SHiP
Search for Hidden Particles

Summary of test-beams for the CES and emulsion-micromegas coupling

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- University of Naples and INFN –

Outline

- Target trackers
    - Requests
    - Options
    - Test beam summary
- Compact Emulsion Spectrometer
    - Description
    - Test Beam summary

Target trackers

Target Tracker Requirements

- **Features:**
  - Provide Time stamp
  - Link track information in emulsions to signal in TT
  - Link muon track information in ν target to muon magnetic spectrometer
- **Requirements in 1T field:**
  - 100 μm position resolution on both coordinates
  - high efficiency (>99%) for angles up to 1 rad
- **Options**
  - Scintillating Fibers: solid technology, expensive
  - Gas chambers: cheaper, test beams to demonstrate technological challenges in magnetic field
    - Micromegas
    - GEM

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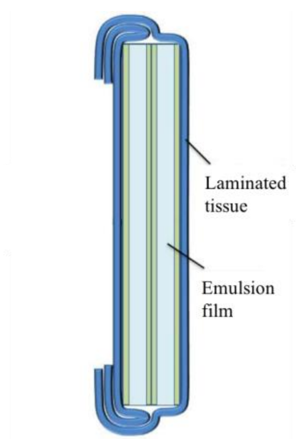
    - GEM → **Test beam performed in October 2015**

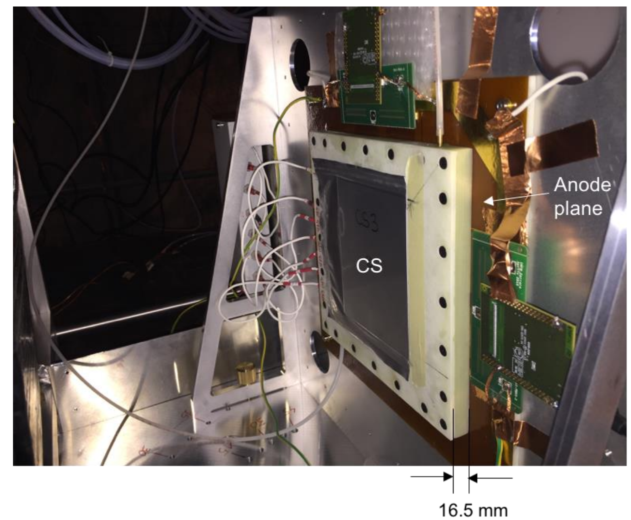
GEM–Emulsion Test Beam Summary (2015)

In collaboration with Frascati GEM group

- Emulsion doublets (2 emulsion films vacuum packed) exposed attached to GEM detector
- Exposures performed at SPS – H4 beam line with:
  - different magnetic field polarizations (B=0T,±1T)
  - different track incident angles (0°, 7.5°,15°)

Emulsion doublet (CS)





Matching procedure:

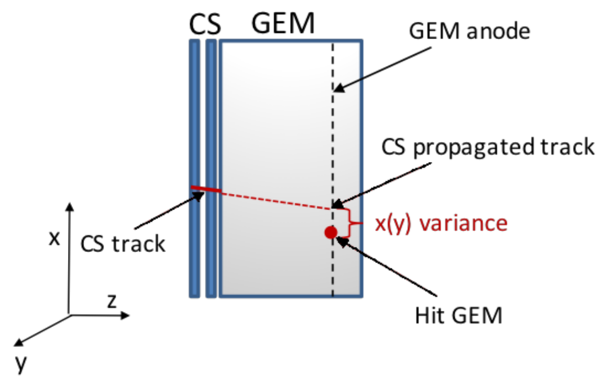
1. Track reconstruction in emulsions
2. For each peak: hit reconstruction in GEM performed by Frascati group
3. Alignment between CS doublets and GEM
4. Track reconstruction in the system CS+GEM

GEM–Emulsion Test Beam Summary (2015)

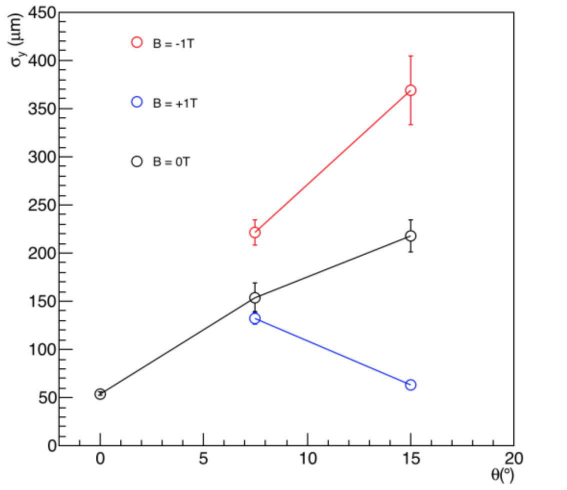
In collaboration with Frascati GEM group

