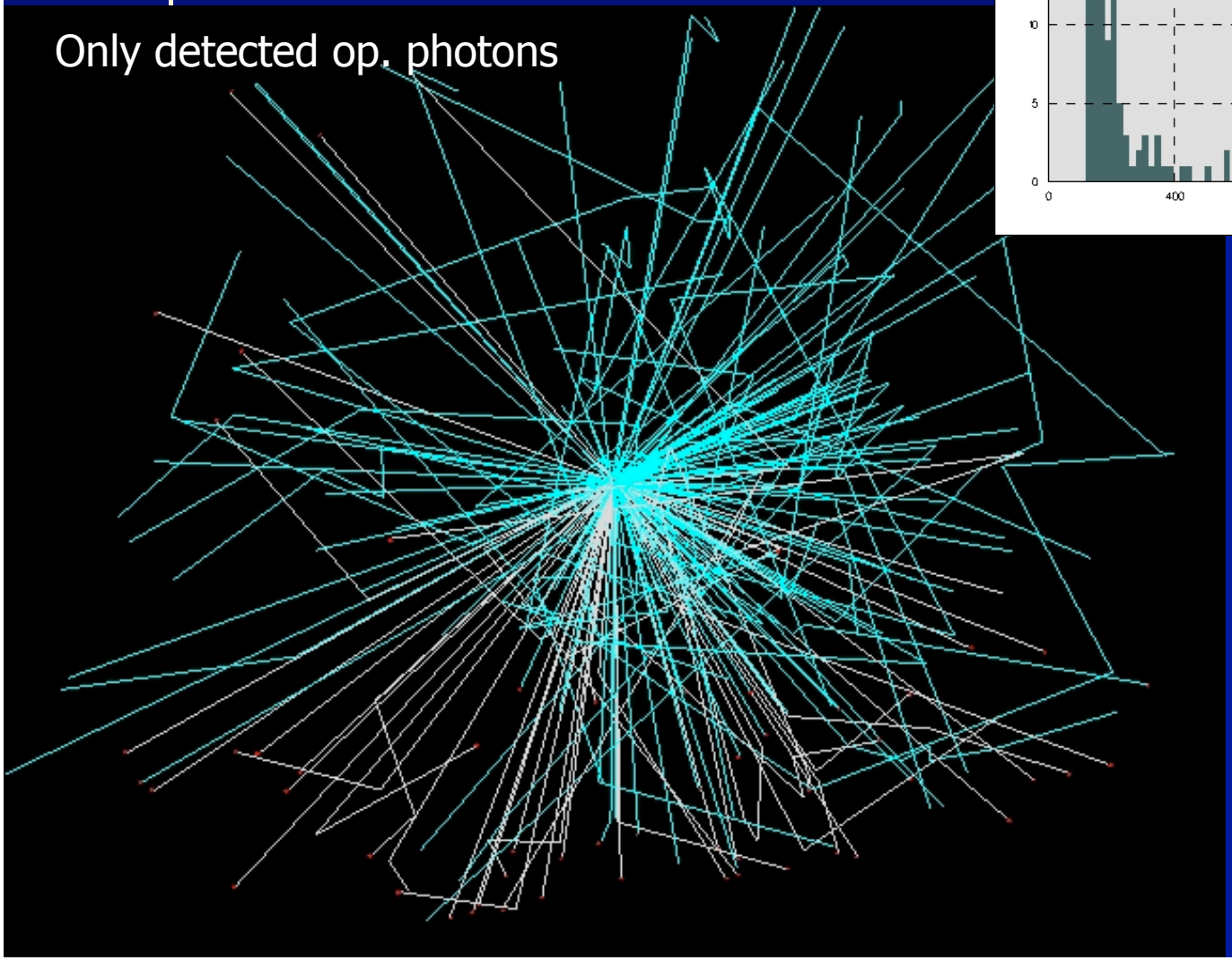


10% de γ Č | 1% de γ Č | 0.1% de γ Č

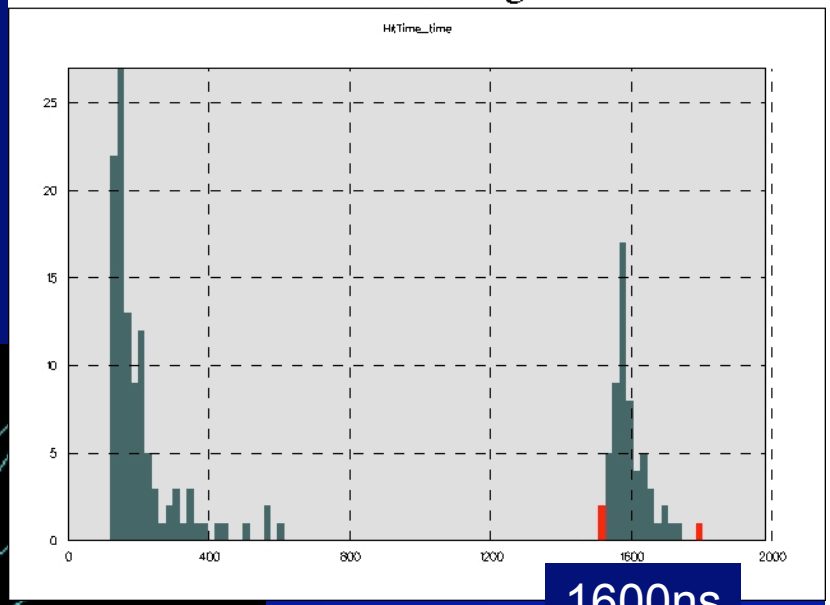


$\nu_\mu \rightarrow \mu^- \rightarrow e^-$

Only detected op. photons



HEPVis/SoPage

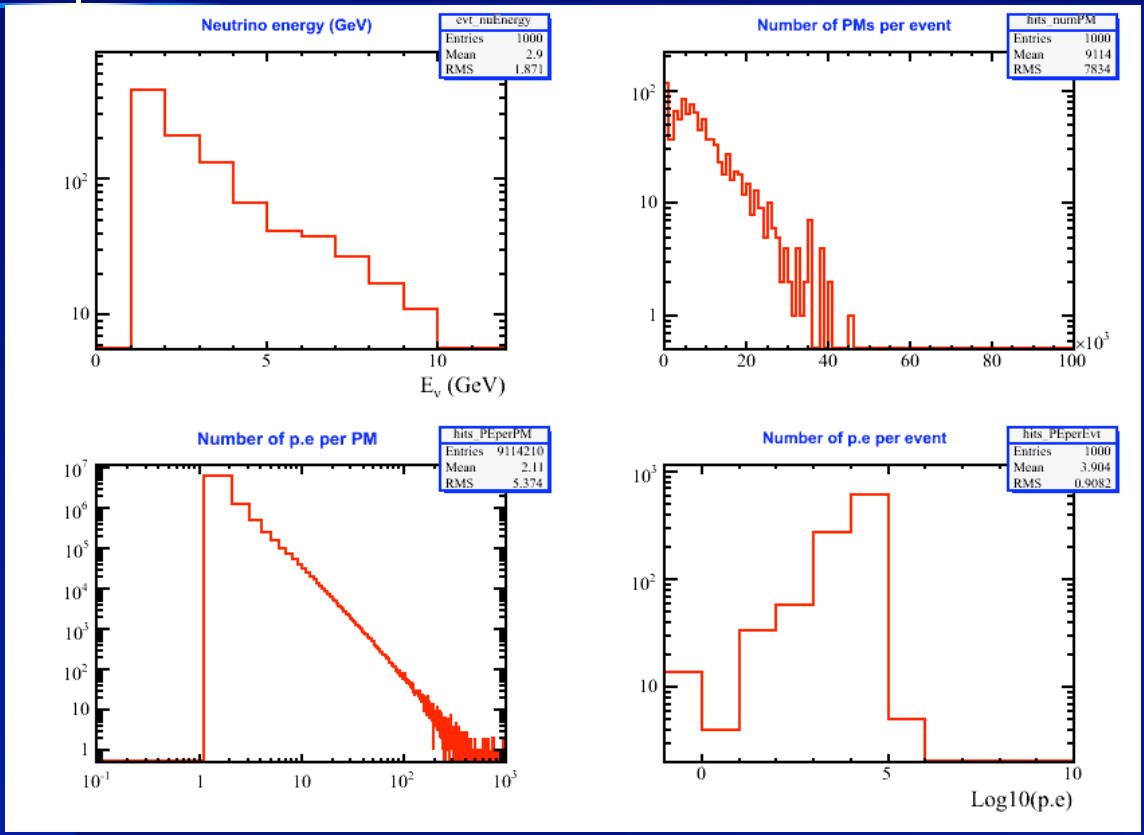


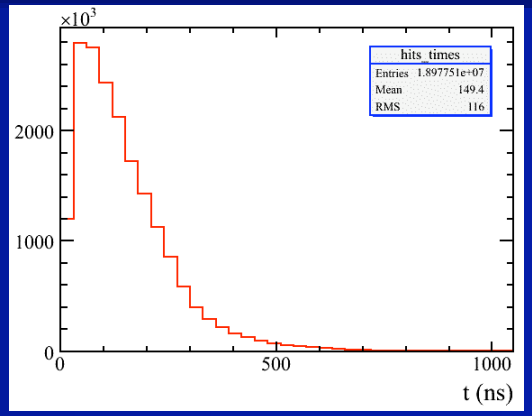
1600ns

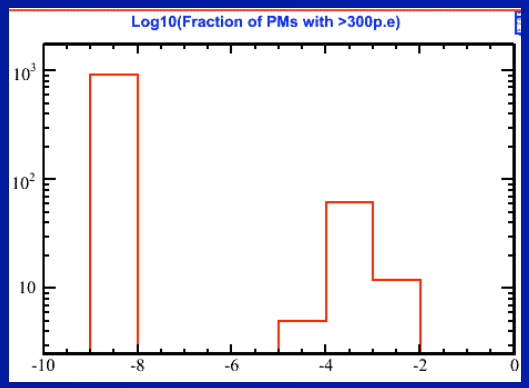
Interactive histogram to identify the e Michel optical photons…

MEMPHYS v7

ν atmospheric (1-10GeV)







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a small-scale MEMPHYS prototype

- purposes :

  1. full test of electronics and acquisition chain
  2. trigger threshold studies
  3. self-trigger mode

- volume ~10 t

- at least one matrix of 16 PMTs with DAQ system (developed by **PMM2** project, J.E.Campagne et al.)

- install at APC, then at Fréjus lab: max available space: 3x3x3 m^3

- tests with radioactive sources (monoenergetic, point-like) and cosmic muons (direction selected with hodoscope) on surface

- measure background level @ underground site

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simulation parameters

- MEMPHYS simulation & visualization code
  by Jean-Eric Campagne, Guy Barrand et al. (based on GEANT4)

- 2x2x2m³ water volume
- 2 different PMTs' modules simulated at bottom side :
  - 4x4 12in PMTs =
    - ~35% coverage (for one side, shown)
  - 4x4 10in PMTs =
    - ~20% coverage (for one side, available)
- water refraction & blacksheet parameters a la SK
- MEMPHYNO detector display

