Neutrino detector studies and possible experiment at CERN PS

most from AIDA neutrino meeting 17-18 March 2010
http://indico.cern.ch/conferenceDisplay.py?confId=87234

Framework and origin:

ISS detector study + IDS-NF detector group

Neutrino Factory ➔ mostly scintillator based
(magnetized TASD, MIND)
also Magnetized Liquid Argon and magnetized emulsion detectors

➔needs for R&D on detectors

➔submission of Work-Package in AIDA

good reception final news in spring 2010 (see Paul Soler)

➔ R&D program of development for neutrino detectors

Proposed Location: test beam H8 in North area *)

An additional opportunity: a neutrino beam at CERN?

PS beam →building 181, 182/191

Meeting took place at CERN 17-18 March 2010
Expression of interest in preparation

A CERN neutrino beam possibility?

Once upon a time (in 1999 with extruded scintillator WLS readout) and more recently (LArg) at the workshops in May and in October it has been suggested to refurbish the old Gargamelle neutrino beam to do short distance neutrino physics
-- (final word?) LSND oscillations with two detectors is the argument given
-- my take: near detector → neutrino cross sections?

References

EUROPEAN LABORATORY FOR PARTICLE PHYSICS

CERN-SPSC/99-26
SPSC/P311
August 30, 1999

PROPOSAL

SEARCH FOR $\nu_\mu \rightarrow \nu_e$ OSCILLATION
AT THE CERN PS

35 years after Gargamelle:
the Renaissance of the "Bubble chamber" neutrino physics

Carlo Rubbia
CERN, Geneva, Switzerland
INFN-Assergi, Italy

European Strategy for Future Neutrino Physics
1-3 October 2009 CERN

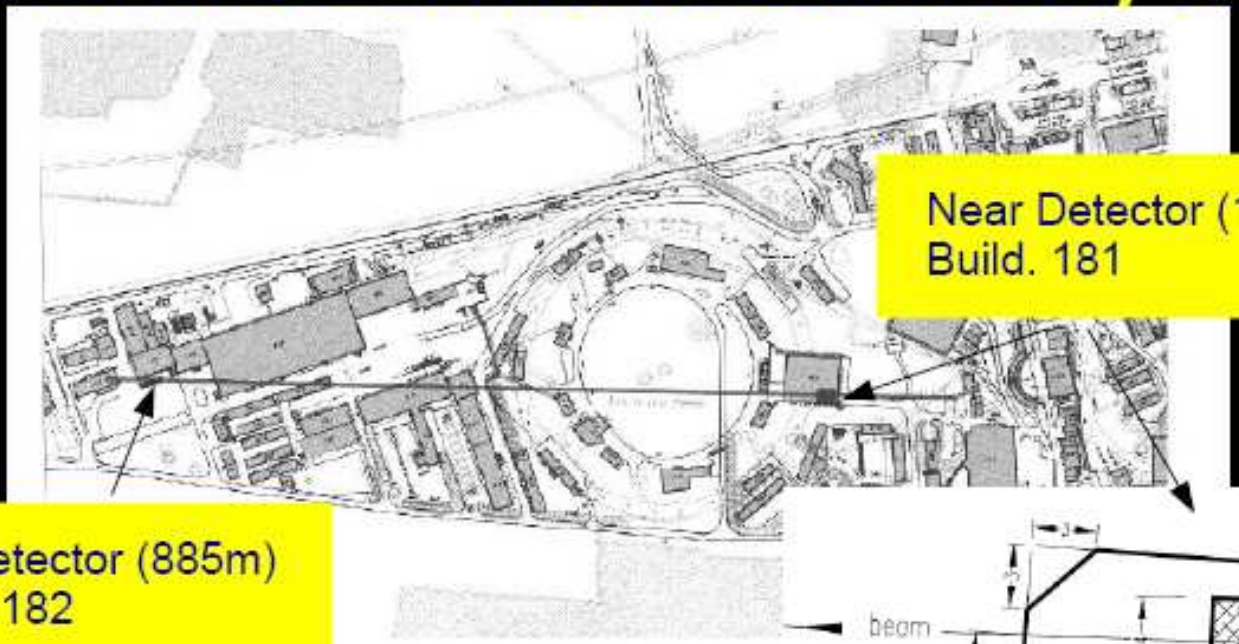
CERN-PS and neutrinos

- CDHS(PS-169) Phys.Lett.B134 (1984)281
- CHARM(PS-181) Z.Phys C40 (1988) 171
- BEBC(PS-180) Phys.Lett.B179 (1986) 307
- CHARMII in the Jura, CERN-PSCC/89-27 24/07/1989
- I216/P311 LoI, CERN/SPSC/97-21, 10/10/1997
  Proposal, CERN/SPSC/99-26, 30/08/1999

numbers from the proposal

PS neutrino beam layout

Ludovici



Near Detector (127m)
Build. 181

Far Detector (885m)
Build. 182

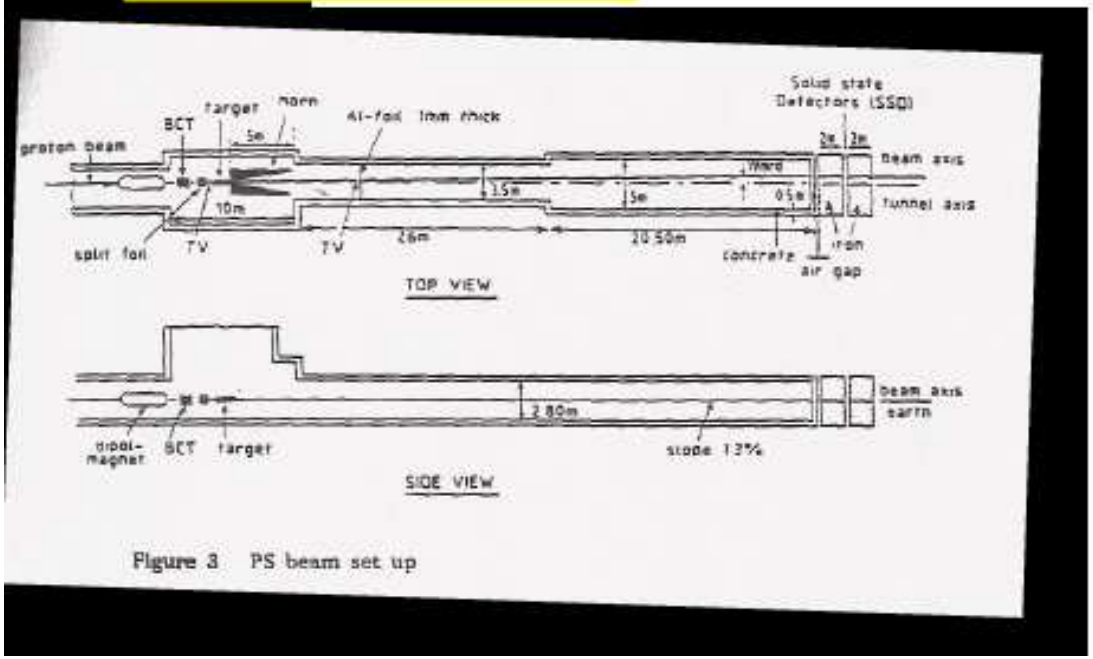
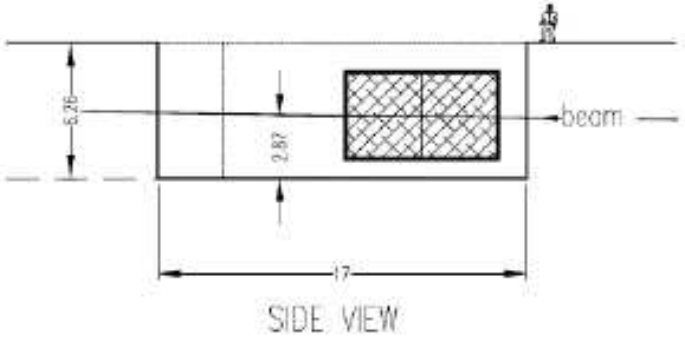


Figure 3 PS beam set up



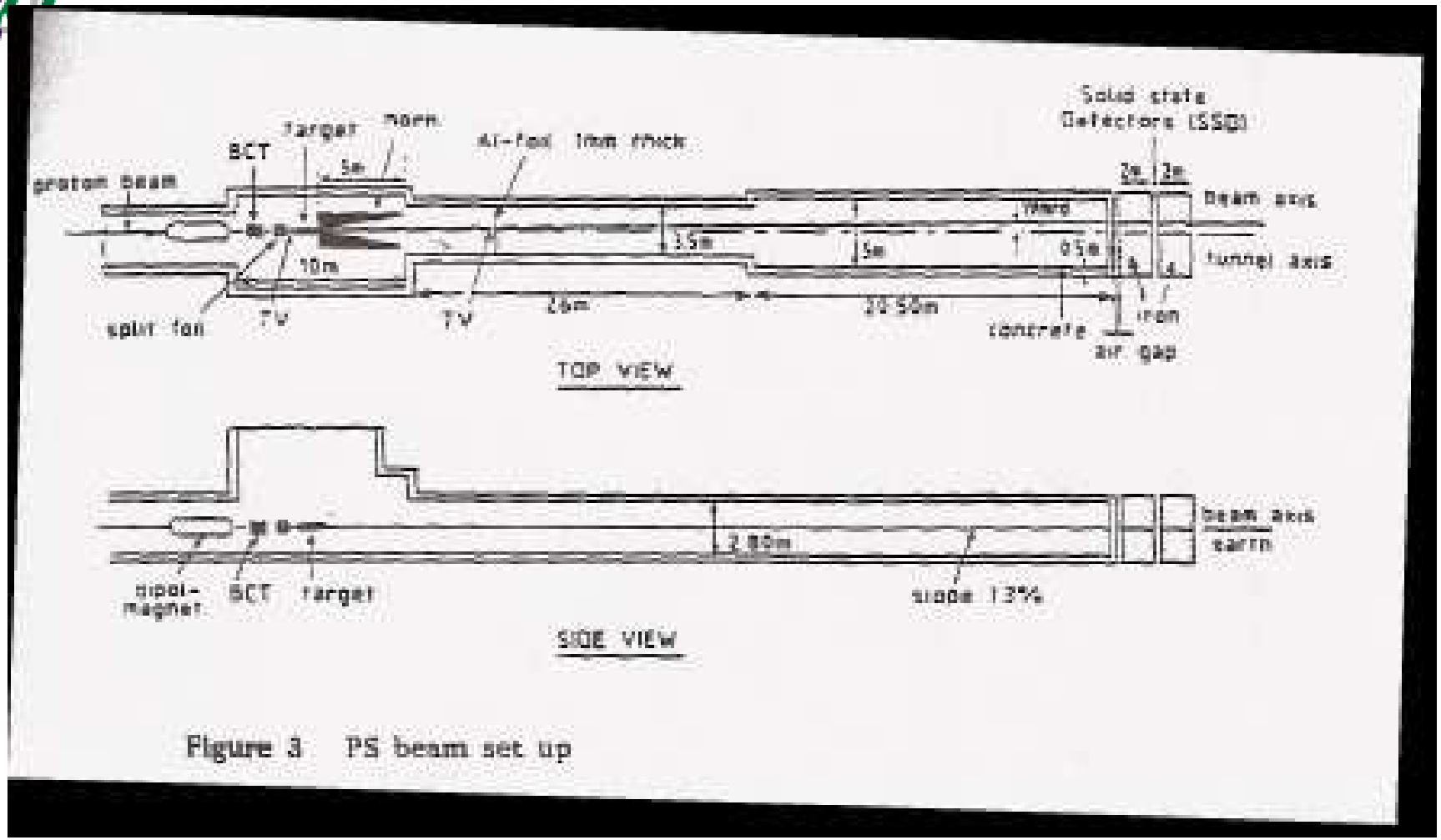
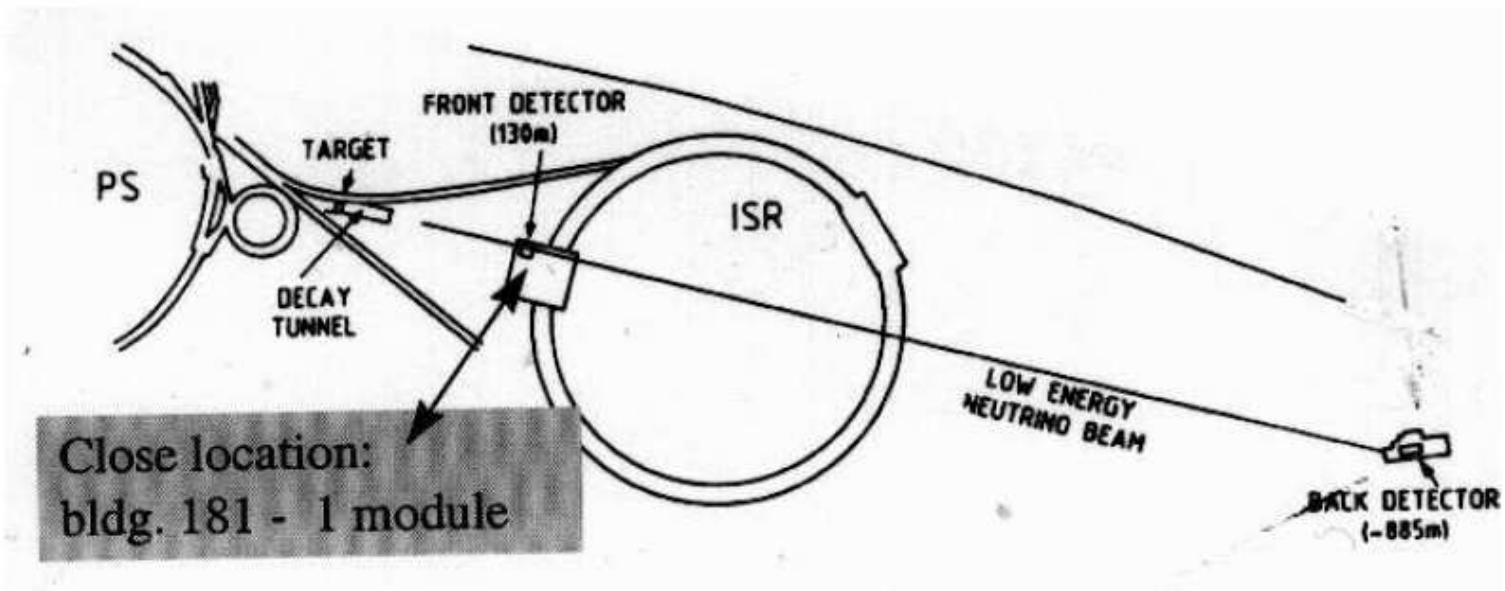
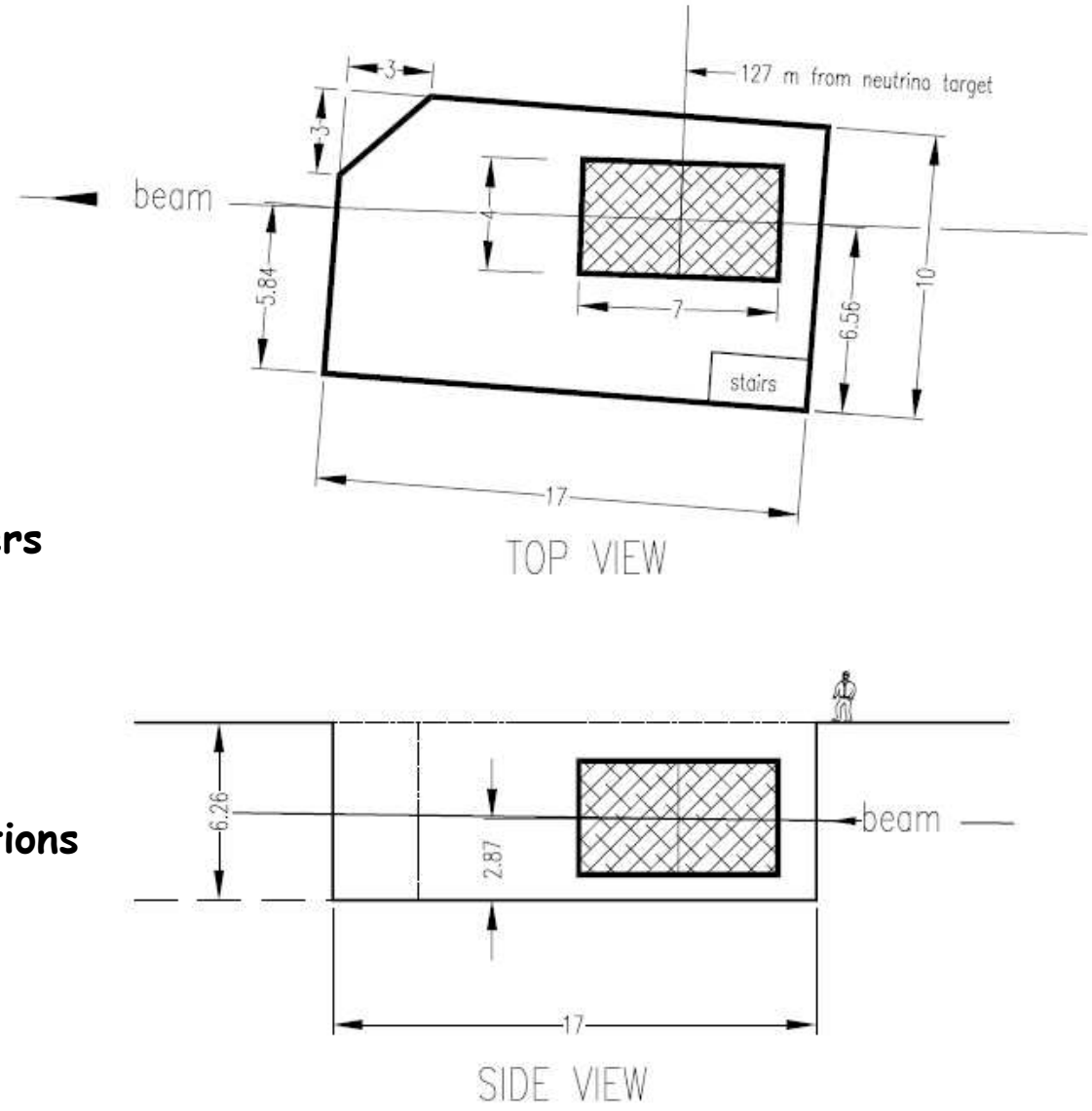


