WP8 – T8.5.2 TASD and MIND Detectors

E. Noah - 28.03.2012

(on behalf of T8.5.2 collaborators: expressed interest: Fermilab, Virginia, CERN, Geneva, Glasgow,

Imperial, RAL, Brunel, Liverpool, UCL, Valencia, Sofia, INFN Como, Trieste, Milano, LNF, RomaI/III, Bari, Padova, Milano, INO, INR, Annecy, Strasbourg, LLR Palaiseau)

Outline

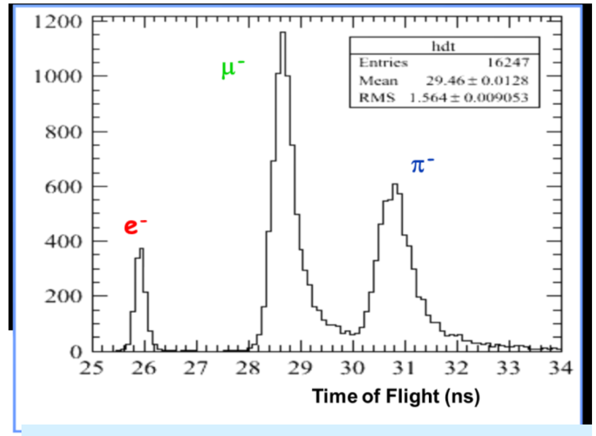
- AIDA neutrino detector activities
- Motivation
- Current neutrino physics landscape
- WP8.5.2 related activities: hardware
- WP8.5.2 related activities: software
- Milestones and deliverables

AIDA Neutrino-Related Activities

- Task 8.2.1:
  - Develop test beam area in H8 beamline (North Area at CERN)
  - A study of the upgrade of the H8 beam to deliver low energy electrons, muons and hadrons for neutrino experiment prototypes
- Task 8.5.2:
  - Build a Magnetised Iron Neutrino Detector (MIND) prototype
  - Install a Totally Active Scintillating Detector prototype inside the Morpurgo magnet
  - This will allow to **test both electron and muon charge ID** in the same test beam
  - Apart from the equipment, detectors and electronics we would also need a DAQ (would the common DAQ be suitable?)
  - MIND prototype becomes a facility for other users in the test beam

Motivation

Physics issues needing test beam input (from ISS report)

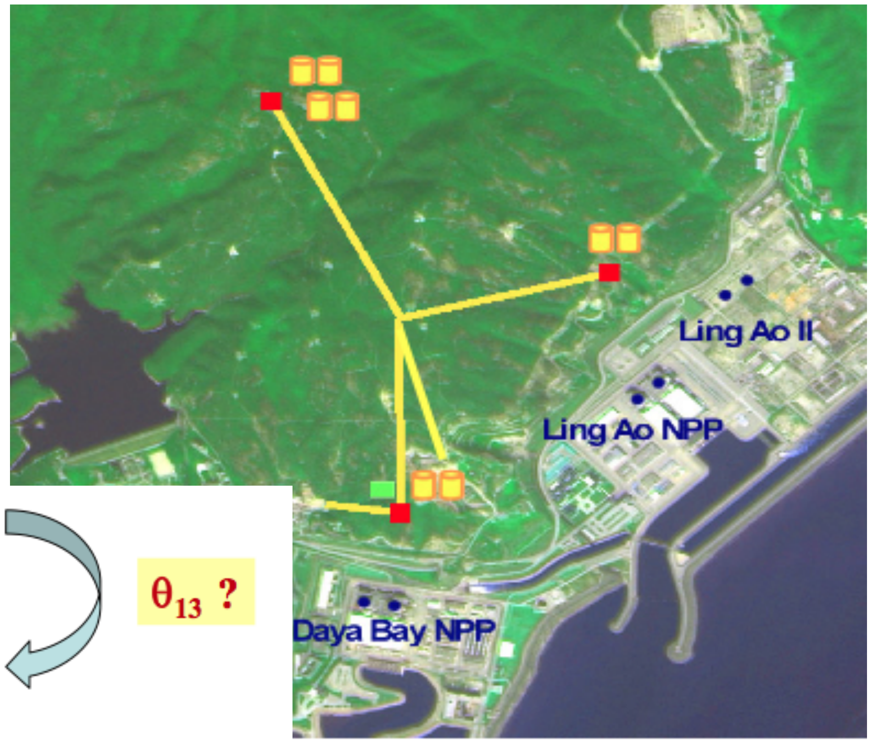


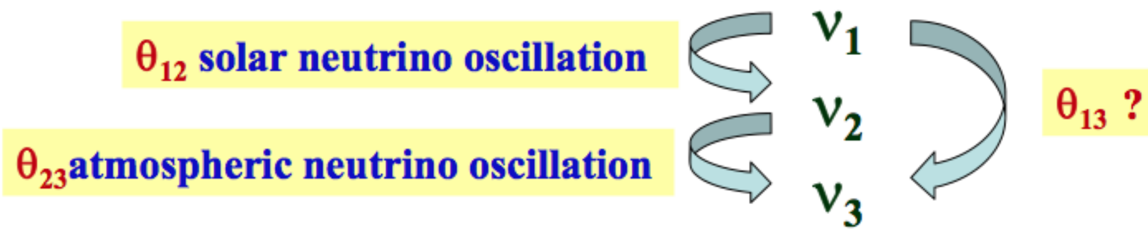
200 MeV/c e/mu/pi beam at RAL

- Stopping properties of pions and muons in
  - Minerva-like detector
  - This will be studied in the MICE EMR at RAL
  - using stopping e/mu/pi of both signs
  - For LArg/LENA could also be tested at RAL
  - (there exist a EUCARD TNA for that)
- Charge separation for electrons in magnetic field (TASD, Larg)
  - This can be studied in the MORPURGO magnet at CERN
- Muon Charge separation in MIND-like detector
  - This can be studied in a baby-MIND detector at CERN
- hadronic shower angular and transverse momentum resolution in
- TASD and MIND or LArg or LENA
  - (tau detection in superbeam or high energy neutrino factory)
  - this requires about 2m deep MIND (that is CDHS shower box)
  - and 5m deep (?) TASD or LArg
  - in hadron test beam e.g. at CERN or Fermilab
- How many interaction lengths are needed?

Latest Neutrino Measurement

- Daya Bay measurements:
  - March 2012: “Observation of electron-antineutrino disappearance at Daya Bay”
  - $\sin^2 2\theta_{13} = 0.092 \pm 0.016$ (stat) $\pm$ 0.005 (syst).



