SHiP
Search for Hidden Particles

The neutrino/LDM detector: towards the CDS and beyond

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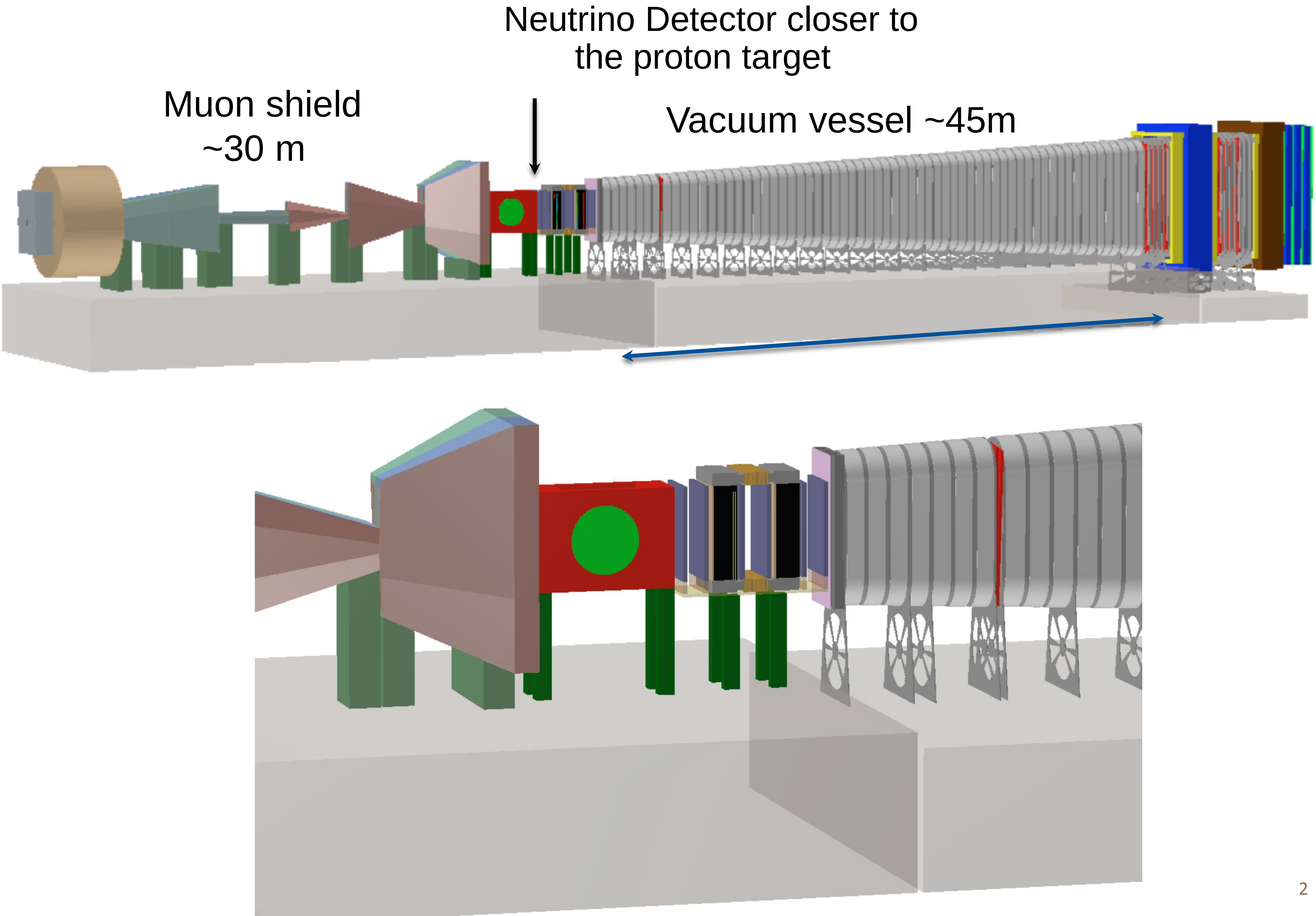
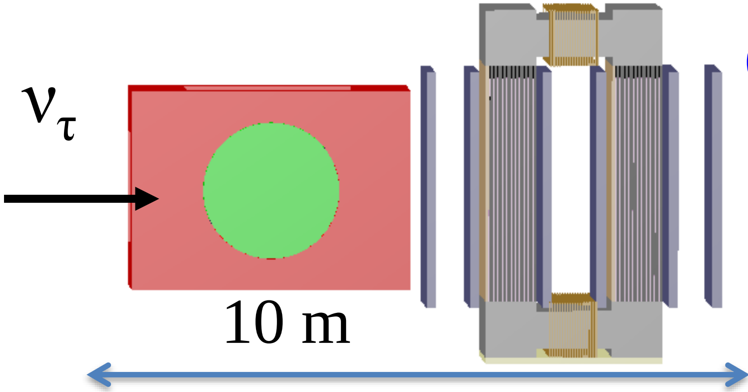
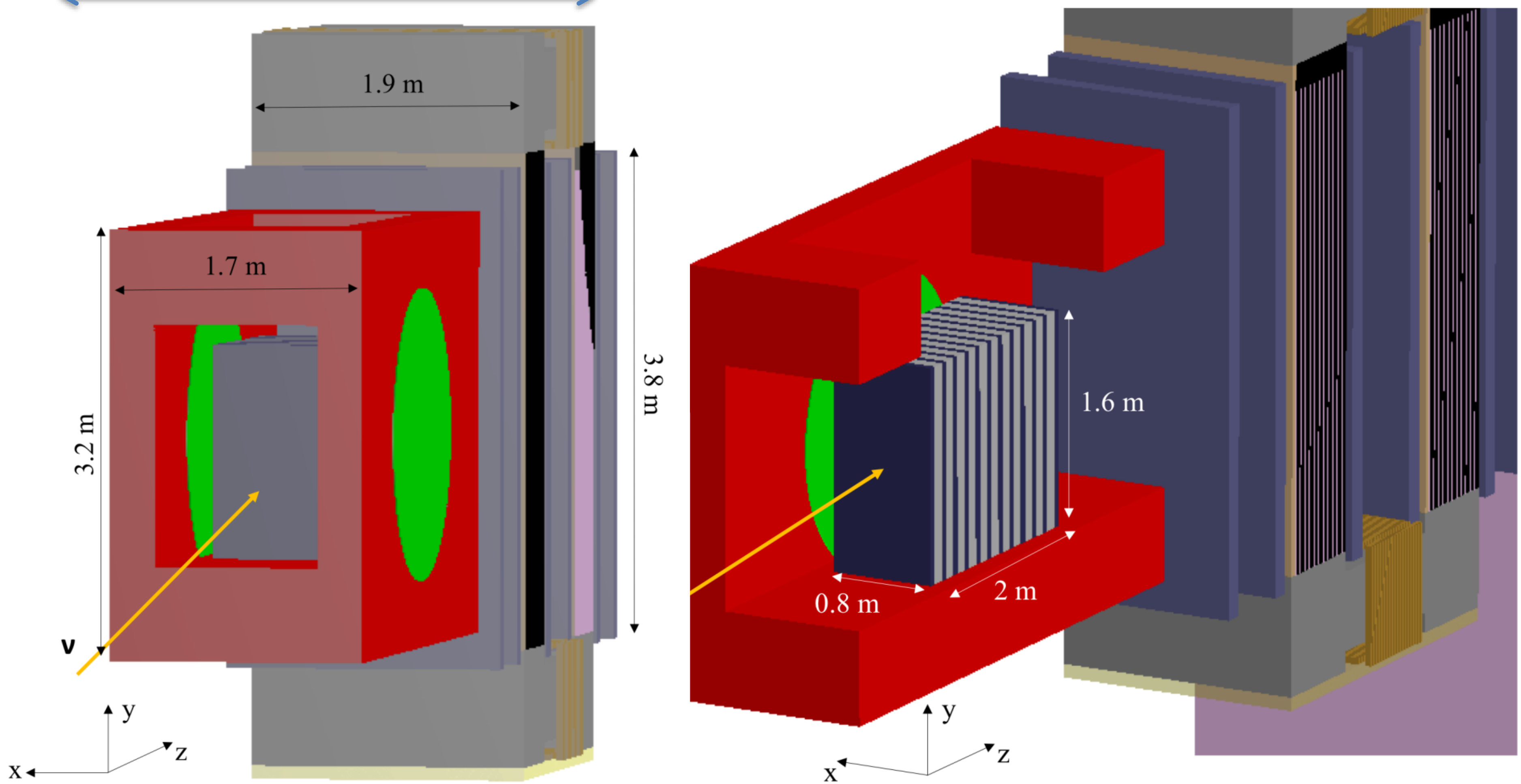
Project involving many groups from several Countries:
Bulgaria, Germany, Italy, Japan, Korea, Russia and Turkey
+ interest from France