Figure 3 PS beam set up

the tunnel and shielding still exist in good condition.
Radiation and humidity protection at top of target pit to be re-evaluated
Proton beam line, target and horn have all been dismantled

A more sophisticated horn system (a la T2K) would probably be more efficient


FRONT DETECTOR
(130m)
TARGET
PS
ISR
DECAY
TUNNEL
LOW ENERGY
NEUTRINO BEAM
BACK DETECTOR
(~885m)
Close location:
bldg. 181 - 1 module



NB: 6 meters at 127 meters is 50mrad ~3 degrees from beam axis
Ev = 500 MeV to 2 GeV
Across the detector

Measurement of cross sections in that energy range.

Is magnet necessary?

Figure 11: Top view and side view of the neutrino pit in Hall 181, showing schematically the location of the near detector.

Building 181 Occupation

PS Neutrino Facility

CERN NEG Coating Plant

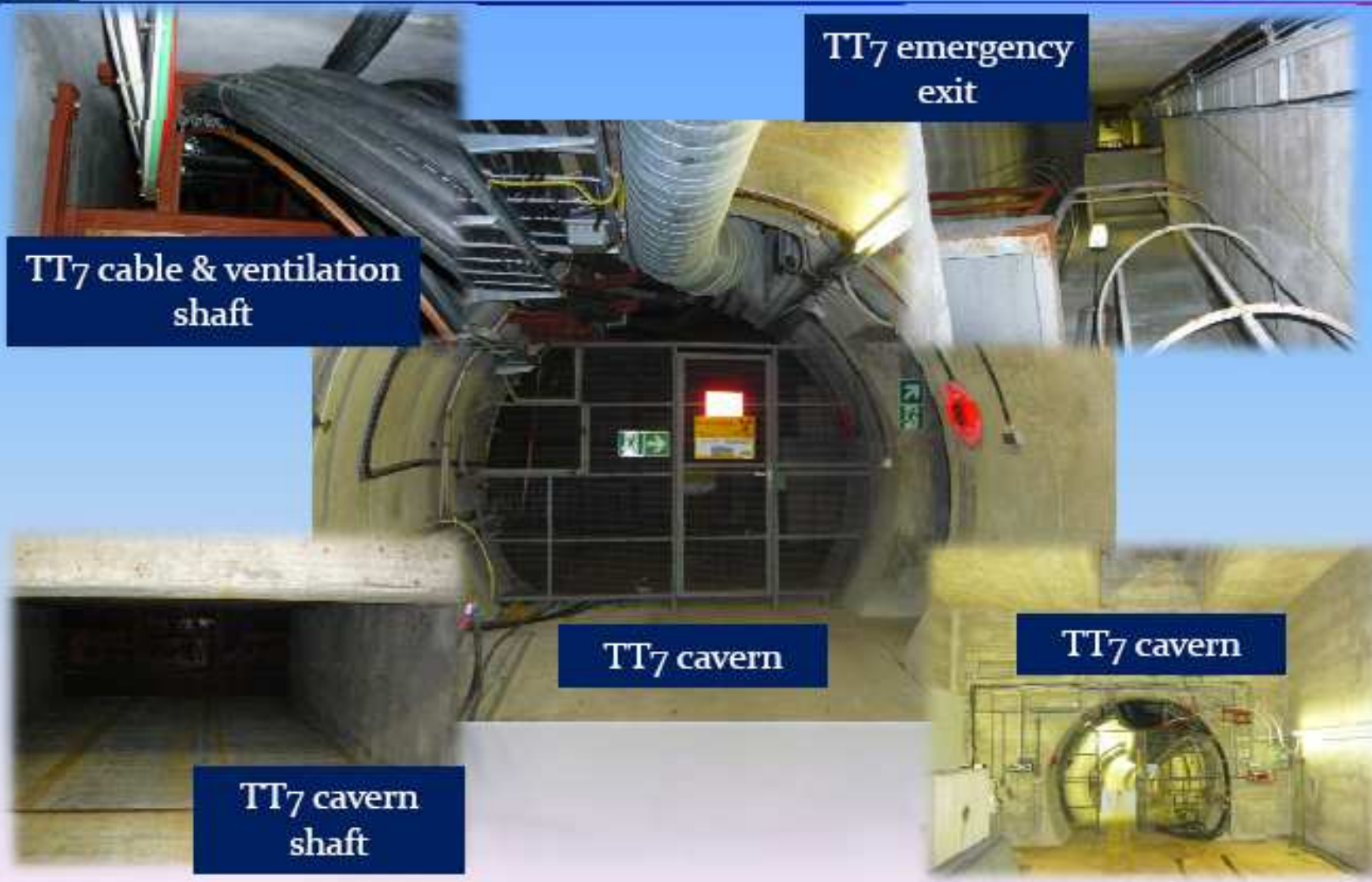
Courtesy of Jose-Miguel Jimenez

CERN LHC Magnet Repair Facility

Courtesy of Paolo Fessia

The TT7 Target Cavern

PS Neutrino Facility

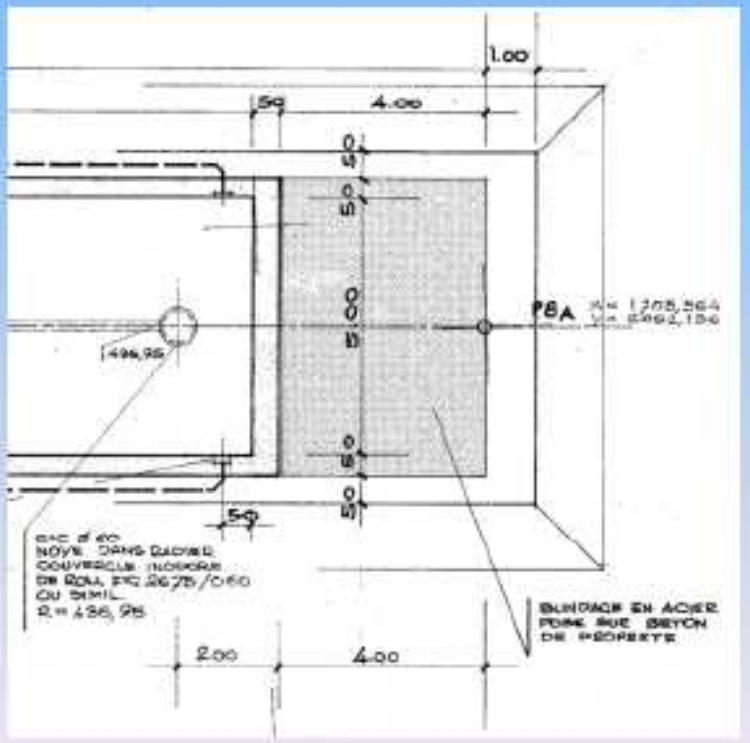


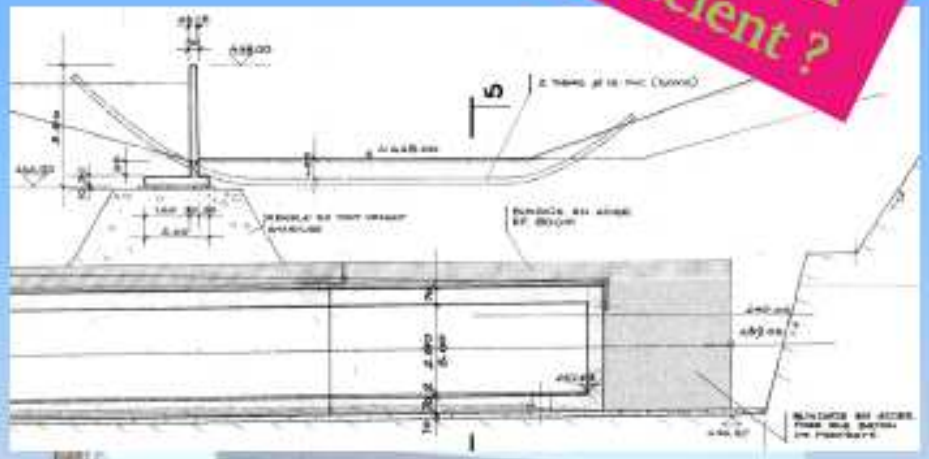
Beam Dump / Hadron Stopper

PS Neutrino Facility

- 4 meter thick iron beam dump
- ~60 meters of earth

Is this still sufficient ?





Strawman event rates

Assume:

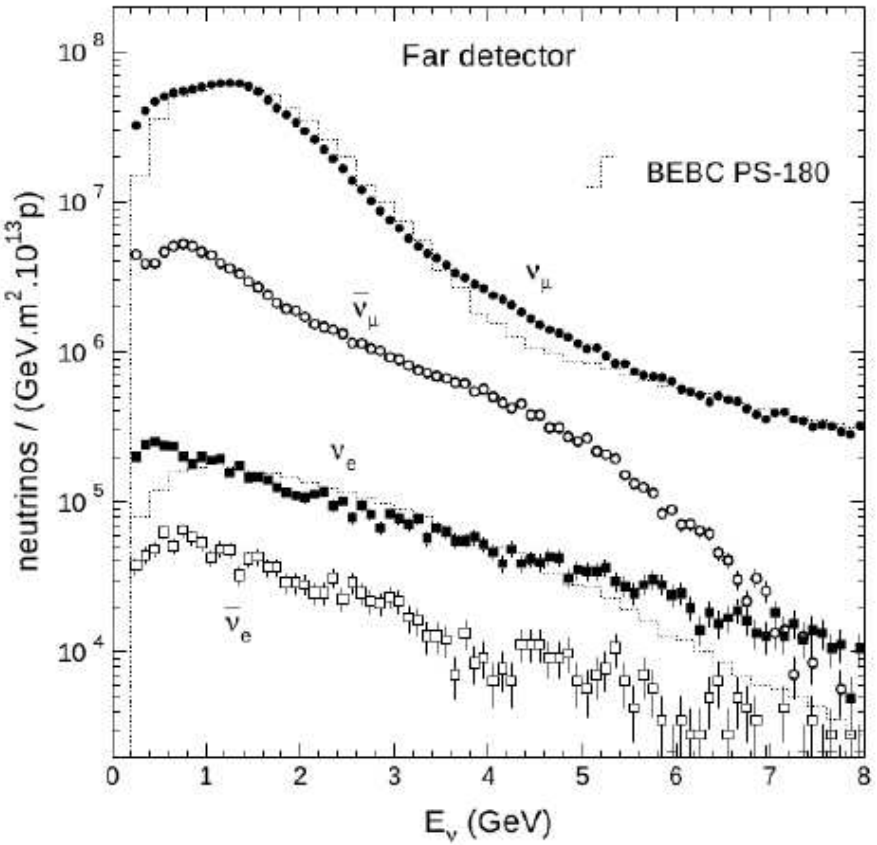
- σ_{CCQE} = 0.85 10^{-38} cm^2 for E_ν>0.2GeV
- Iso-scalar target
- 2.5 10^{20} PoT