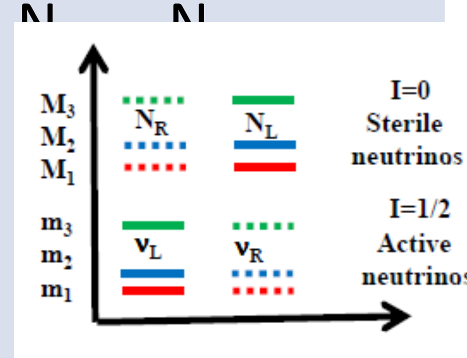


Y. Wang – IHEP – 08/03/2012

Potential physics in neutrino sector

- Neutrino mass
  - Neutrino oscillations giving rise to mixing and masses.
  - Measurement of absolute neutrino masses (e.g. tritium decay)?
  - Do neutrino masses obey a generation hierarchy (maybe reactor, long baseline Nova, Laguna)?
  - To what extent do massive neutrinos contribute to the hot dark matter in the universe?
- Neutrino identity
  - Majorana- or Dirac-neutrinos: are neutrinos identical with their antiparticles (dbl β decay: Gerda/Majorana GS, Exo US)?
  - Do sterile, right-handed neutrinos exist in nature?
- Neutrino structure
  - Does the neutrino have a non-vanishing magnetic moment?
- Conservation laws
  - Is lepton number conserved/violated in charged lepton sector?
- Non-standard weak interactions
  - Do scalar or tensor-type Lorentz structure interactions contribute in neutrino production reactions (deviations from V-A)?
- New decay modes
  - Do pions and muons obey new and exotic decay modes (MEG/μ3e PSI)?
- Coherent neutrino scattering
  - Does coherent scattering of low energy neutrinos off nuclei exist?
  - Is neutrino coherent scattering the dominant mechanism of energy transfer in supernove explosions?
- Weak interaction neutral current – charged current interference
  - To what extent is neutrino electron scattering affected by the destructive NC/CC interference of W- and Z-gauge boson exchange as predicted by the Standard Model (dynamic properties of weak interactions)?

Neutrinos : the New Physics there is… and a lot of it!

SM	Dirac mass term only	Majorana mass term only	Dirac AND Majorana Mass terms
ν_L ν_R I= ½ ½	ν_L ν_R ν_R ν_L ½ 0 ½ 0	ν_L ν_R ½ ½	N N 
X 3 Families	X 3 Families	X 3 Families	X 3 Families
6 massless states	3 masses 12 states 3 active neutrinos 3 active antinu's 6 sterile neutrinos… 3 mixing angles 1 CP violating phase	3 masses 6 active states No steriles 3 mixing angles 3 CP violating phases 0νββ	6 masses 12 states 6 active states 6 sterile neutrinos… More mixing angles and CPV phases 0νββ → Leptogenesis and Dark matter

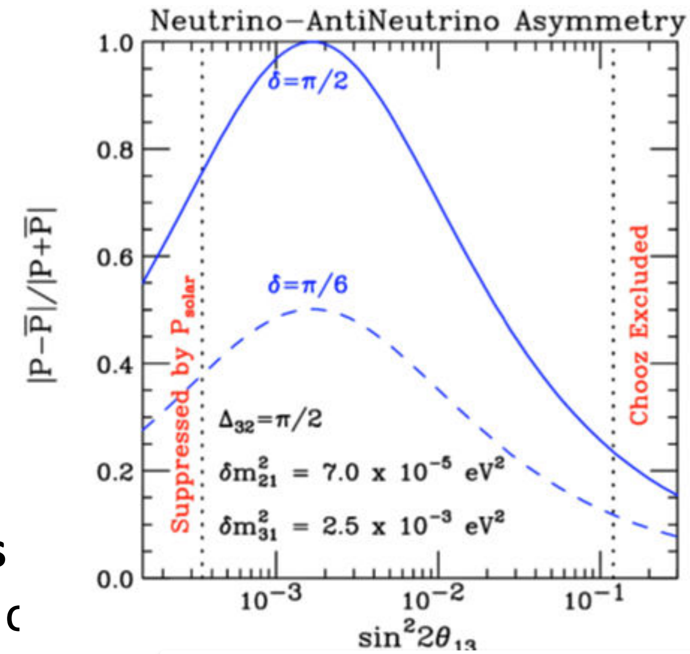
Mass hierarchies are all unknown except $m_1 < m_2$

Preferred scenario has both Dirac and Majorana terms …

… a bonanza of extreme experimental challenges

A. Blondel

Neutrino detector challenges



CP asymmetry decreases as $\sin^2 2\theta_{13}$ increases… Systematics!

Challenge of precision

- $\sin^2 2\theta_{13}$ is large: challenge is signal **systematics**
- Asymmetry is at most 25% and 5% systematics on each of neutrino and antineutrino leads to
  a) signal cross-section systematics (including selection cuts!)

$$\frac{P(\nu_\mu \rightarrow \nu_e) - P(\nu_\mu \rightarrow \nu_e)}{P(\nu_\mu \rightarrow \nu_e) + P(\nu_\mu \rightarrow \nu_e)} \rightarrow \Delta A_{CP} = 2\,\Delta \frac{\sigma^{signal,far}(\nu_e)/\sigma^{signal,near}(\nu_\mu)}{\sigma^{signal,far}(\nu_e)/\sigma^{signal,near}(\nu_\mu)}$$

  b) near-far flux systematics
  c) systematic errors e.g. coming from uncertainty in matter effect.

Fluxes and cross-sections must be known to better than 5%

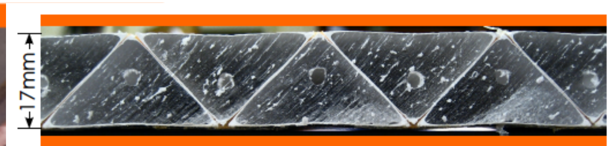
Neutrino detector requirements

- consider here near detector in two functions:
  - provide normalisation of experiment
  - provide cross-section measurements that are necessary for
    - background subtraction
    - interpretation of experiment in terms of oscillation probabilities

- requirements for near detector:
  - must be as good or better than far detector
  - (not as easy as it sounds, because the far detector is huge and provides excellent event containement)
  - must be located so as to allow good near/far extrapolation (not too close)
  - must allow precise measurements of cross-sections
  - (well defined fiducial mass and chemical composition)

- -- do we need magnetic detector?
- -- is detector location critical? (distance to beam, alignment to far detector?)
- -- detector chemical composition?