Detector Optimization

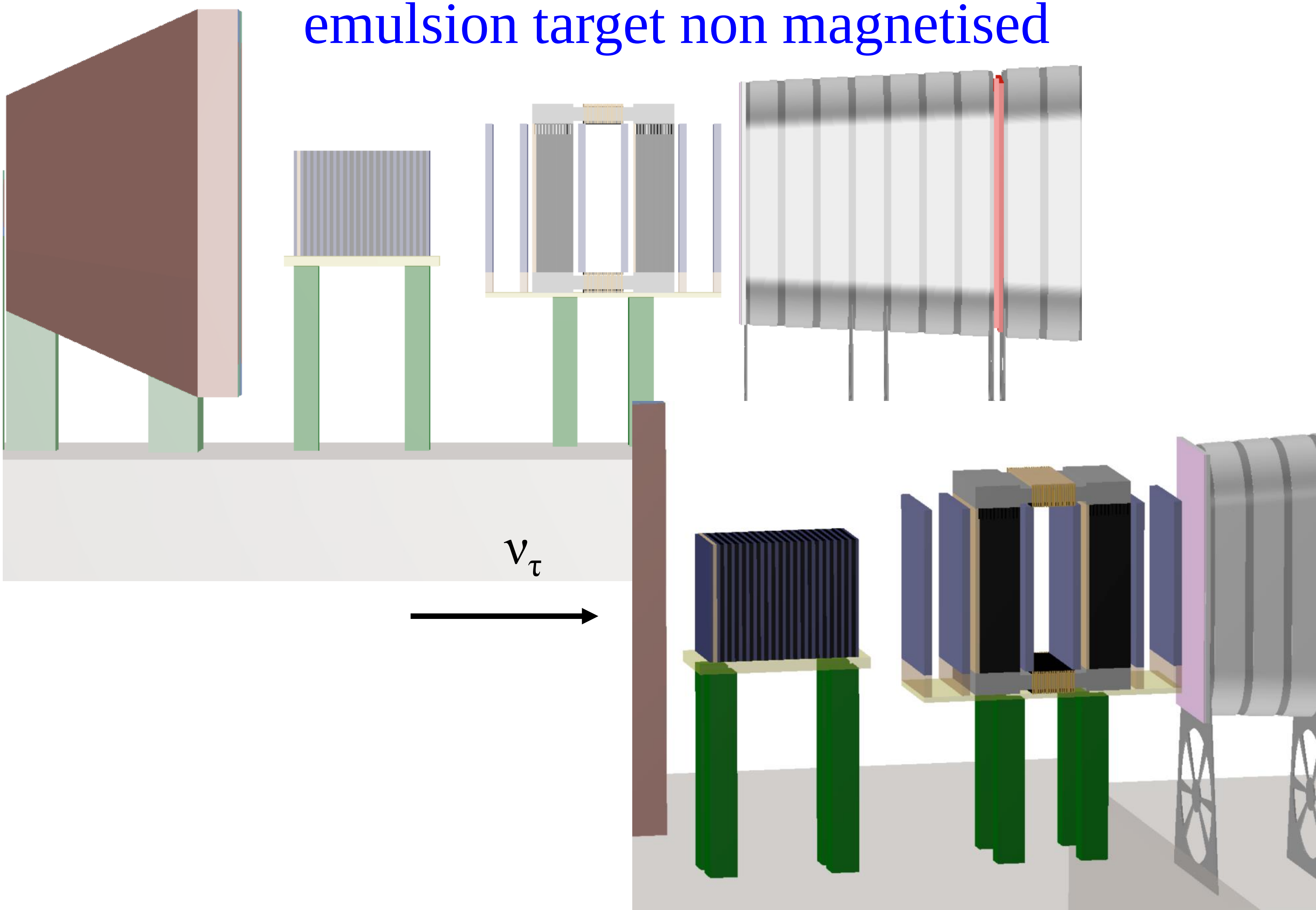


FairShip implementation (A. Buonaura) emulsion target magnetised

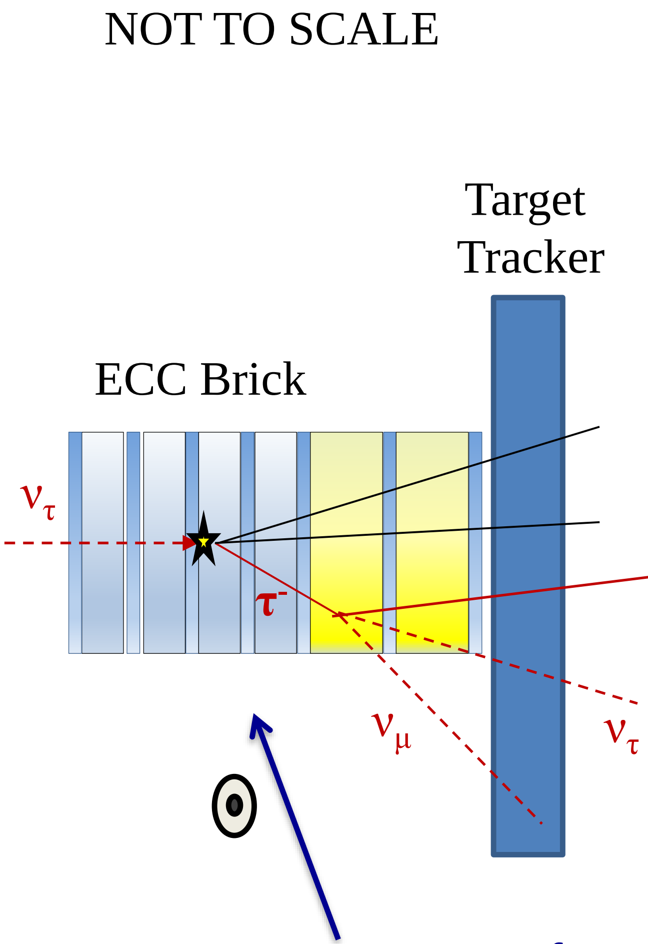


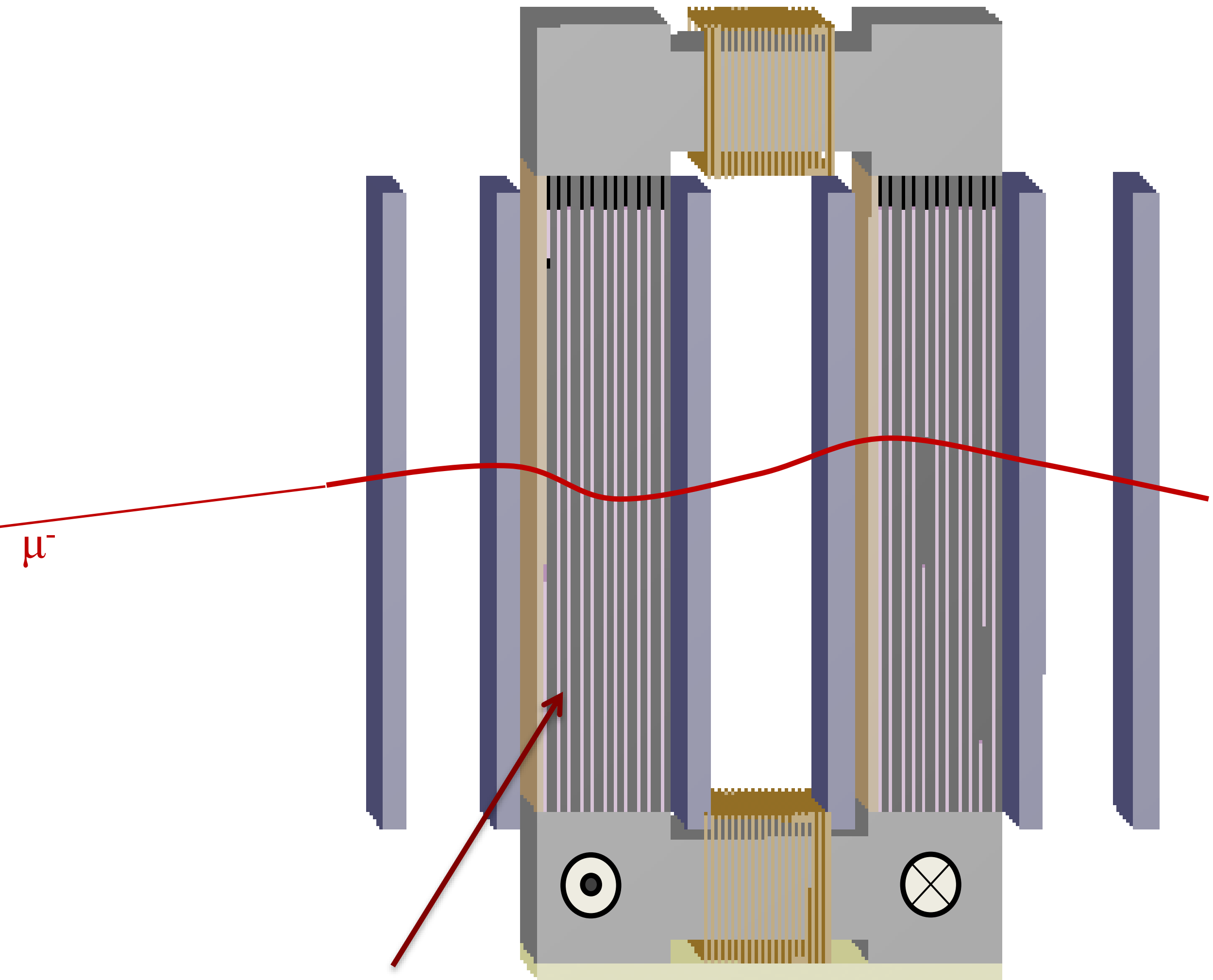


FairShip implementation (A. Buonaura)
emulsion target non magnetised



ν_τ detection



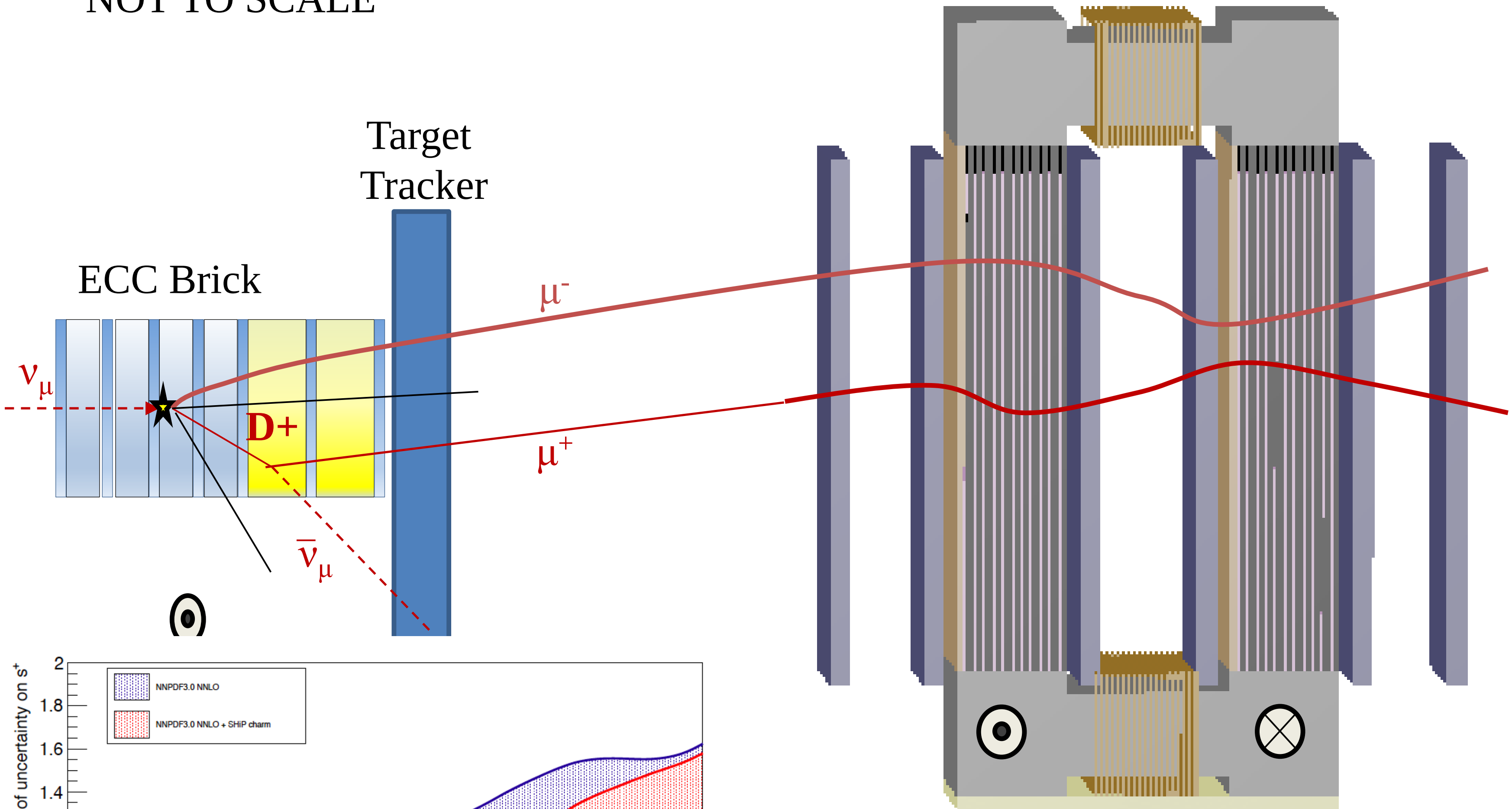


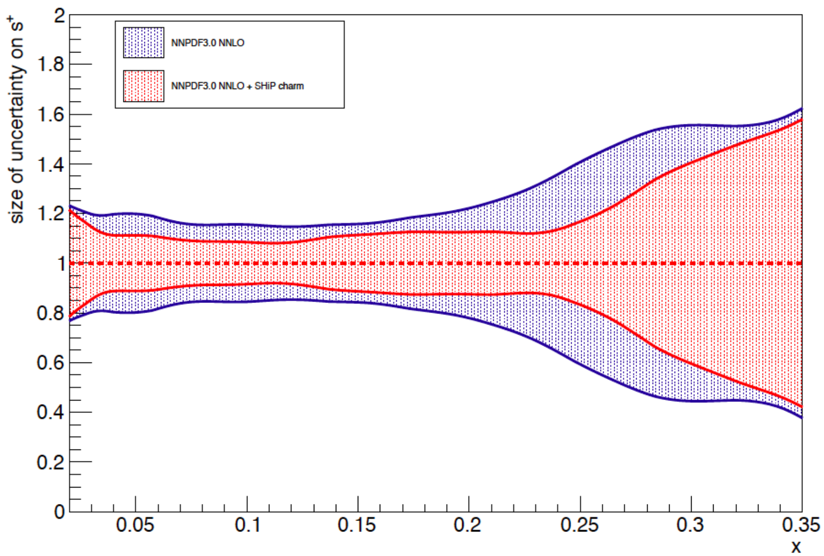
- Micrometric accuracy for τ identification