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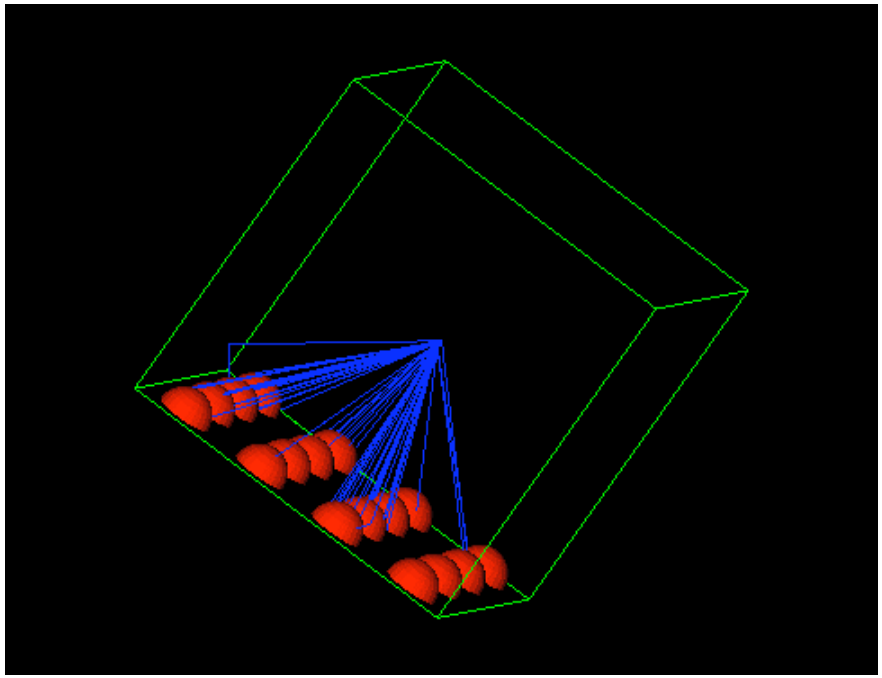
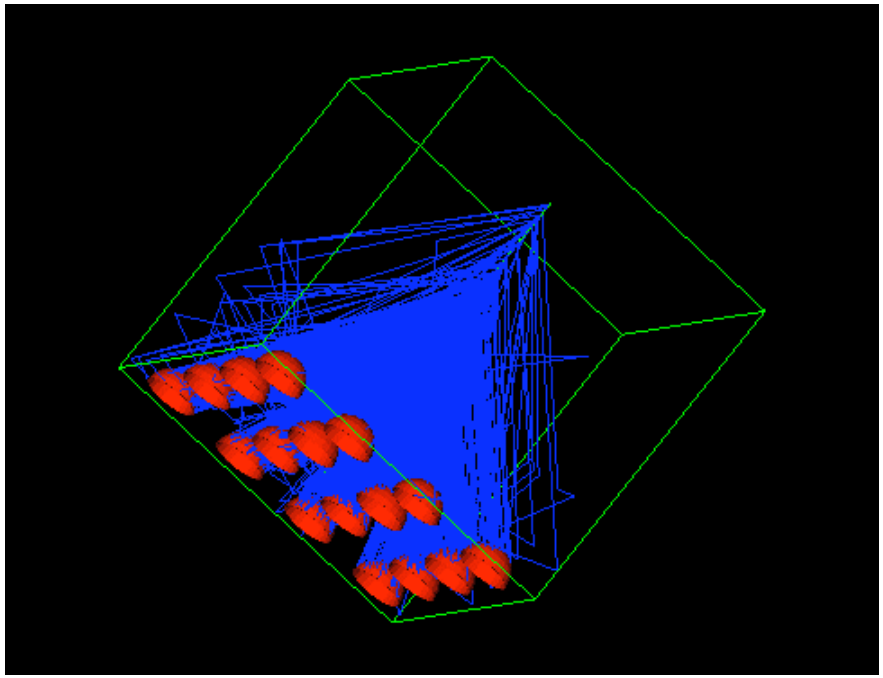
detector visualization

electron 10 MeV, pz / p = -1, vtx : centre



muon 1 GeV, pz / p = -1, vtx : top centre



shots taken only for optical photons detected

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event reconstruction

- particles generated (10k events samples per particle per energy) :
  1. electrons: E = 1 to 25 MeV
     → point-like sources deployed at the detector centre
  2. muons: E = 1 GeV, pz/p = -1 (also pz/p < 0)
     → downward selected muons

- plots of the following event (particle) characteristics:
  1. # of hit PMTs
  2. # of PEs per PMT
  3. opticalphotons' arrival times at PMTs

- preliminary analyses for vertex reconstruction & light propagation

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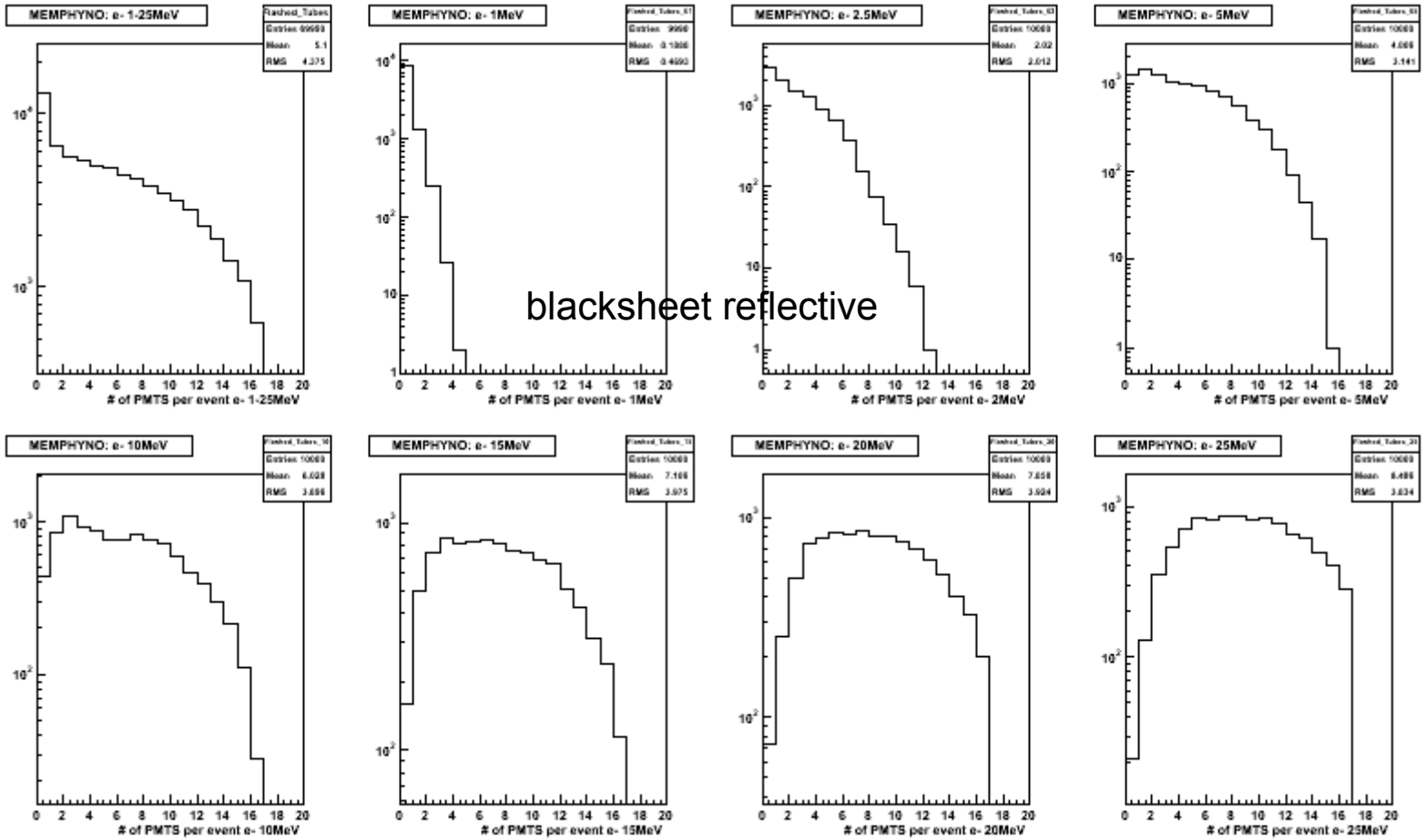
electrons 1 to 25 MeV