Matching results

- For each angular peak evaluated the variance between the position of the track in the CS doublet and the position of the corresponding hit on the GEM detector
- ***B field*** is along the x direction so we expect to see its ***effects on the y direction***



GEM resolution for different θ+ different B



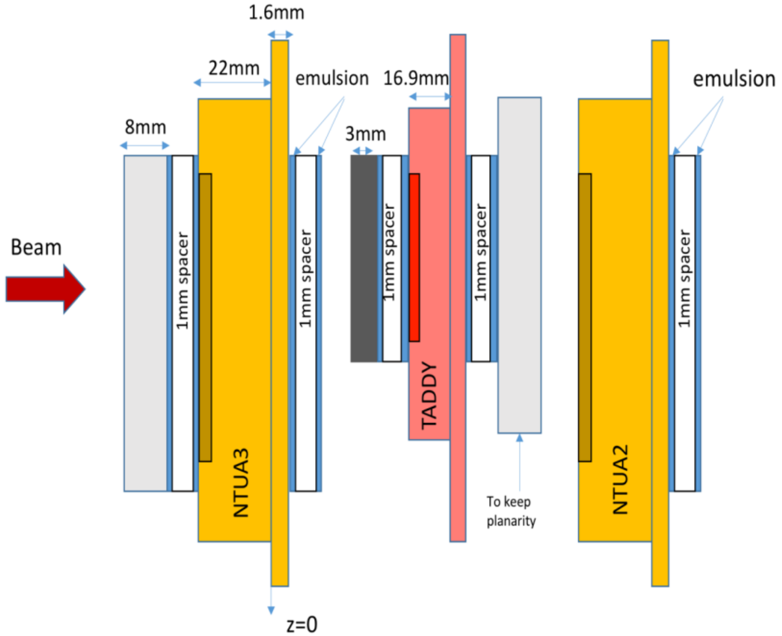
Conclusions

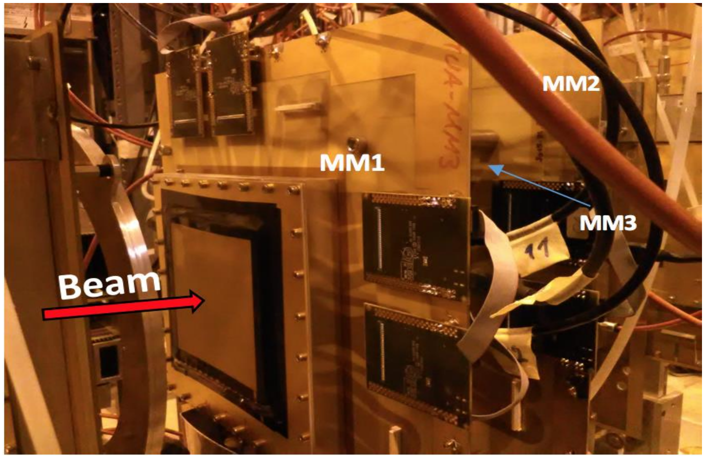
- Resolution at θ=0° and B=0T complies with the needs of the SHiP experiment
- Degradation of the resolution for inclined tracks spoils GEM detector performances.
- ***Frascati group is implementing micro-TPC mode algorithm for the reconstruction of tracks in the GEM detector: re-evaluation of the performances to be done***

Micromegas–Emulsion Test Beam Summary (October 2016)

In collaboration with RD51 group

- 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°)





Micromegas–Emulsion Test Beam Summary (October 2016)

