Neutrino detector

The path from conceptual design to TDR

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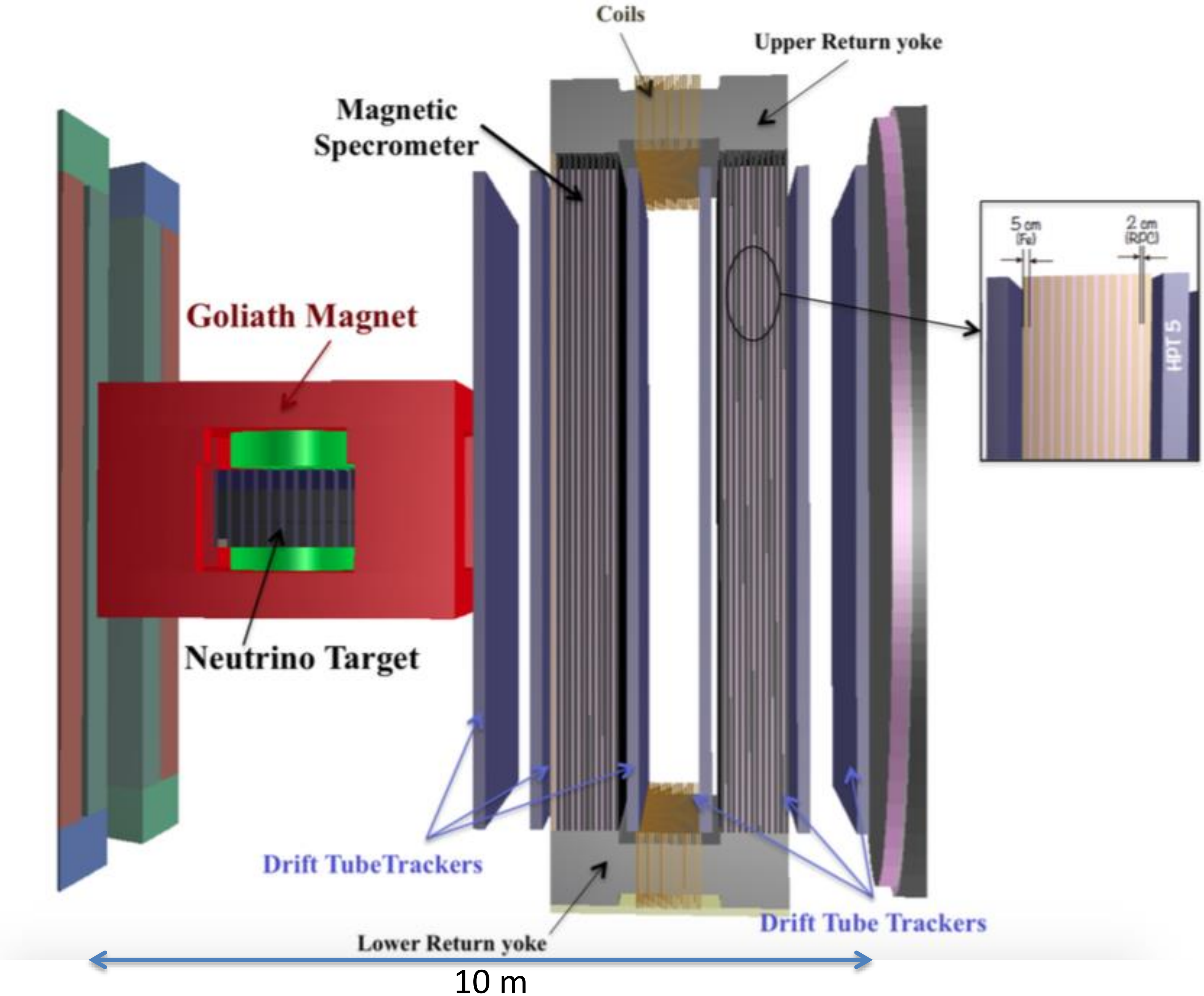
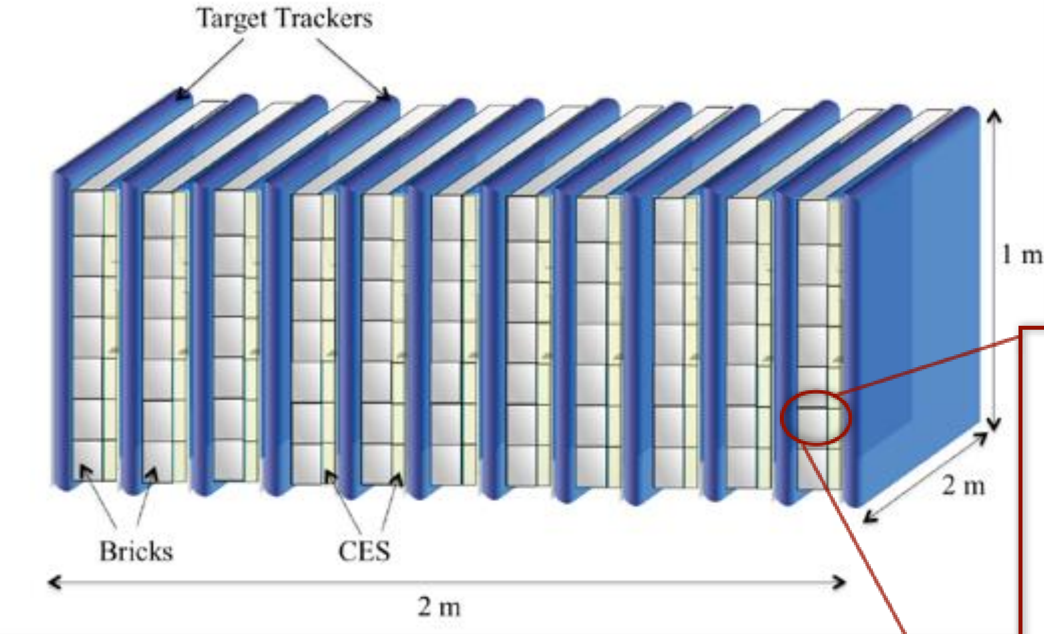
Project involving 15 groups from several Countries:
Bulgaria, Germany, Italy, Japan, Korea, Russia and Turkey
+ interest from France

