SHIP in Irfu

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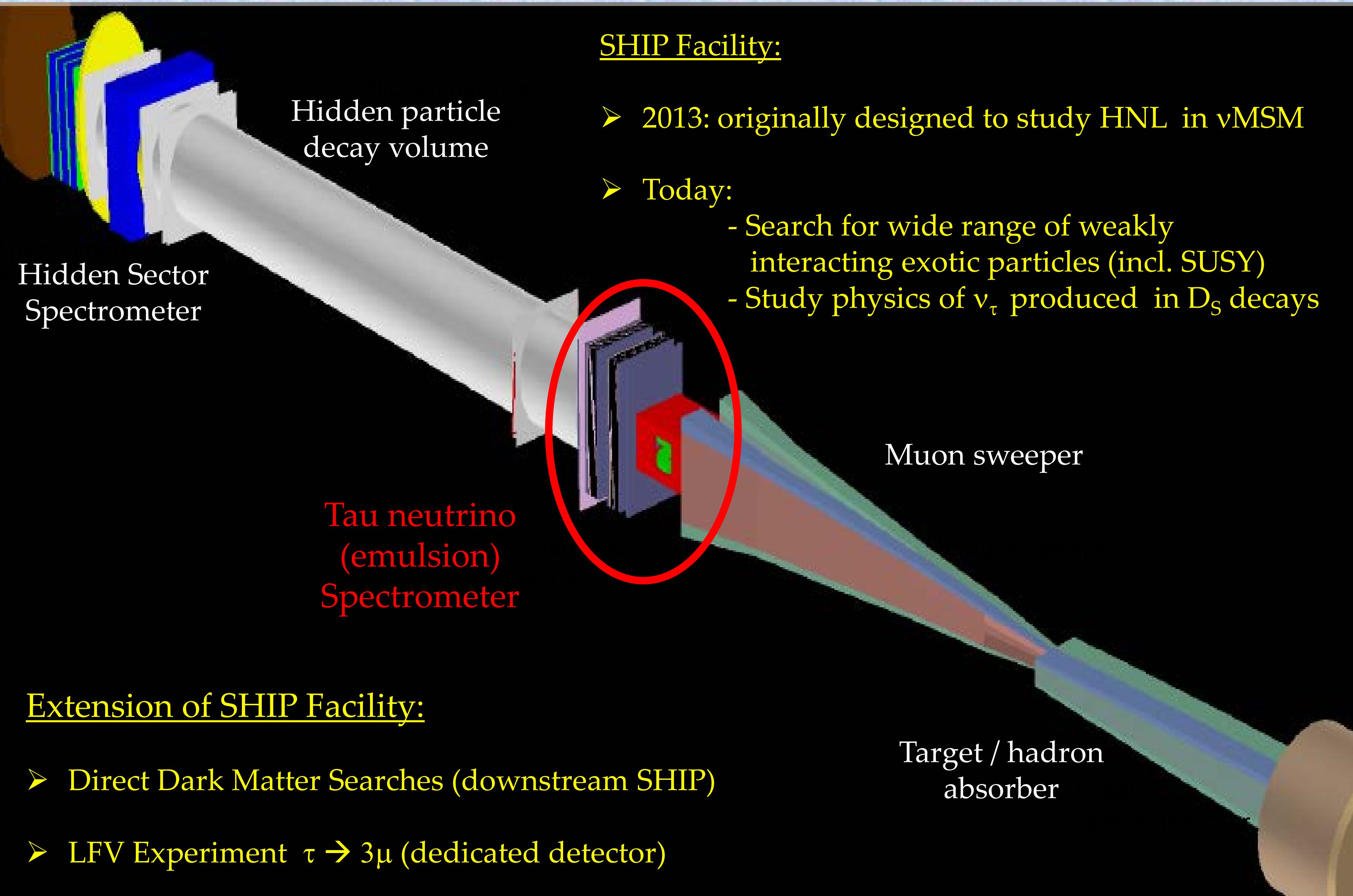
SHIP Experimental Facility: Technical Proposal (2014)