Far Detector: 940 QE ev./ton

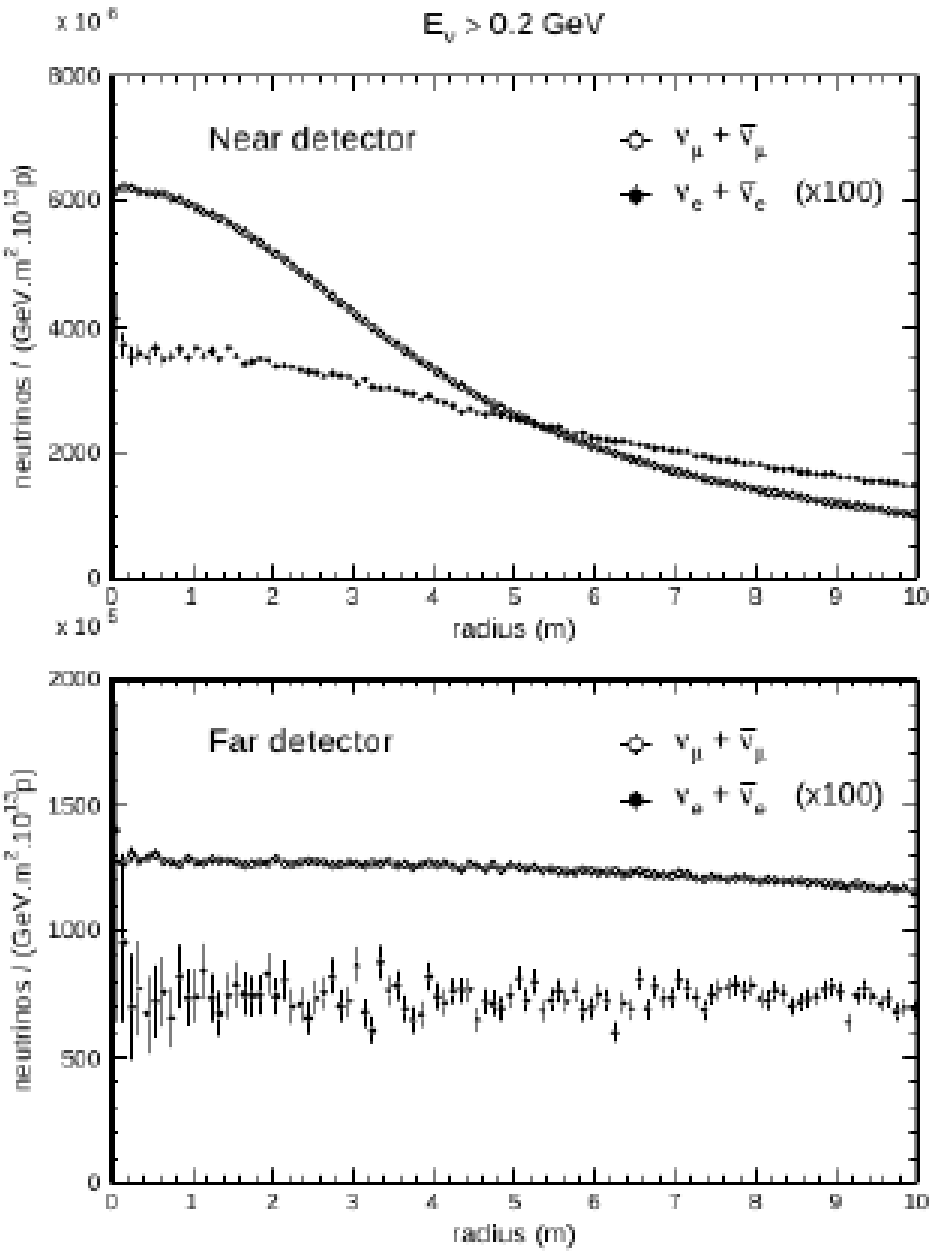
Near Detector$^{(2m<R<5m)}$: 31,000 QE ev./ton

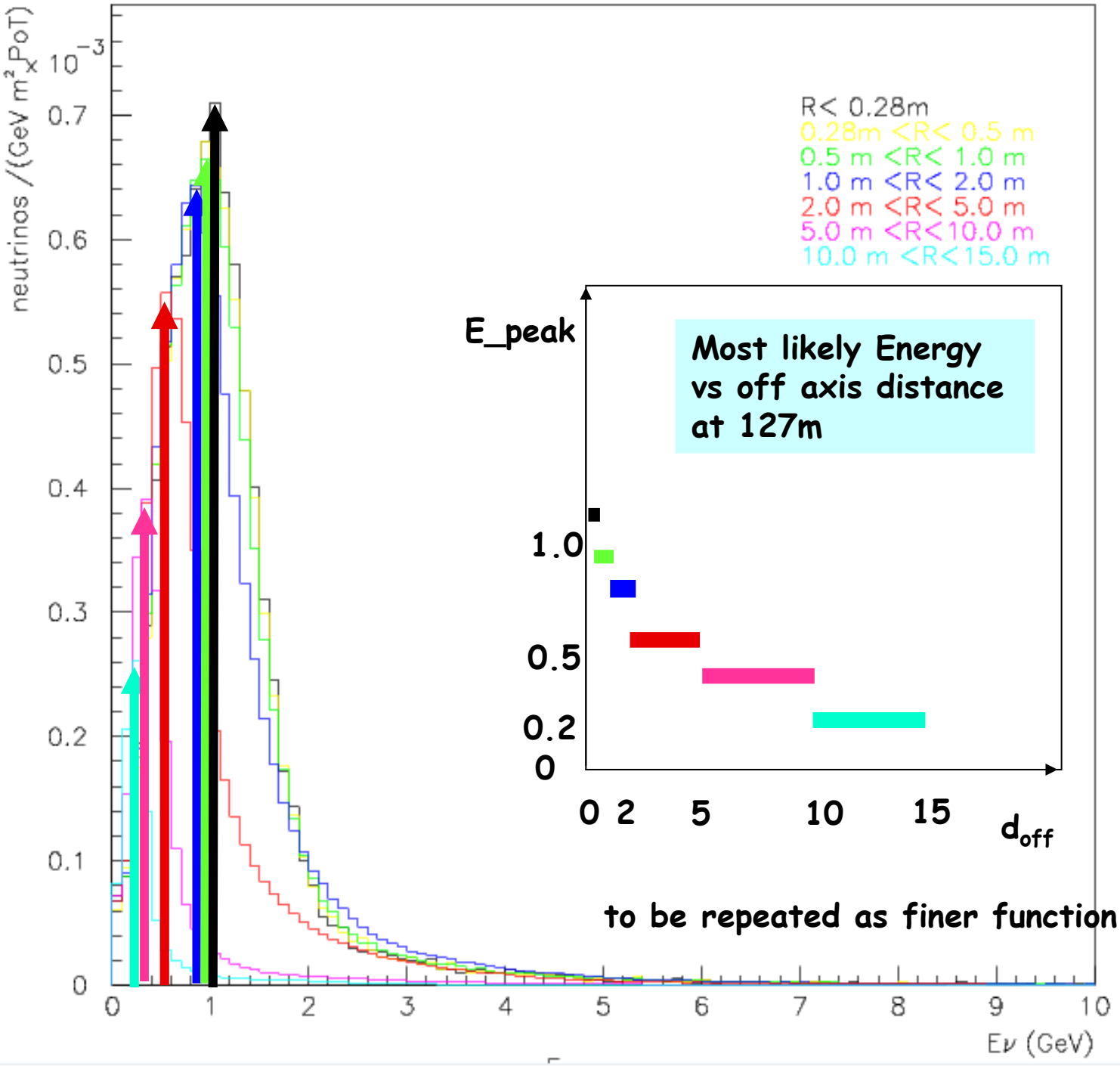
Fluxes and event rates

ON AXIS



OFF axis

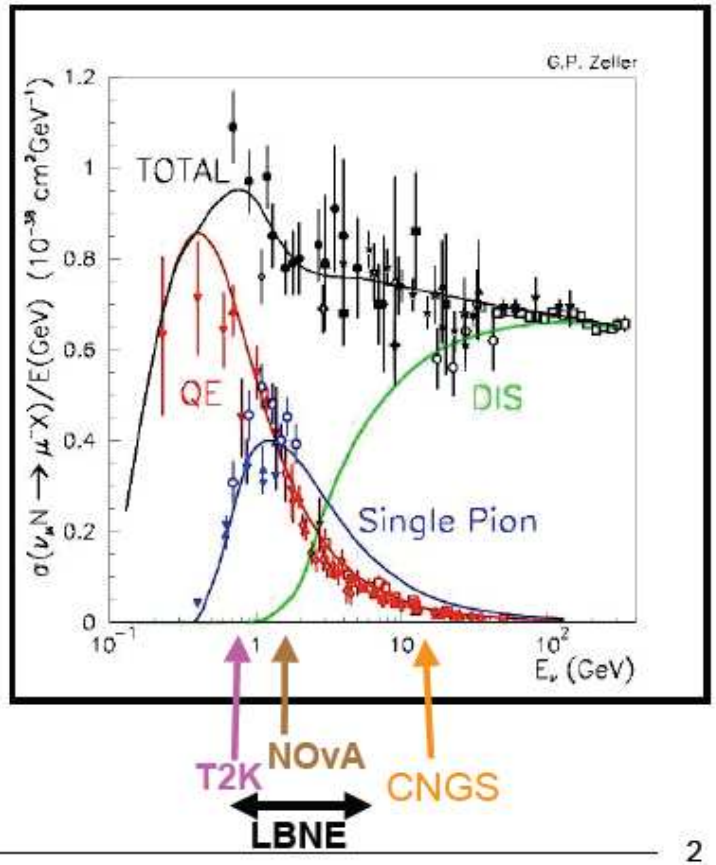




to be repeated as finer function of position

Neutrino Cross Sections

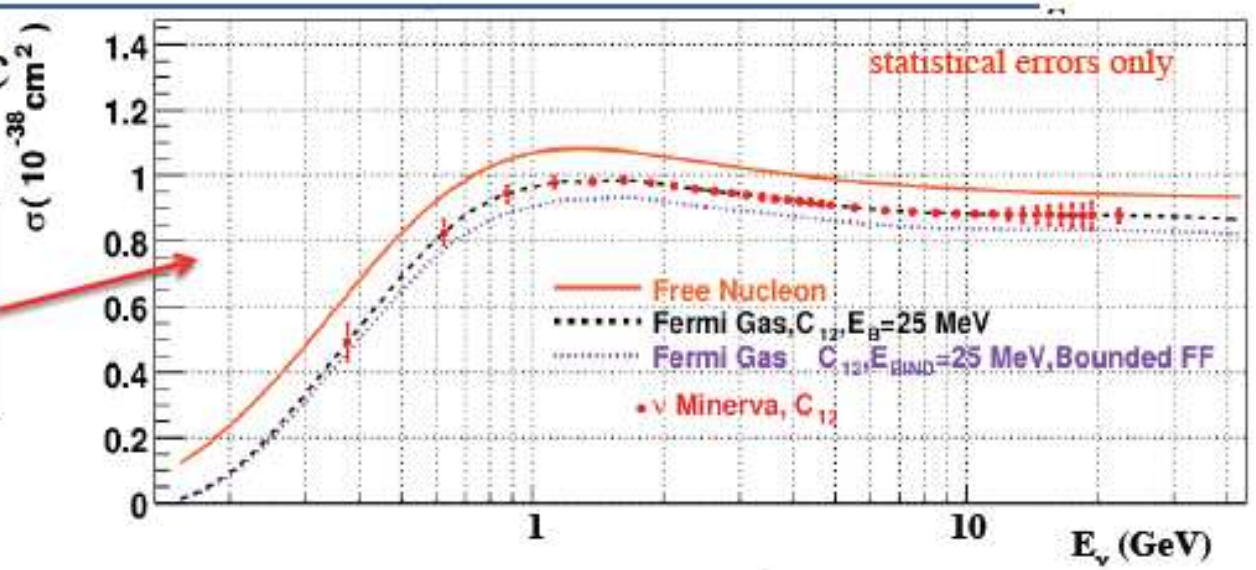
- historical measurements of ν_μ CC cross sections
- low E data are ~30 years old
  - low statistics
  - a lot on D_2
    (not all that relevant for ν osc)
- this is situation have been in for past 30+ years
- luckily has been improving!

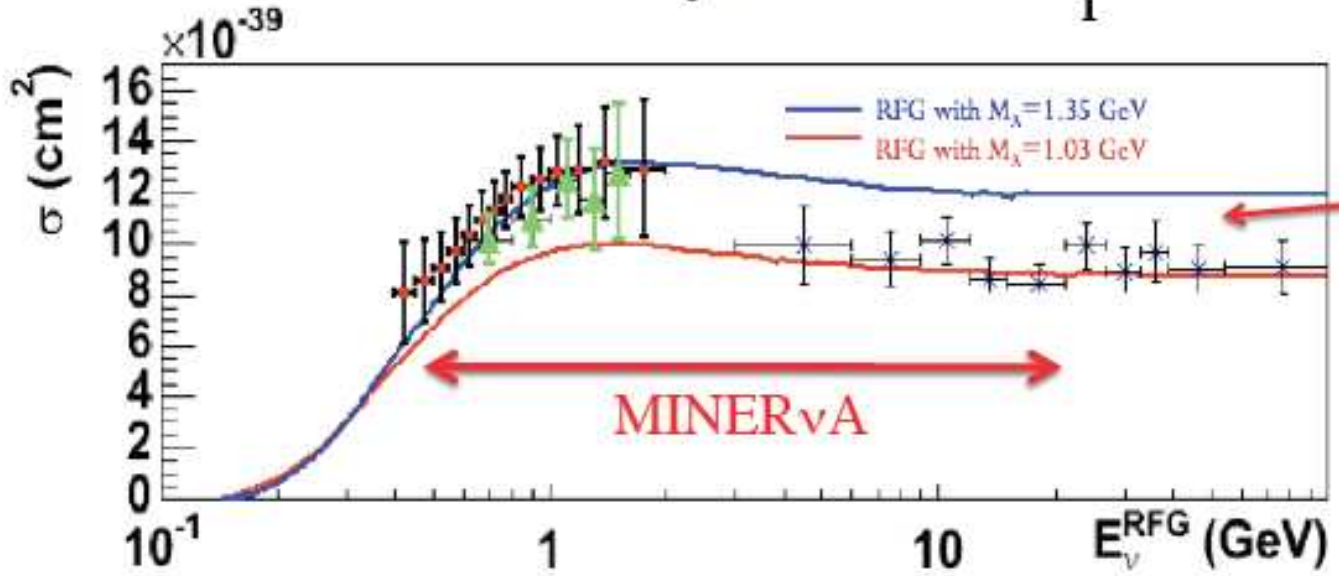


MINERvA Quasi-Elastic Cross Section II

- CC Quasi-Elastic

Expected MINERvA CCQE results including efficiency estimates





MiniBooNE, SciBooNE, NOMAD CCQE data

MINERvA should resolve this mystery!