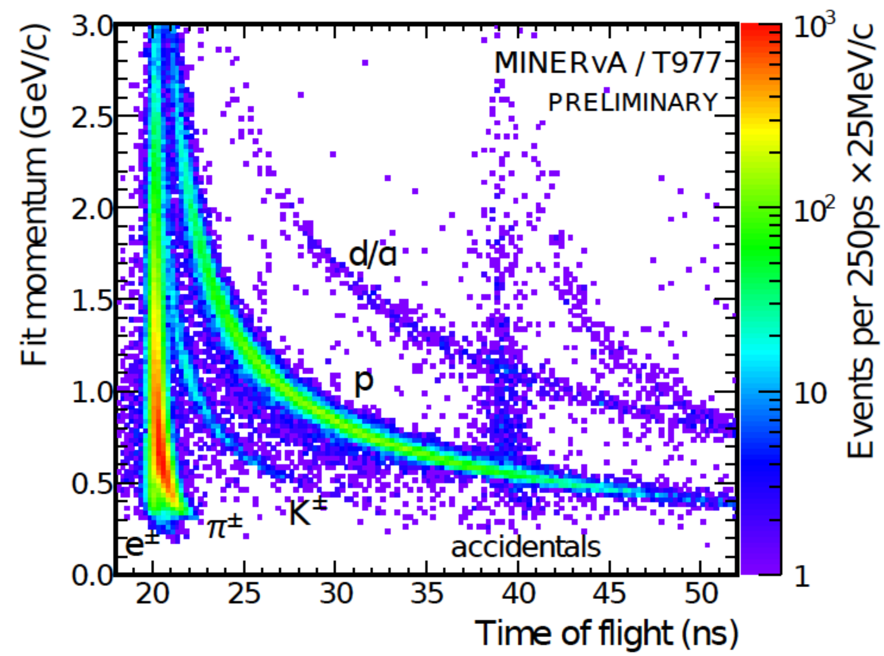
Minerva detector description



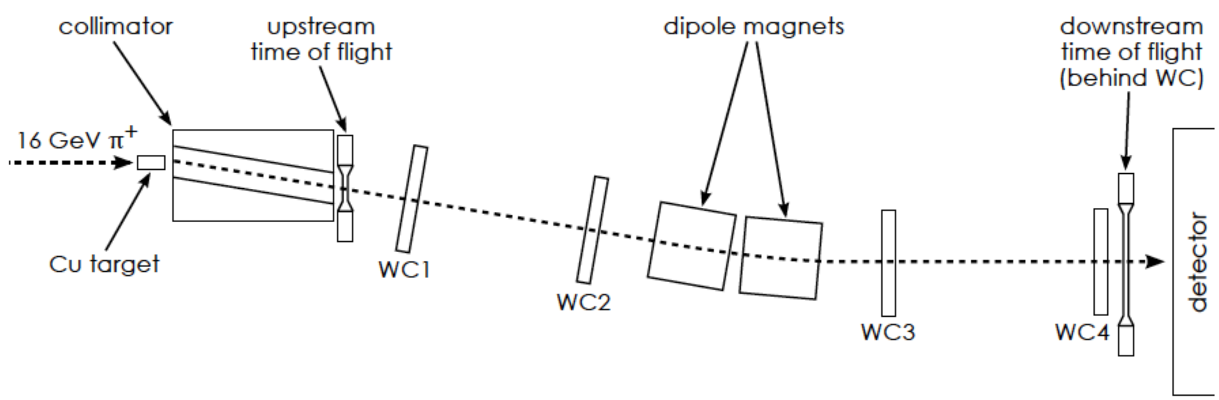
The detector is constructed of planes of triangular, extruded polystyrene scintillator laced with wavelength-shifting optical fiber.

MINERvA is a neutrino scattering experiment in the NuMI beamline at Fermilab, designed to measure neutrino cross-sections, final states and nuclear effects on a variety of targets in the few-GeV region. The MINERvA collaboration consists of scientists from both the nuclear physics and neutrino oscillation communities.

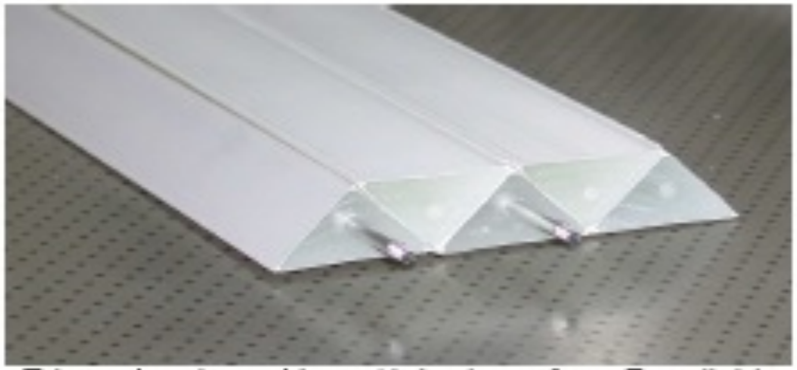
Minerva test beam



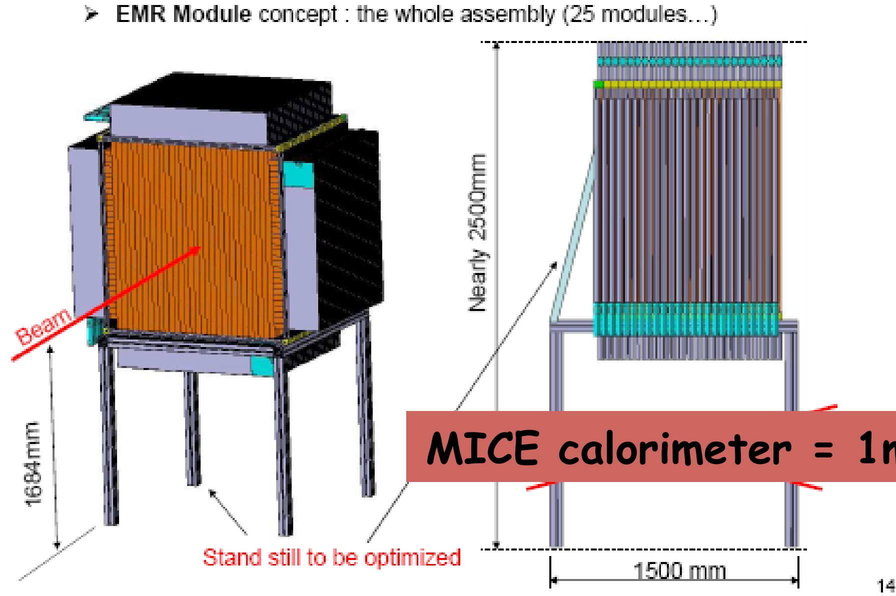
Purpose:



Fast detectors for magnetized near detectors in
Superbeam, beta-beam, neutrino factory



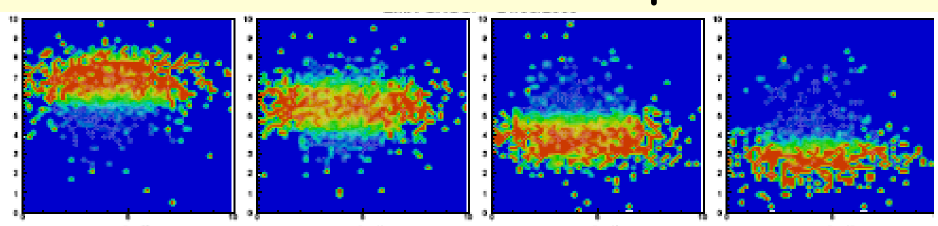
Triangular shaped bars (1.1m long, from Fermilab)