The neutrino detector

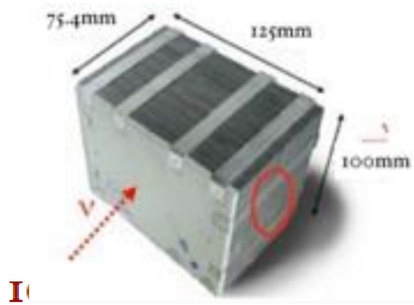


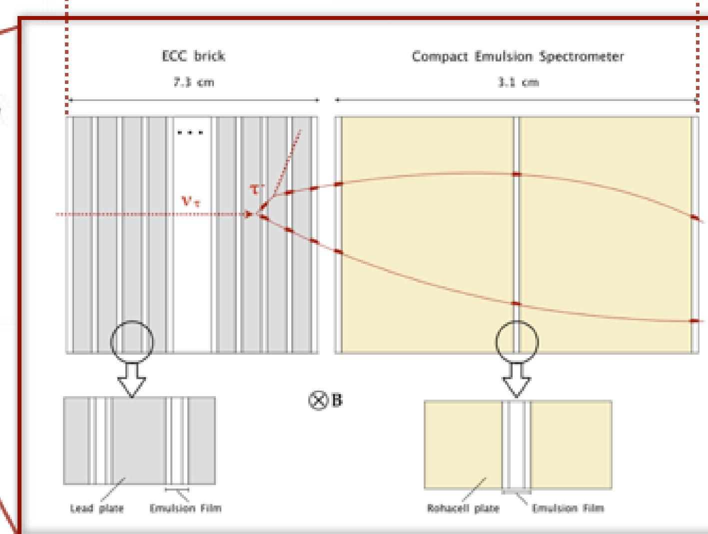
The neutrino target

ν target + vertex detector



Fundamental unit: **Brick**

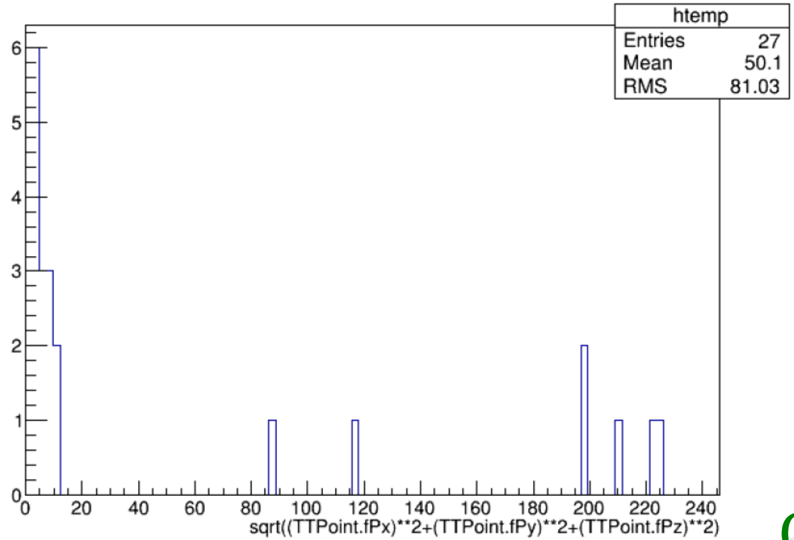




- **Emulsion Cloud Chamber technology**
- **Lead plates** interleaved with **emulsion films**

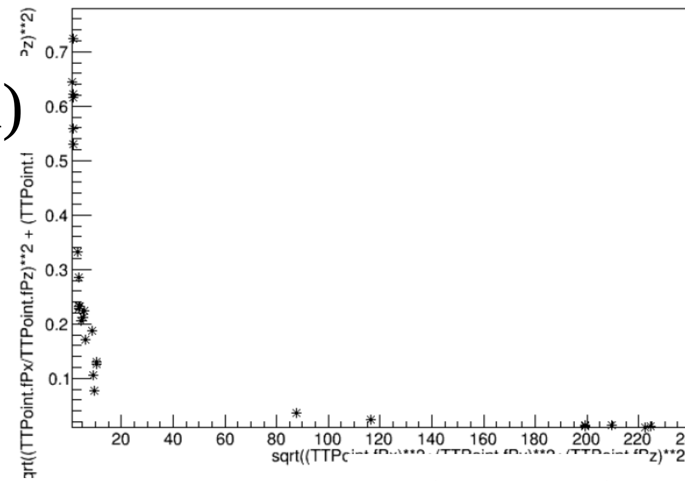
- Tau neutrino topology in emulsion: first signal/noise discrimination
- No challenge: OPERA as a demonstrator
- Important difference is the high muon flux → film replacement
- Define the replacement frequency (part of test program)
- Now assume twice a year, replacement easy but expensive

Muon flux at the neutrino detector: Thomas & Annarita



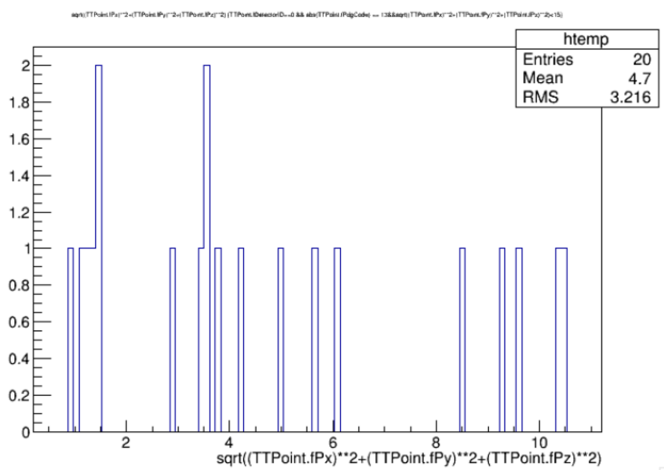
P (GeV/c)

ϑ (rad)

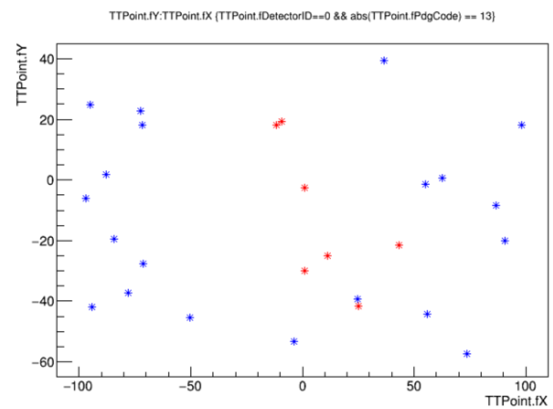


P (GeV/c)

Cascade included



P (GeV/c)



27 muons in 2.4×10^{11} pot and 2 m^2

equivalent to $\dfrac{2250}{m^2\,spill}$

in 6 months $\dfrac{2250 \cdot 5 \cdot 10^5 spills}{10^6 mm^2\,spill} \sim 1.1 \cdot 10^3/mm^2$

High density!