Physics case (three approaches)

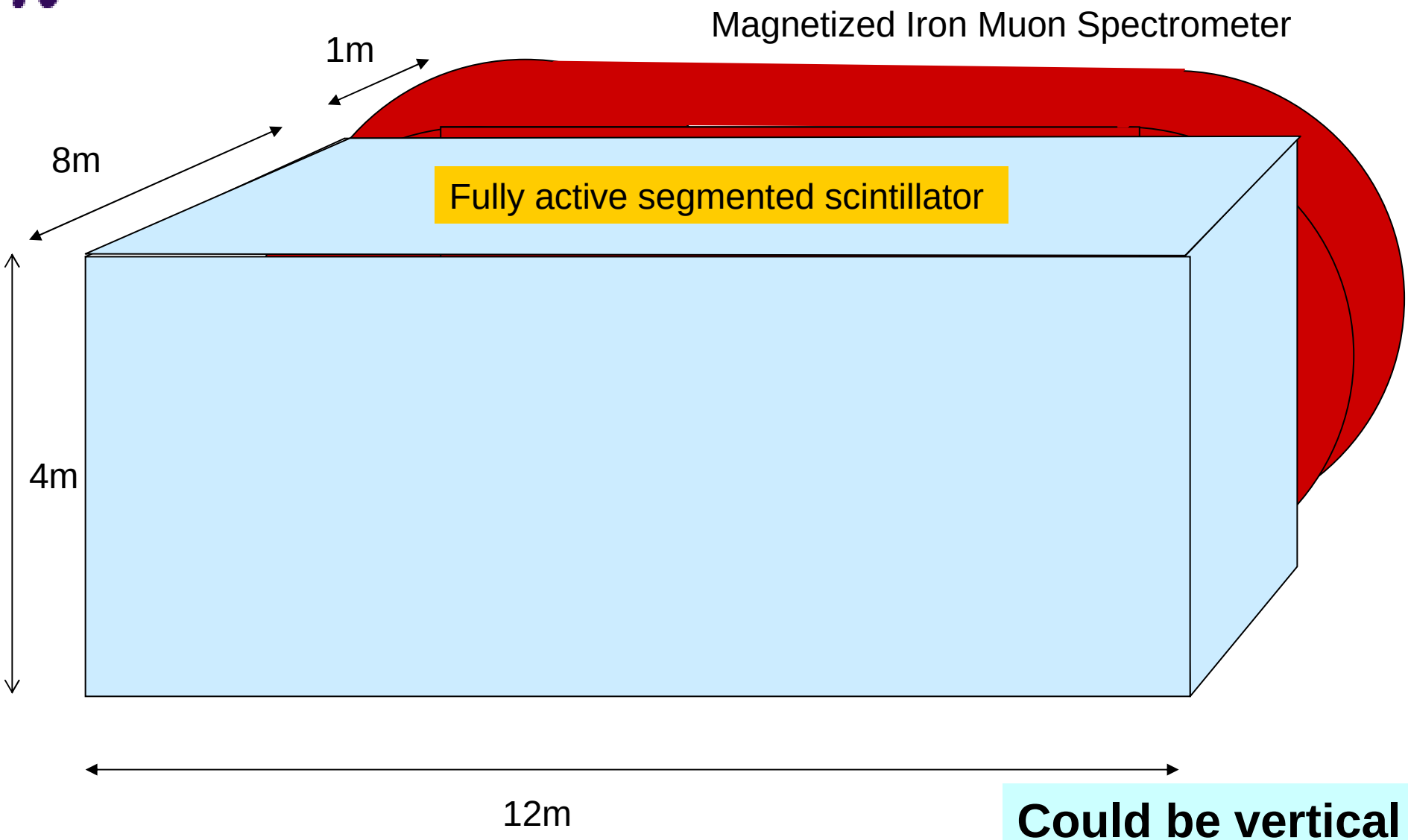
1. perform the LSND oscillation search with two detectors
   ("eliminate any doubt")

   exist a letter of intent from C. Rubbia et al.

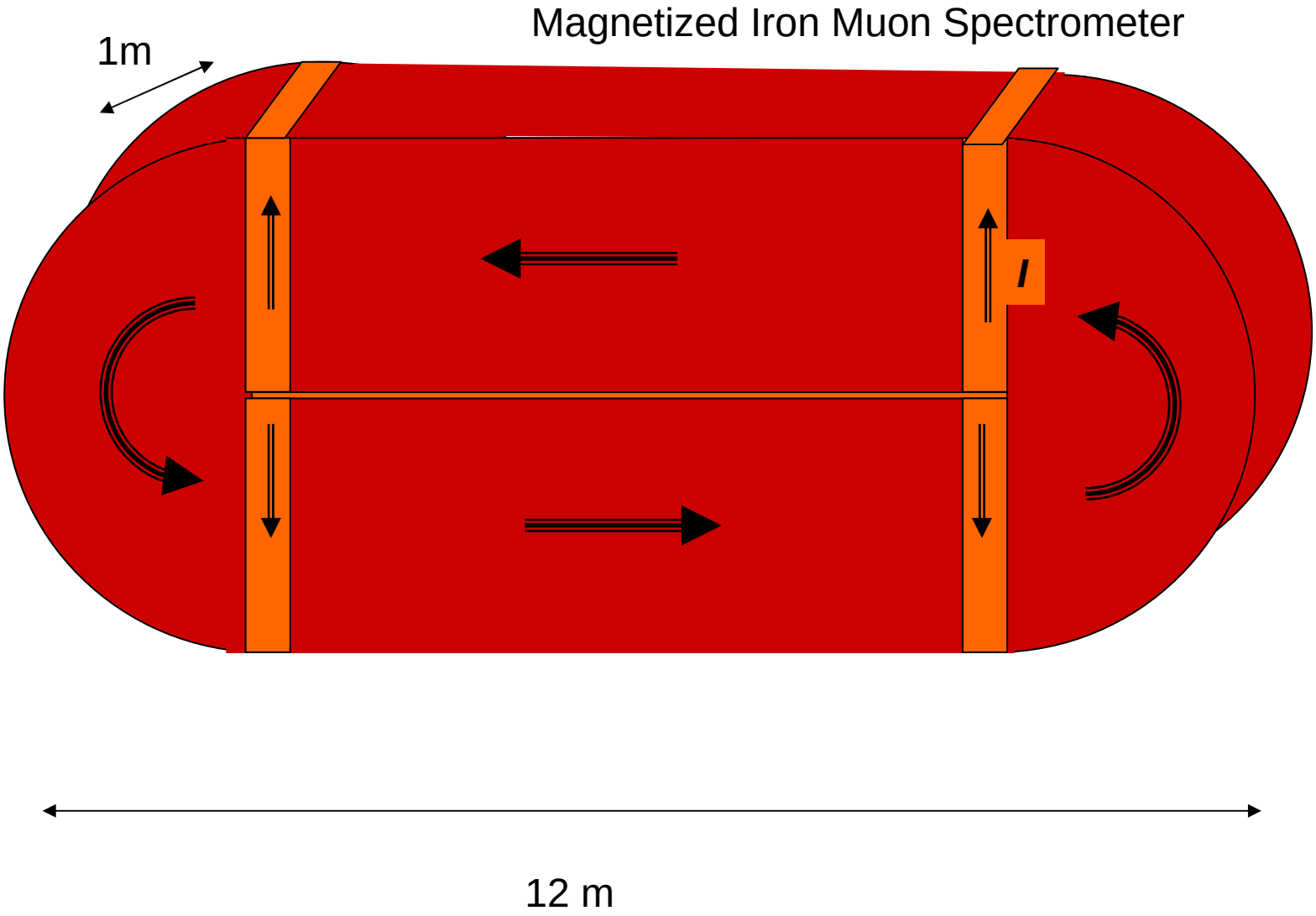
2. perform measurements of cross sections on axis at the far detector
   with a large Liquid argon detector (1 kton) (KEK – ETHZ)

3. perform measurements of cross-sections at the near detector station
   with a 'minerva-like' detector with ability to go >=10m off axis.
   (AIDA follow-up)

   motivation:
   The energy region 200~600 MeV will be only measured so-so
   with MINERvA (low energy tail of the on-axis beam)
   and T2K (low energy tail of 650 MeV off-axis beam)
   in particular: onset of pion production.
   Also good occasion to test detector ideas.
   EOI to be drafted. Some first ideas follow:



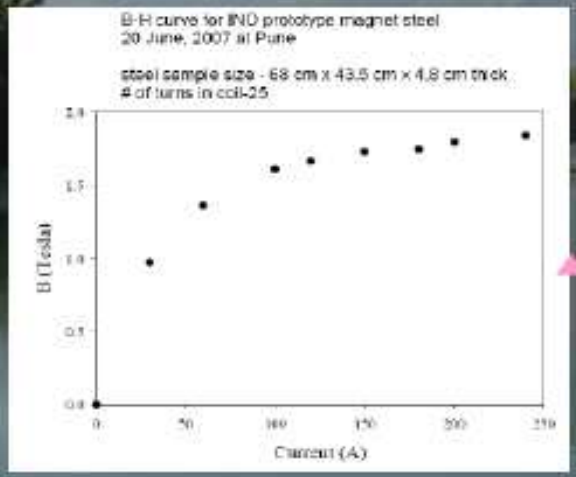
WHAT IS THE FID. VOLUME?



Could be vertical

INO Prototype Magnet now at VECC

- *12, 1m² RPC layers*
- *13 layers of 5 cm thick magnetised iron plates*
- *About 1000 readout channels*



- *Possible participation in CERN detector studies:*
  - *INO plan to use 5 cm thick iron plates*
  - *MIND detector is planning to use 2.5 cm thick iron plates*
  - *INO plan to use RPC as active detector elements*
  - *MIND is planning to use scintillator with SIPM read out*
  - *Need some thinking on how to accommodate these differences.*

We had several talks describing competences required to construct such a detector.

long scintillator:

Yuri Kudenko: light output with 10m of wavelength shifter
Marcos Dracos: 7m long extruded scintillator from OPERA
(missing: Alan Bross on latest developments on TASD)

M. Dracos

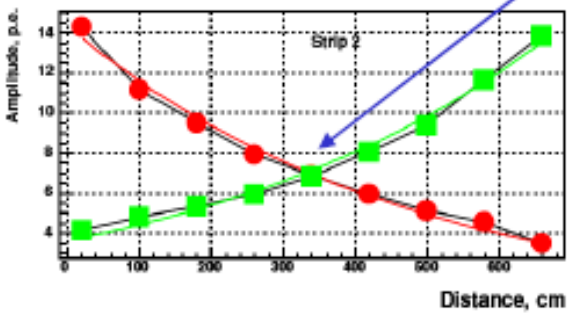
Conclusions

- The OPERA Target Tracker provides x-y information over a surface of 3000 m^2,
- It is composed of:
  - plastic scintillating strips, 7 m long,
    - 75 tons in total
    - fluors: p-terphenyl+POPOP
  - WLS fibers: Kuraray (300 km),
  - multi-anode Hamamatsu PMT's (8x8 channels),
- The m.i.p. detection efficiency is higher than 99%,
- The "noise" trigger rate is 20 Hz/channel without lead bricks and 8 Hz/channel with lead bricks,
- The OPERA TT production lasted about 20 months
- more details in: NIM, A 577 (2007) 523 and NIM, A 581 (2007) 465