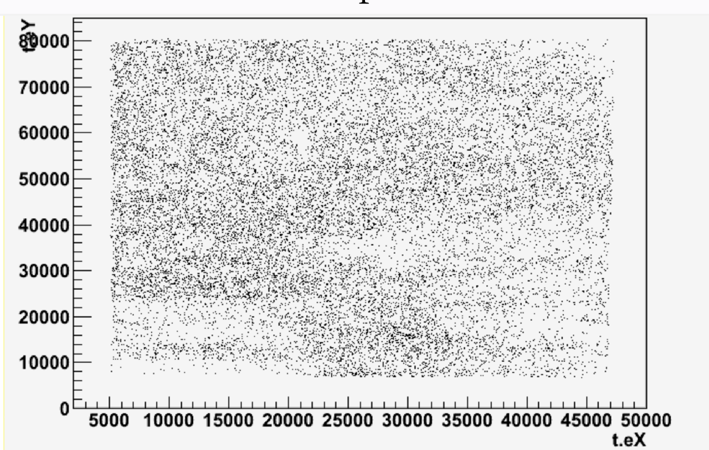
In collaboration with RD51 group

Bricks with small amount of chemicals for test development

AT CERN

- Assembling of emulsion target
- Development
- Glicerine treatment & drying

Reconstructed track position distribution



Non uniformity due to local distortions (to be corrected)

IN NAPLES

- Scanning of all exposed emulsion films
- Track reconstruction in the emulsions

Waiting for data from micromegas to perform matching procedure

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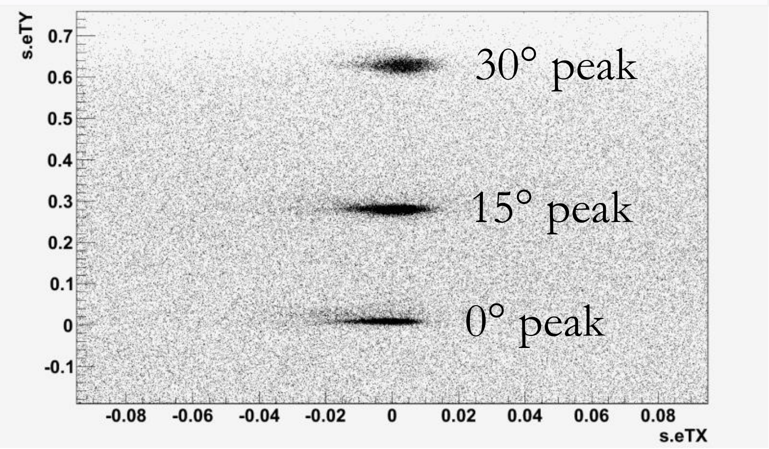

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New option for target trackers

- Matching between detector providing time stamp (TT) & emulsion would improve if TT had micrometric resolution
- ***Necessary to provide time sensitivity to emulsions***

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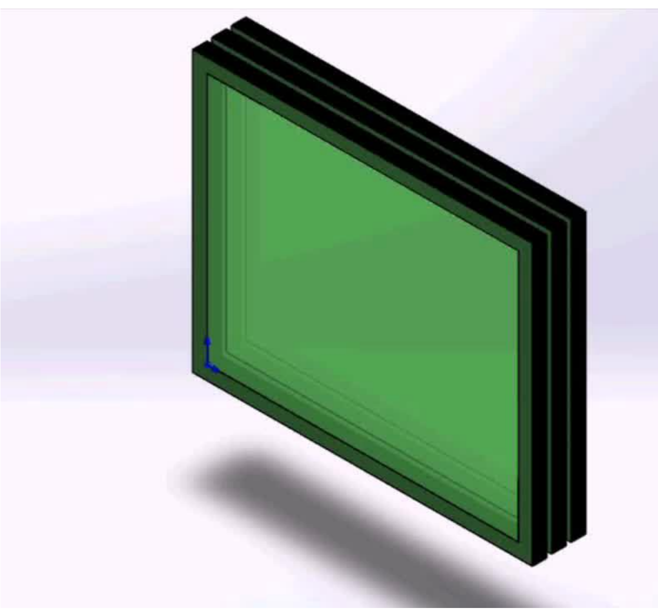
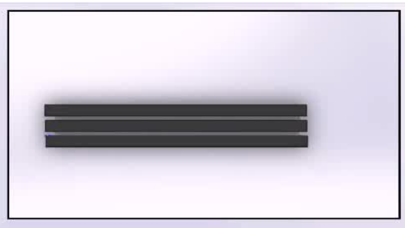
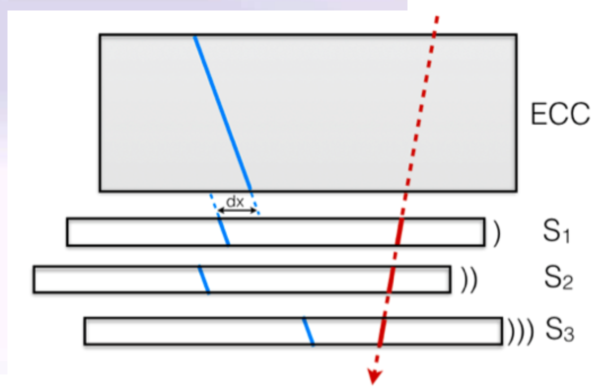