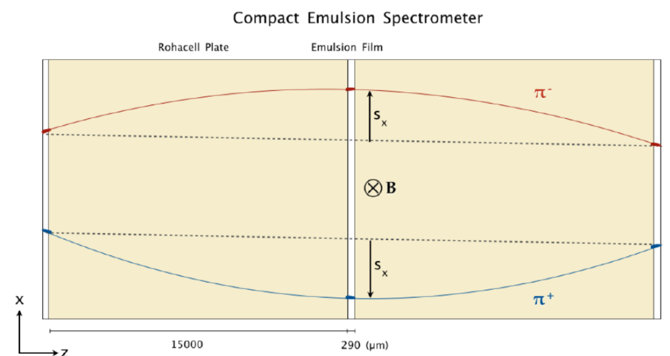
~1/4 of them high energy → useful for alignment purposes

Separation ν_τ /anti-ν_τ

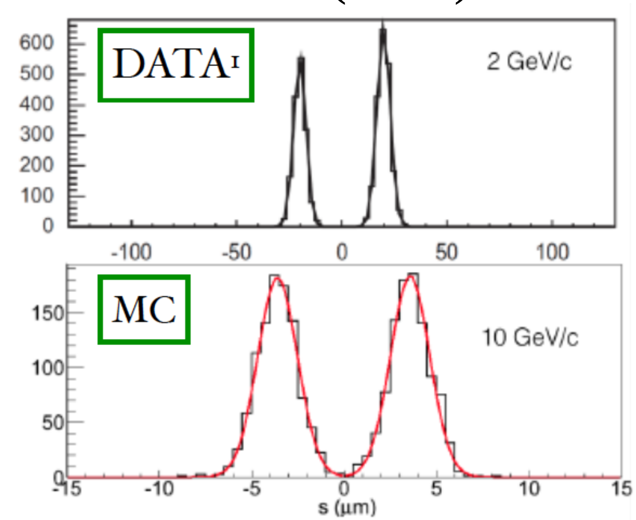
Magnetised target → charge and momentum measurement for hadrons

Use Compact Emulsion Spectrometer (CES) → challenge (see later)

- 1T field
- 3 films interleaved with 2 Rohacell layers (15 mm)
- 90% efficiency for hadronic τ daughters reaching the CES
- Sagitta to discriminate between positive and negative charge



NIM A 592 (2008) 56–62



Performances

- charge measured up to 10 GeV/c (3 sigma level)
- $\Delta p/p < 20\%$ up to 12 GeV/c

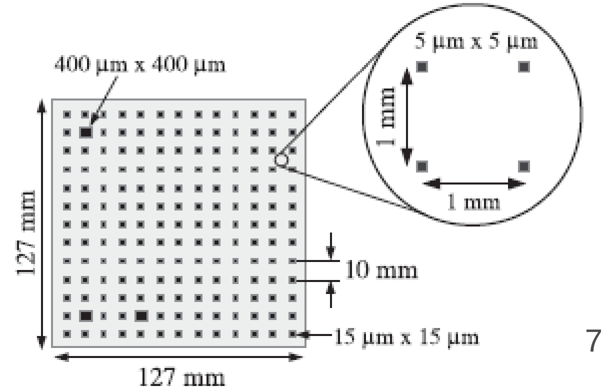
Compact Emulsion Spectrometer

- Although the principle was confirmed by a test beam experiment and by simulations, a few remarkable differences:
  - Extend the range from 2 to 10÷12 GeV
  - Use Rohacell instead of air gaps
- Rohacell (low density → MCS low) acting as a spacer without any additional frame, to avoid fiducial volume losses
- Rohacell difficult to keep perfectly planar
- Thickness accuracy ±0.2 mm granted by the maker (15 mm)
- Planarity and non-uniformity in the gap, ~ 1 mrad → ~ 100 um over 10 cm (brick size)
- Motivation for the tests with pion beams in 2015 (see Valeri's talk)

Compact Emulsion Spectrometer: Need for R&D

Practical problems may deteriorate its intrinsic performance:

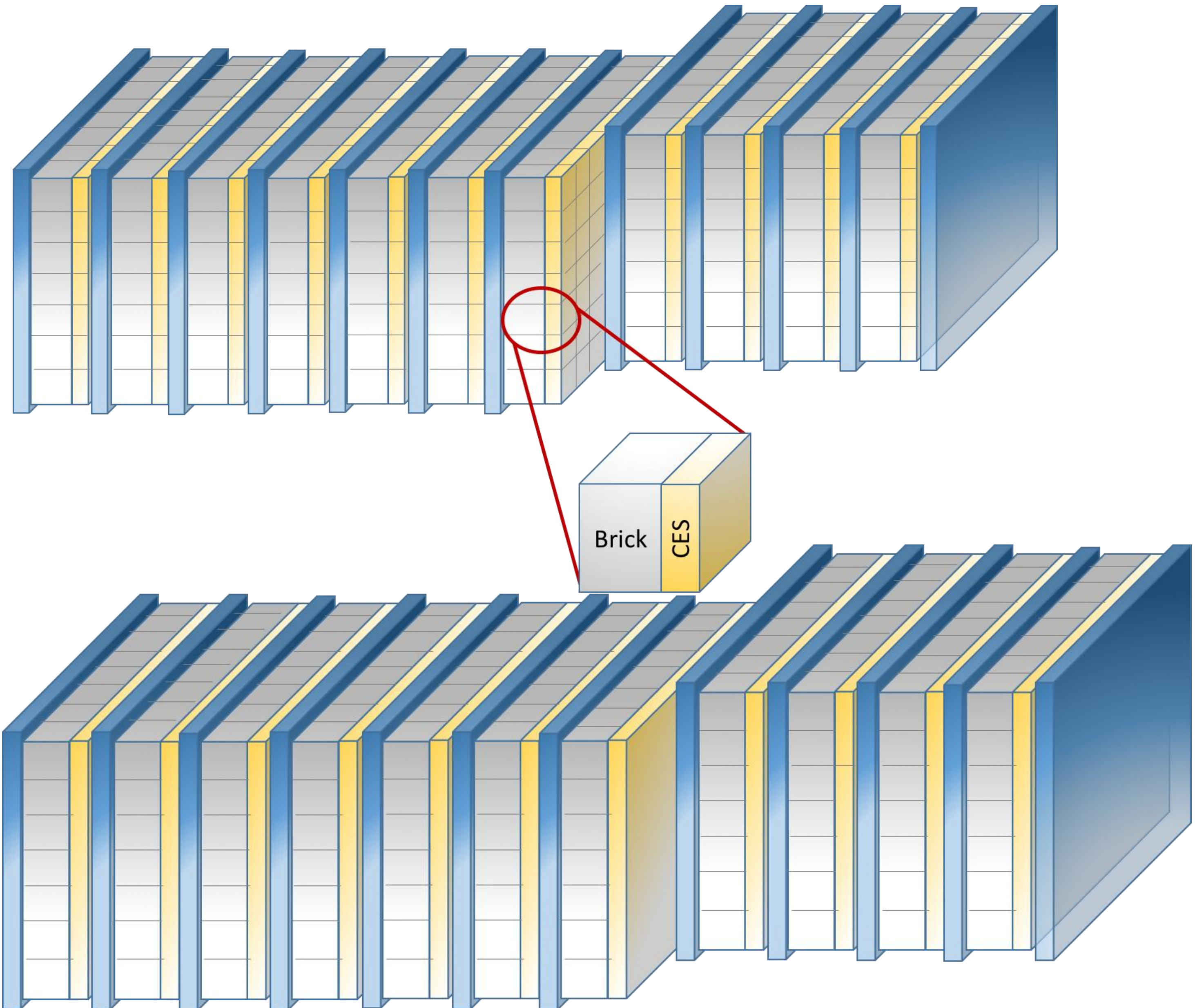
1. Structure of the CES
   – Ensure flatness of emulsion films
   – Choice of low density material: e.g. Rohacell, Airex
2. Deformation of emulsion films
   - Temperature effect: keep films at a stable temperature (in magnetic field)!
   - Distortion during development: use a photo-mask to correct deformations