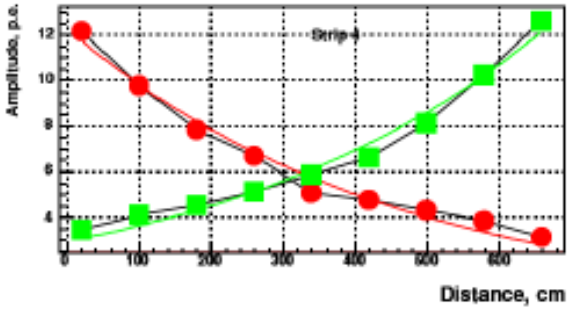
Calibration

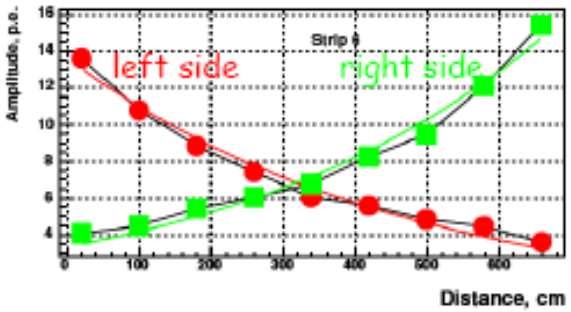
module 400
9 points/strip

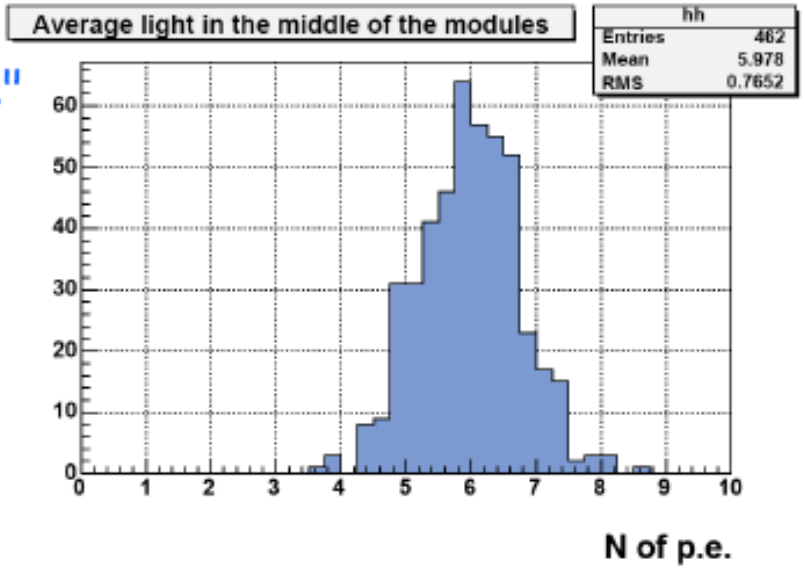
"reference" position

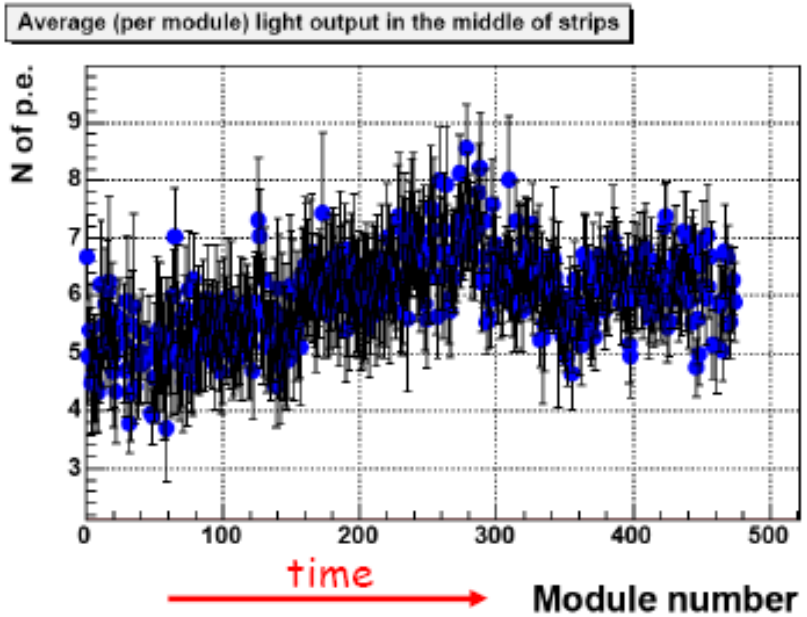


number of p.e



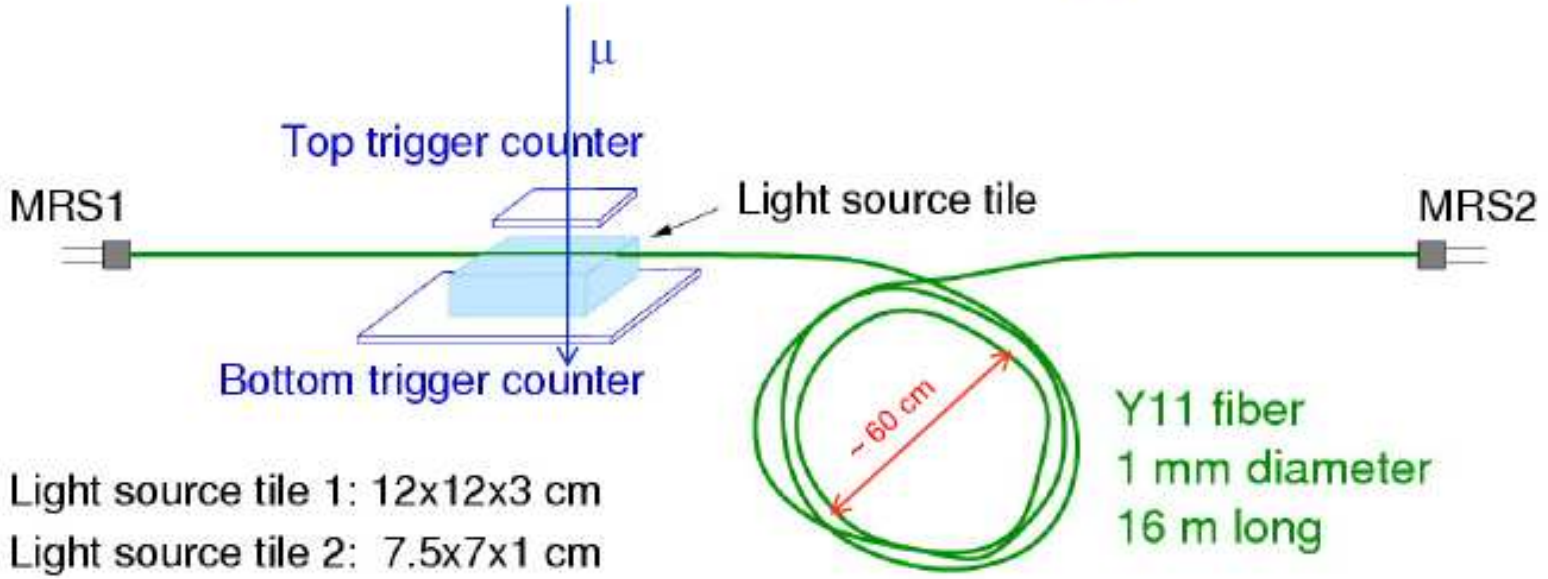






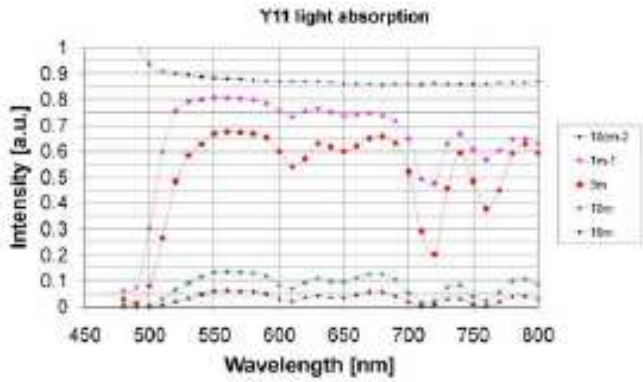
For the whole production: <Npe>= 6

Measurements with long fibers



Light source tile 1: 12x12x3 cm
Light source tile 2: 7.5x7x1 cm

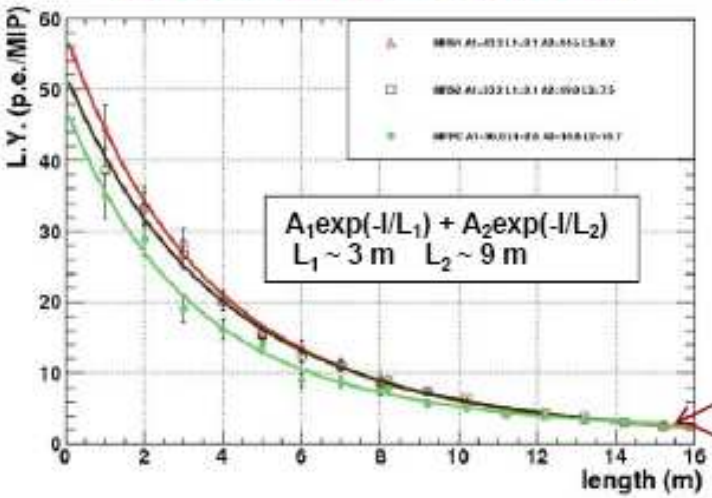
Measurement of light absorption
in Y11 as a function of wave length



KUDENKO

Light yield

One-end readout
no reflector at far end



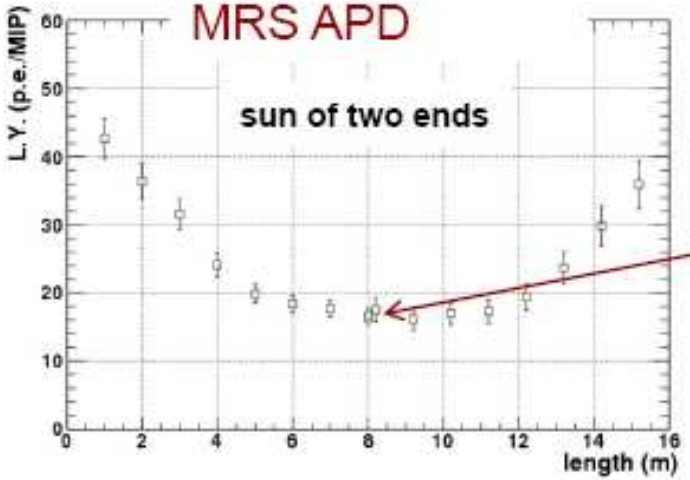
2 p.e.

3 p.e. with Al mylar

Tile 2 → MIP ~ 2 MeV

T =20 C, dark rate (th=0.5 p.e.) < 500 kHz

both-end readout
MRS APD



14 p.e.

REFLECTOR

1 m long Y11, scintillator 1 cm thick
reflector at free fiber end, one-end readout

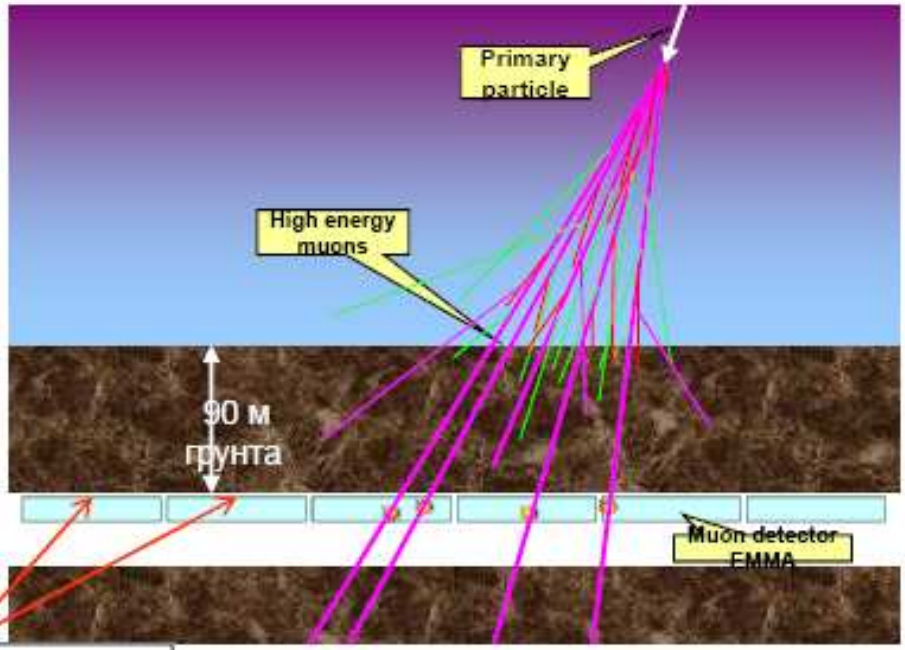
	l.y./MIP, p.e.
Polished , no reflector	24.4
Polished, teflon tape	33.9
Polished, Al mylar	36.9

KUDENKO

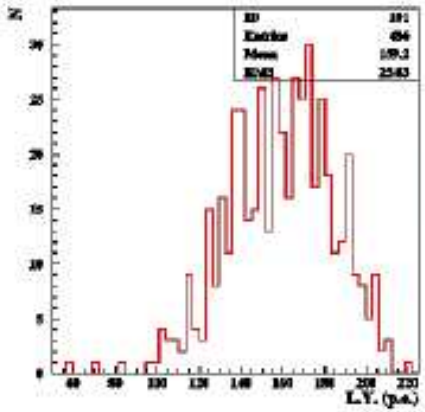
Detectors for underground lab at Pyhäsalmi, Finland

kUDENKO

1600 scintillator detectors
12 x 12 x 3 cm
Y11 WLS fiber
MRS APD readout



Sci detectors



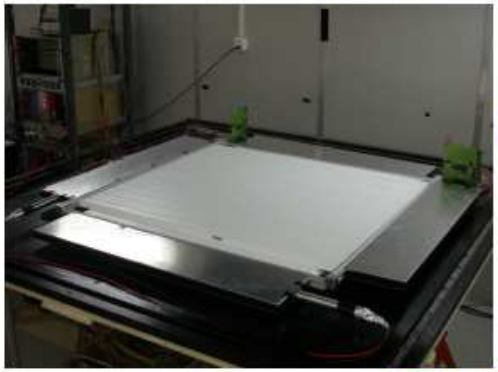
Average l.y. = ~160 p.e./MIP
→ ~27p.e./MeV

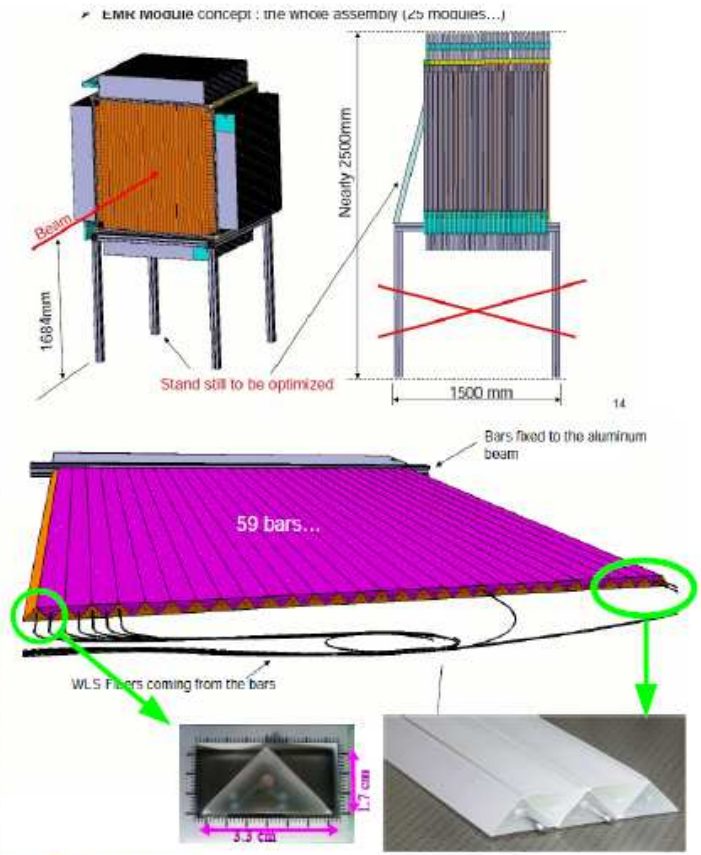
16 counters form one 4x4 module

EMR – Electron Muon ranger

PREST

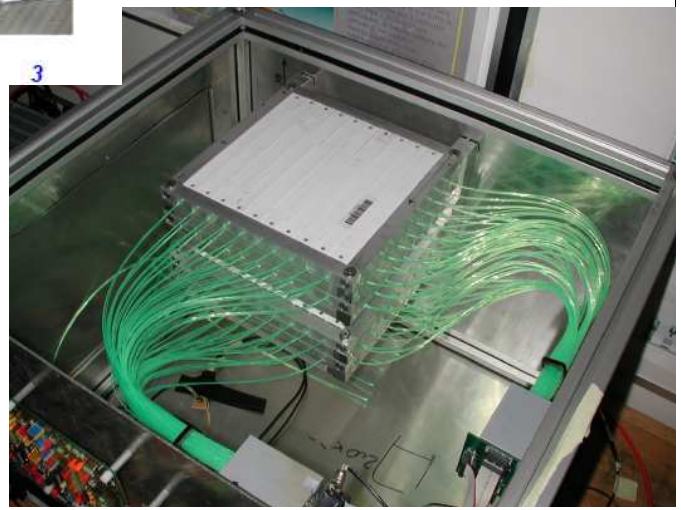
- *48 layers of scintillator bars organized in a x-y configuration*
- *Each layer → 59 triangular bars 1.1m long*
- *Light collection: 1 WLS 1.2mm fiber per bar inserted in the bar hole and glued*
- *Readout on both sides:*
  - *on one side, a single channel PMT (XP2972, Philips) for total charge measurements*
  - *on the other, a multianode PMT (H7546B, Hamamatsu)*
- *Multianode PMT readout: MAROC ASIC → sampling of the trigger output of each bar*