- Momentum and charge measurement for τ^+/τ^- separation in hadronic decays

- Muon identification and momentum/charge measurement

Charm production for QCD measurements

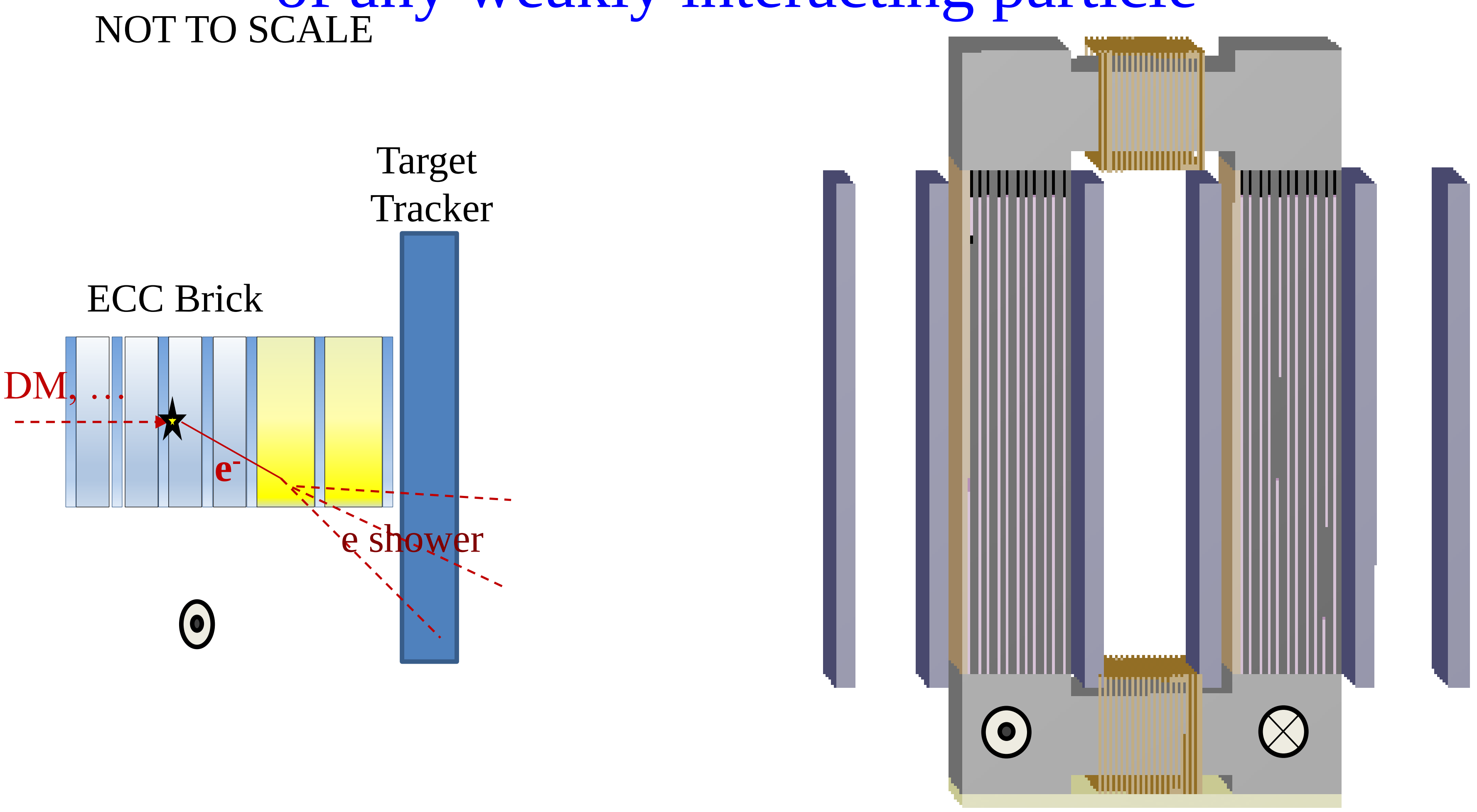
NOT TO SCALE





Measuring s-quark content of the nucleon

Interactions with atoms (electrons and nucleus) of any weakly interacting particle



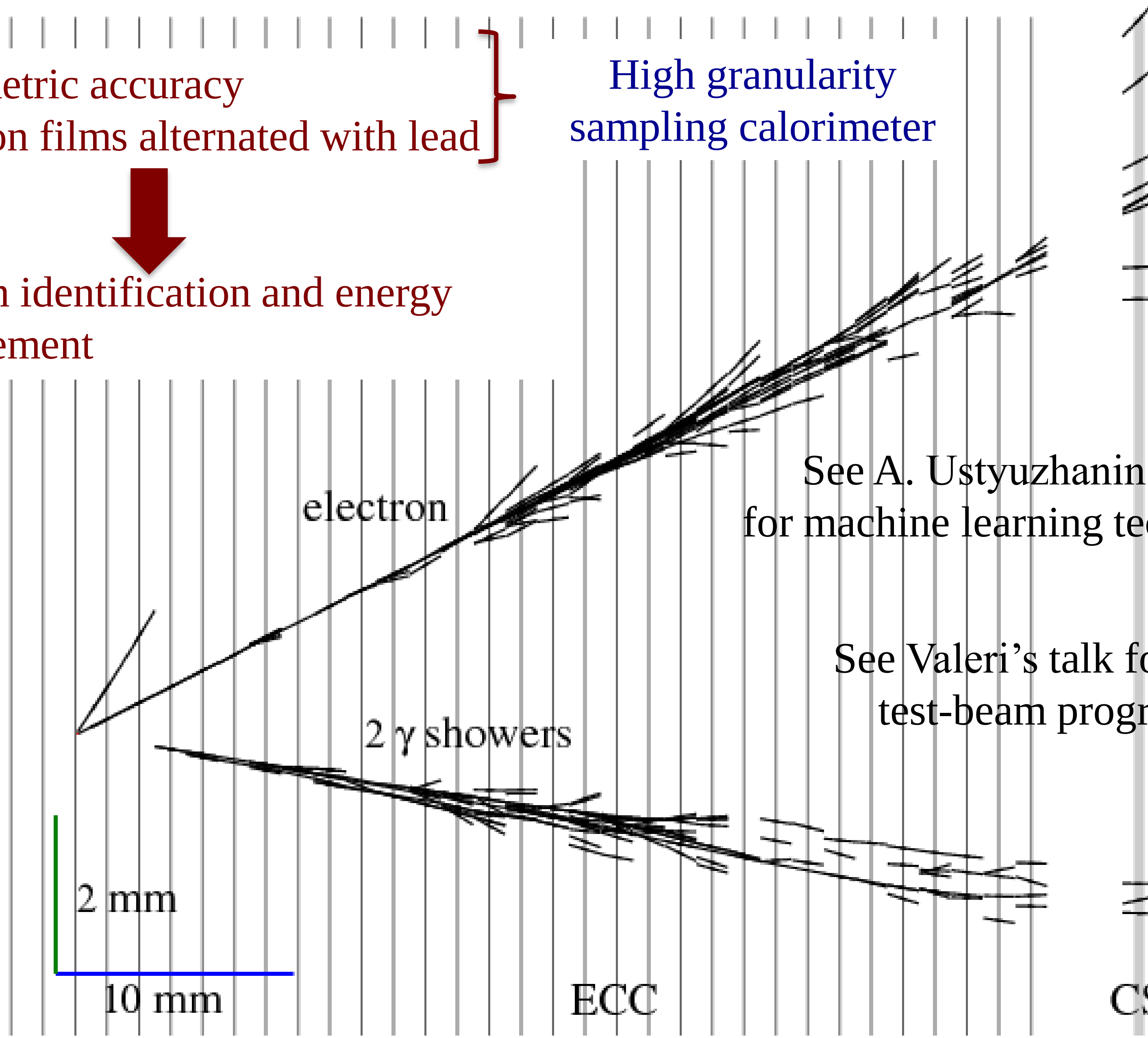
Typically without any muon in the final state