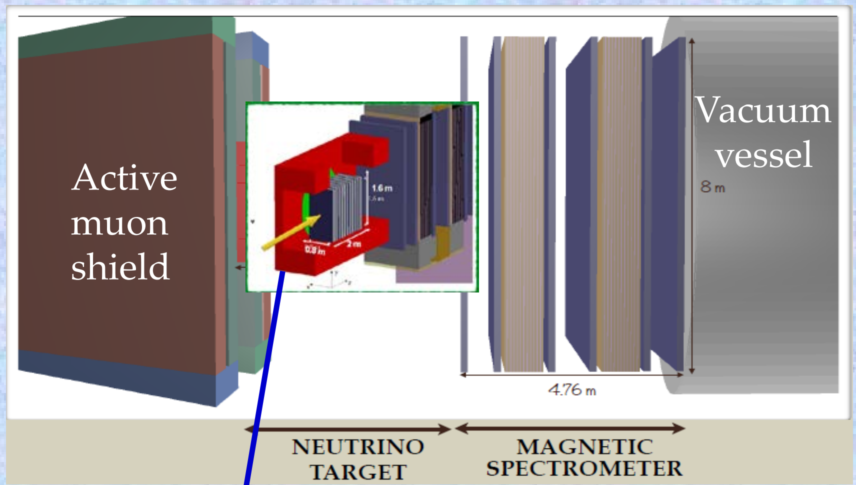
SHIP Facility:

- 2013: originally designed to study HNL in νMSM
- Today:
  - Search for wide range of weakly interacting exotic particles (incl. SUSY)
  - Study physics of ν_τ produced in D_S decays

Extension of SHIP Facility:

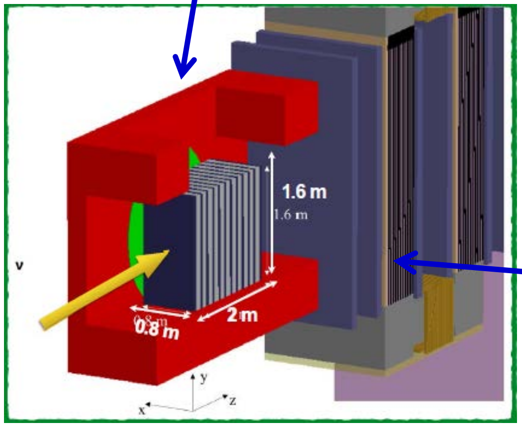
- Direct Dark Matter Searches (downstream SHIP)
- LFV Experiment $\tau \rightarrow 3\mu$ (dedicated detector)

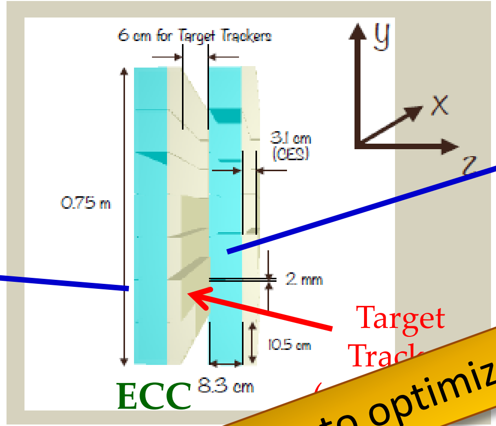
Tau Neutrino (Emulsion) Spectrometer Layout

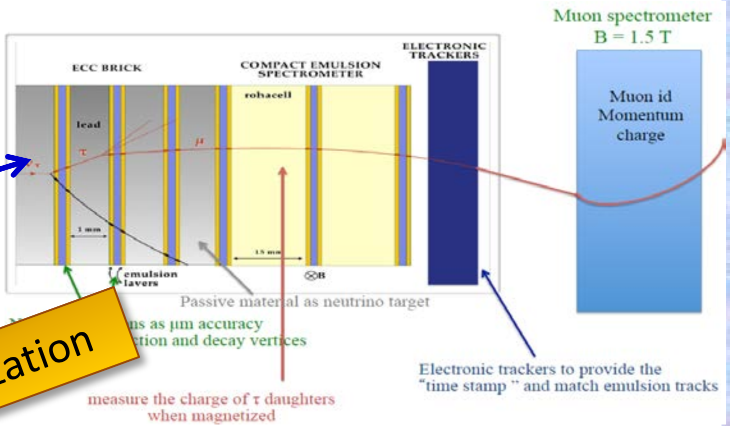


- ❖ High spatial resolution to observe the τ decay (~1mm)
  → *EMULSION FILMS*
- ❖ Electronic detectors to give "time" resolution to emulsions
  → *TARGET TRACKER PLANES*
- ❖ Magnetized target to measure charge of τ-products
  → *DIPOLAR MAGNET*
- ❖ Magnetic spectrometer to perform muon identification and measure its charge and momentum
  → *MUON SPECTROMETER*