- # of hit PMTs :

7x10k electrons generated at the detector's centre with random direction



blacksheet reflective

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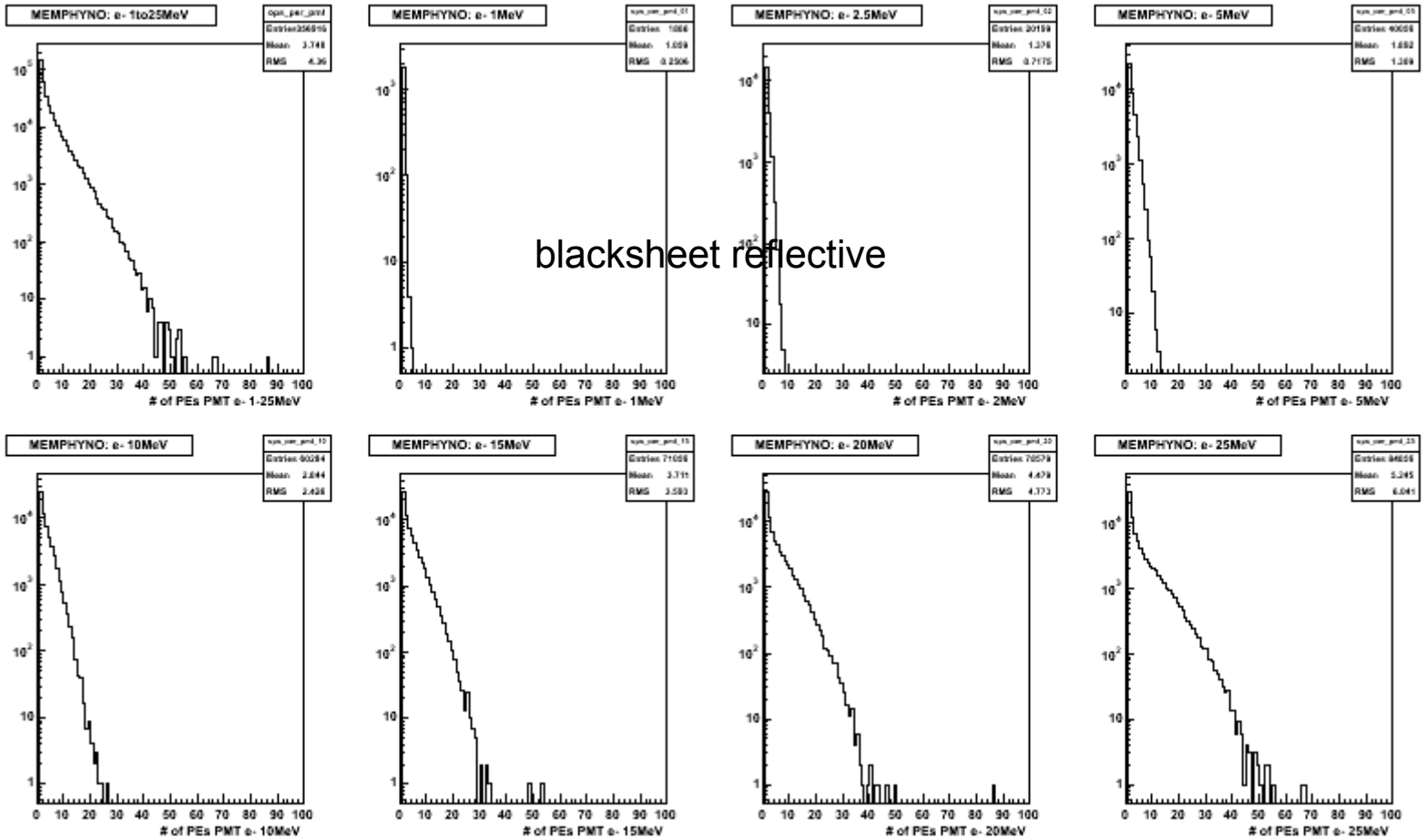
electrons 1 to 25 MeV

- # of PEs per PMT :

7x10k electrons generated at the detector's centre with random direction



blacksheet reflective

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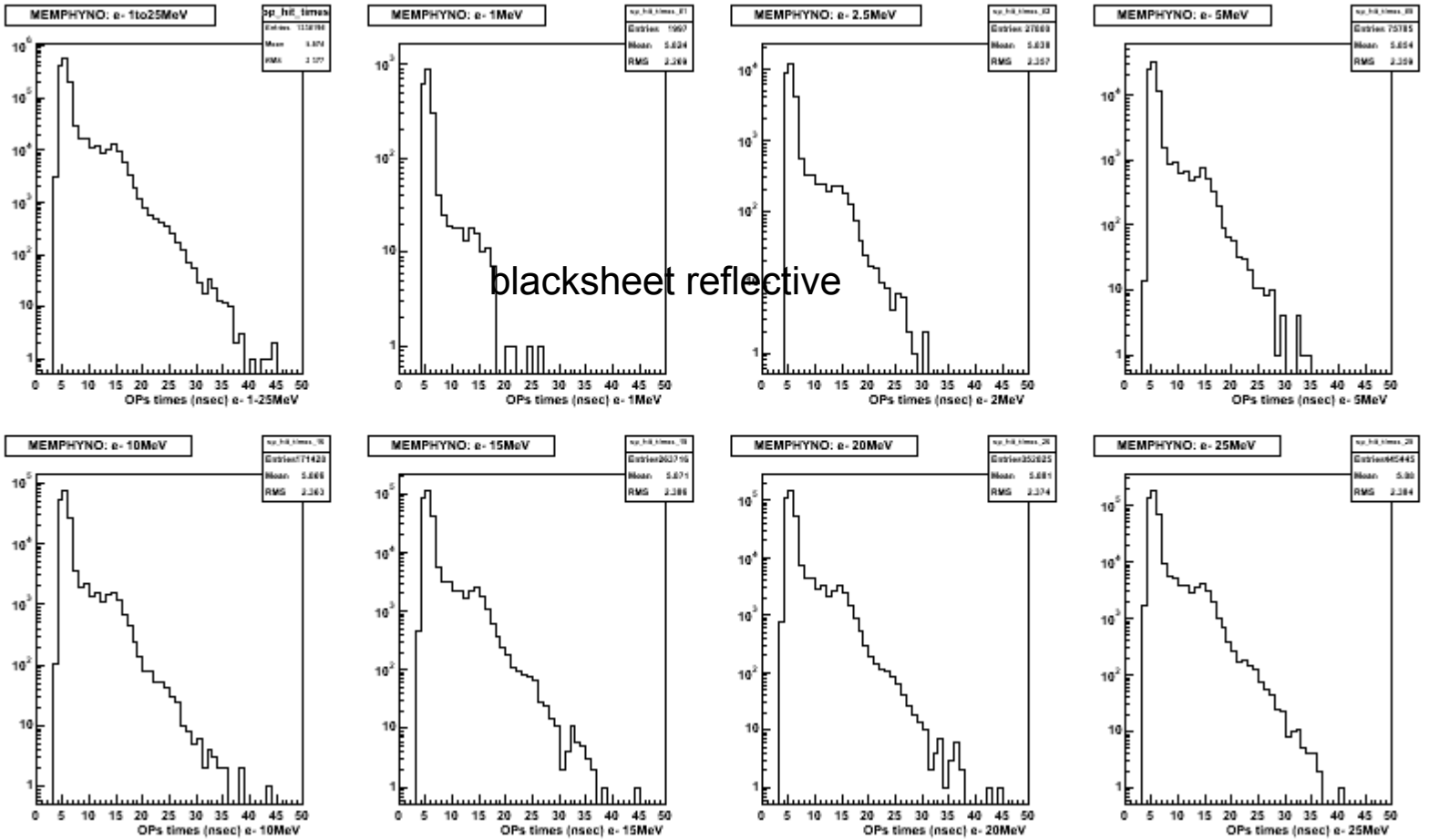
electrons 1 to 25 MeV