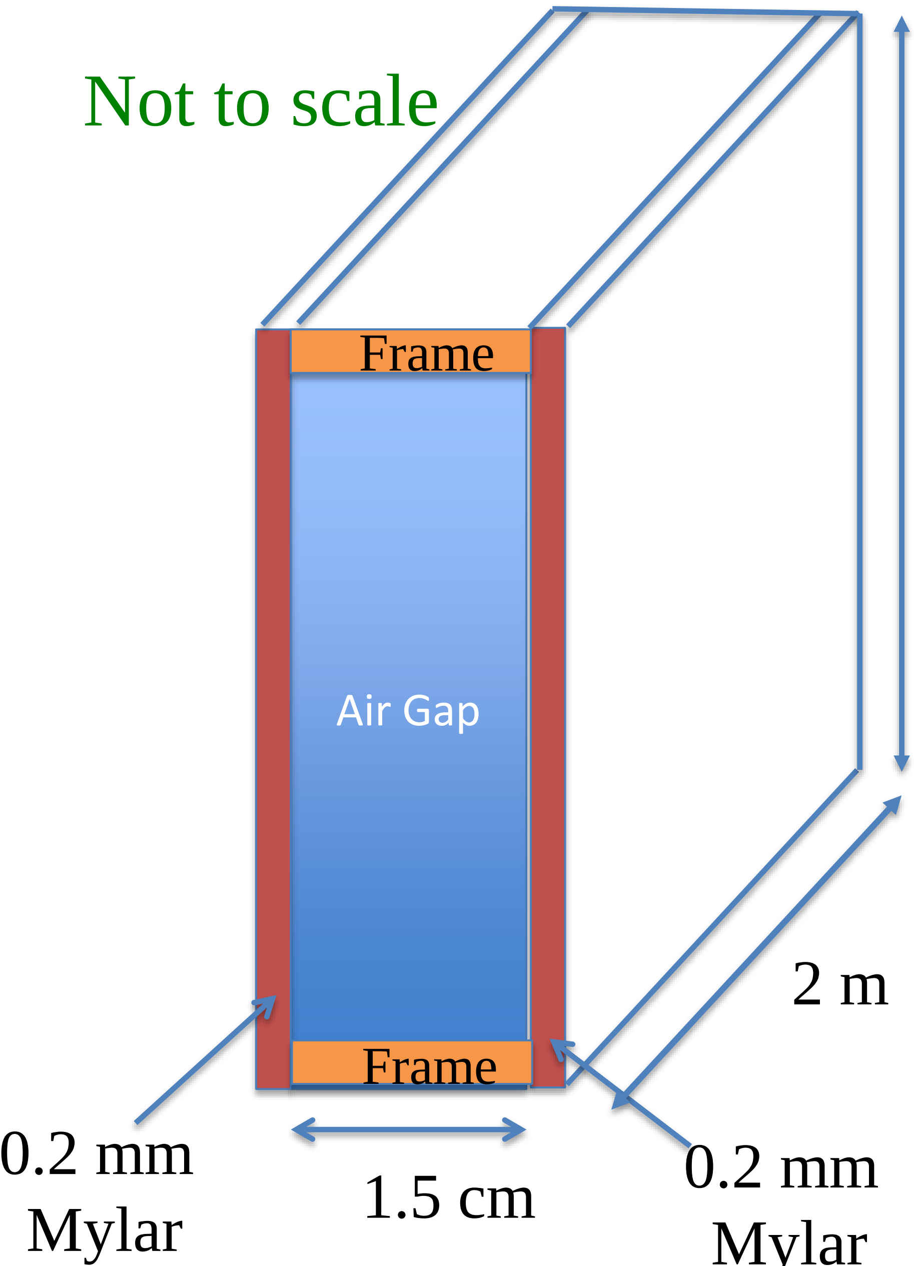


Need for R&D

- Good alignment between emulsion films
  - use high energy muons
  - Rate and momentum distribution of muon tracks (current plots based on low statistics)
- Identification (and connection) of tau daughter tracks
  - low background tracks
  - changeable (replace frequently) CES

Use large modules (one for each wall)

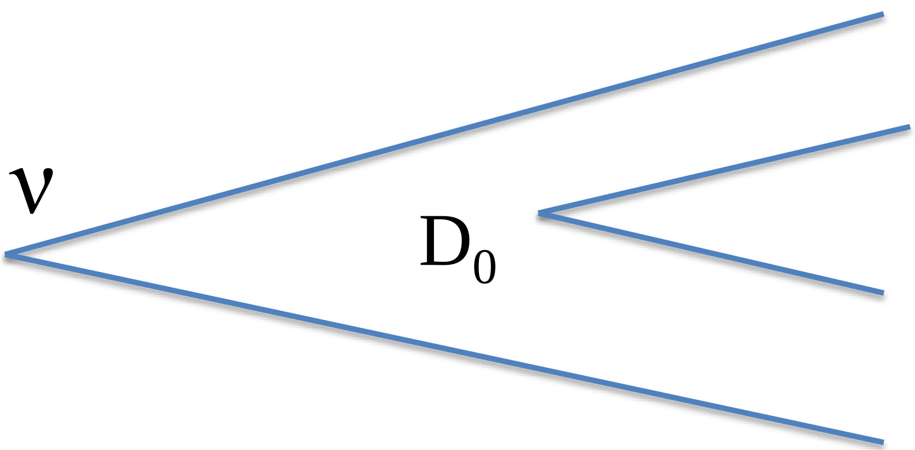




- Replace Rohacell with air gap
- Air gap with a frame
- Frame outside the emulsion area to avoid fiducial volume losses
- Mylar tape tensioned with the same technology used for gas chambers
- Pour emulsion layers on both sides of mylar
- Prepare a small-scale (10 x 10 cm^2) prototype to be tested in August 2016