B-field in emulsion and muon-filters in μ-spectrometer: **distinguish ν_τ / from anti-ν_τ**







From SHIP TP (2014) → subject to optimization

Neutrino target:

- ➢ 1155 ECC bricks to be repl... es
- ➢ 260 ν-interactions i... 1 ECC brick (during 6 months ex...sure)
- ➢ Total emulsion surface: 8700 m2 (5% OPERA)

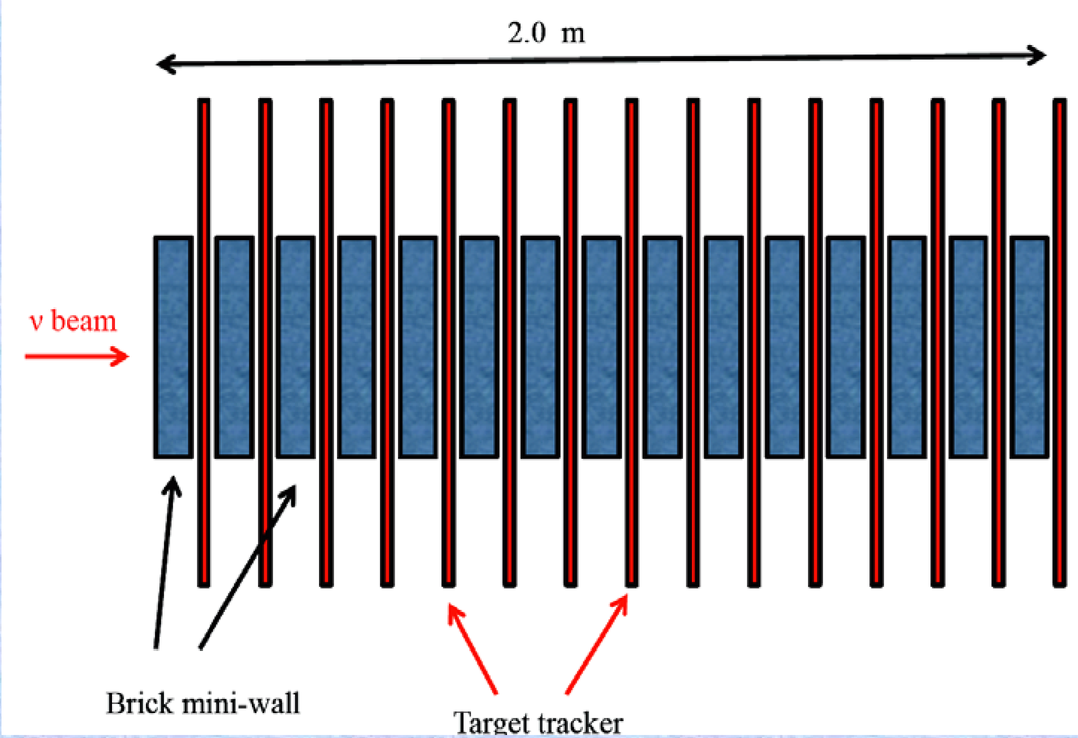
Emulsion Cloud Chamber (ECC)

→Passive material (Lead 1mm) - 56 layers
→ High resolution (Nuclear emulsions) - 57 films

❖ *Compact Emulsion Spectrometer:*

→ 3 OPERA-like emulsion films
→ 2 Rohacell spacers (low density material)

Electronic Target Tracker (TT) for the Tau Neutrino Detector



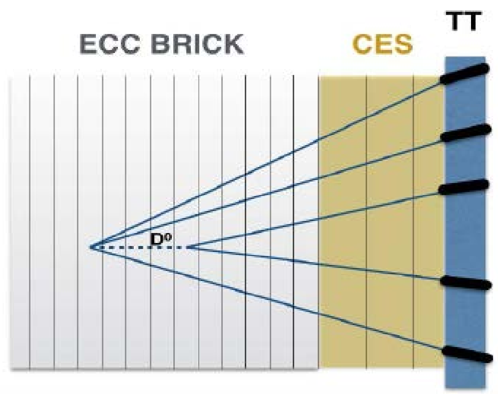
Target Tracker Requirements:

- Max. thickness for a plane - 5 cm; small dead space (< 1mm)
- Spatial resolution (~ 100μm), uniform tracking capabilities
- High efficiency (~ 99%)
- Capability of measuring the angle in each plane (efficiency versus the track angle: up to tg(θ) = 1)
- Good performance in magnetized region

Target Tracker Layout:

→ **12 planes of 1.6x0.8 m^2 surface**

- Provide time stamp of the neutrino interaction in the brick"
- Matching between the electronic detectors and the emulsion tracker
- Matching the muon track with the downstream muon spectrometer



High spatial resolution needed, *e.g.* to distinguish a 2-vertices topology (D^0 decay) from two neutrino interactions occurring at different times

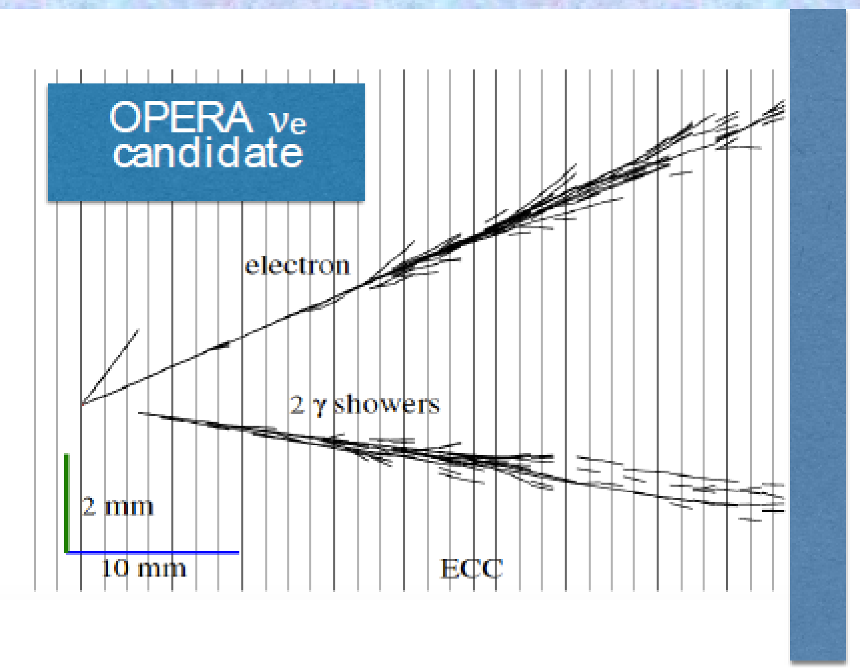
Three possible technologies:

- Scintillating fiber tracker (250 μm scintillating fibres readout by SiPMs)
- GEM / u-RWELL / **Micromegas**

Optimization of the SHiP Emulsion Spectrometer: New Approaches

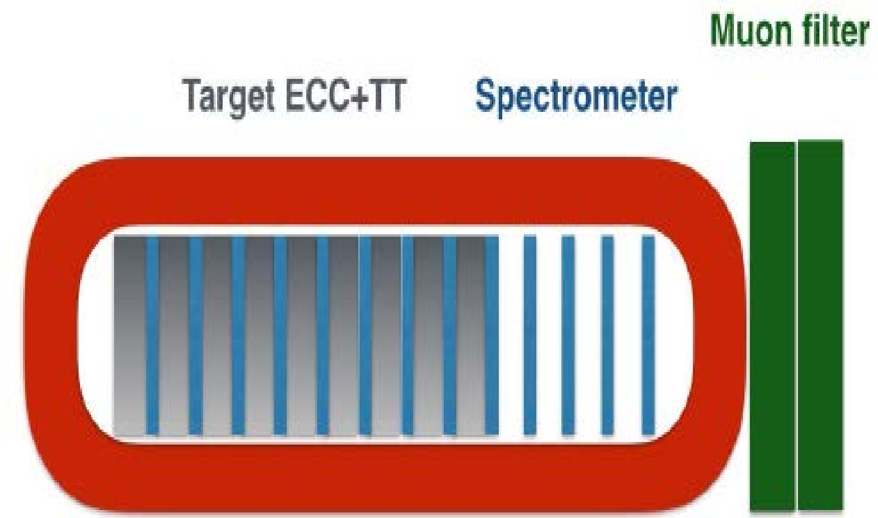
Possible Improvements:

- Exploit analog readout of TT to provide calorimetric information
- Optimize the distance between consecutive TT planes (currently ~10 X_0)
- Use combination of ECC and TT to measure the hadronic and electromagnetic energy of the event → "particle flow" method



New Layout Under Study:

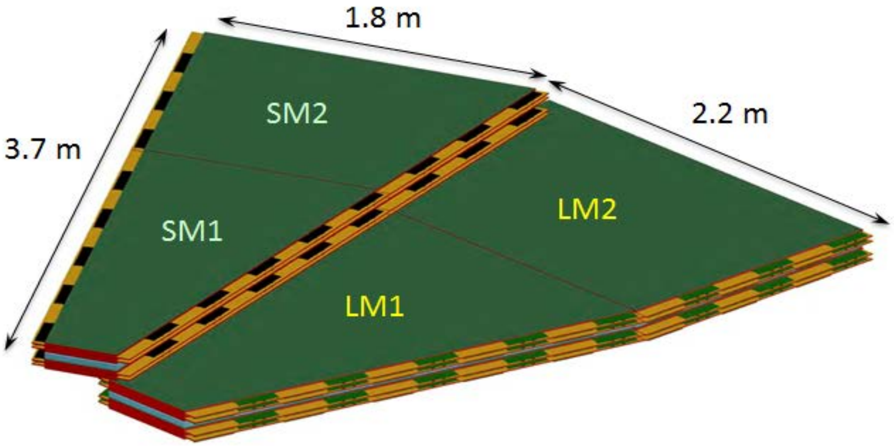
- study one magnet with larger longitudinal dimensions hosting the target (upstream region) and the spectrometer (downstream region)
- muon identification performed using muon filter outside magnet



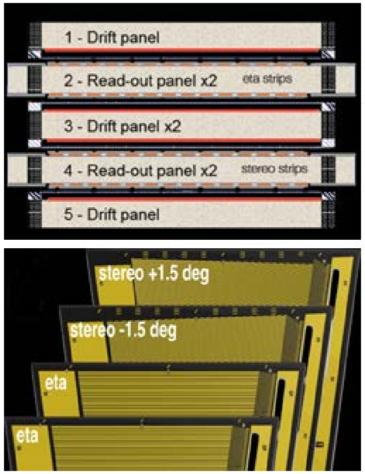
A. Golutvin, R. Jacobsson

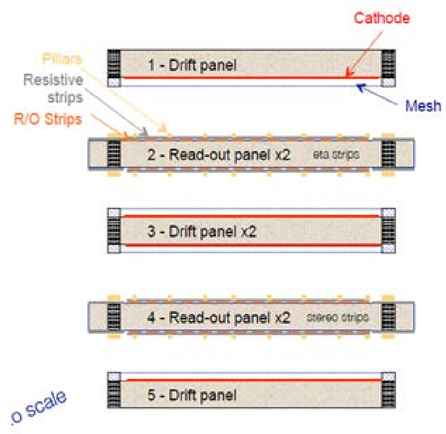
Micromegas for Target Tracker (based on ATLAS NSW Experience)

~ 2x1 m^2 MM can be built as a single module with min. dead space : ~ 1-strip pitch (300 μm) on each PCB



4-plet thickness total budget (ATLAS NSW -7.8 cm → to be reduced by 20-30% or use 3-plet of MM chambers

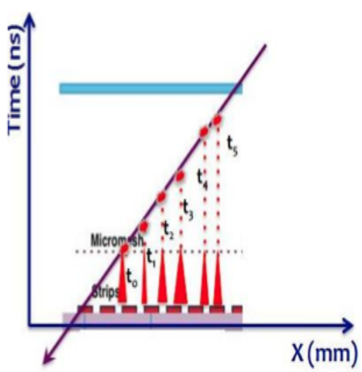


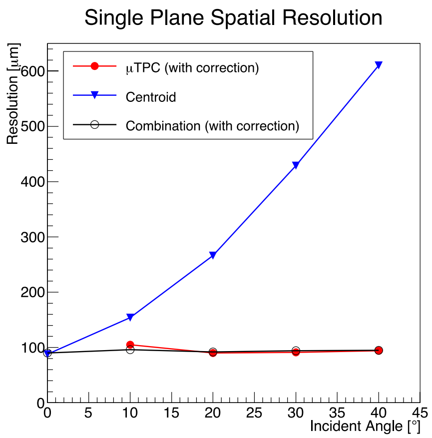


Measuring the arrival time of the signals opens a new dimension; in this case the MM functions like a TPC