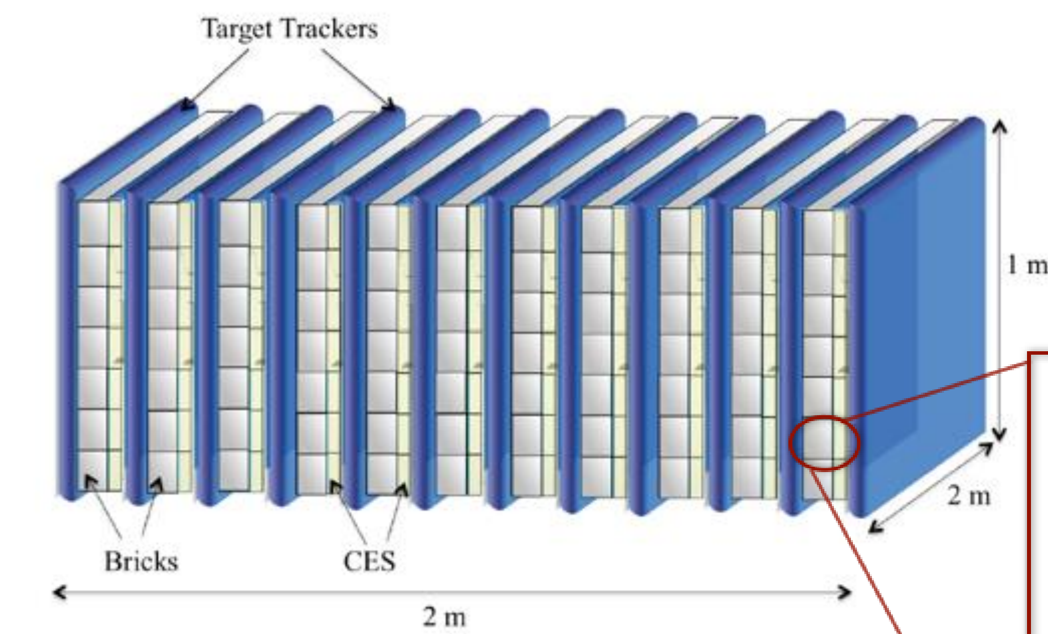
- 3 stages, each moving cyclically at a different speed
- Track displacement linked to the recorded time