- opticalphotons' arrival times :

7x10k electrons generated at the detector's centre with random direction



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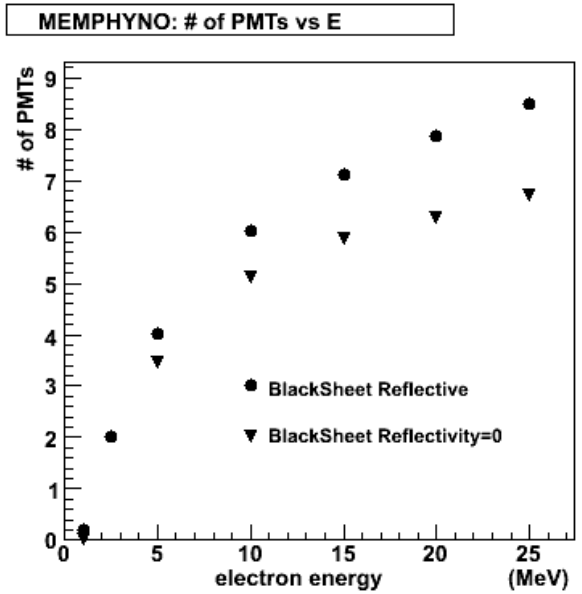
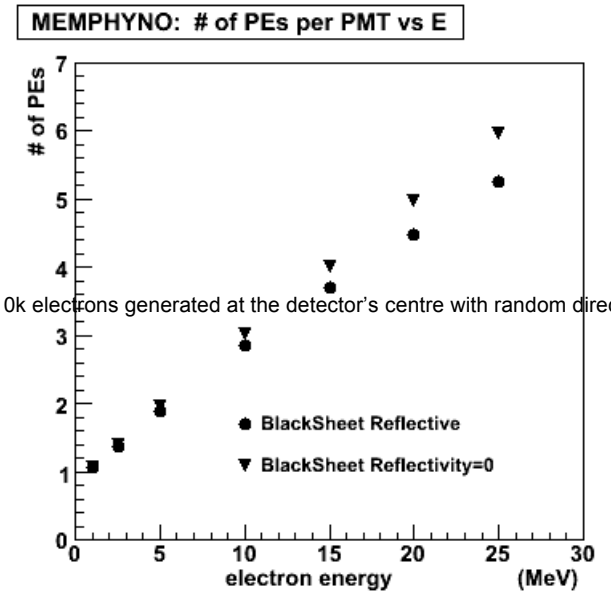
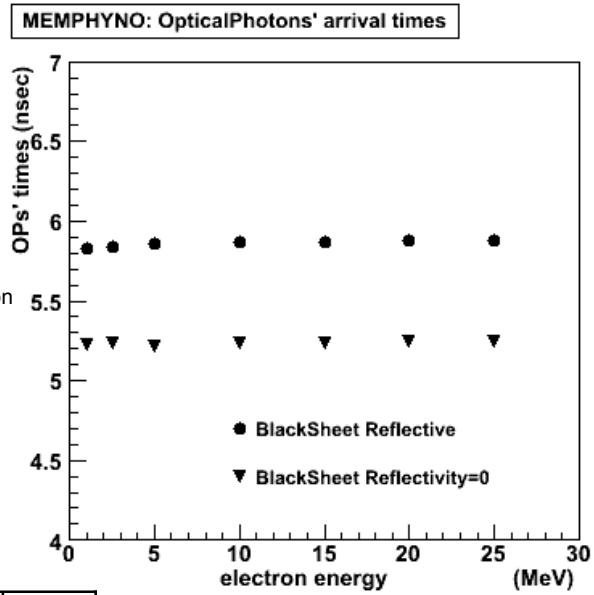
electrons 1 to 25 MeV

- average values of
  - # of PMTs per electron
  - PEs per PMT
  - OPs' arrival times
- plots for
  - blacksheet reflective a la SK
  - blacksheet 100% absorption





7x10k electrons generated at the detector's centre with random direction



el E (MeV)	1	2.5	5	10	15	20	25
PEs / MeV / el	0.2	1.1	1.5	1.7	1.8	1.8	1.8
X 6 (sides)	1.2	6.6	9	10.2	10.8	10.8	10.8
MEMPHYS	2	7.7	10	10.9	11.1	11.2	11.1