⇒ Track vectors/plane for inclined tracks

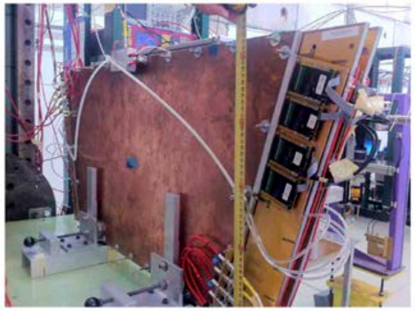
σ < 100 um independently of track incident angle!

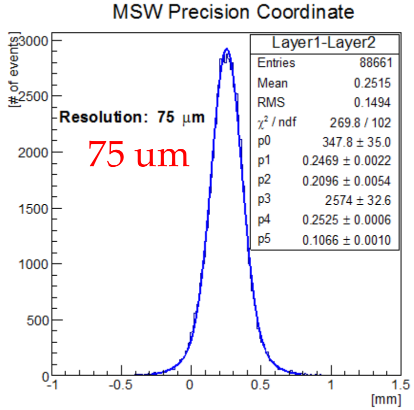




Cost Effective Solution (compared to fiber tracker):
~40 kEUR for one MM module (i.e. for 4 layers of ~3 m^2 MM plane within a module) without electronics

MM spatial resolution:
Strip pitch ~ 400-450 um
Strip width ~ 300 um



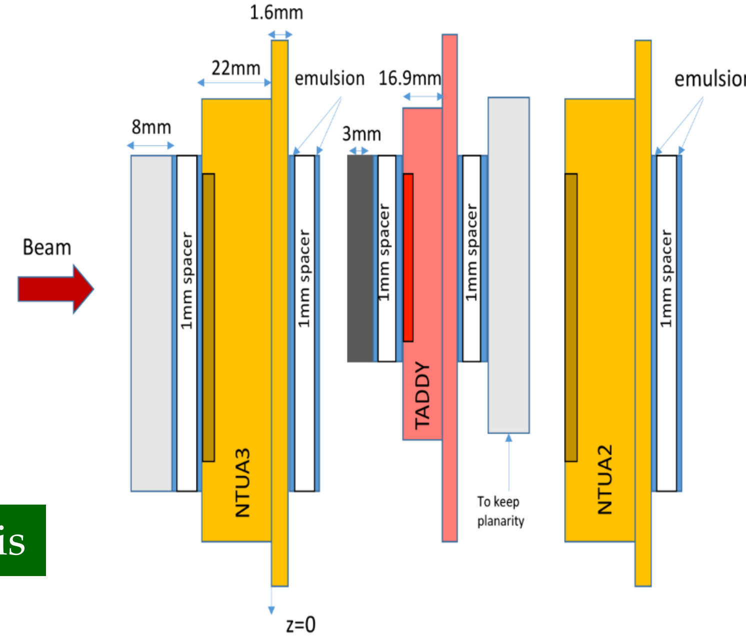


Oct. 2016: Common Test–Beam of Emulsion and Target Tracker (Micromegas)

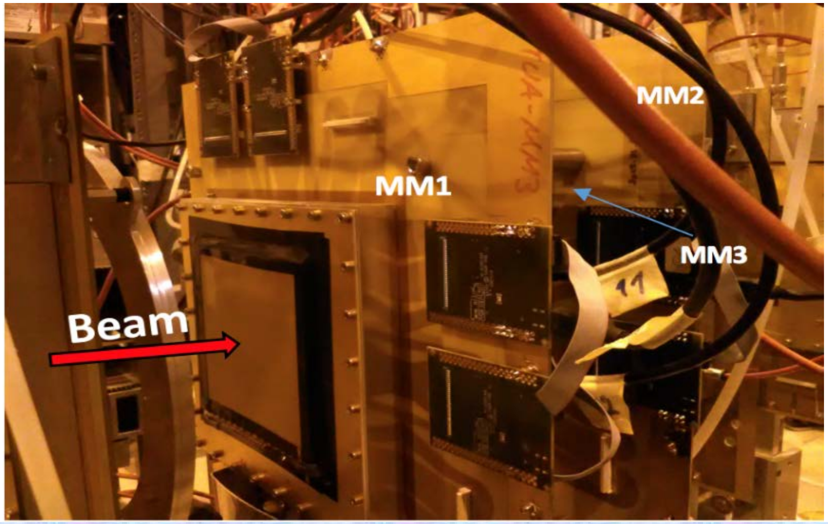
Bari group and RD51 (Paolo Iengo, Givi Sekhniaidze)