Prototype to be prepared for test beam in 2017

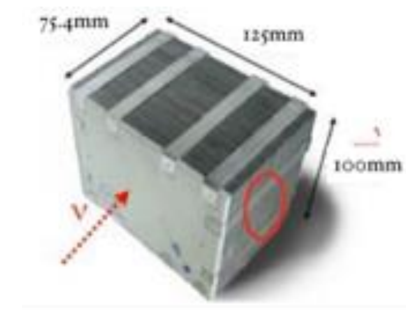
Compact Emulsion Spectrometer

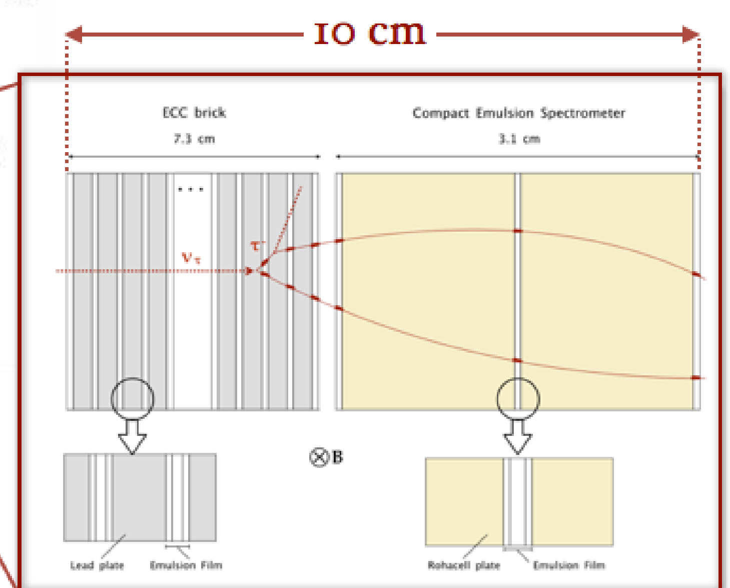
The Emulsion Target

ν target + vertex detector



Fundamental unit: **Brick**



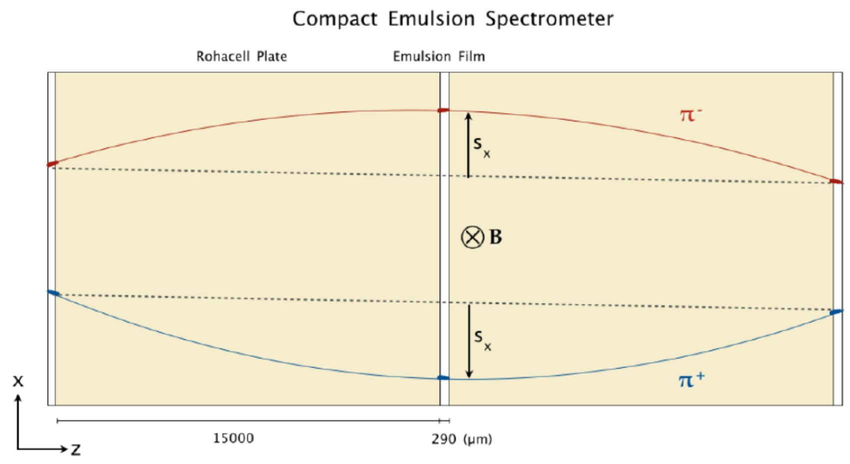


- **Emulsion Cloud Chamber technology**
- **Lead plates** (high density material for the interaction) interleaved with **emulsion films** (tracking devices with **μm resolution**)

Compact Emulsion Spectrometer (CES)

Basic layout

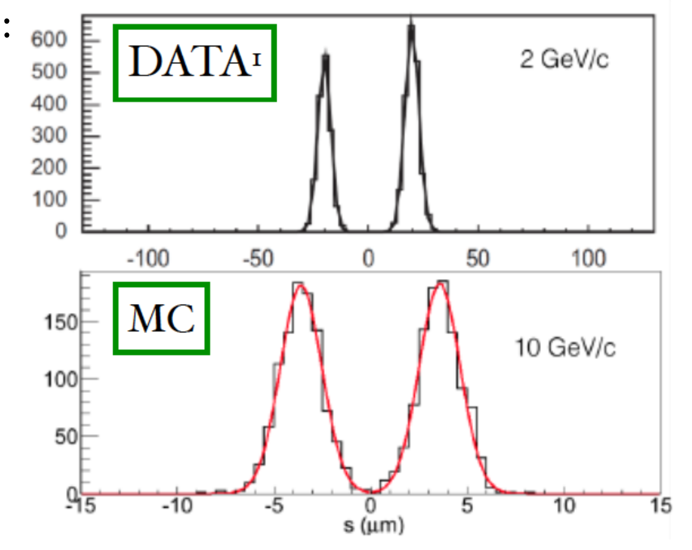
- Three emulsion films interleaved with two, 15-mm thick, light material layers
- Measure hadron track curvature
- Required 90% efficiency for hadronic τ daughters reaching the end of ECC brick in a 1 T field
- sagitta method to be used to discriminate between positive and negative charge



Compact Emulsion Spectrometer

Performances from Physics Research A 592 (2008) 56–62 57

- From simulation, extrapolating experimental results:
  - electric charge can be determined with better than 3 σ level up to 10 GeV/c
  - Momentum estimated from the sagitta Δp/p < 20% up to 12 GeV/c



SHiP CES in TP

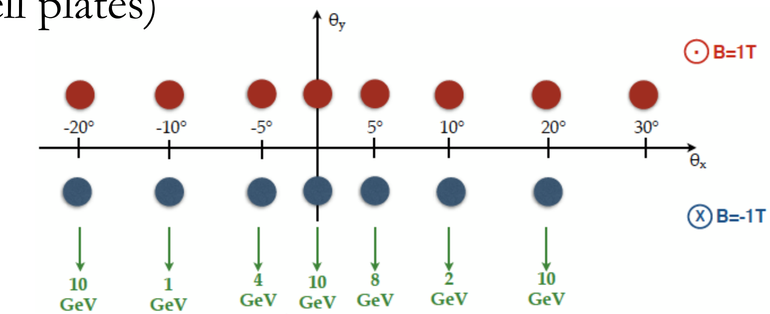
Challenges:

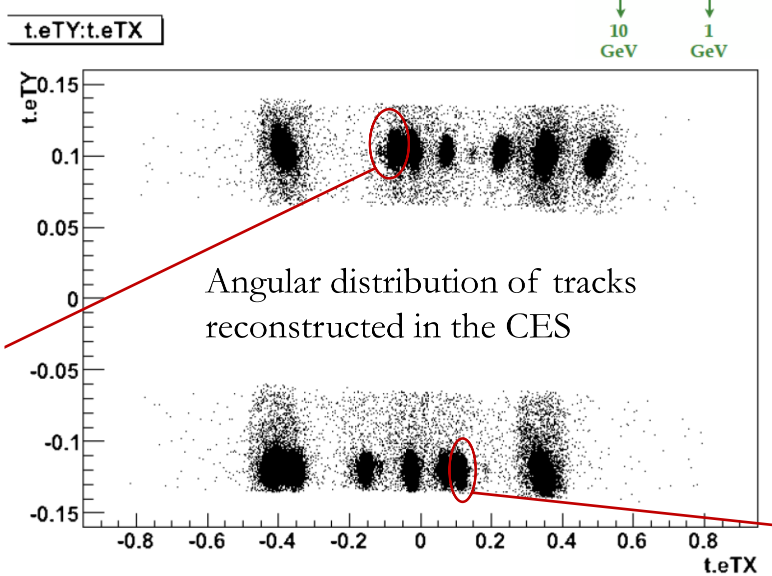
- Extend the range from 2 to 10÷12 GeV
- Use Rohacell instead of air gaps
  - Avoid fiducial volume losses (spacer without any additional frame)
  - Difficult to keep perfectly planar
  - Thickness accuracy ±0.2 mm granted by the maker (15 mm)

=> Test Beam performed in September 2015 at CERN PS

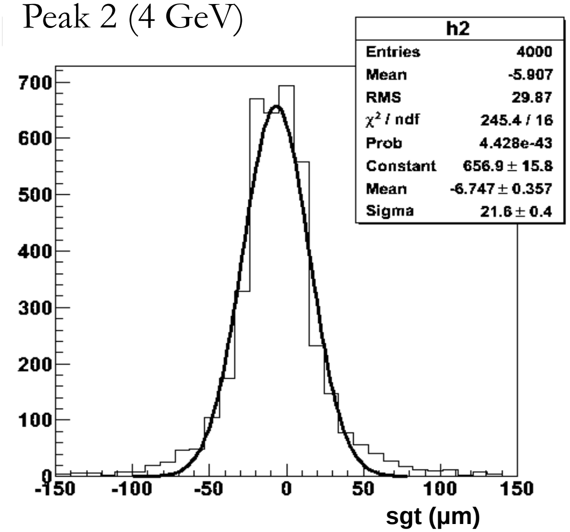
Results – CES test beam 2015

- Target: CES (10 emulsion films interleaved with Rohacell plates)
  - Low density: 700 - 1500 tracks/cm2/angle
  - Magnetic field: 1T, -1T
  - 15 angles, 5 momenta

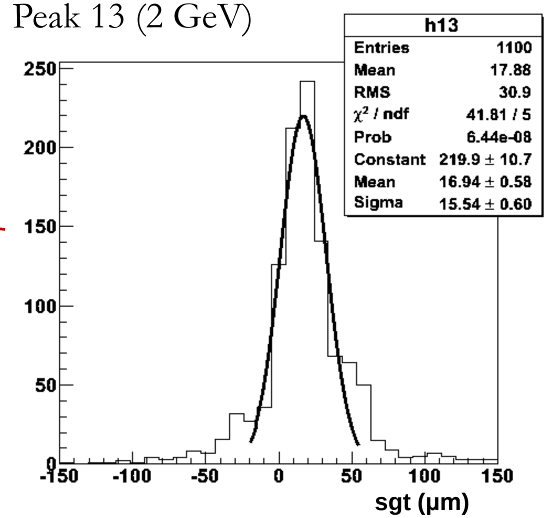




Peak 2 (4 GeV)



Peak 13 (2 GeV)



Results – CES test beam 2015

- ***2 GeV peak:***
  - <μ> =16.9 μm
  - σ = 15.5 μm
- ***4 GeV peak:***
  - <μ> = - 6.7 μm
  - σ = 21.6 μm