MICE calorimeter = 1m^3

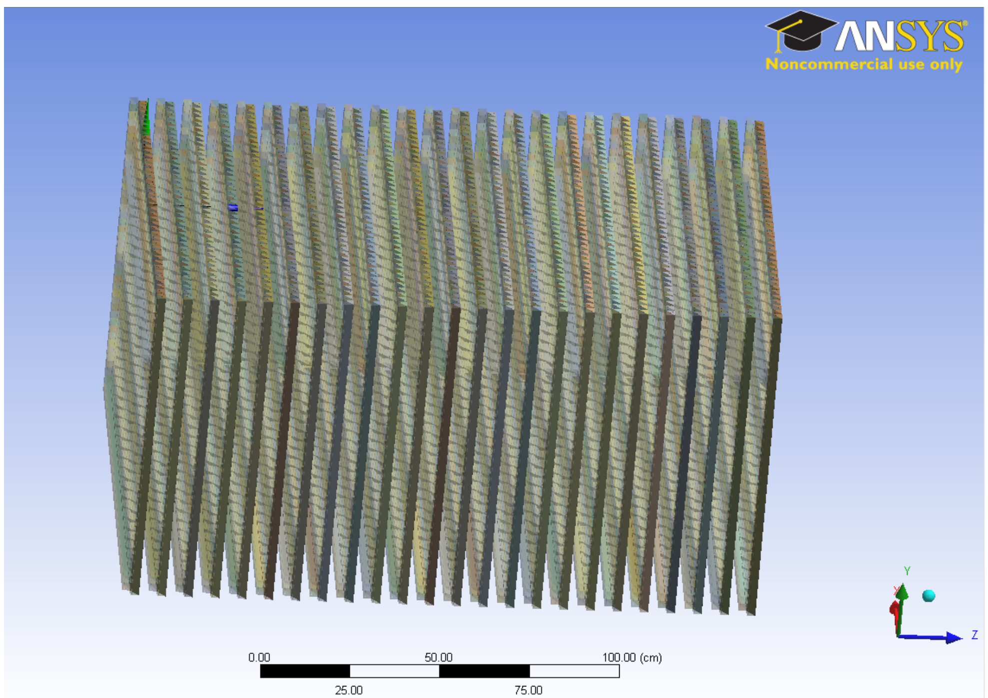
Accurate position resolution (mm)
→ triangular shaped scintillator bars
Magnetic field → si-PMT readout