- Emulsion doublets (2 emulsion films with 1mm spacer vacuum packed) exposed attached to 3 micromegas chambers

- Exposures performed at SPS – H4 beam line with:
  - no magnetic field B=0T
  - different track incident angles (0°, 15°,30°)



G. De Lellis



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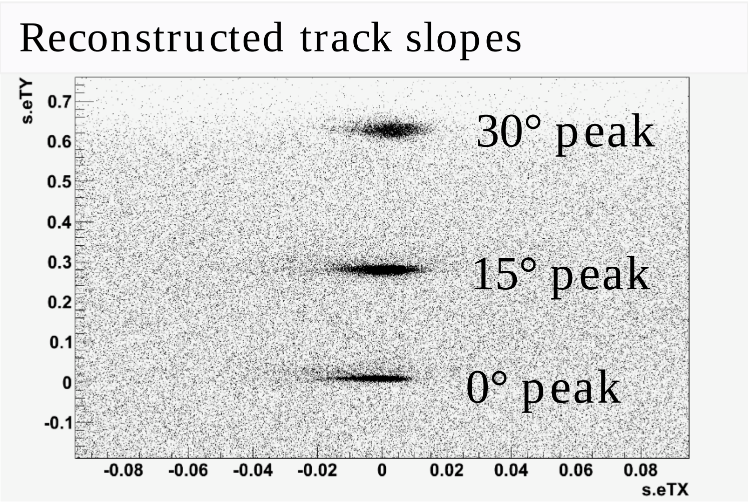
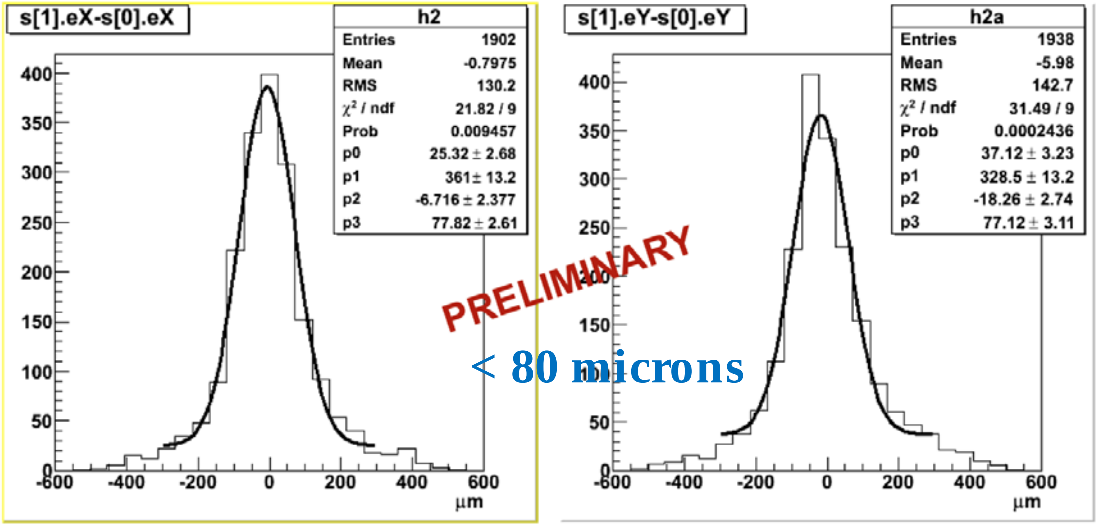
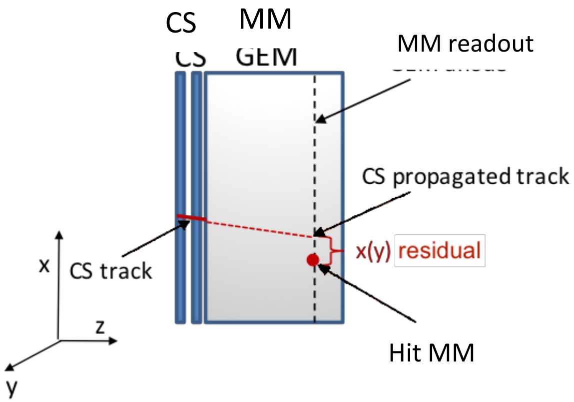