Dark matter interaction with electrons: ν_e-like event

- Micrometric accuracy
- Emulsion films alternated with lead

High granularity sampling calorimeter

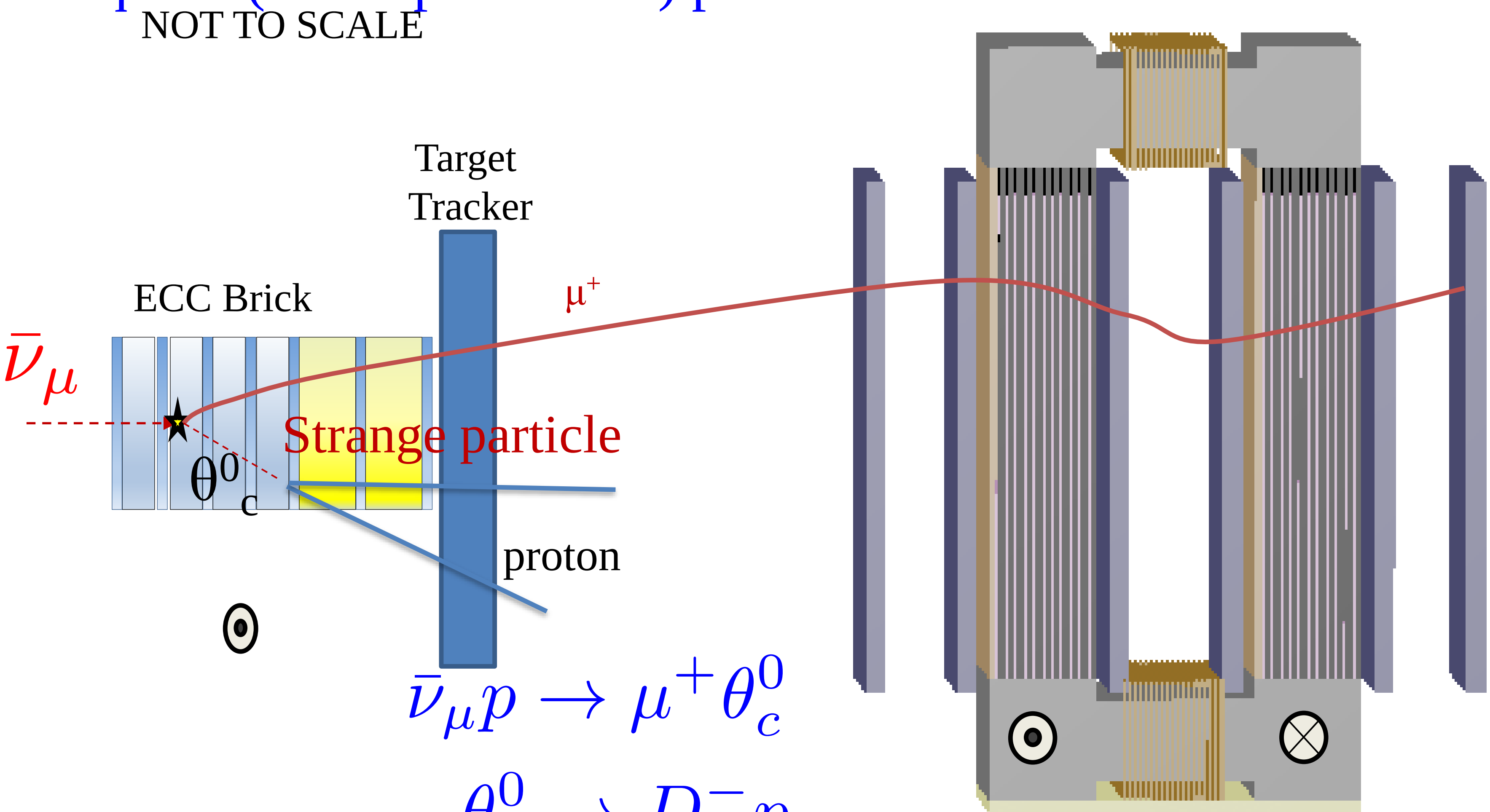
- Electron identification and energy measurement



See A. Ustyuzhanin's talk for machine learning techniques

See Valeri's talk for the test-beam program

Pentaquark (with open charm) production in neutrino interactions



$$\bar{\nu}_\mu p \rightarrow \mu^+ \theta^0_c$$

$$\theta^0_c \rightarrow D^-_s p$$

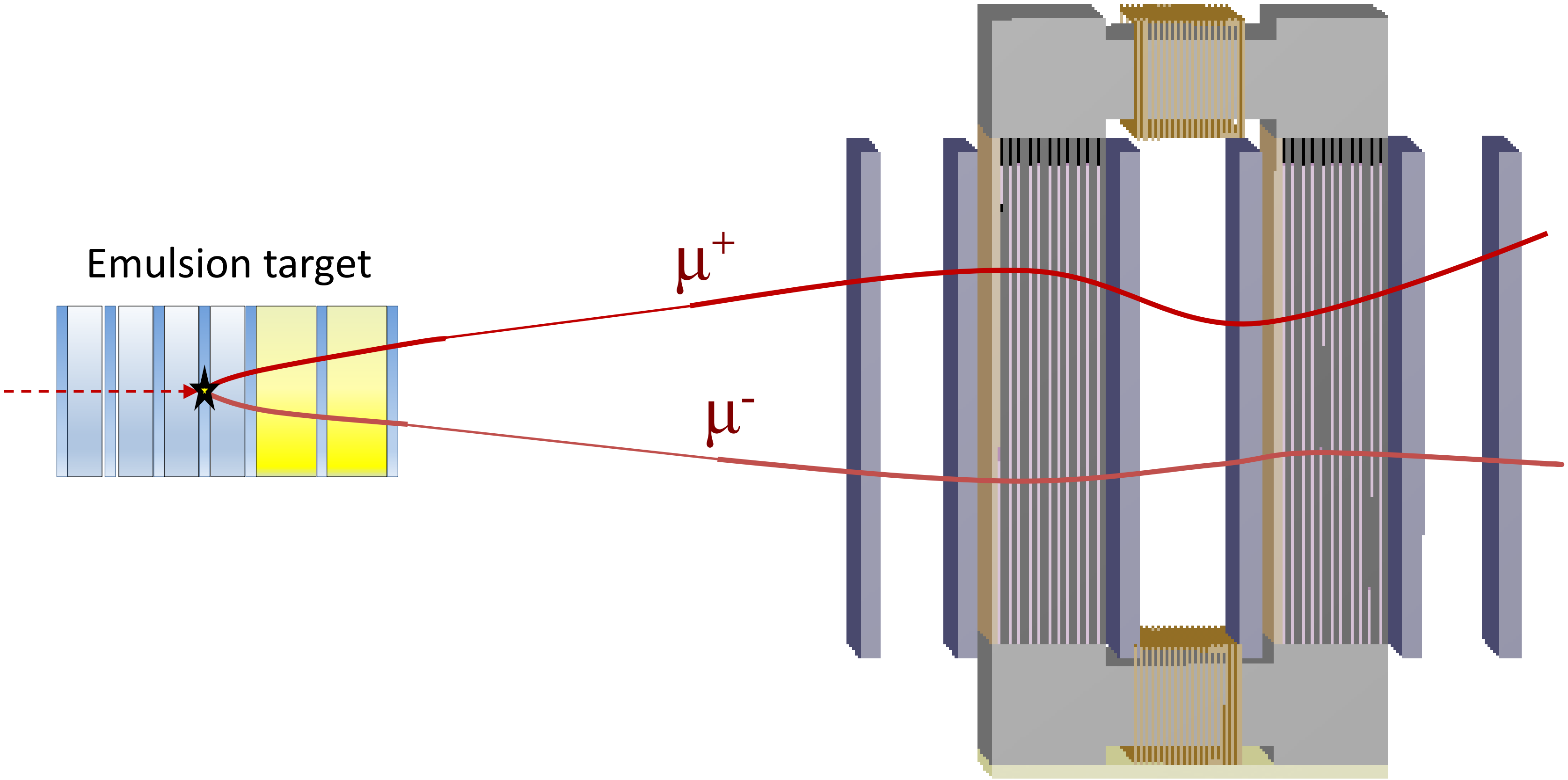
$$\theta^0_c \rightarrow \phi p \pi^+$$

$$\theta^0_c = \bar{c}suud$$

Depending on the mass, θ^0_c can decay weakly

Proton identification (dE/dx) to tag unambiguously this particle

Other exotic particles



THE EMULSION TARGET

Magnetised

- 6 columns, 14 rows, 11 walls
- 12 Target Trackers layers
- 924 bricks
- 0.8 x 1.6 x 2 m^3