First test in T9 beam at CERN – position resolution few mm

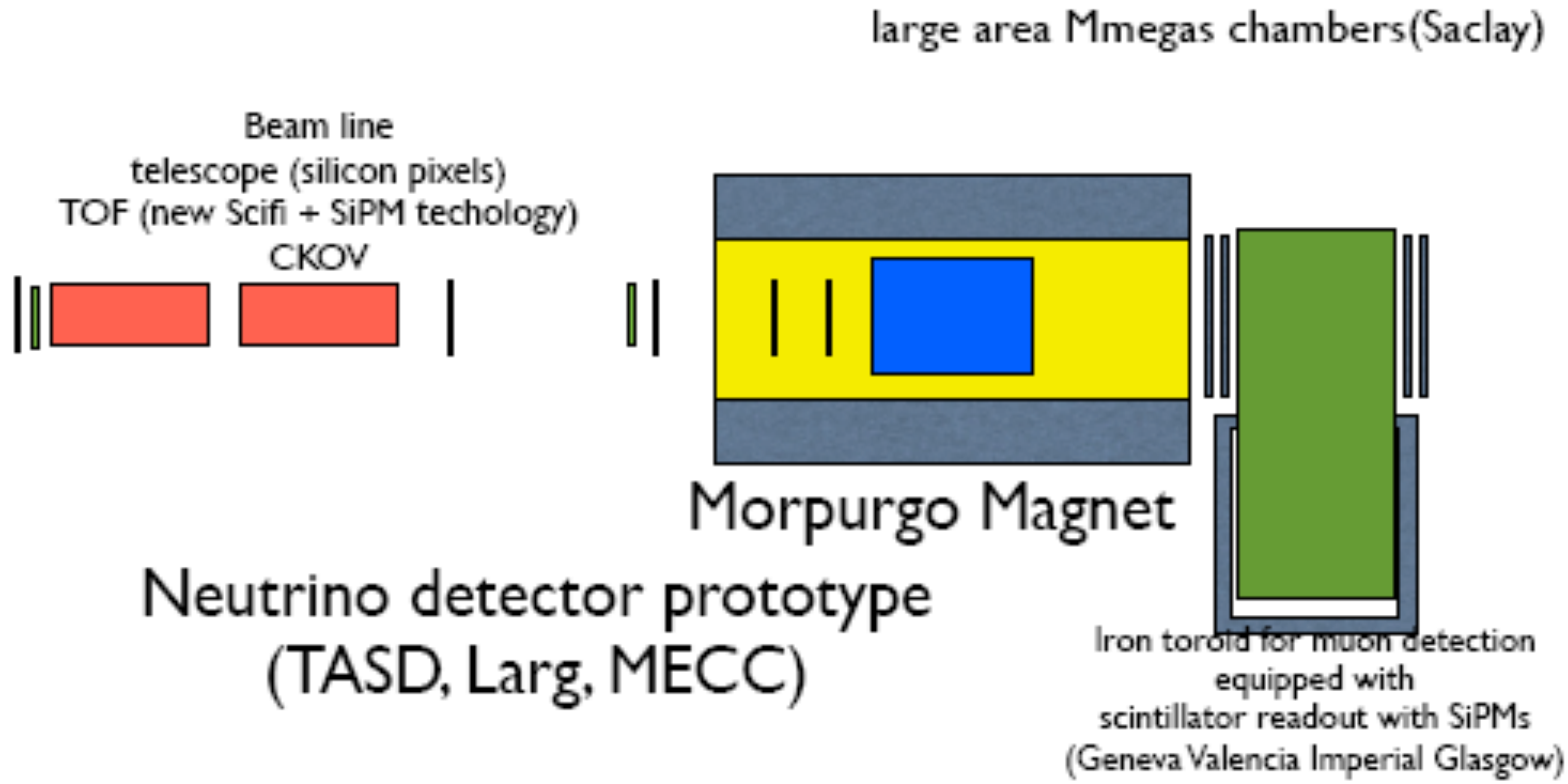


Next step: B field test

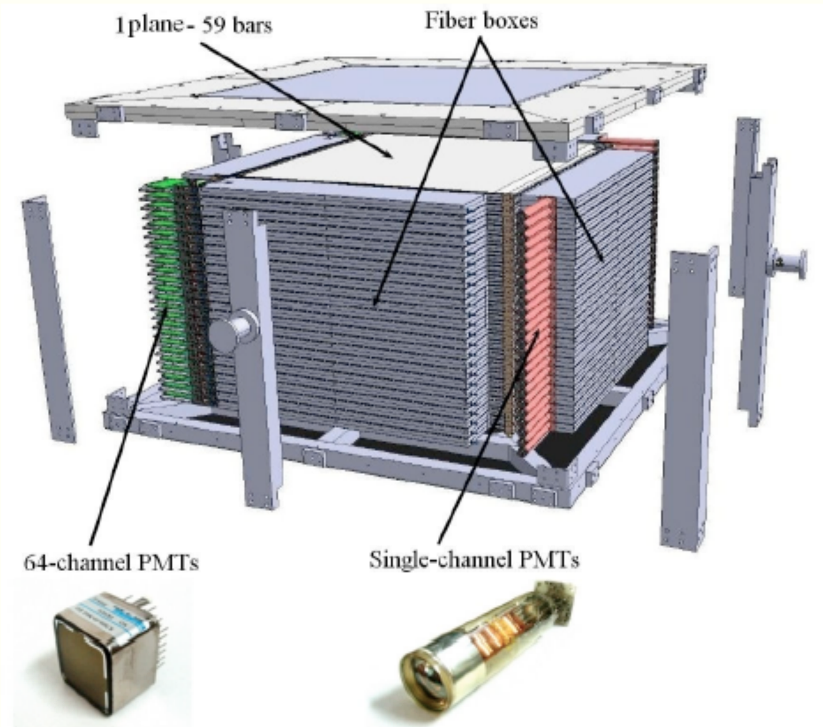
Next step: test at CERN in Dipole magnet in H8 →
1.6m diameter. Variable density by spacing planes
-- reconstruction of showering electrons
-- stopping properties of pions and muons



AIDA Preliminary layout



WP8.5.2 Related Activities: MICE EMR



EMR detector is designed to fully stop muons from the MICE cooling channel, provide distinct signatures for muons and electrons and measure their range.

Characteristics

- 24 modules (module = 2 X&Y planes)
- 59 triangular scintillator bars per plane $\rightarrow$ 2832 bars
- light is collected by WLS fiber transfered to PMTs by light guide
- total energy per plane is detected by single-channel PMT (PHILIPS)
- energy in every bar is detected by 64-channel PMT (HAMAMATSU)
- readout is performed by custom made electronics based on MAROC/FPGA ISICs and CAEN fADC
- custom made buffer board stores all hits (time over threshold) within MICE spill gate; pulse hight information is available at low rate

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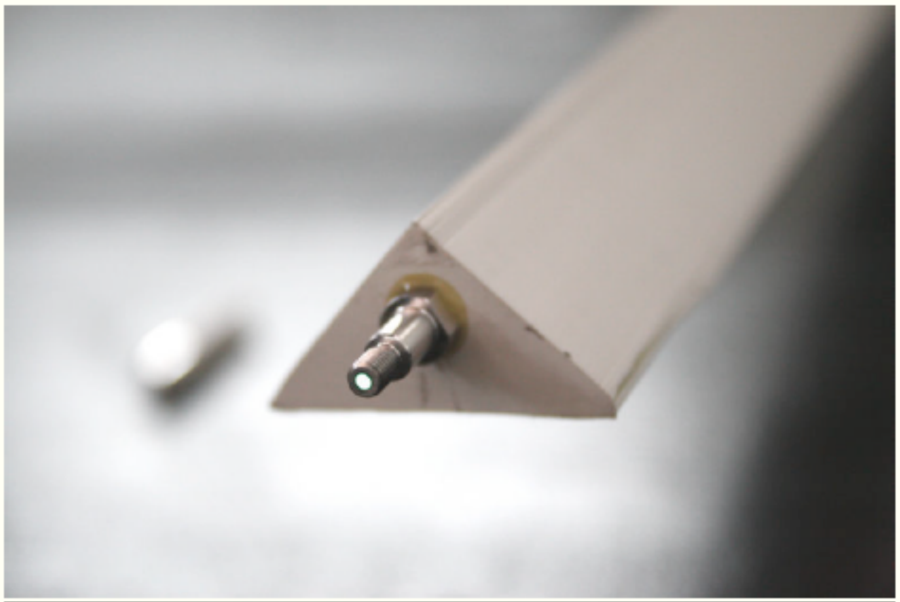
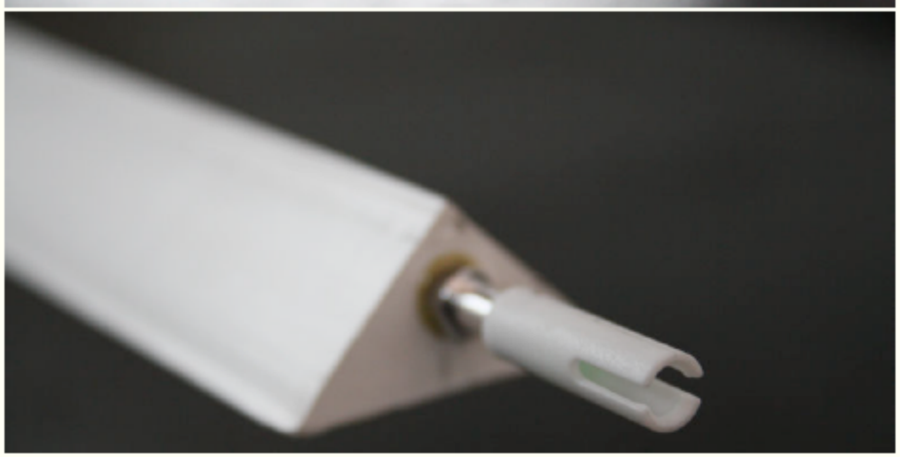
EMR: WLS-to-light guide coupling





- All connectors manufactured (plastic injection and machining)
- Light guide selected and tested
- Light losses and attenuation parameters measured
- Special polishing stand for bar connectors assembled