Target tracker

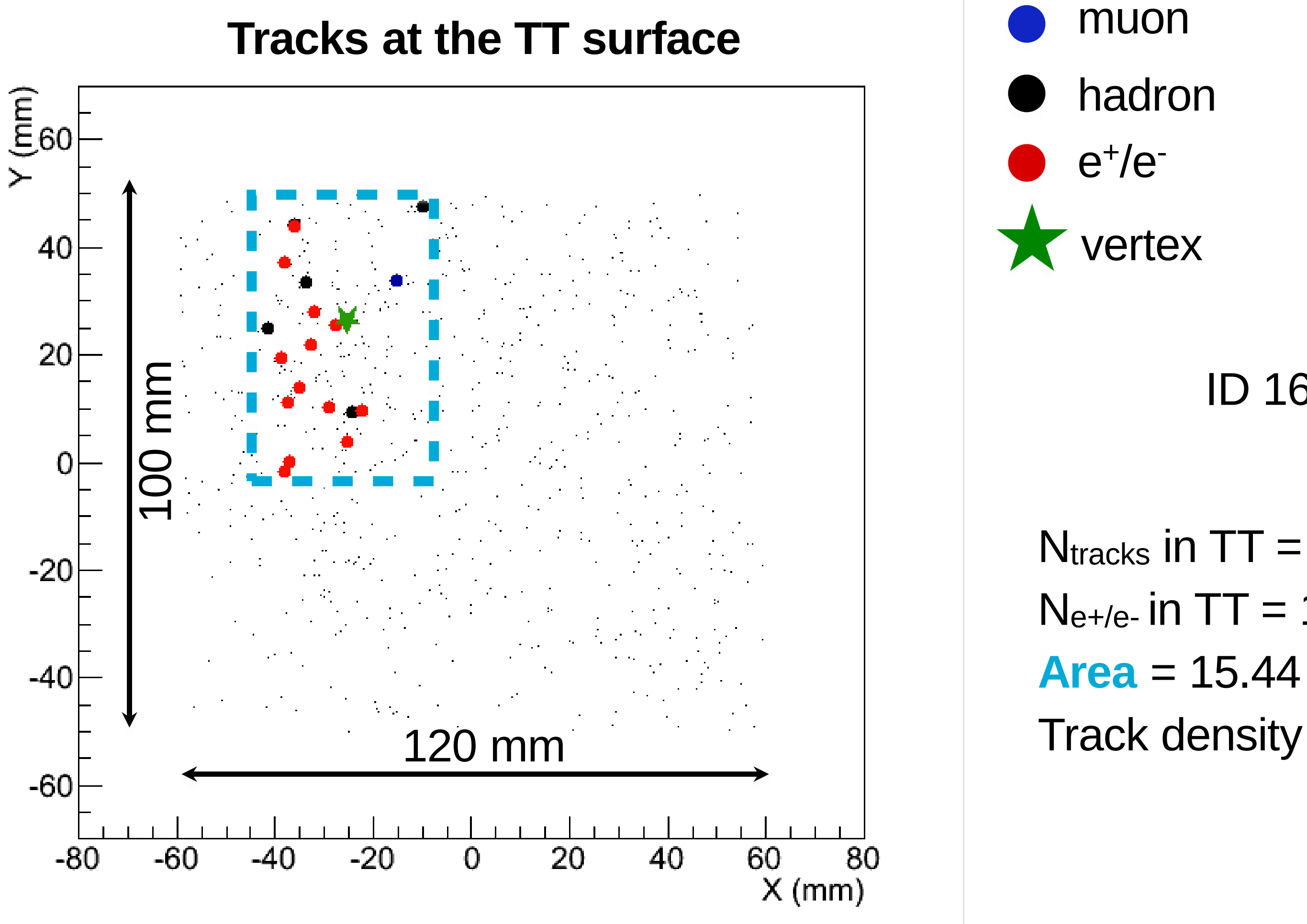
- Time stamp to the event and high spatial resolution to separate tracks within the same event
- Target tracker: 100 μm or better, time sensitive
  - Scintillating Fibres: solid technology, expensive
  - Gas chambers: cheaper, test beams to demonstrate technological challenges in magnetic field



e.g. charm production in neutrino interactions for QCD measurements

ν tracks in the TT (A. Di Crescenzo Dec 2014)

An event with electromagnetic shower



ID 169

N_{tracks} in TT = 18

$N_{e+/e-}$ in TT = 13

Area = 15.44 cm^2

Track density = 1.2/cm^2

TT Resolution (A. Di Crescenzo Dec 2014)

- Requirement: TT-Emulsion alignment with high (>98%) purity and (>90%) efficiency
- Assume 100 GeV muons at zero angle uniformly distributed on the surface
- 2 mm gap between CES and TT
- Relationship between single point and fitted position to be assessed