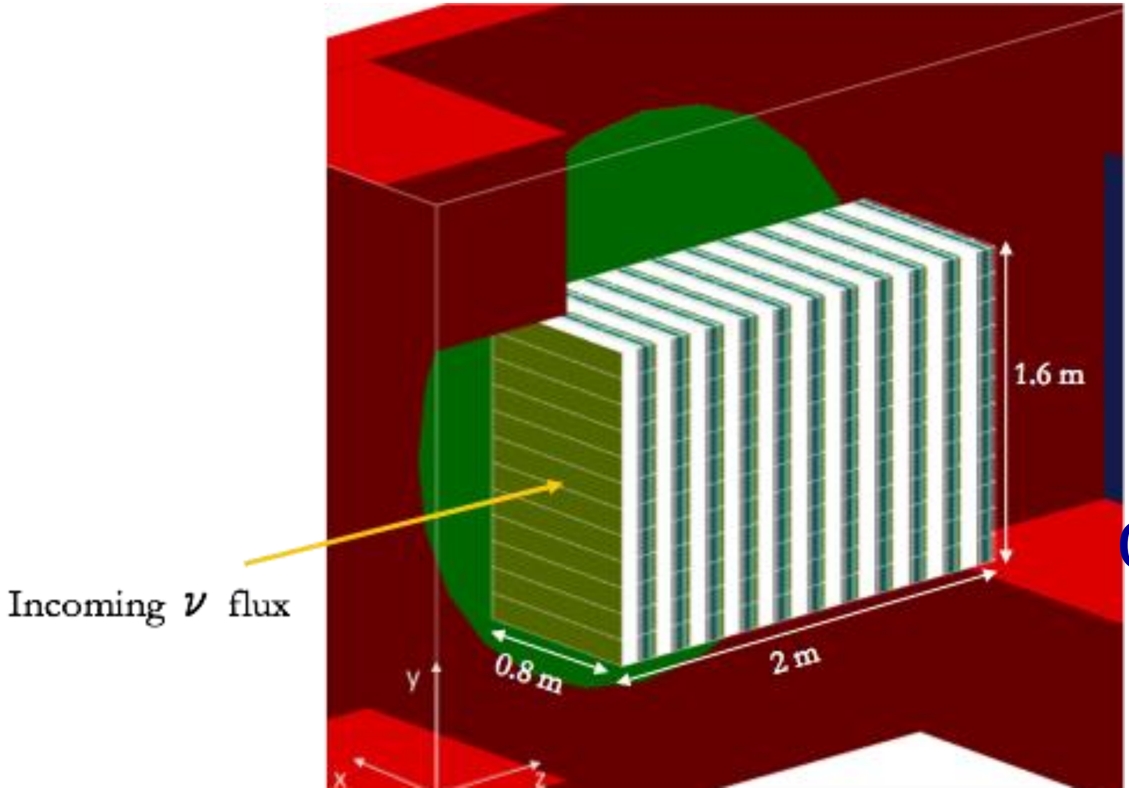
~6900 m^2 emulsion films

Non-magnetised

- 9 columns, 20 rows, 20 walls
- 21 Target Trackers layers
- 3600 bricks
- 1.12 x 2.04 x 2.68 m^3

~25600 m^2 emulsion films

Assume 10 times replacement (depending on the muon flux)

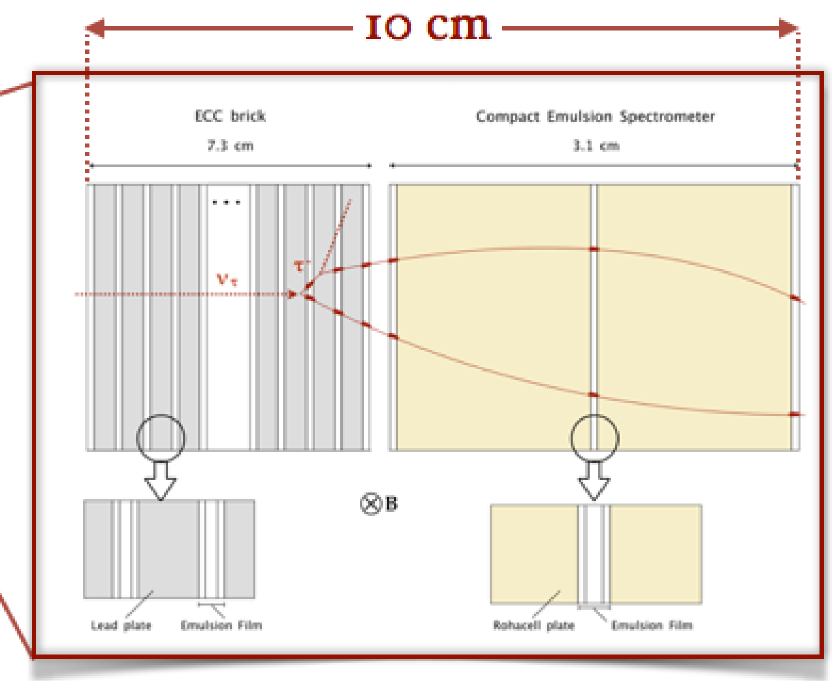


OPERA 110000 m^2 !
by Fujifilm

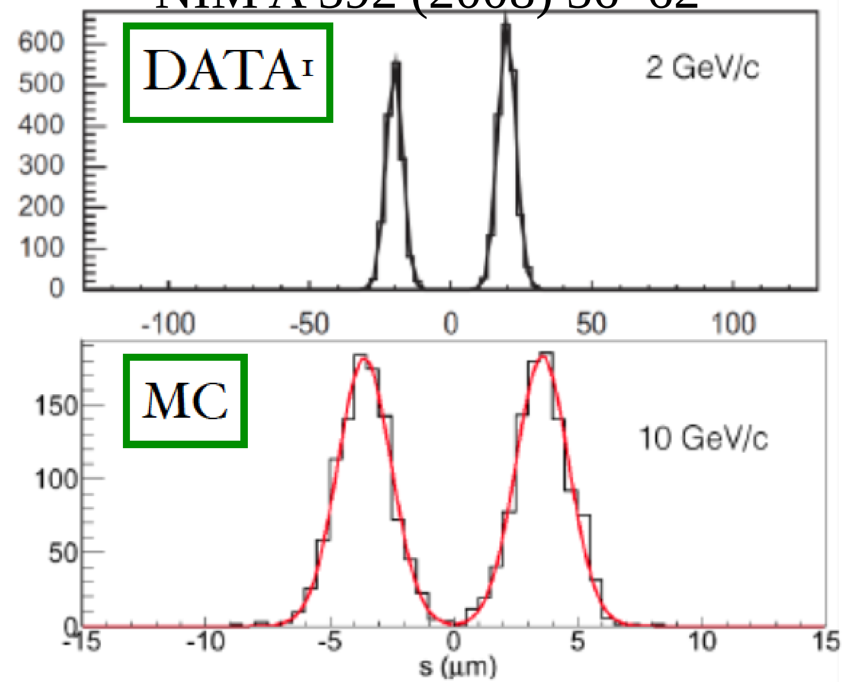
Comments on the emulsion target

- Tau neutrino topology in emulsion: first signal/noise discrimination
- OPERA as a demonstrator (no challenge)
- Important difference is the high muon flux → film replacement
- Define the replacement frequency (part of the test program)
- Now assume twice a year, replacement easy but expensive
- Japanese groups committed for the production of emulsions as needed in the baseline option (~7000 m^2)
- Exploring production/pouring in other facilities (Slavich, Moscow)
- Full volume emulsion scanning won't be an issue in ten years from now.
- Common project with MISiS (Andrey is PI). Emulsion Spectrometer is one of the four sub-projects of "Prospective technological, methodical and material solutions for searches of new physical effects"

Compact Emulsion spectrometer



NIM A 592 (2008) 56–62



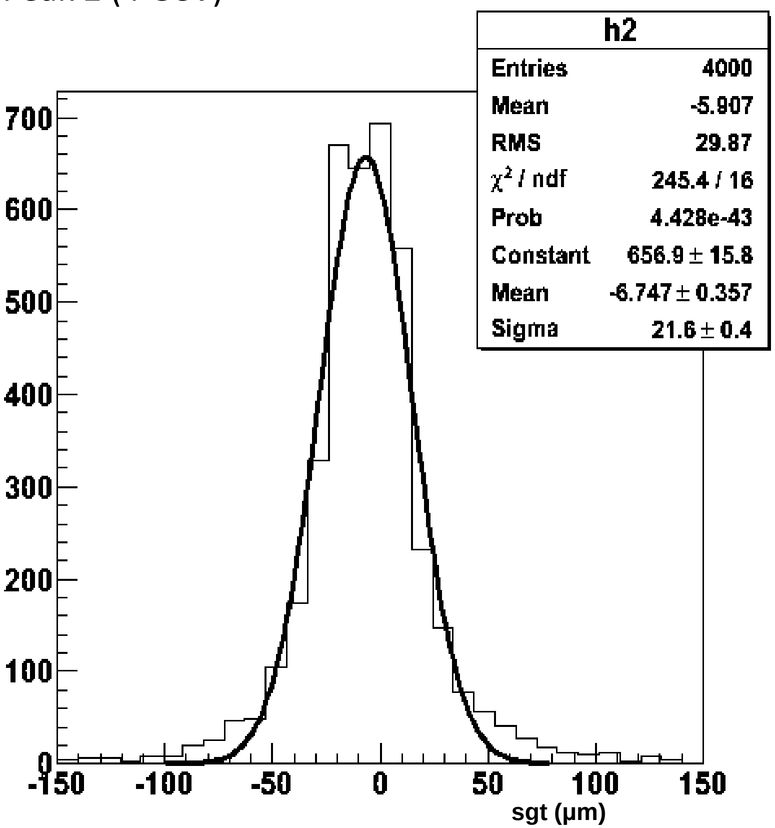
Preliminary results – CES, Naples, Japan, Russia

- Rohacell gaps demonstrated to be unsatisfactory (high deformability)
- New options under study → test beam activity

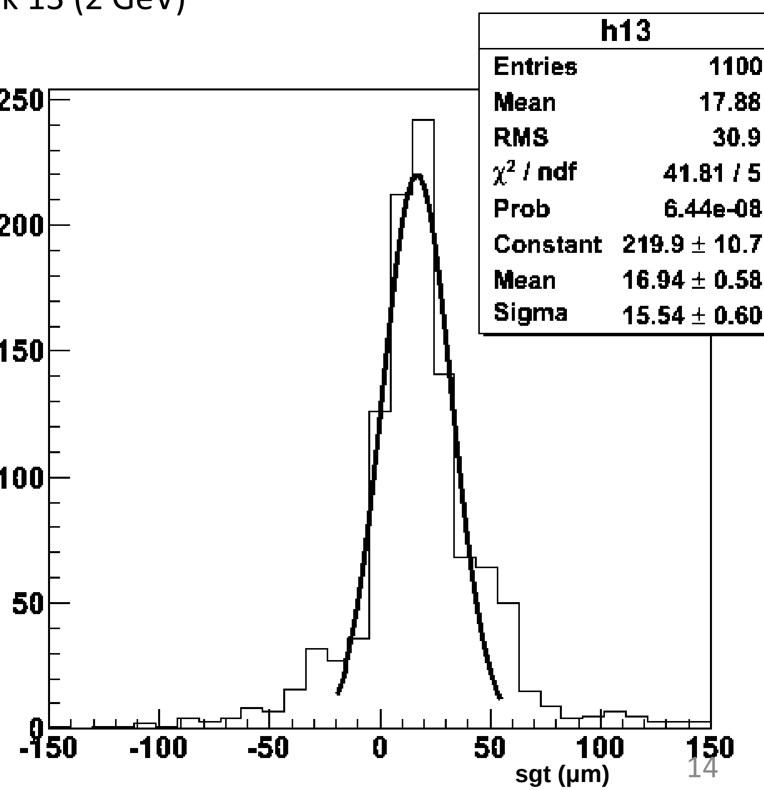
p (GeV/c)	Sagitta(μm)
1	34
2	17
4	8.5
8	4.3
10	3.4