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EMR: New module assembly

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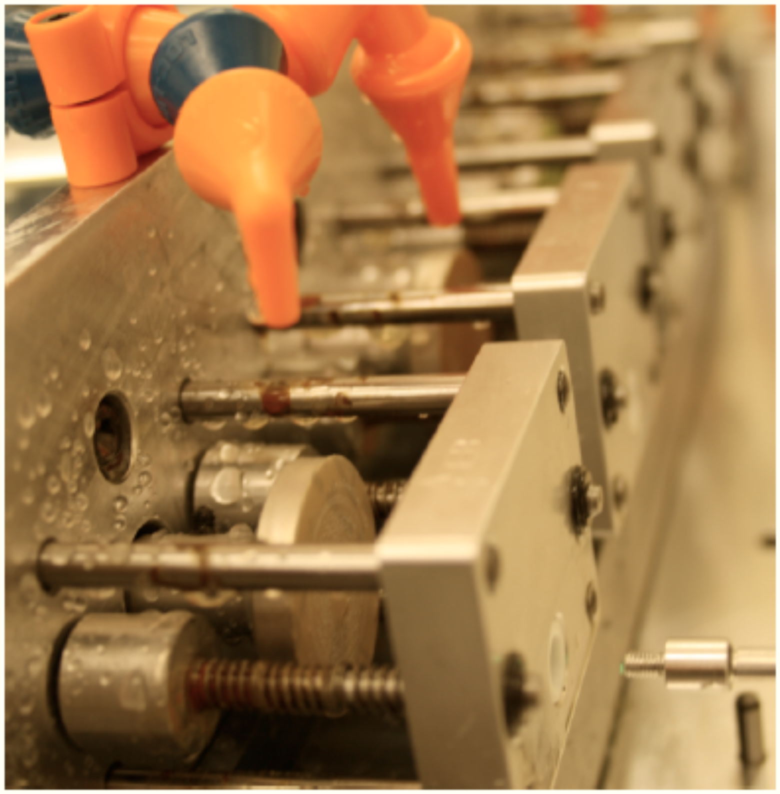
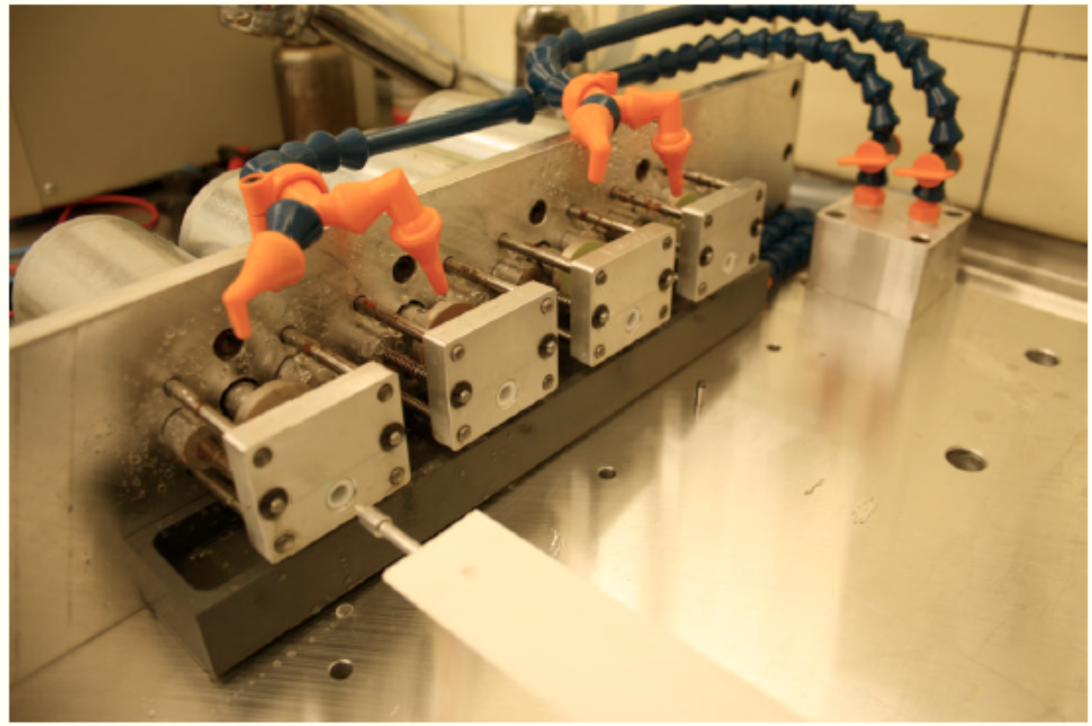
EMR: New polishing stand





- 5664 connectors (on bars) need to be polished
- 4 motors equipped with different polishing papers from course to fine grade

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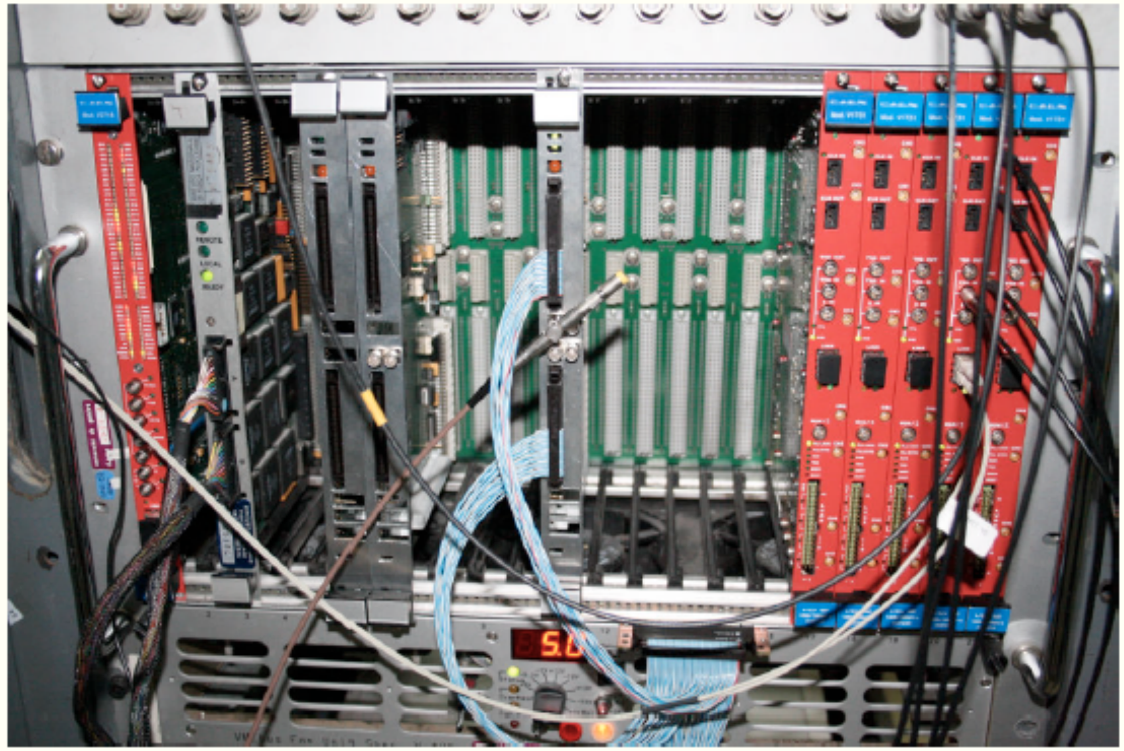
EMR: Electronics racks



- All high voltage and low voltage channels set up
- Monitoring and testing equipment set up
- All available boards are under tests