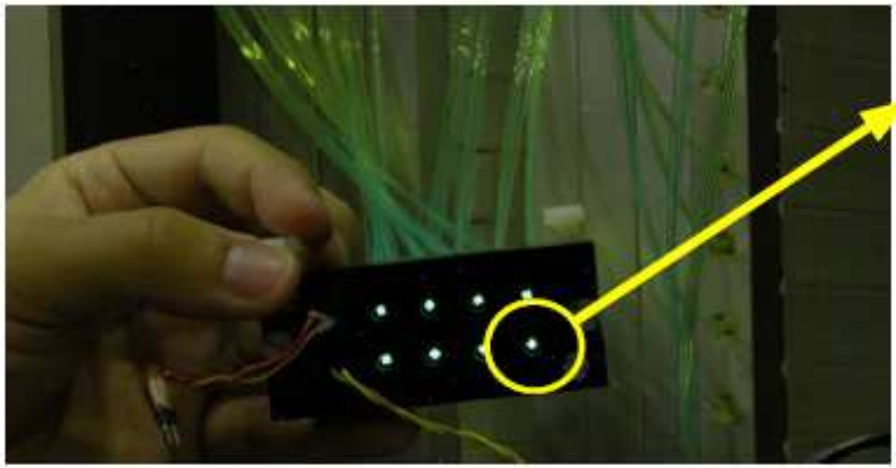


CERN, Como/Trieste group

SMALL PROTOTYPE

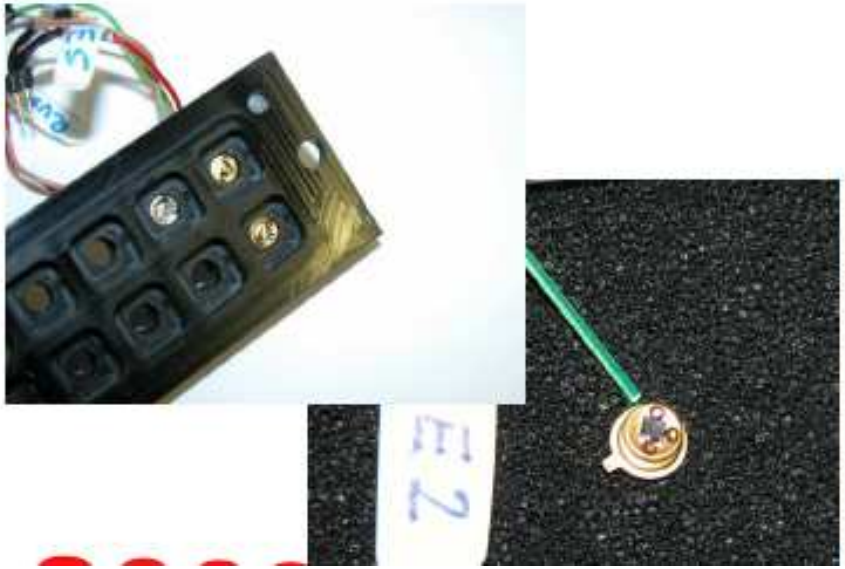


EMR and the SiPMs of the INFN FACTOR project



4 0.8mm fibers coming out from one of the bar sides

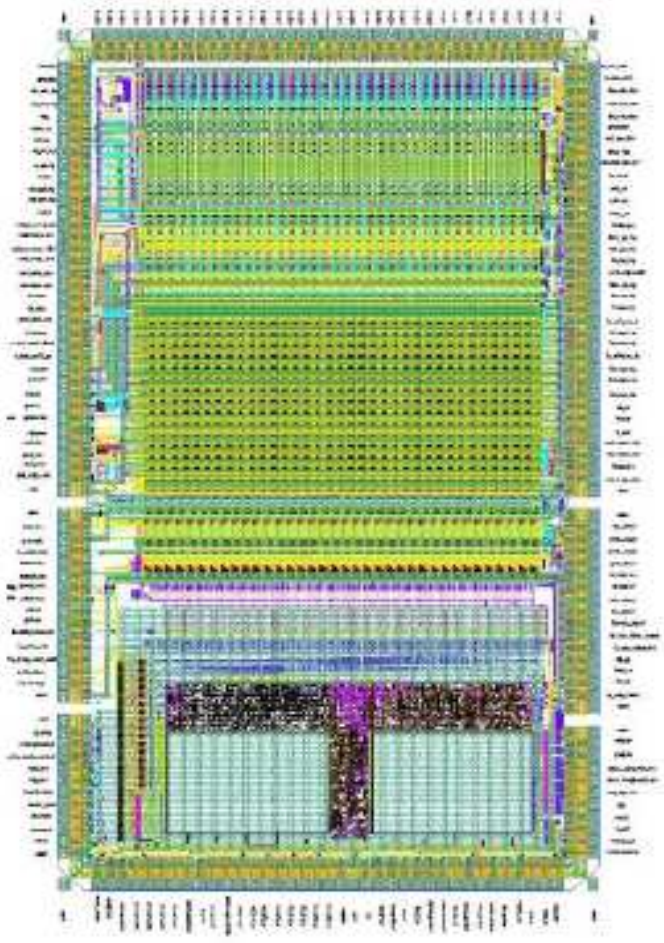
- **SiPM readout chain:**
  - Signal fed to an AMP_0604 Photonique amplifier
  - Delay of 150ns
  - Sampled by a CAEN V792 12 bit QDC
  - Bias provided by a 3412 AGILENT
  - Time measurements: CAEN V775 TDC
- **SiPM features:**



SiPM	Radiation	Voltage (V) breakdown	Voltage (V) bias
Hama199	0	68.3	70.2
Hama200	0	68.1	70.2
Hama209	3 kGy (γ)	68.3	70.2
Hama212	4.5×10^{10} n/cm^2	68.2	69.4
FBK E5	0	30.5	34.0

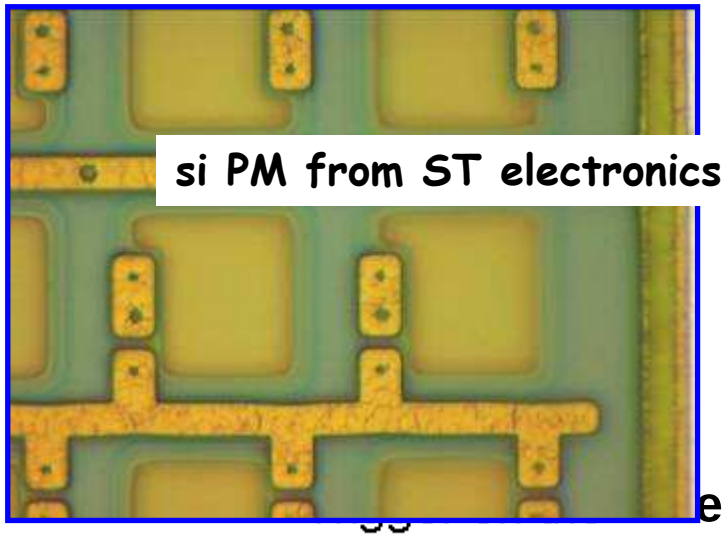
Readout with the SPIROC ASIC

- *36-Channel ASIC developed at LAL-Orsay (Ch. De la Taille et al.)*
- *Designed for SiPM (ILC Calorimeter) with tunable bias to equalize gain*
- *Large dynamic range with charge and time sampling*
- *Very complex digital part*
- *NO parallel trigger outputs (in the present version)*



- ➢ *GOAL: compare MAROC and SPIROC performances*
- ➢ *Make electronics changeable on the new EMR prototype to go from MAROC to SPIROC*
- ➢ *Readout the calorimeters with SPIROC*

Electronics developed at CERN (Group of Pierre Jaron)



Keithley 2410
33V

Current measurement

SiPM

i(t)

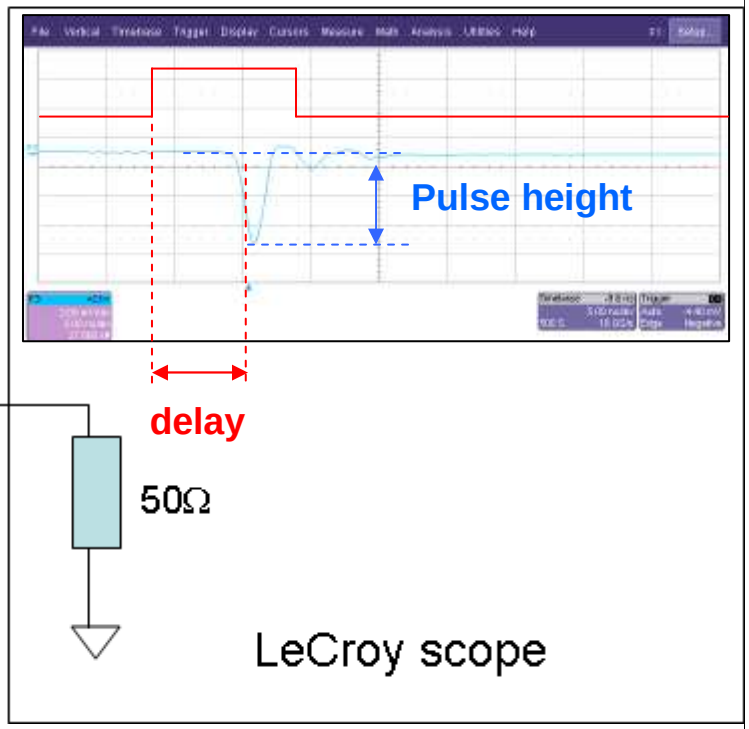
x26dB

50Ω

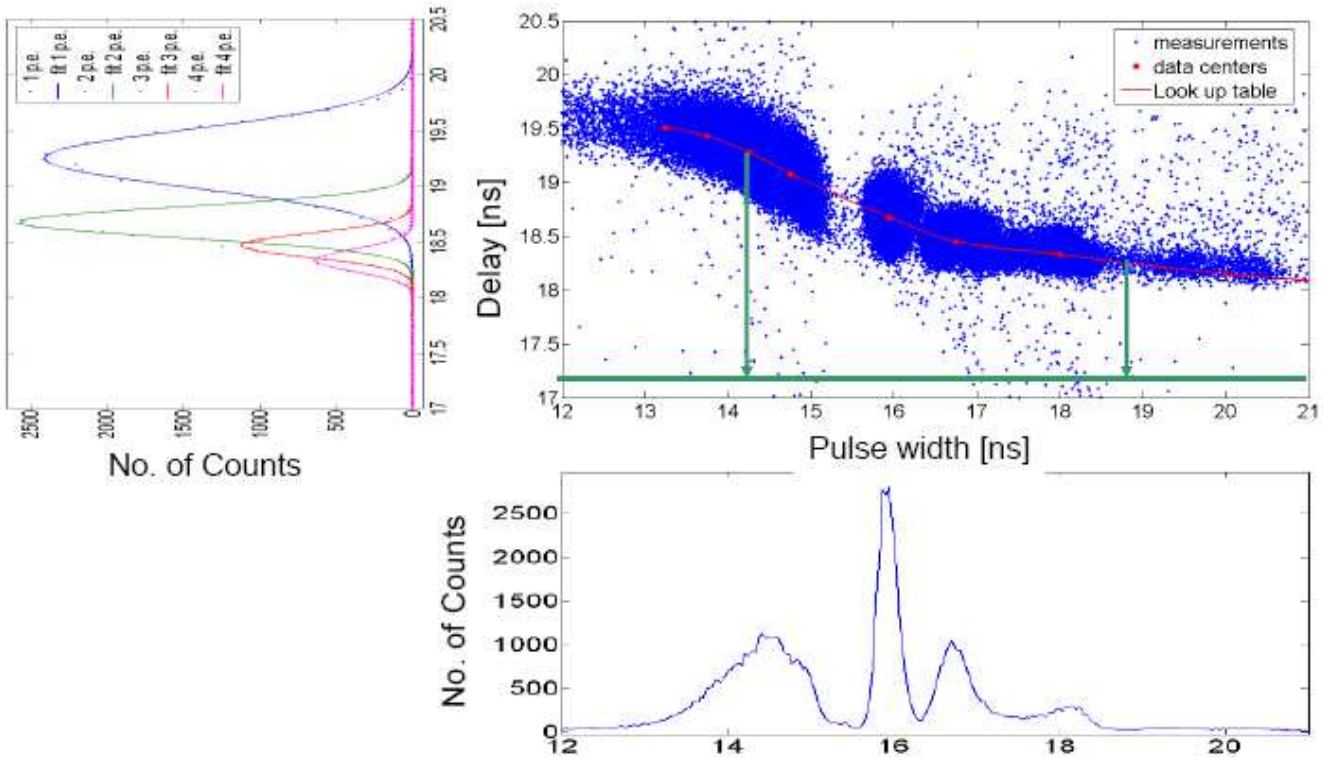
50Ω

Fast amplifier

Laser pulse
50ps FWHM



Pulse width vs. delay scatter plot



Neutrino detector studies *F. POWOLNY* *17 / 03 / 2010* *14*

TAKING OUT DEPENDENCE ON ph AND ON SCINTILLATOR
resolution of 160 ps is dominated by scintillator (not siPM wich is<~50ps)

The special slide for a neutrino factory IDS meeting:

so we could measure muon-neutrino AND anti-neutrino cross-sections

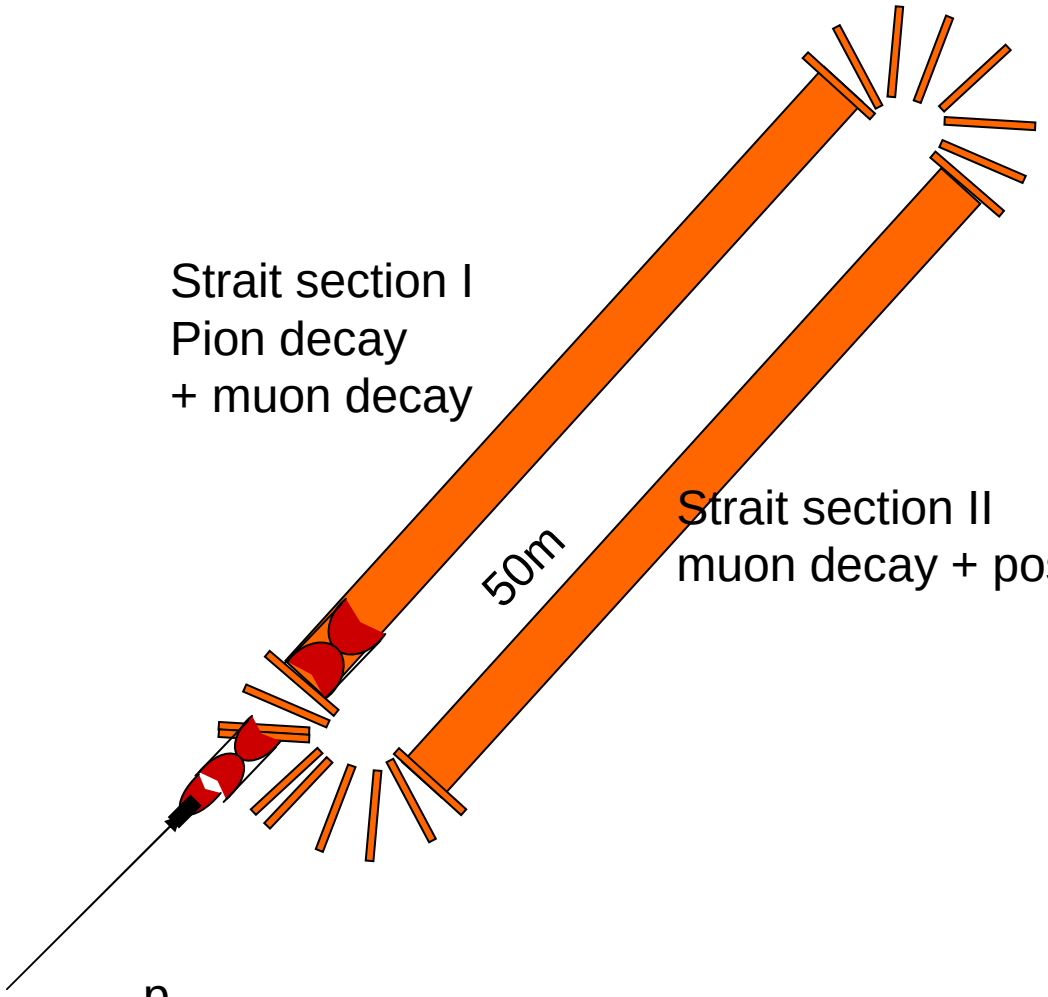
what about electron neutrinos?

crucial for CP/T asymmetry!

a mini beta beam? (but $E=2Q\gamma$ so we need SPS type rigidity….☹

a muon storage ring (mini-neutrino-factory)?

storing 600 MeV muons gives same spectrum as γ=100 6He or 18Ne…



how do we store the muons?