See Komatsu's presentation for further results

Peak 2 (4 GeV)



Peak 13 (2 GeV)

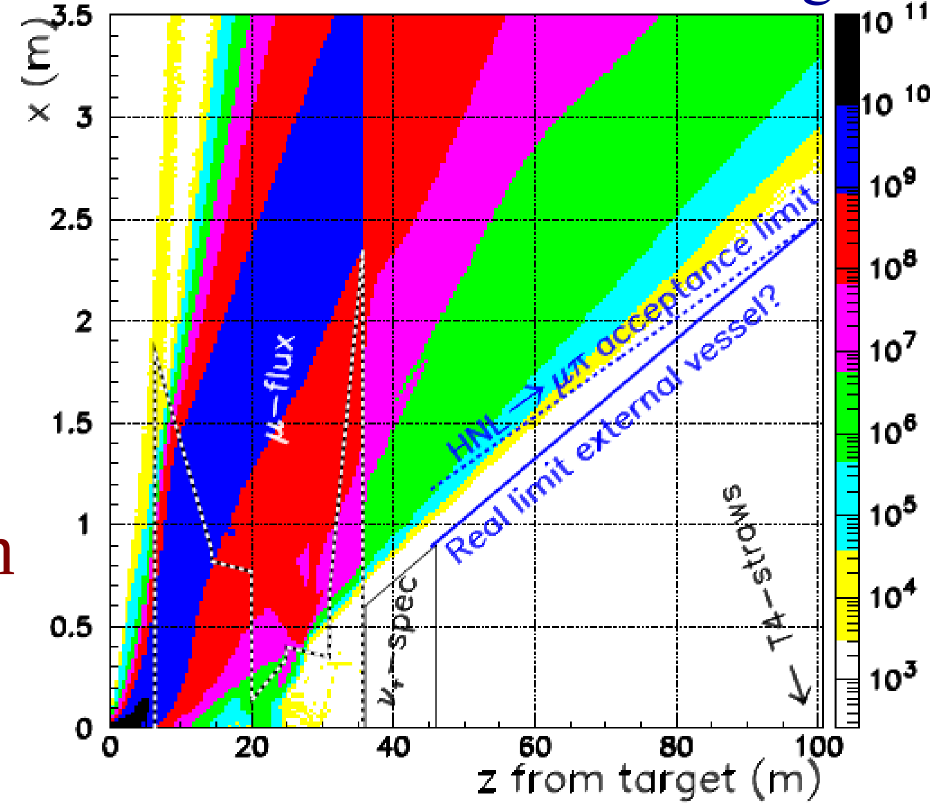


Comments on the magnet

- Emulsion target defined by the physics sensitivity
- Design of the magnet linked to the available space cleaned by the muon sweeper

- Options
  - Reshape the magnet to avoid intercepting the muon flux
  - Place the magnet a few m downstream

Hans' design

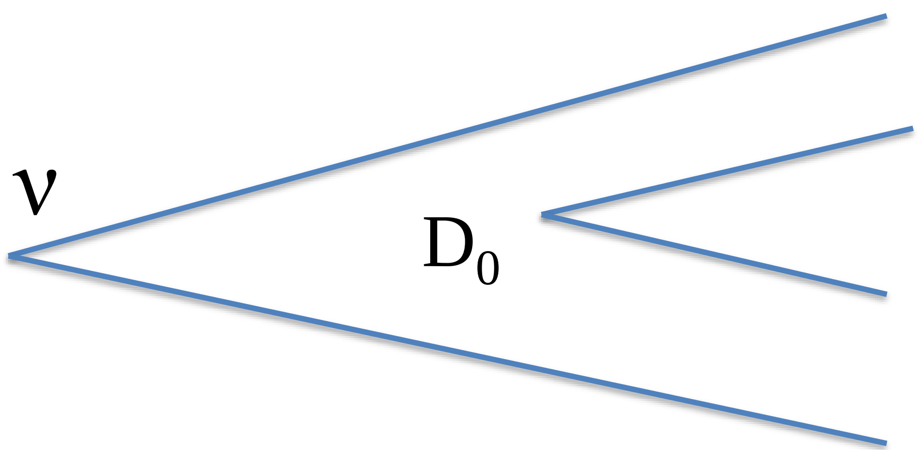


Magnetised versus non-magnetised

- Magnetised version:
  - Pros: measure the charge also in hadronic decay channels → reduce the target mass and films with comparable physics output
  - Contras: add the complication (heating, insulation, mechanics design, passive material, …) of the surrounding magnet
  - Challenge: demonstrate that the charge and momentum can be measured for particles up to 10-12 GeV
- Non magnetised version:
  - Pros: simplified detector concept without the CES and without the magnet
  - Contras: increase the target mass (and density) and emulsion film production for a comparable physics output

Target tracker

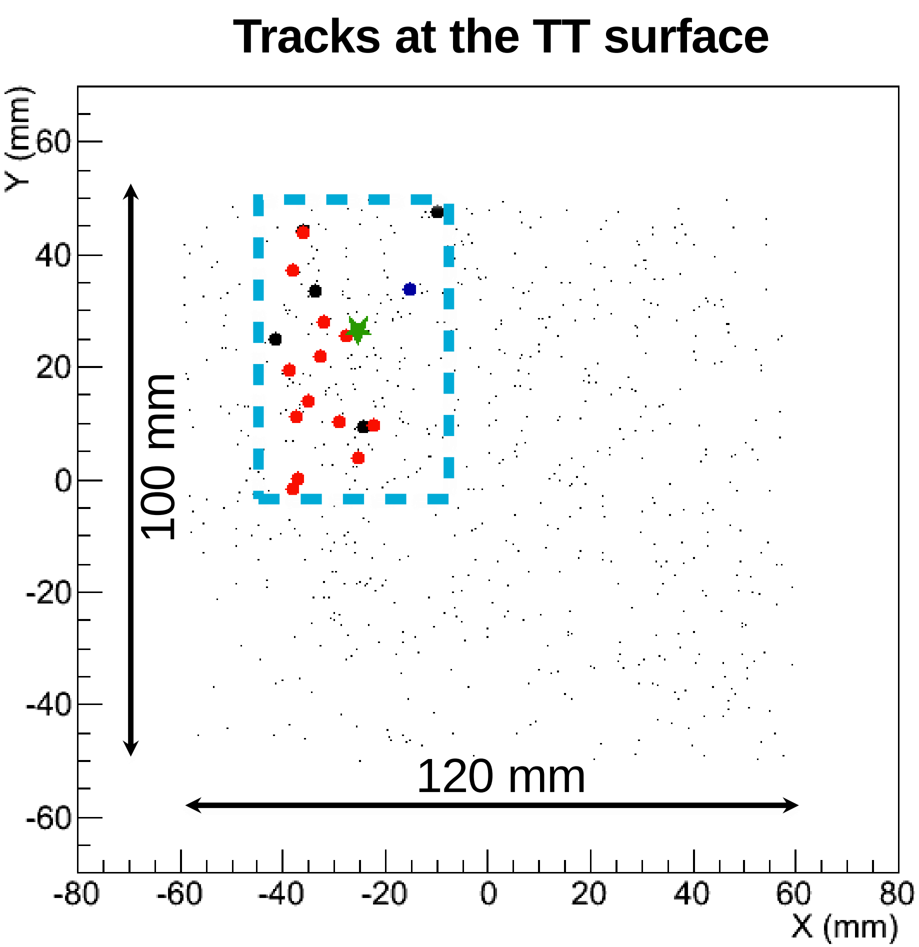
- Time stamp to the event and high spatial resolution to separate tracks within the same event
- Expected rate ~ 0.4 ν/spill over a muon rate of ~kHz/m^2
- Target tracker: 100 μm or better, time sensitive
  - Scintillating Fibres: robust technology
  - Gas chambers: cheaper, test beams to demonstrate technological challenges in magnetic field



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

ν tracks in the TT (A. Di Crescenzo)

An event with electromagnetic shower



- muon
- hadron
- e^+/e^-
- vertex

ID 169

N_{tracks} in TT = 18

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

Area = 15.44 cm^2

Track density = 1.2/cm^2

Occupancy of the emulsion films largely dominated by the μ/e flux

Target Tracker resolution

- Requirement: TT-Emulsion alignment with high (>98%) purity and (>90%) efficiency
- 2 mm gap between CES and TT
- In the early studies, 100 GeV muons assumed to be at zero angle uniformly distributed on the surface → Test this assumption with current muon Monte Carlo samples
- Relationship between single point and fitted position resolution to be assessed