Density (muons/mm^2)	**Resolution (μm)**
100	20
10	60

Note: muon tracks passing through → can be discarded

The muon density here is made of those not discarded for inefficiency

First tests on emulsion-TT matching performed in 2015

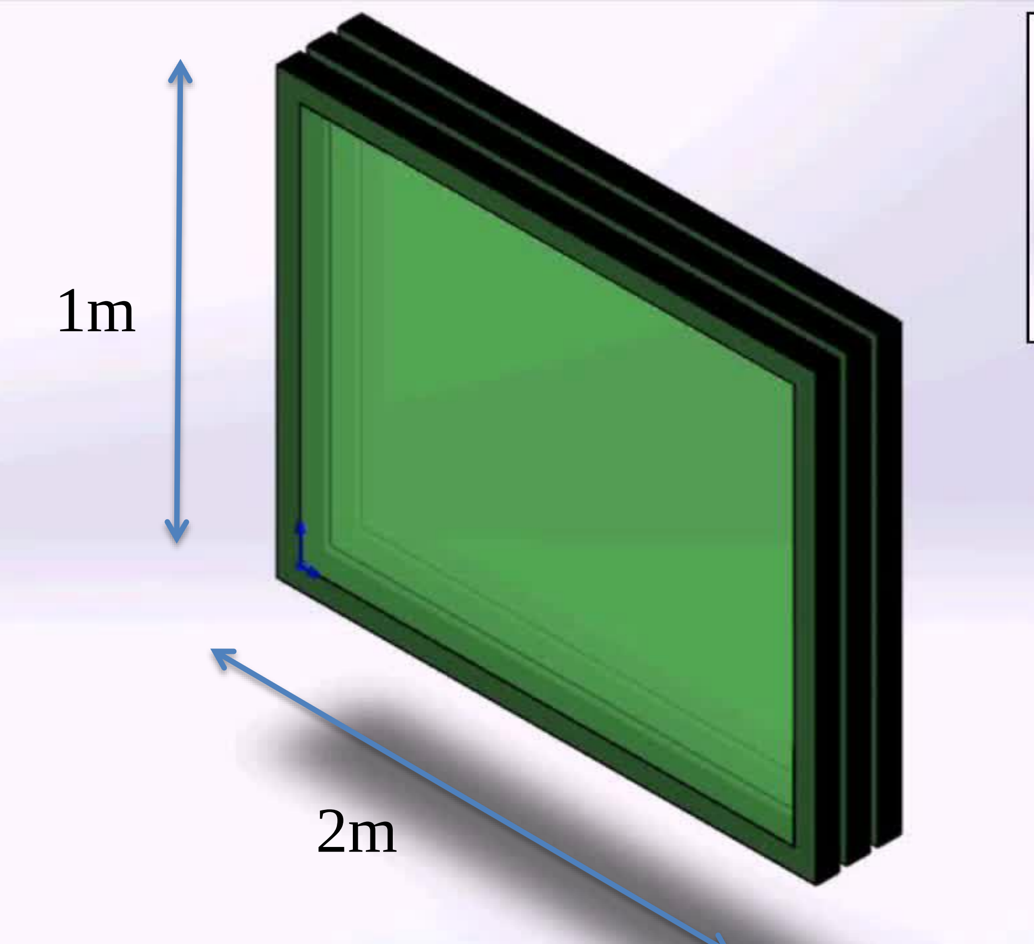
(see Valeri and Bencivenni talks)

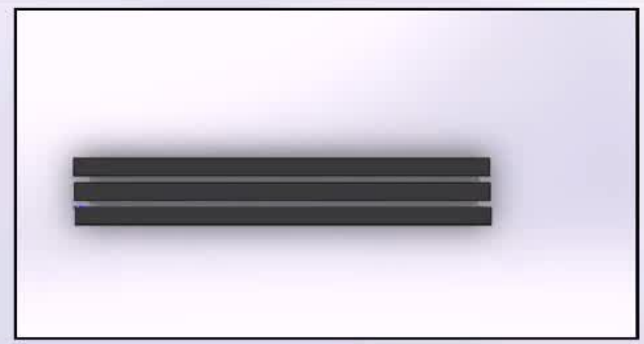
TT-Emulsion connection

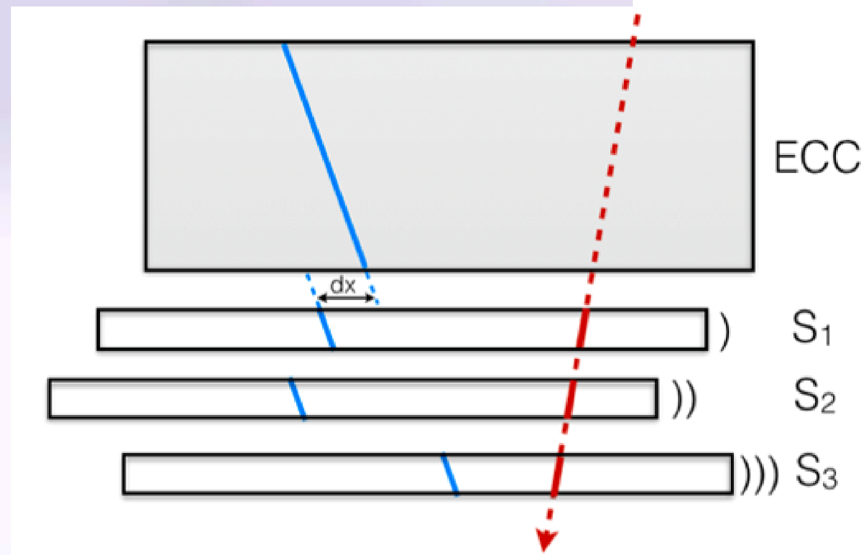
- Nuclear emulsions: 1 μm (~ 1 mrad), time insensitive
- Connection challenging due to time insensitive emulsions & ~100 μm TT resolution
- Measure TT resolution in magnetic field, improve it?
- Provide time sensitivity to emulsions
- NIM A620 (2010) 192

$$\frac{2 \cdot 10^6 \nu_{int}}{5 \cdot 10^6 spills} = 0.4\ \nu_{int}/\mathrm{spill}$$

Another R&D option





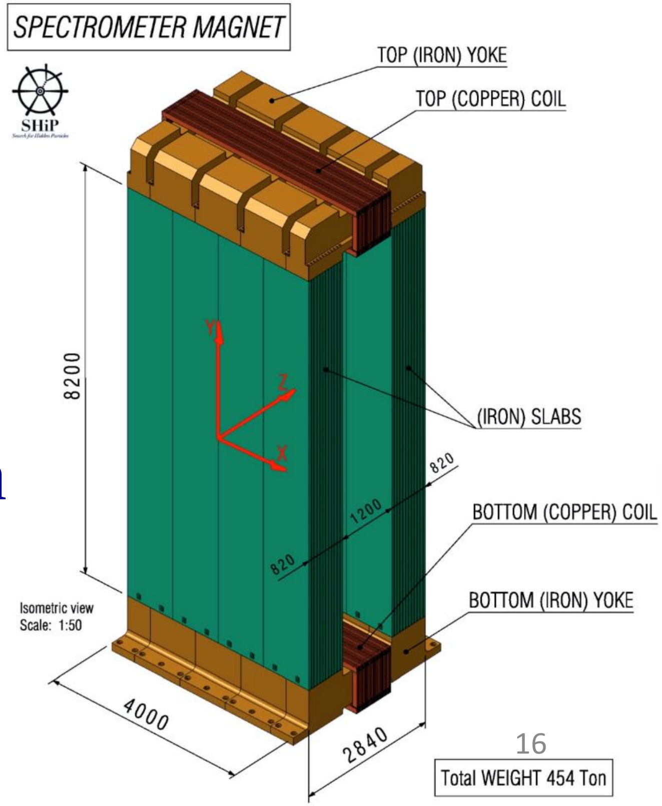


Emulsion Shifter consisting of 3 stages, each moving cyclically at a different speed
Track displacement linked to the recorded time