- Scanned all exposed emulsion films
- Track reconstruction in the emulsions
- For each angular peak the residual between the position of the track in the CS doublet and the position of the corresponding hit on the MM detector can be evaluated

Results 0 ° peak

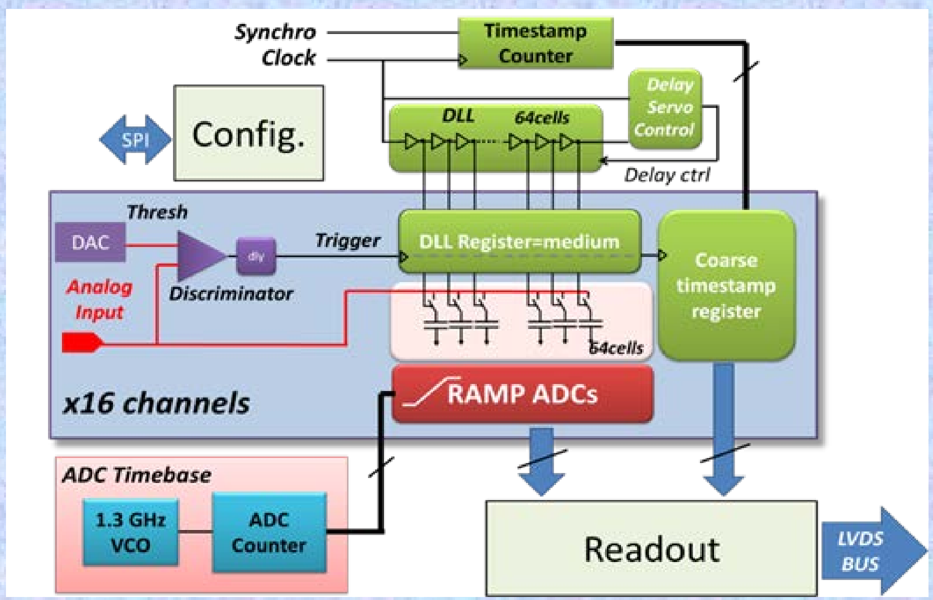
G. De Lellis





SAMPIC Chip for the ECAL Calorimeter and Timing Detector

Collaborative effort between CEA and LAL:



SAMPIC chip can be used for:

- The TIMING detector requires ~50ps resolution → corresponds exactly to the initial target of SAMPIC. The expected rate is several orders of magnitude smaller than the limit of SAMPIC.
- The ECAL calorimeter using scintillators read by PMT → SAMPIC can be used in the low-speed mode with a timing resolution far better < 0.5ns required and allowing to fully capture pulses as long as 60 ns. Some optimization to the current SAMPIC chip for bi-gain operation is mandatory.

SAMPIC development
has direct application for Calorimetry
and Timing Detectors for SHIP

→ Dominique Breton with Jihane Maalmi (LAL) has accepted to specify the electronics for the SHIP needs

Irfu: Outlook and Prospects

- SHIP is the universal tool to Probe New Physics at the Intensity Frontier
  - → to increase diversity of the particle physics program world-wide
  - → to explore the Fermi scale and to provide guidance on the scale of New Physics
- Future extension of the SHIP facility into DM and LFV searches is possible

- The electronic target tracker is the key element of the Tau-neutrino detector
  - → Irfu has invented / matured Micromegas technology for HEP/Nuclear Physics
  - → Design and specifications of neutrino target tracker are (largely) following experience developed for the ATLAS NSW construction

- Irfu is not an official member of the SHIP project and did not sign the SHIP TP (2014)
  - → contributions from Irfu SPP/SEDI people have been acknowledged in the TP

- Some R&D activity can be envisaged for optimization of MM for the SHIP tracker
  - → no major financial investment is possible before the SHIP TDR (~ 2021)

- Opportunities to contribute on projects of common interest (jointly with IN2P3) has to be investigated and would be highly desirable