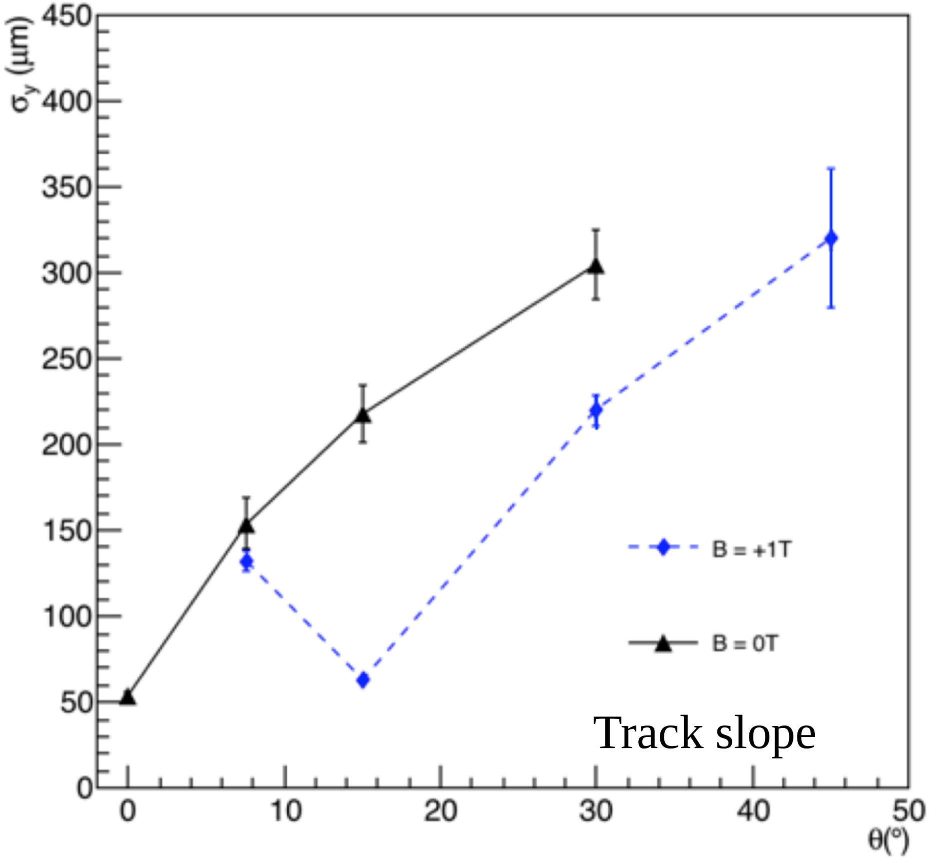
Density (muons/mm^2)	Average track distance (µm)
1000	30

Note: muon tracks passing through can be discarded. Remaining one are due to tracking inefficiency. Electrons matter

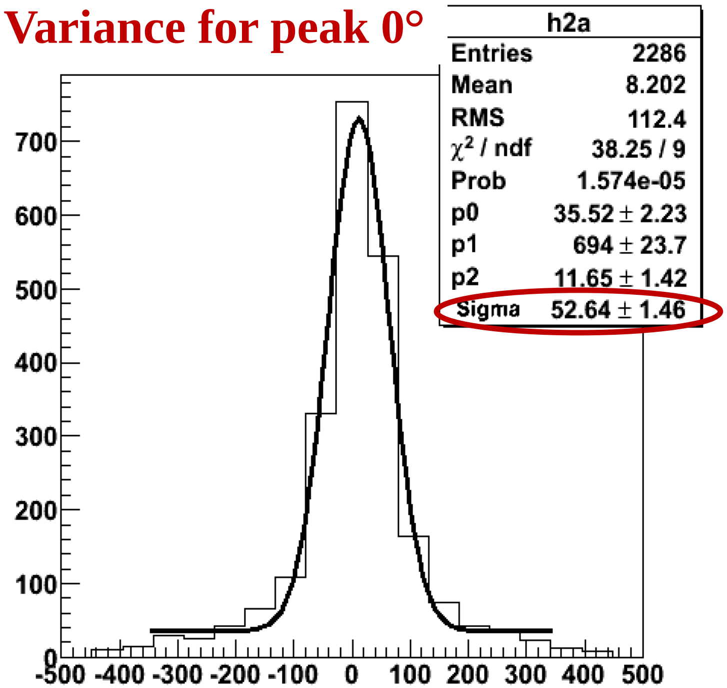
Need to reduce the muon (and electron!) density

GEM/emulsion chamber (LNF, Naples, Nagoya)

Micro-TPC mode not used yet (planned)



Variance for peak 0°

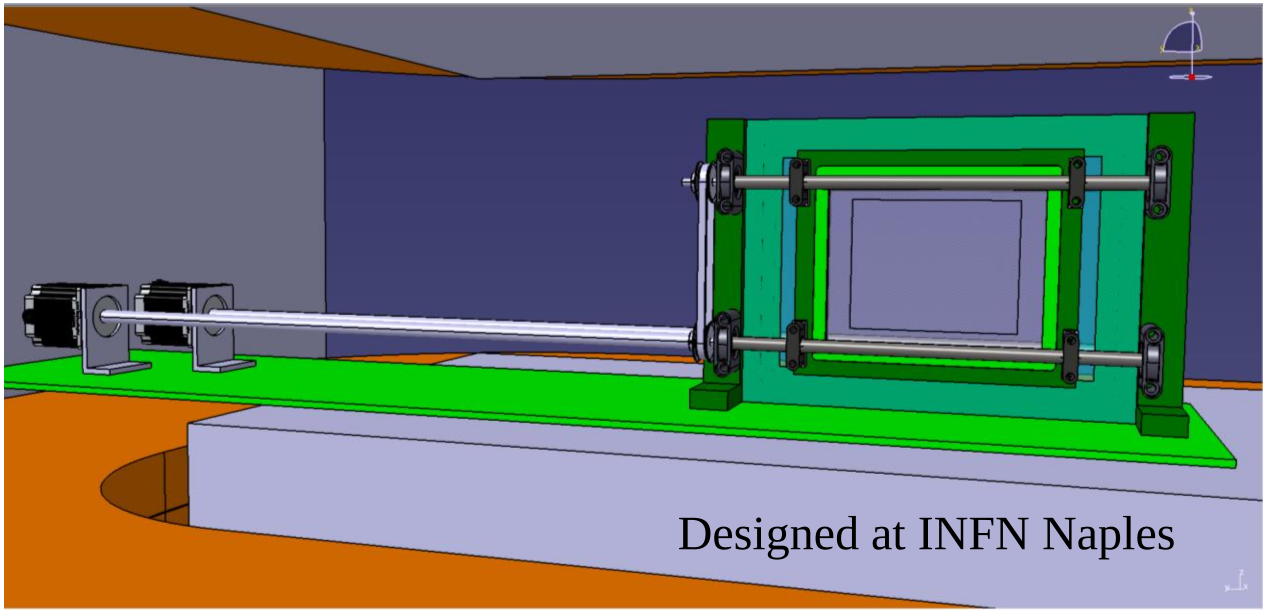


Micro RWells: to be tested in October with LNF group

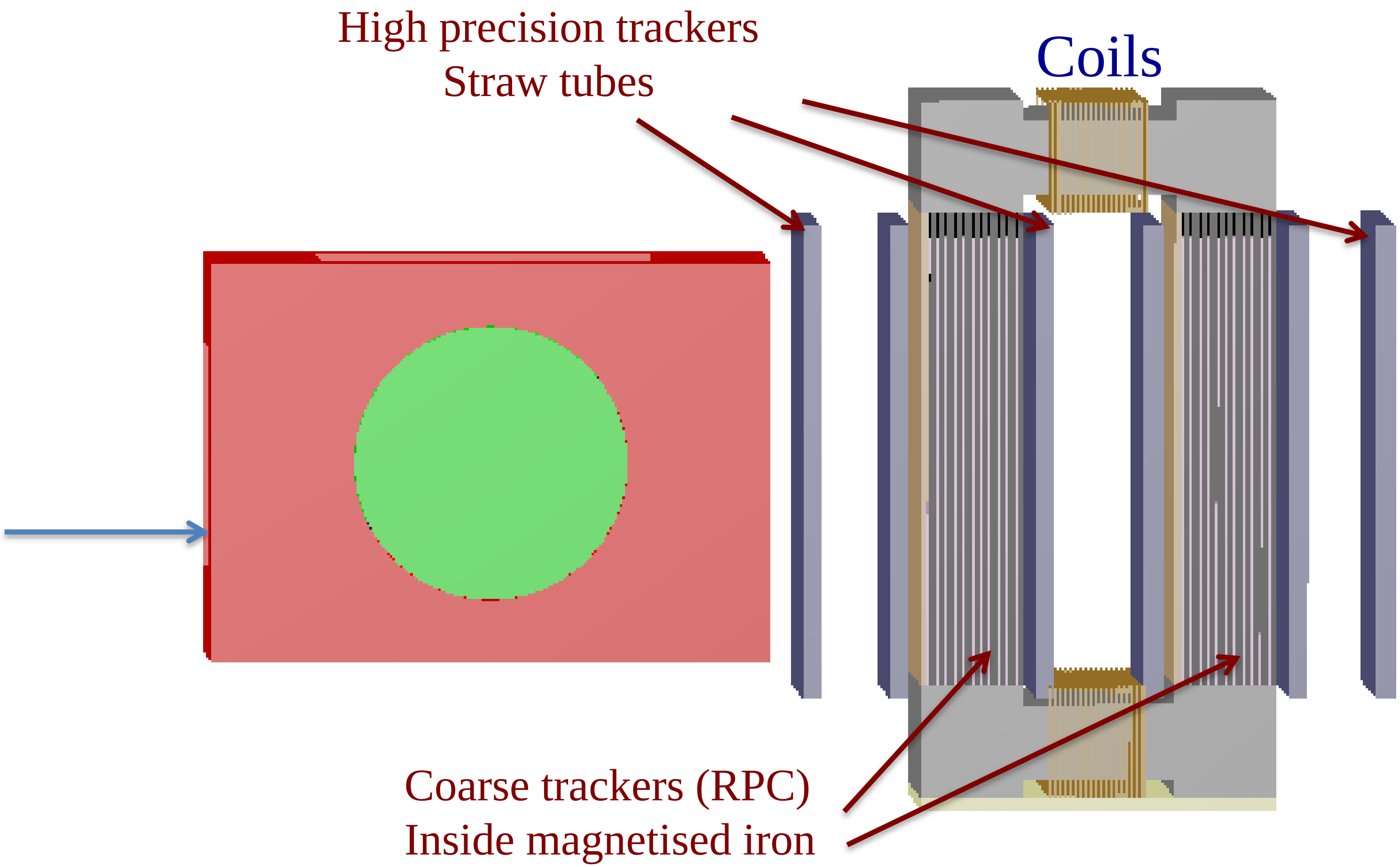
	B = 0T		
θ = 0°	54±2		
	B = -1T	B = 1T	B = 0T
θ = 7.5°	221±13	132±6	154±15
θ = 15°	369±36	63±2	218±17

Different Target Tracker option

- **Emulsion clock**
  - 3 stages, each moving cyclically at a different speed
  - Track displacement linked to the recorded time
  - Operate in magnetic field
  - Test program in 2017 (see Valeri's talk)