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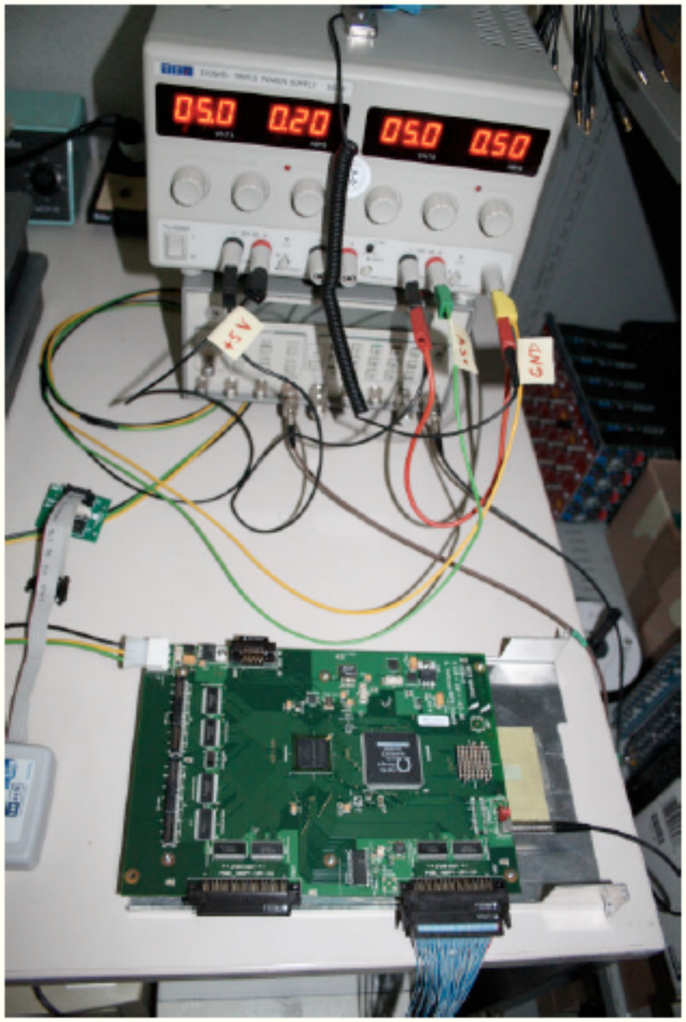
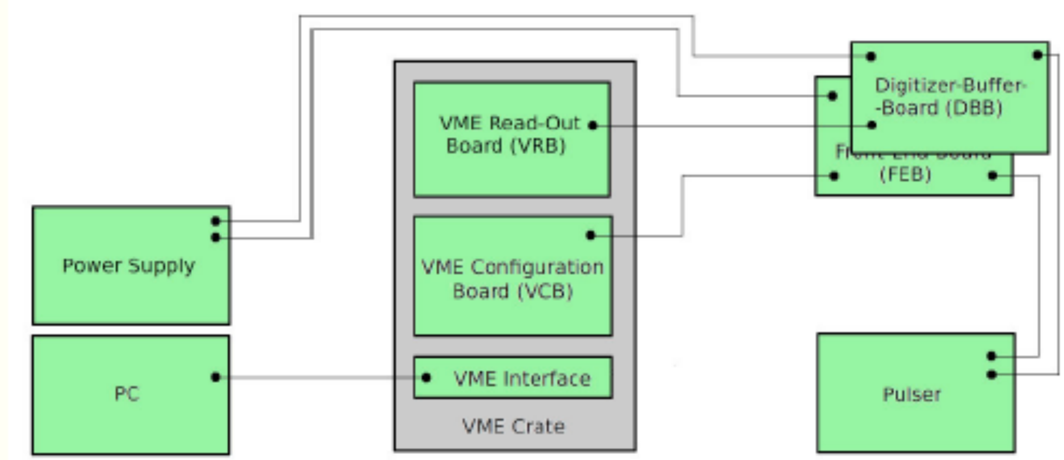
EMR: FEB/DBB Test bench





It is used to:

- test Front-End and Buffer Boards
- develop DAQ software
- test 64-ch PMTs

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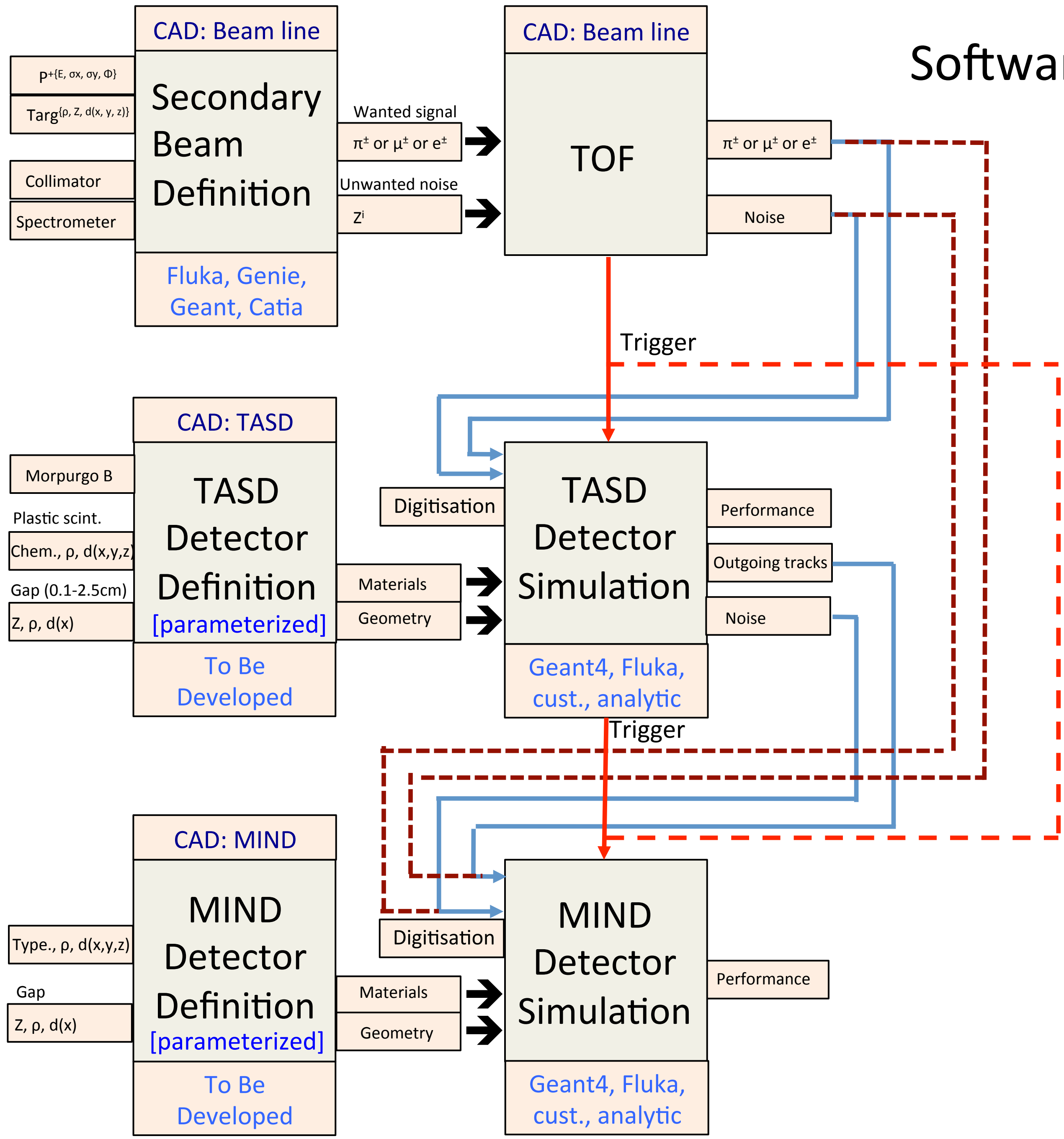
Software activities



Laguna LBNO near detector: Software

We started the development of the software infrastructure for simulation of the near detector. The major components are now in place.
No real physics results at this early stage of the work.
Done so far:

- Very naive simulation of the neutrino flux in the near detector: Pion decay in flight is simulated.
- Dedicated flux driver for GENIE.
- Simplified geometry of the detector: couple of volumes filled with different materials.
- Interface between GENIE and GEANT4 and tracking of the secondary particles are under development.