Produce a small-scale prototype (10 x 10 cm^2) to be used in magnetic field for the test beam in August 2016 (challenging)

Muon spectrometer

- Based on RPC
  - Available from OPERA
  - Magnet originally ~ same size
- TP size requires new chambers to be built to fit the different width (add to existing one)
- New electronics to be designed (Bari working on it)
- Prove that resistivity is good enough at our rates, otherwise develop new chambers (Tests at Frascati)
- RPC technology preferred to scintillator bars (for the same position resolution) in environments with γ and neutron background



Target nuclear effects and electron neutrinos

- In order to study nuclear effects → replace the target material: from light to heavy target, see for instance CHORUS, EPJ C30, Issue 2, (2003) 159-167 (37k)
- In a dedicated run (at the end typically)
- Measure nuclear effects in neutrino DIS with unprecedented precision
- Such measurement could shed light on a long-standing problem: nuclear effects in DIS appear to be different in electron scattering at HERA compared to neutrino charged-current scattering at NuTeV
- Target optimisation to separate electron neutrinos and anti-neutrinos

Infrastructure at CERN
Emulsion handling room

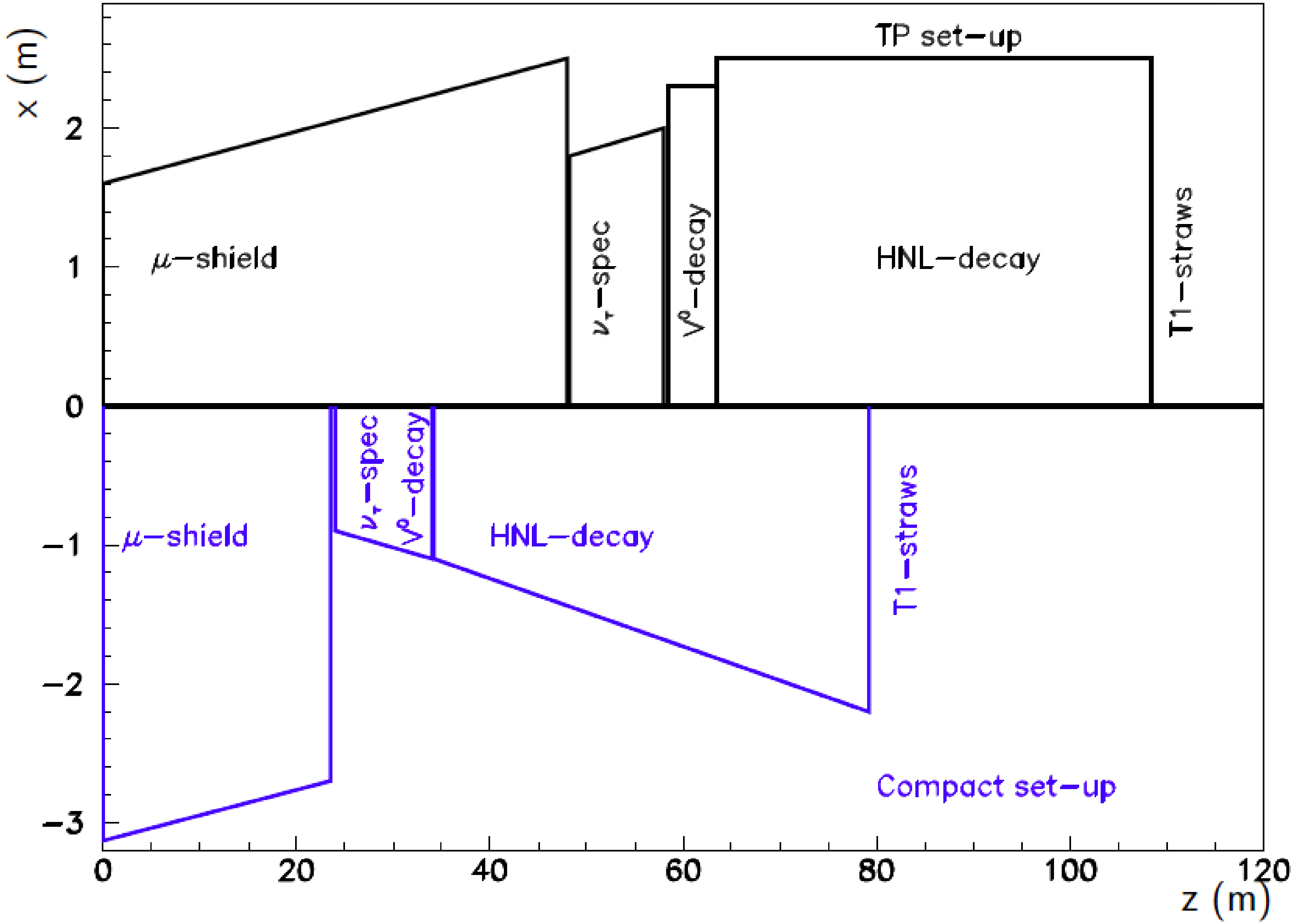
Laboratory used for past emulsion experiments (CHORUS, OPERA preparatory phase)
Partial refurbishment, environmental conditions to be optimised