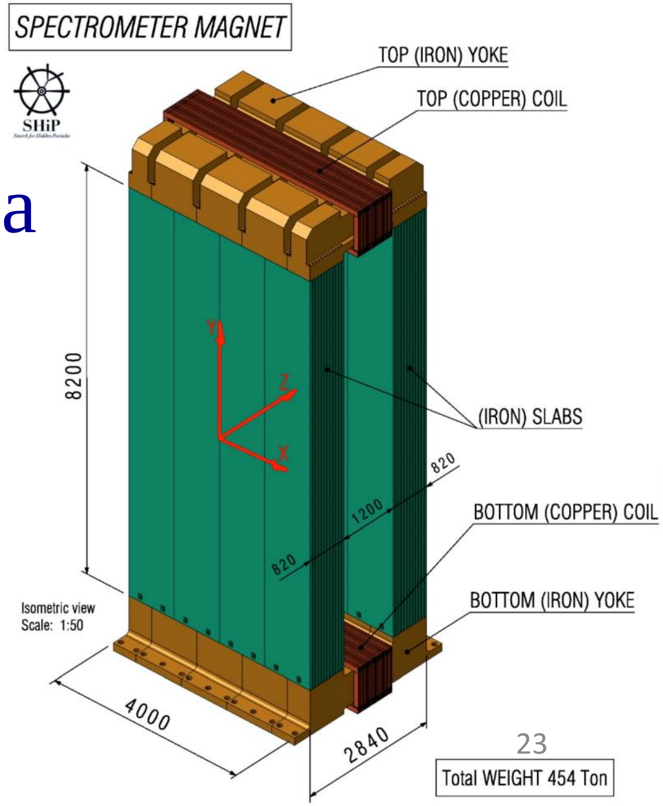
Muon spectrometer



High precision trackers (see Daniel's talk)
Interesting synergy emerged with the straw tracker of the hidden sector
Similar resolution (~150 microns)

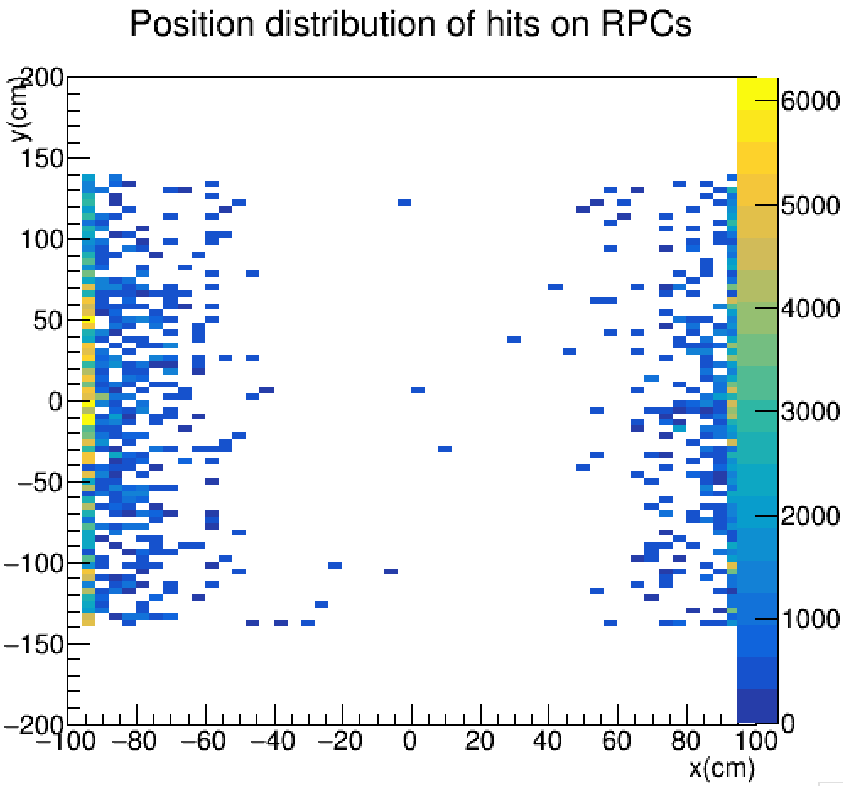
Coarse tracking in the muon spectrometer

- Based on RPC
  - Available from OPERA
  - Magnet originally ~ same height
- New configuration requires new chambers
- Their characteristics (electronics, resistivity, ..) being defined through a number of tests (see Saverio's talk)
- RPC technology suitable in environments with γ and neutron background



Issues to be addressed: highly non uniform rates

Hits distributions on RPCs

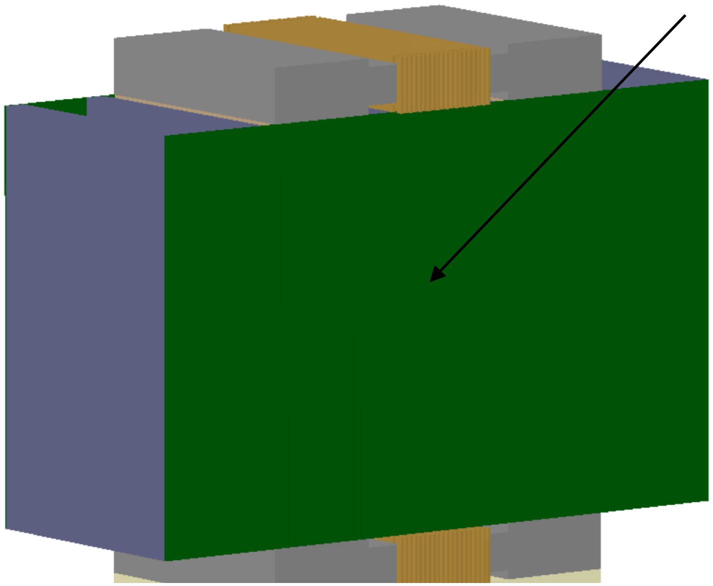


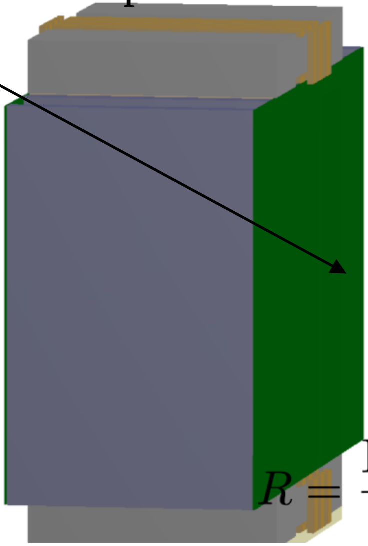
- High rates at the edge

- Muons: ~ 1÷5 Hz/cm^2 in the last (first) RPC layer, with a sizeable (~50%) low momentum component
- Electrons (mostly from muon bremsstrahlung):
- ~ 2÷60 Hz/cm^2 in the last (first) RPC layer

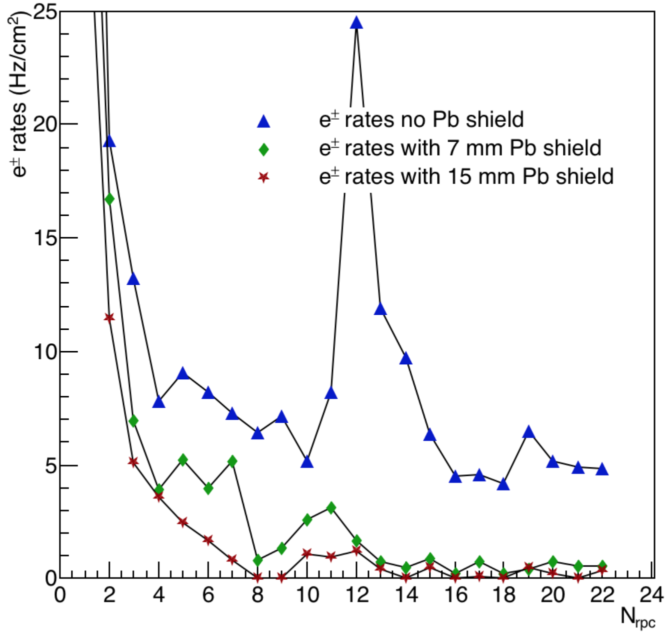
Shielding electrons with Pb Shield (A. Buonaura)

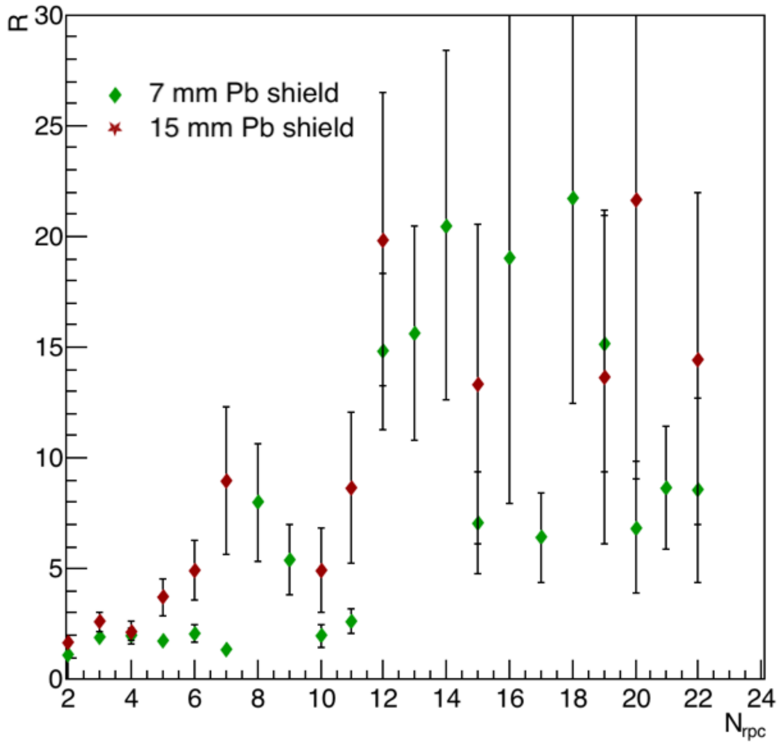
lead attached to both sides of the spectrometer





$$R = \frac{\text{Rates without Pb shield}}{\text{Rates with Pb Shield}}$$





Final considerations

- Emulsion target being optimised according to the physics sensitivity
- Options with and without magnets are being compared
- Wide test-beam program on-going and planned
- Machine learning techniques very promising
- Avoid low energy muons and large non-uniformities in the rates for all detectors
- Magnet design still to be optimised (avoid intercepting the muon flux)
- True also for the muon spectrometer
- Lead shield around the spectrometer helps but it might be a fine tuning rather than the solution
- The Emulsion Spectrometer optimisation will largely benefit from the project "Prospective technological, methodical and material solutions for searches of new physical effects"