- similar to MEMPHYS

Table: MEMPHYNO's PEs per MeV per electron with blacksheet reflective

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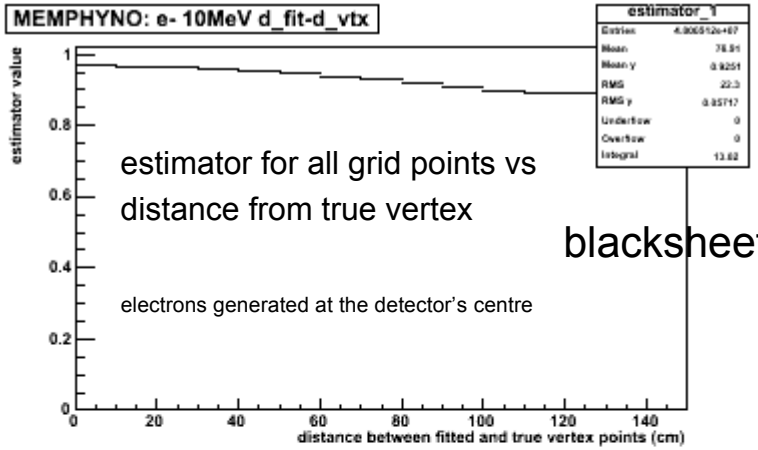
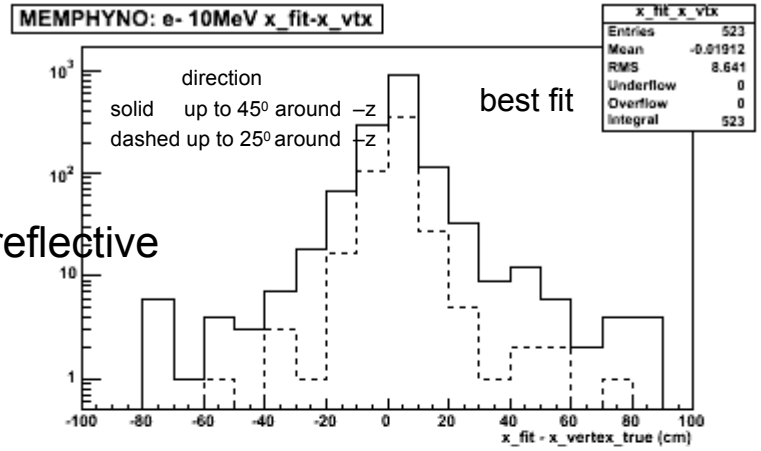
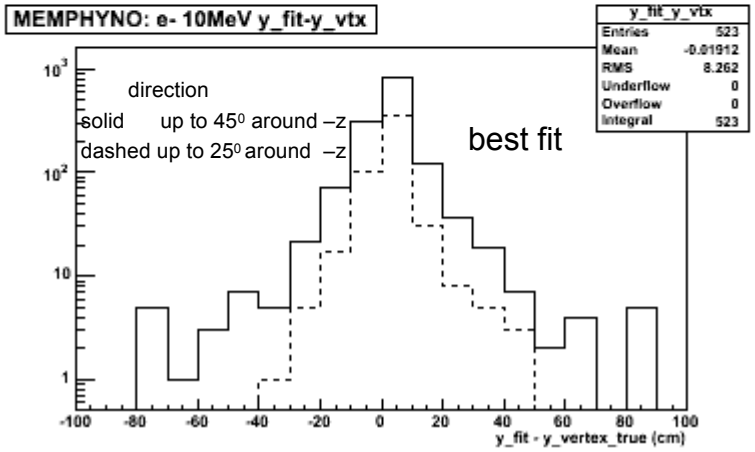
electrons 10 MeV : vertex finding

- primary vertex fit based only on each PMT's timing info: $t_{i\ PMT} = t_i + TOF_i \Rightarrow t_i = t_{i\ PMT} - TOF_i$, where $TOF_i = (n / c) \times D$, D = distance between each PMT and grid's coordinates
- maximize estimator $E(t_i)$ a la SK to find the true vertex of electron :



blacksheet reflective





for the primary fit :

- grid analysis (5cm spacing) in MEMPHYNO
- good resolution for downwards electrons in x-y plane where is the PMTs' module (shown)
- resolution becomes worse as pz/p increases due to one PMTs' module : best for perpendicular electrons

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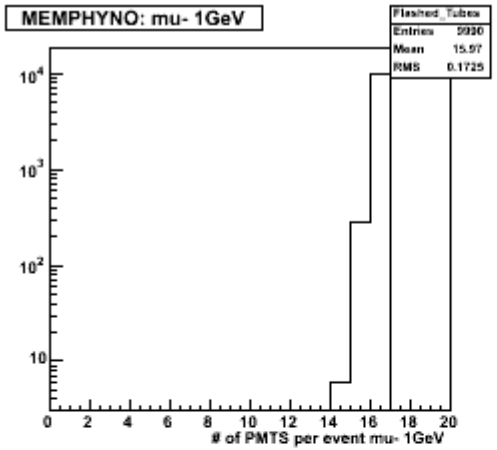
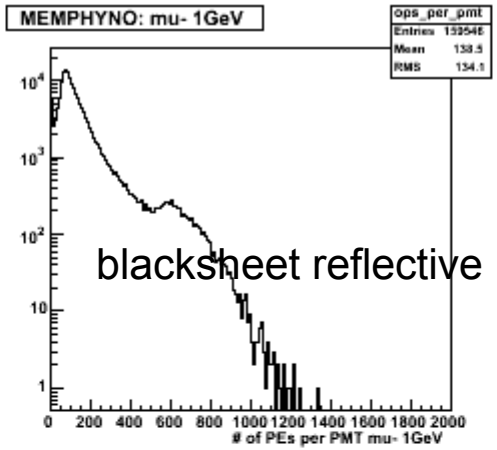
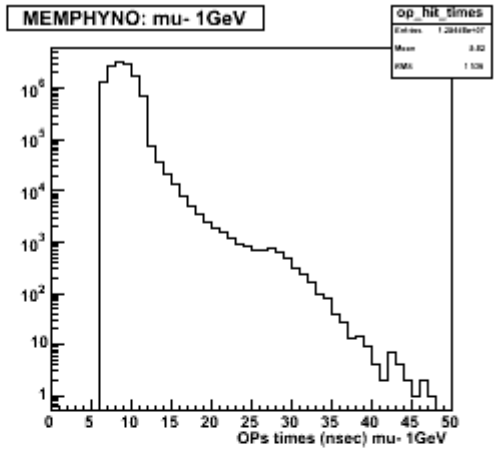
muons 1 GeV

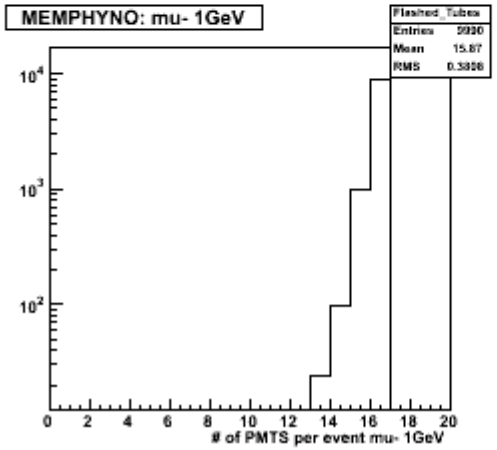
➢ # of PMTs per muon, # of PEs per PMT, opticalphotons' arrival times :