Conclusions and next steps

Physics conclusions

there are various communities (3?) with different interests
in the neutrino beam at CERN

-- oscillation measurement in the LSND region (+sterile neutrino)
   using two detector locations
-- cross-section measurements in GeV region in LArg and 1kton LArg detector
   prototype in the far detector location
-- cross sections measurements in light detector (plastic) down to 200 MeV neutrino
   energy with large detector in the near detector location

Next steps

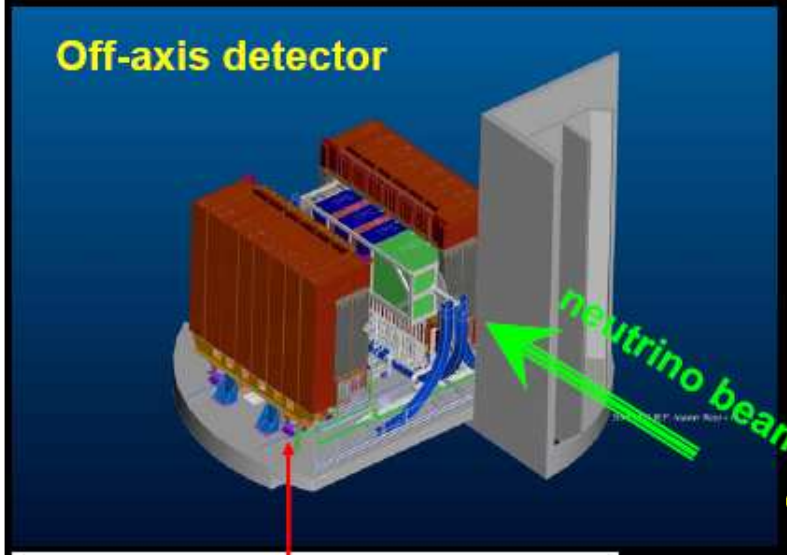
1. need to assemble a 'steering committee' with a few people per country
2. draft Expression of Interest to CERN
3. generate beam study group across communities and with CERN
4. deepen study: more precisely evaluate detector size needed,
   event numbers, physics precision …
5. THEN see who is interested in doing what

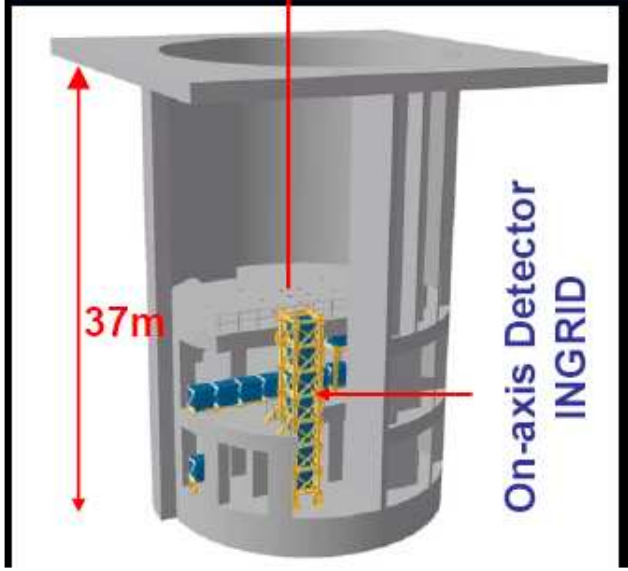
MORE SLIDES

ND280

Most detectors use plastic scintillator with siPM readout 60000 siPMs! 0.2T Magnetic field for tracking of muons and electrons with TPCs up to 1 GeV.

The near detector: ND280





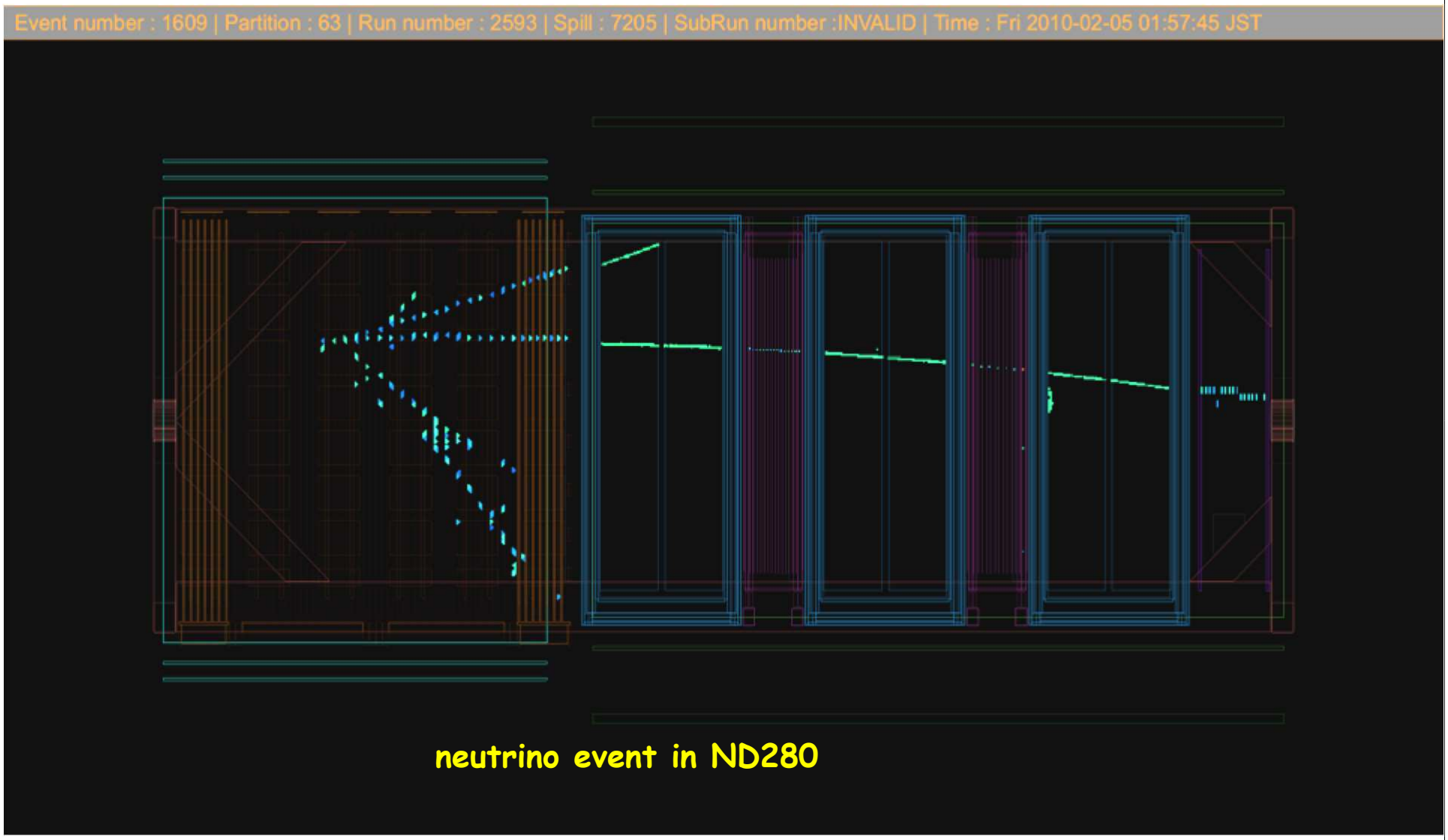
INGRID

- fully installed and operational

Off-axis detector

- Refurbished UA1 magnet: operational, field mapped
- SMRD: fully installed, commissioning
- POD: fully installed, commissioning
- FGD: installation this week
- DS ECAL: installation next week
- TPCs: 2 of 3 at JPARC, installation in October; third one in construction
- Barrel ECAL, POD ECAL: in construction, installation in 2010

With hinsight: could do better
.by integrating
.higher B
->DUSEL?

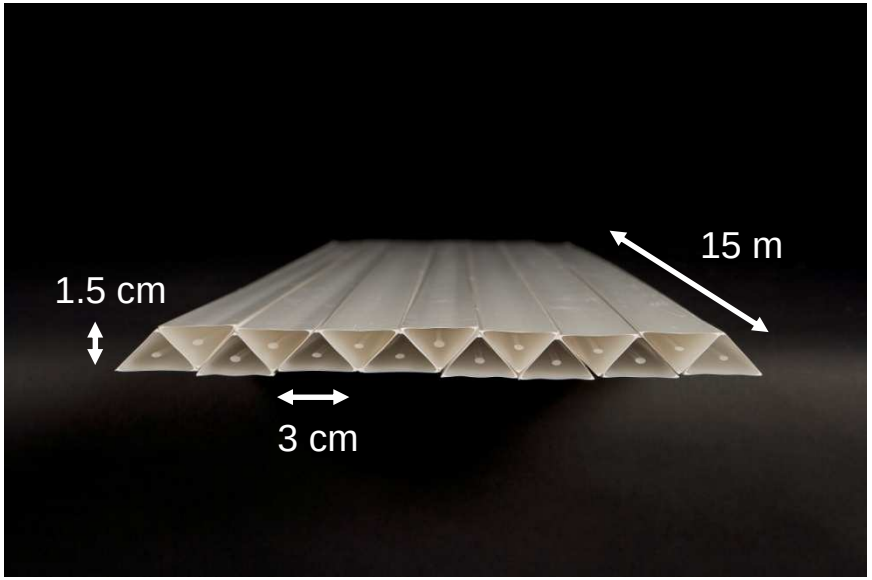


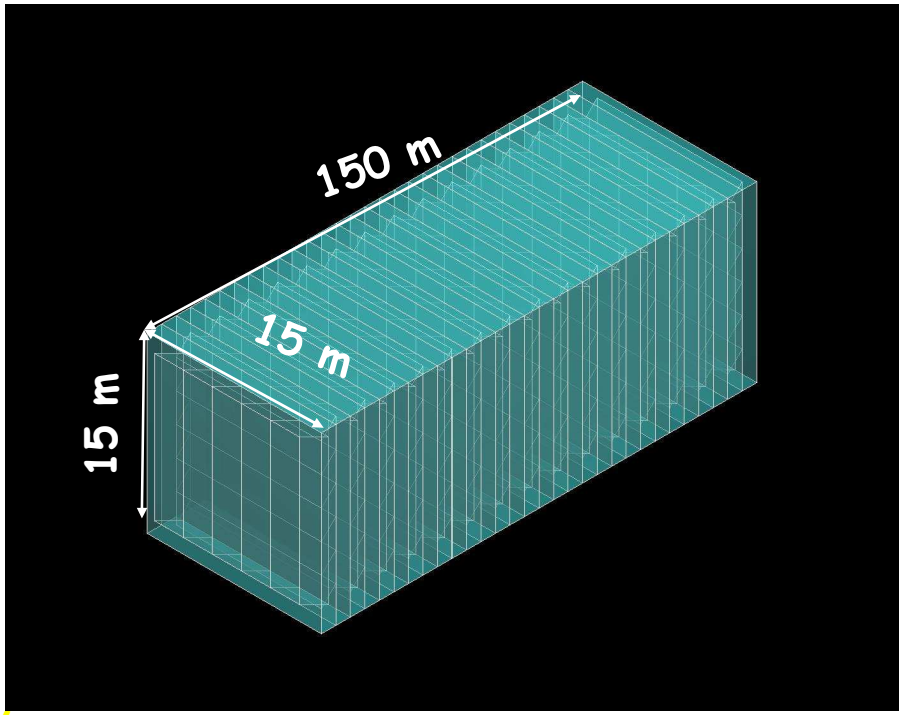
neutrino event in ND280

Fine-Resolution Totally Active Segmented Detector

Totally Active Scintillating Detector (TASD) using Nova and Minerva concepts with Geant4

- 35 kT (total mass)
- 10,000 Modules (X and Y plane)
- Each plane contains 1000 cells
- Total: 10M channels