Nominal sagitta values

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

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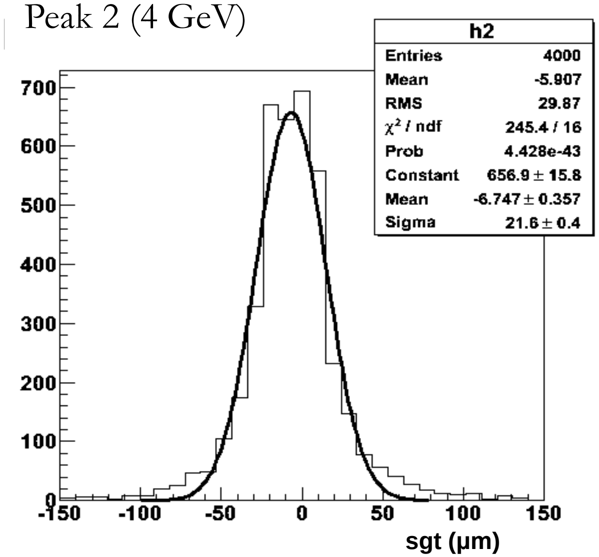


- Fair agreement between average measured sagitta values and nominal ones
- Width of sagitta distribution much wider than expected: ***charge measurement spoiled***

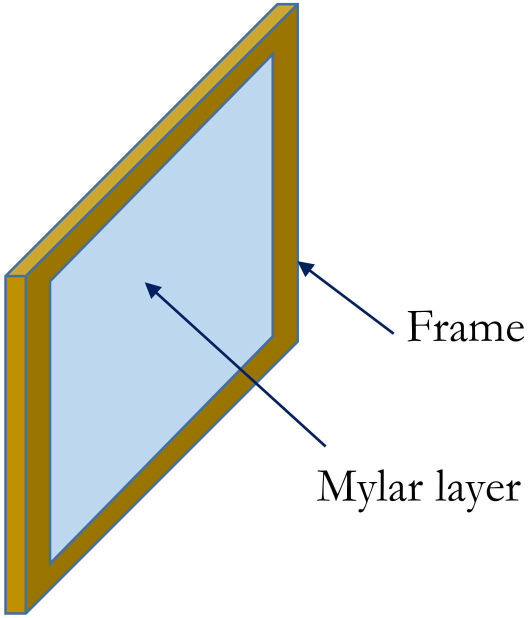
Conclusions

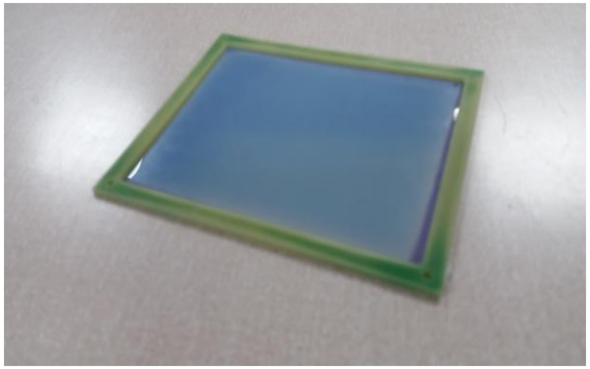
- **Rohacell solution shows:**
  - fine local resolution
  - planarity problems on bigger scales.
  - Difficult to maintain gap stability with the accuracy better then 0.2 mm.

Test Beam Summary 2016

Test for new CES solution

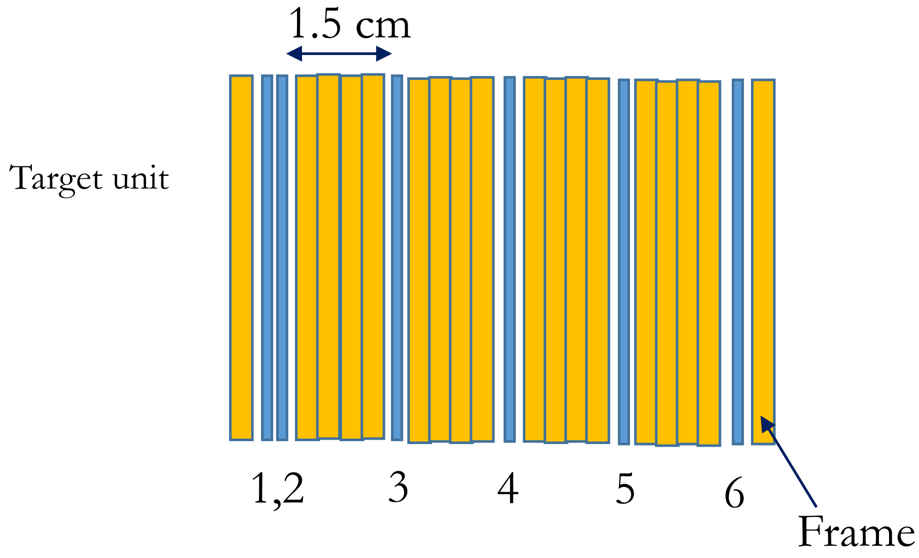
- **Frame solution was tested**: precise rigid frames with a thin film (mylar) stretched over as a mechanical support for the emulsion.
- This guarantees flatness and it's more lightweight solution in respect to the Rohacell