- Dark room
- Brick assembling
- Emulsion development

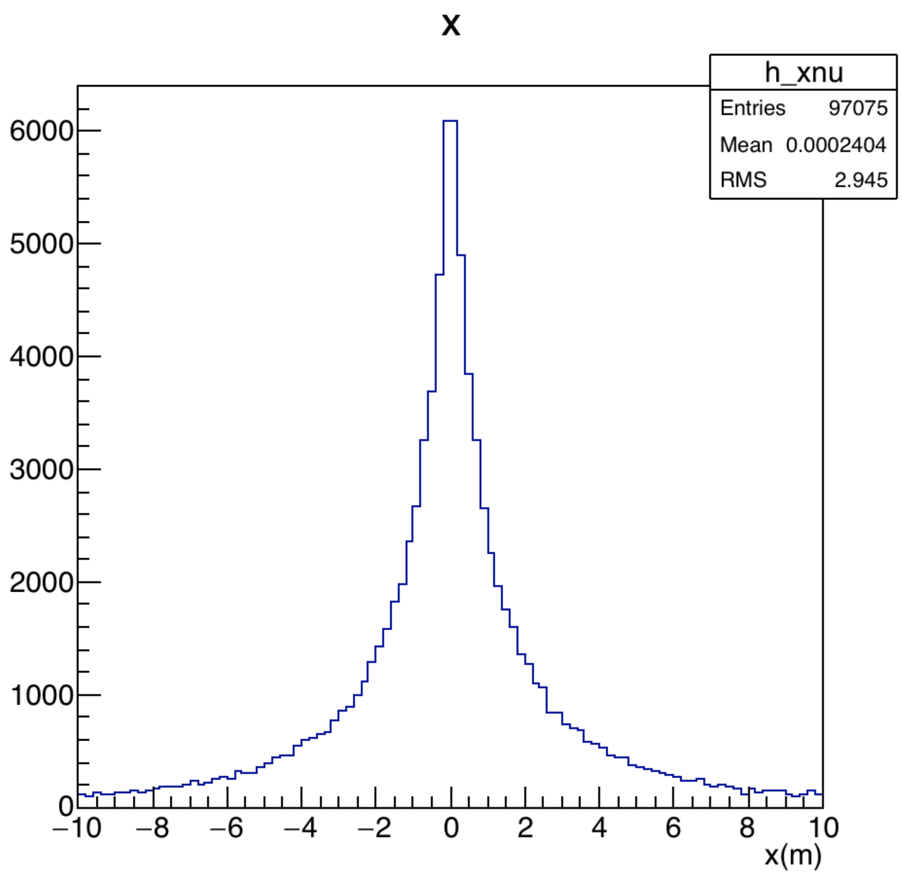
Partial conclusions

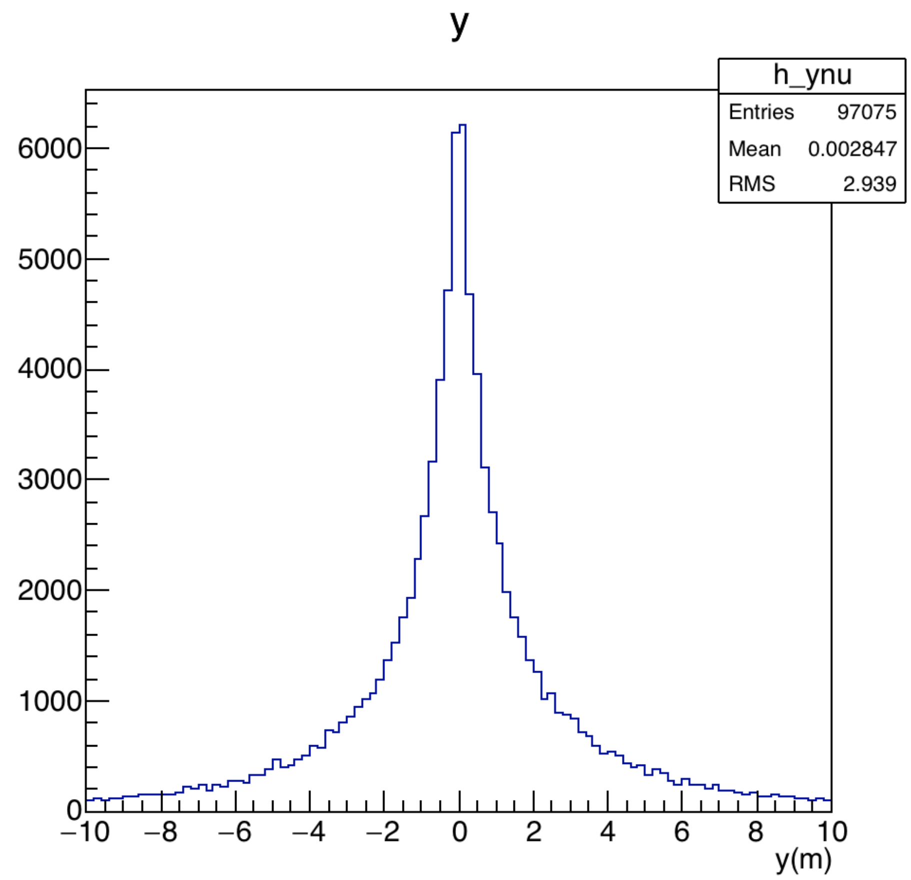
- Several challenges deserve R&D in the coming years
- Intense test beam activity
- Emulsion facility operational again

Hans talk, January 21st



Beam spatial profile 25 m upstream



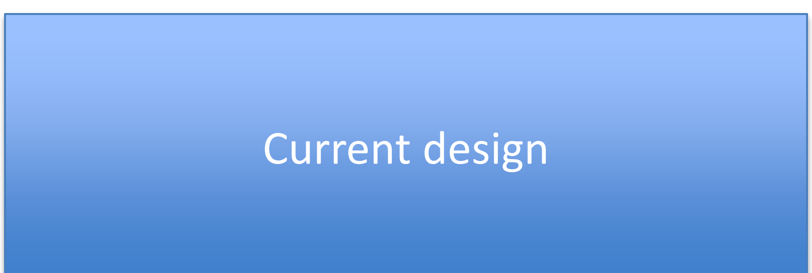


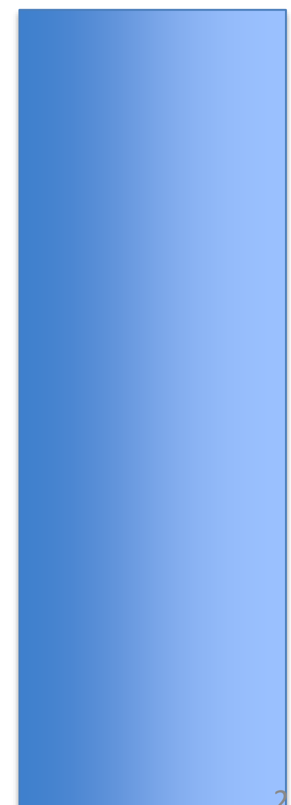
Key point for a good measurement

- Main physics program: tau neutrino cross-section
- A few thousands fully reconstructed events are needed for cross-section studies
- Keep constant the number of interactions as in the TP
- Play with other parameters (shape, mass)

Re-design the neutrino target

- Tau neutrino flux increase by ~ 2.4
- Re-design the neutrino target → keep the same cross-section (2 x 1 m^2) but develop it vertically
- With same cross-section → decrease the length
- Lower mass (less emulsions) → more frequent replacement possible (according to the muon rate)
- Re-design the magnet (Goliath too large)





Optimisation

- Optimise neutrino detector together with V_0 decay
- Assume 10m (TP ~15m) between mu-shield and vacuum vessel (Gain/TP ~ 29%, see Hans)
- Scaling factor 3/2 → from 10 to 7m
- Re-define the target and magnetc
- Re-optimise the muon spectrometer
- Drift tube level arm shorter → better resolution
- Synergies with V0 decay? Straw tubes to measure outgoing muons