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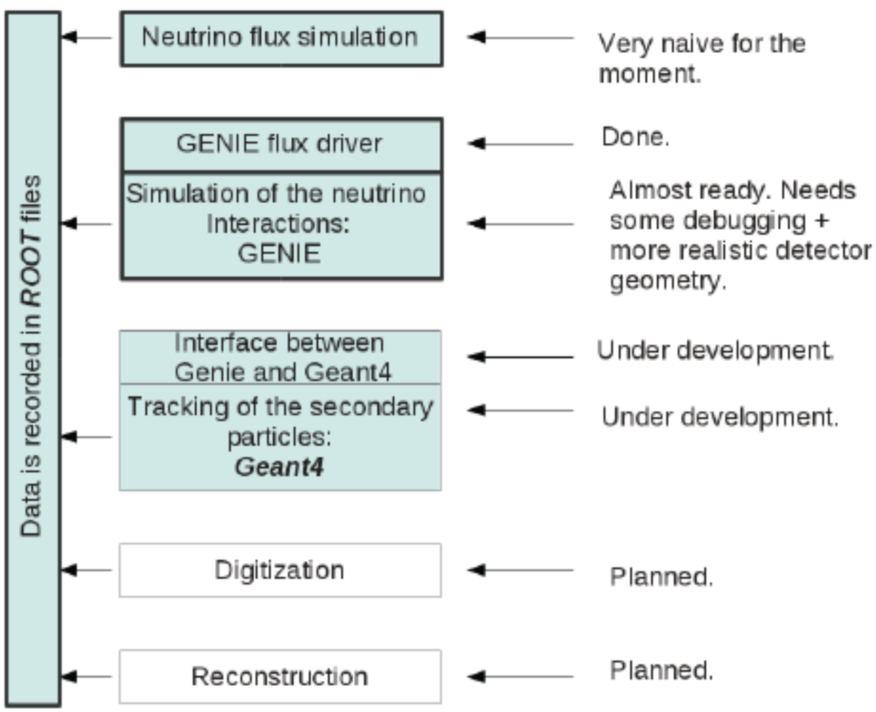
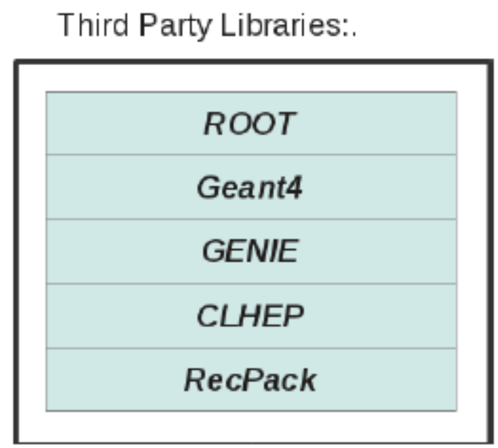
Laguna LBNO near detector: Software

Structure of the software:





- Build system based on CMAKE - done.
- Scripts for automatic installation of the software - under development.

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Simulations – FLUKA - preliminary

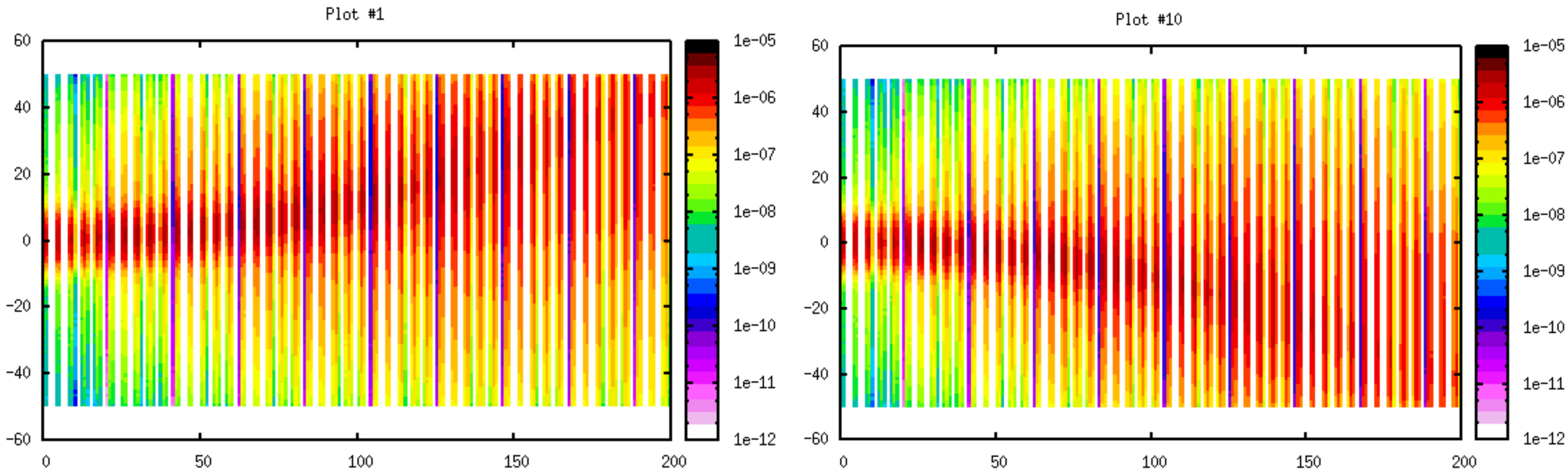
- TASD geometry
  - 17 mm thick plastic scintillator
  - 25 mm gap (vacuum)
  - x48 planes
- Incoming beam on TASD
  - Momentum: 2.5 GeV/c
  - Size(FWHM): 10cm x 10cm
- Incoming particle type:
  - Electrons (TASD2)
  - Positrons (TASD1)
- B-field: 1.5 T

Scoring:

- Energy deposited -21
- All charged particles -30
- All negative particles -31
- All neutral particles -32
- All positive particles -33
- All photons -34

Energy deposited - All

Electron | 2.5 GeV/c B-field: 1.5 T | Positron



Milestones and deliverables

- Task 8.2.1: design study for low energy particle beam line
  - MS27: Specifications for beam line fixed (month 12)
  - D8.3: Design study on low energy beam line: Design and implementation study on a low energy beam to the range of 1 (or possibly less) and 10 GeV (month 26)
- Task 8.5.2: TASD and MIND
  - Test beam proposal ("unofficial" ASAP)
  - MS28: Design of TASD and MIND (month 26)
  - MS36: Installation of TASD and MIND (month 33 – spring 2014)
  - D8.11: Infrastructure performance and utilization - TASD and MIND are constructed and tested for their performance. (Will there be test beams in 2014?)