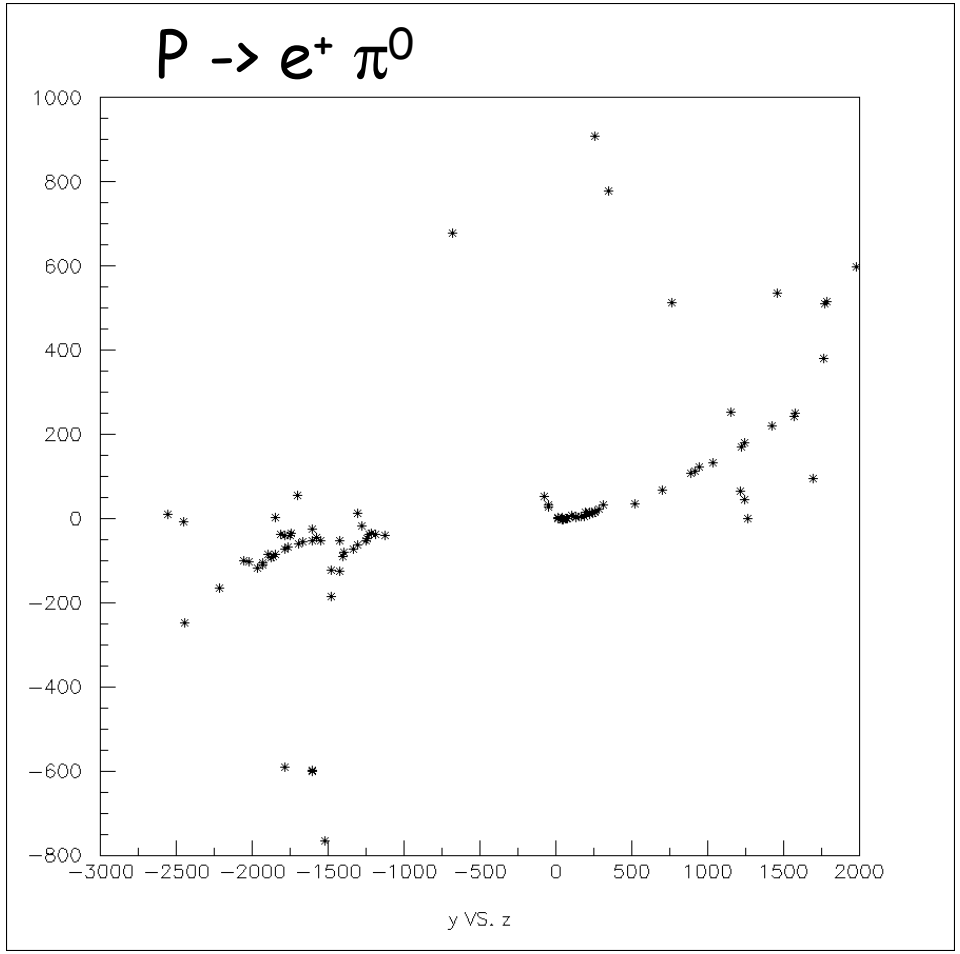


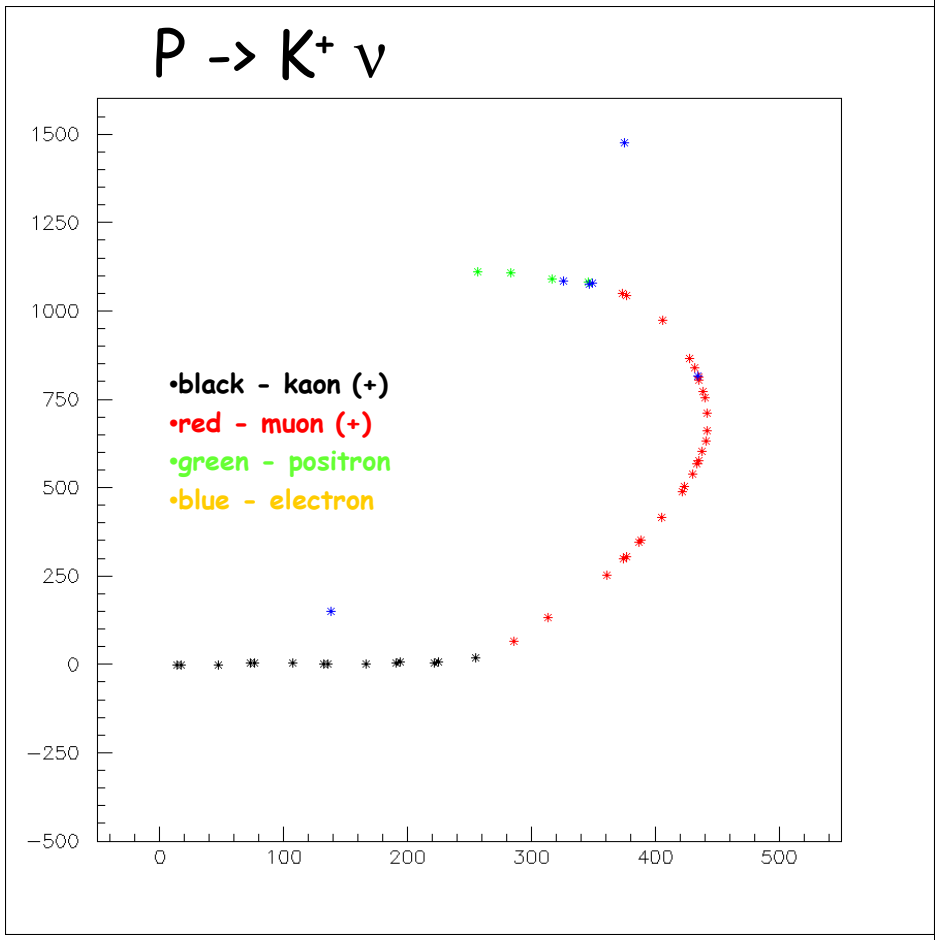


- Momenta between 100 MeV/c to 15 GeV/c
- Magnetic field considered: 0.5 T
- Reconstructed position resolution ~ 4.5 mm

B = 0.5T

Proton Decay





NB in scintillator and MPPC timing resolution is < 1ns (ND280)

Physics issues:

-- Stopping properties of pions and muons in Minerva detector
This will be studied in the MICE EMR at RAL
using stopping e/mu/pi of both signs

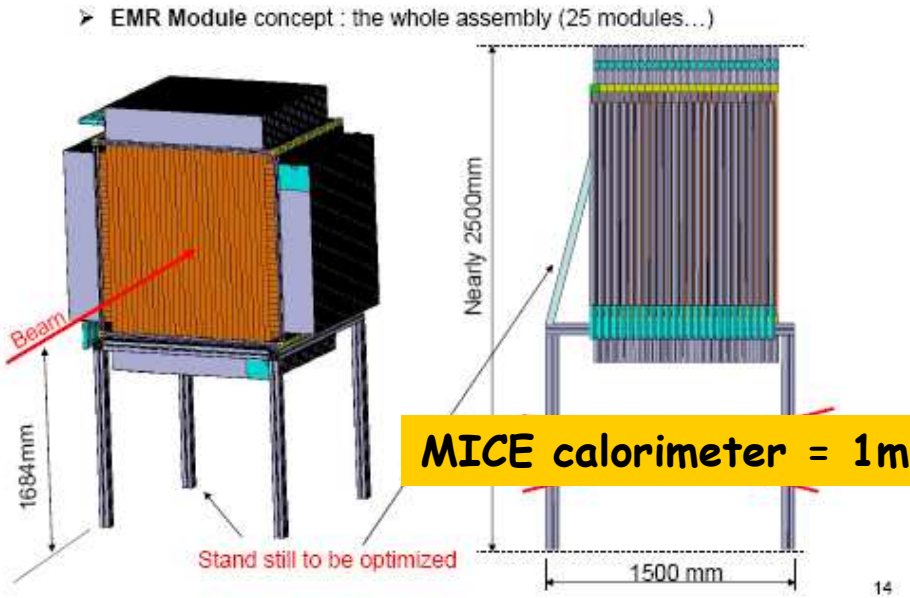
-- Charge separation for electrons in Minerva – like detector (with lower density?) in magnetic field
This will be studied in the MORPURGO magnet at CERN (AIDA)

-- Charge separation for muons in MIND-like detector
This will be studied in a baby-MIND detector at CERN

-- hadronic shower angular and transverse momentum resolution in TASD and MIND or LArg
(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?

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

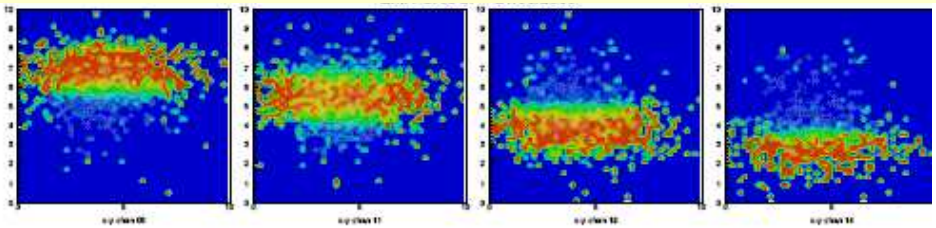
Triangular shaped bars (1.1m long, from Fermilab)



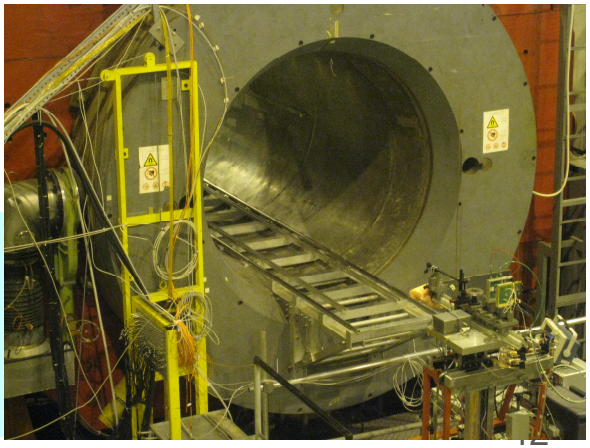
MICE calorimeter = 1m^3

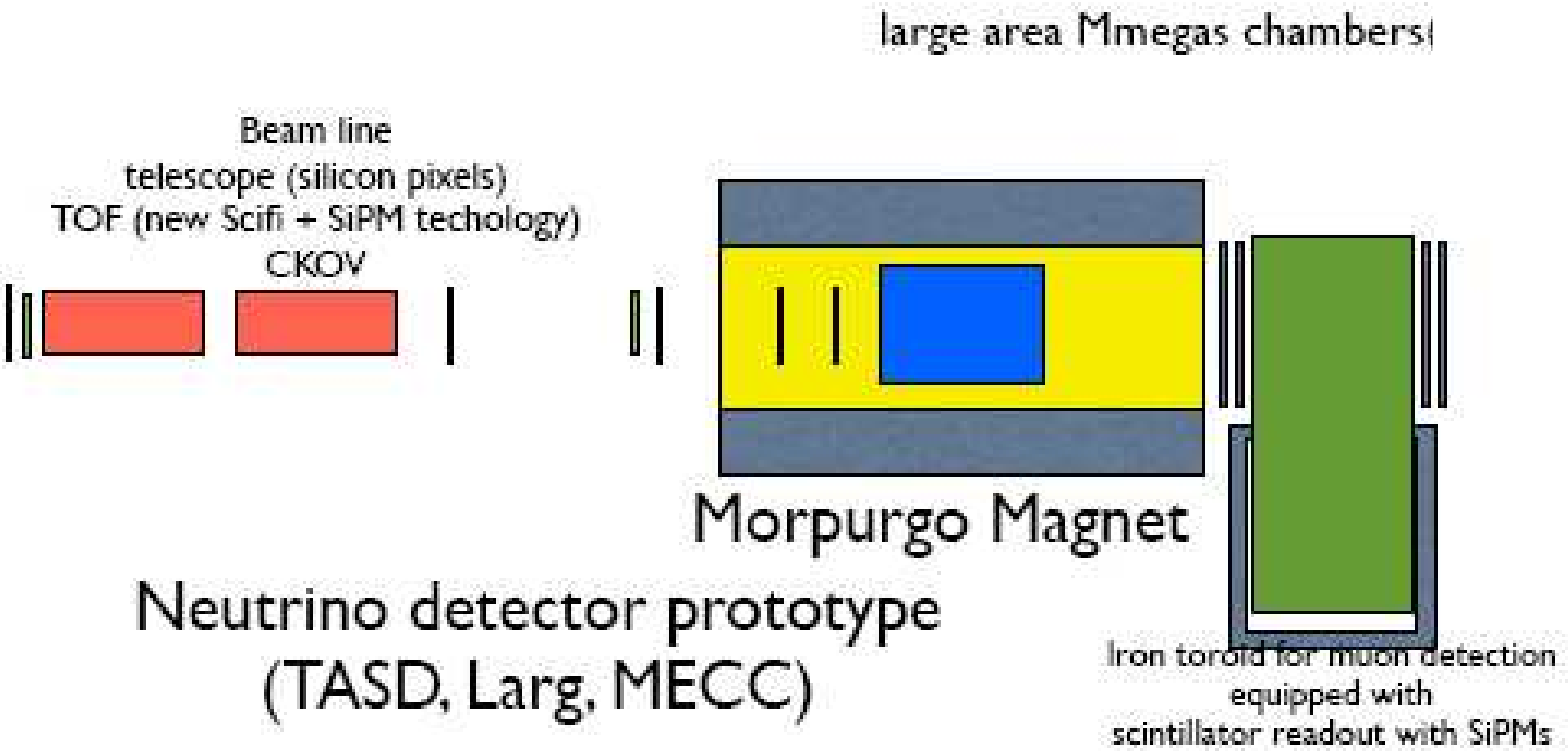
Accurate position resolution (mm)
→ triangular shaped scintillator bars
Magnetic field → si-PMT readout

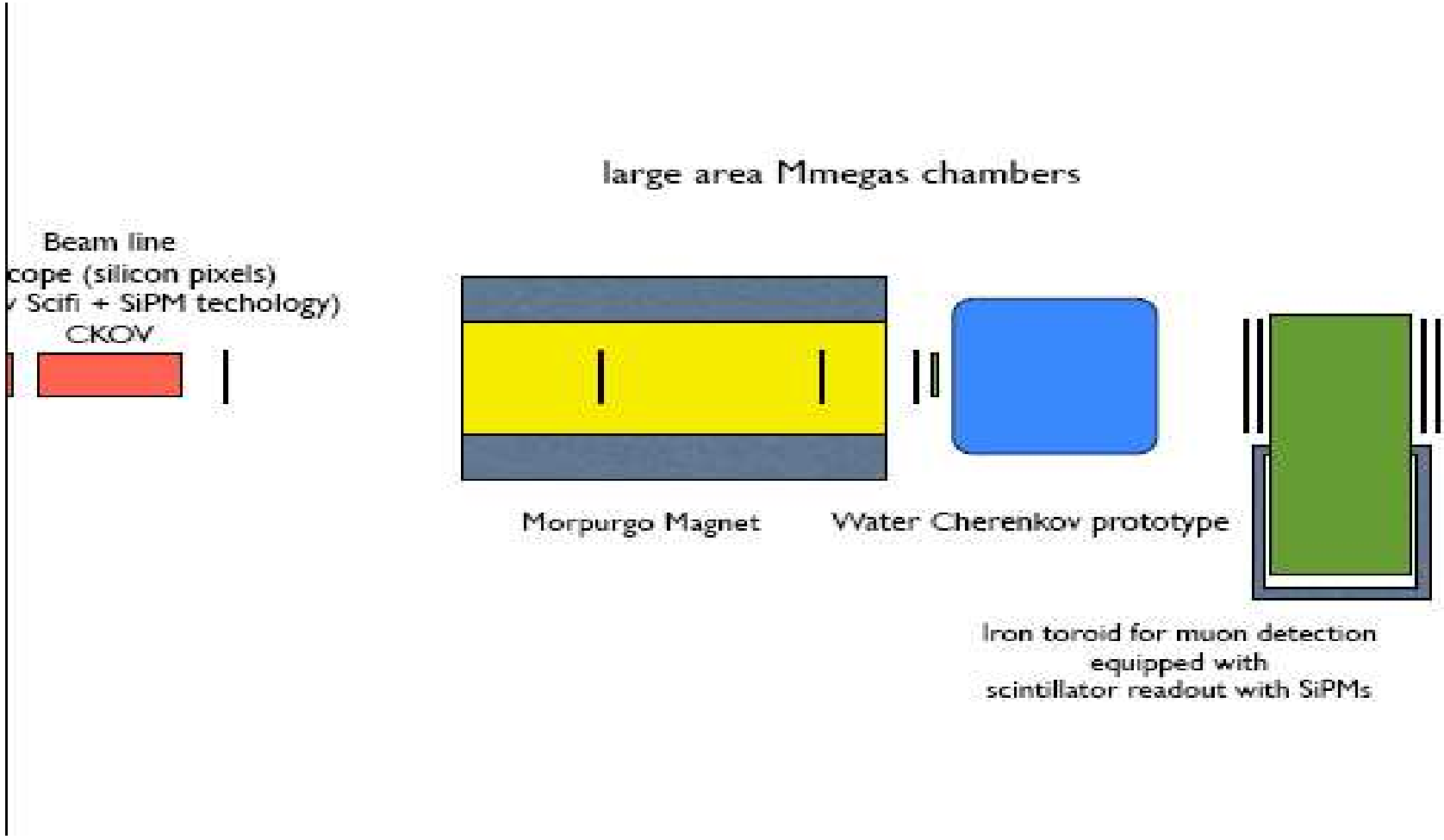
First test in T9 beam at CERN – position resolution few mm



Next step: 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




large area Mmegas chambers
Beam line
telescope (silicon pixels)
TOF (new Scifi + SiPM techology)
CKOV
Morpurgo Magnet
Neutrino detector prototype
(TASD, Larg, MECC)
Iron toroid for muon detection
equipped with
scintillator readout with SiPMs


large area Mmegas chambers
Beam line
cope (silicon pixels)
Scifi + SiPM techology)
CKOV
Morpurgo Magnet
Water Cherenkov prototype
Iron toroid for muon detection
equipped with
scintillator readout with SiPMs

AIMS of the MEETING:

Get together

1. **discuss physics case for experiment (which experiment?) on CERN beam oscillations, sterile neutrinos, cross-section measurements?**
2. **discuss/set-up plan and organization of R&D collaboration**
3. **discuss/set-up plans for EOI, LOI, proposals etc…**
4. **new ideas?**