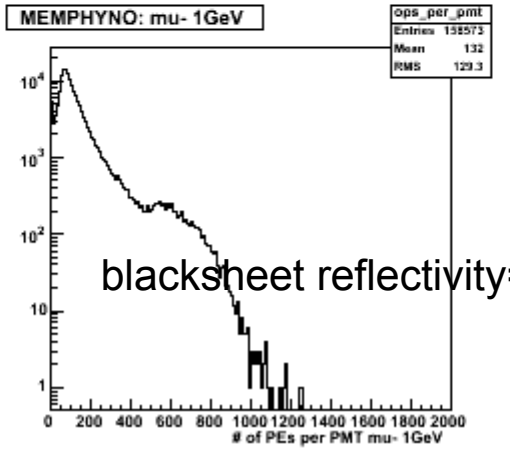




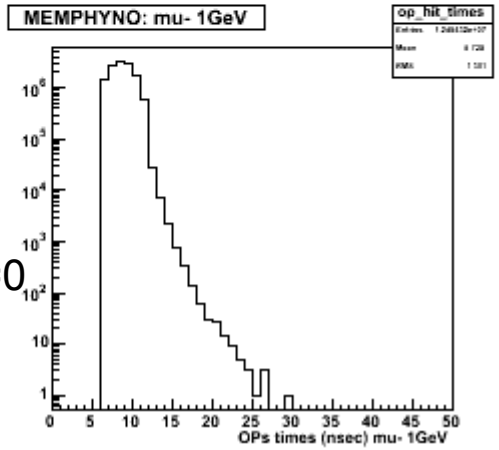
blacksheet reflective







blacksheet reflectivity=0



10k muons generated over the detector's surface with pz / p = -1

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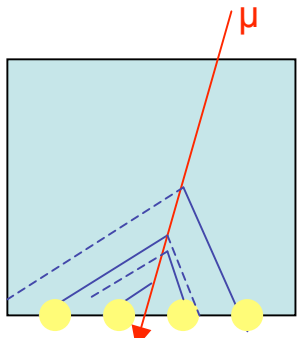
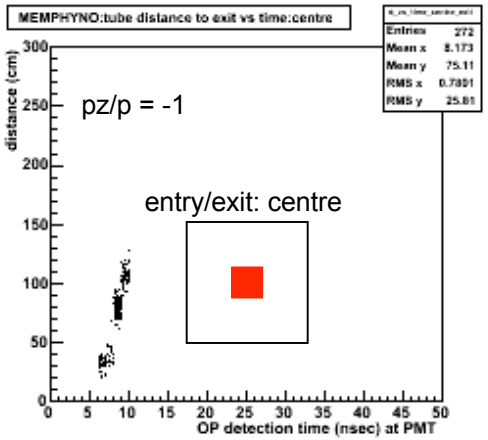
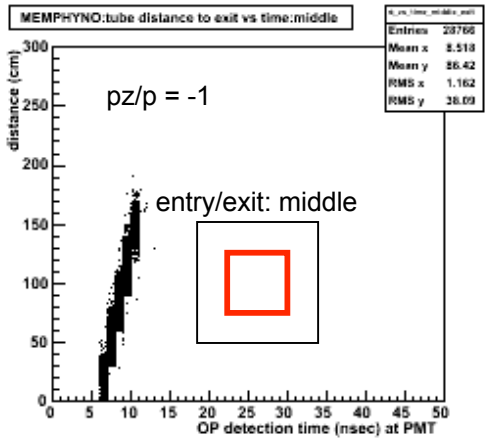
muons 1 GeV

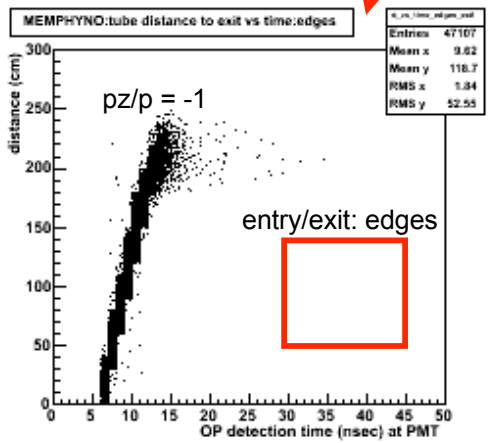


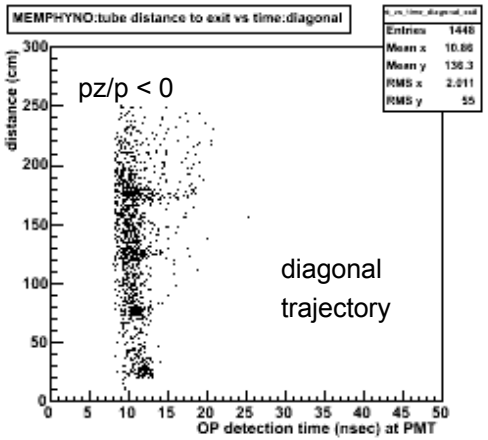
light propagation effect of OPs :

- check correlation of PMT time with distance between muon's exit point and detection PMT's coordinates









blacksheet reflective

- pz/p = -1 : later produced OPs are detected first
- pz/p < 0 : relation not clean

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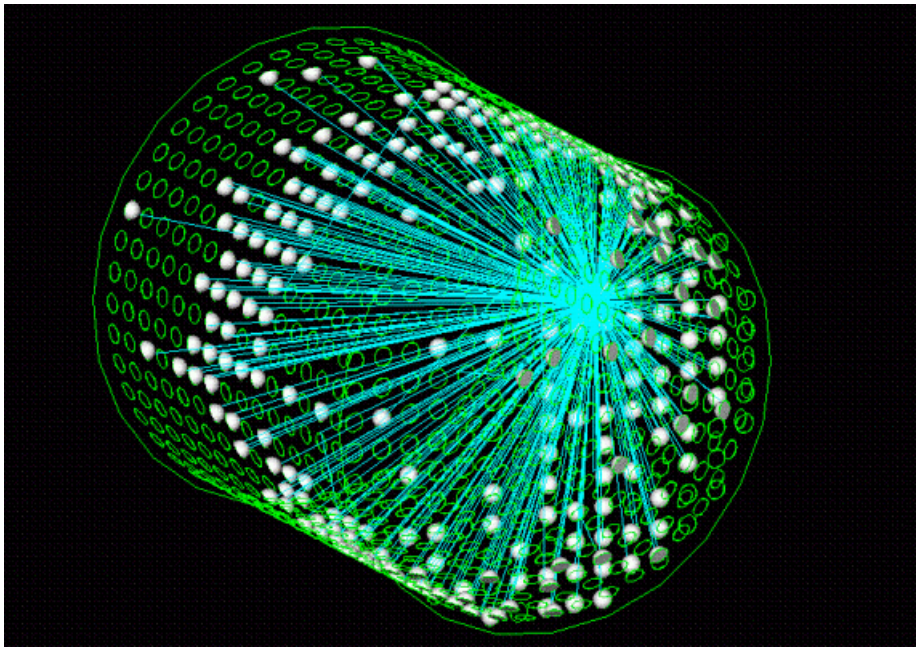
further simulation work

- on-going @ APC :

  - detector layout parametrization and analysis



One example
by E.Richard
Stagiaire @APC

  - ring reconstruction and PMT analysis graphics tools

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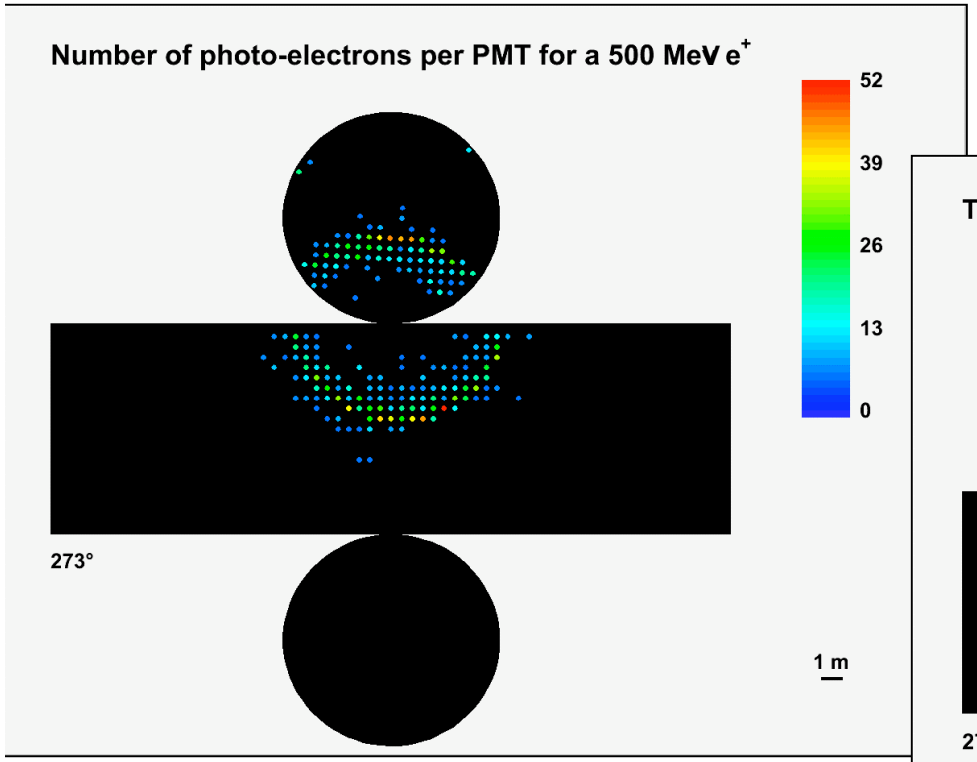
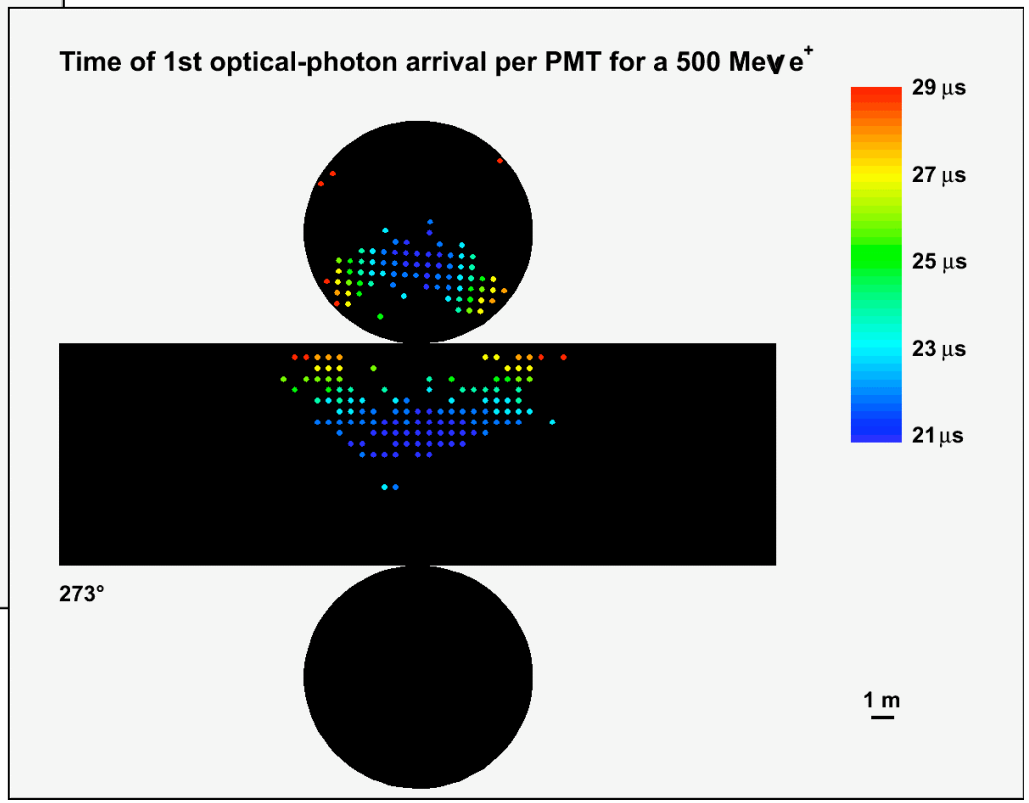
detector analysis tools for MEMPHYS/MEMPHYNO



Plots by E.Richard
Stagiaire @APC



- first steps towards event reconstruction & PID

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conclusions

- a detector prototype, similar to a MEMPHYS module, is going to provide a solid platform to perform tests on electronics :
  - DAQ
  - self triggering
  - threshold studies
- analyses, as far as detector characteristics allow, could be performed for :
  - vertex finding
  - light propagation
- work on simulation, mechanical design, PMT R&D at APC & LAL