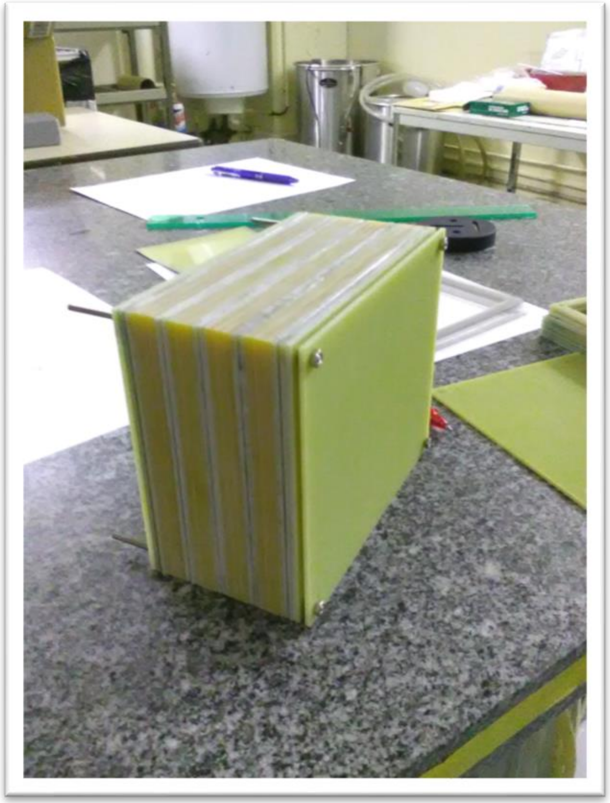


Test Beam Summary 2016

- Target units assembled in the CERN emulsion lab

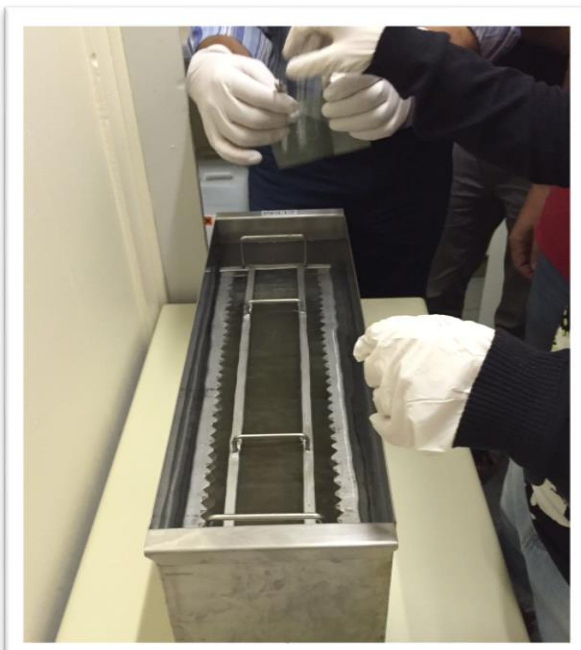


CES assembling



Test Beam Summary 2016

- 3 different exposures performed at CERN PS with different angles/momenta of the beam
  - P_{min} = 1 GeV/c, P_{max} = 10 GeV/c



- Development + glycerin treatment performed in the CERN emulsion lab

Test Beam Summary 2016

- Scanning of ***one of the exposed CES*** performed in Naples
  - Pions with p=1 GeV/c sent with θ_x=0°, θ_y=0° on the target unit with B=±1T
  - Pions with p=1 GeV/c sent with θ_x=0°, θ_y=0° on the target unit with B=±1T
  - Pions with p = 4 GeV/c sent with θ_x=0°, θ_y=15° on the target unit with B=±1T
  - Pions with p = 6 GeV/c sent with θ_x=0°, θ_y=-15° on the target unit with B=±1T
  - Pions with p = 10 GeV/c sent with:
    - θ_x=0°, θ_y=0° on the target unit with B=0T
    - θ_x=±20°, θ_y=-15° on the target unit with B=0T
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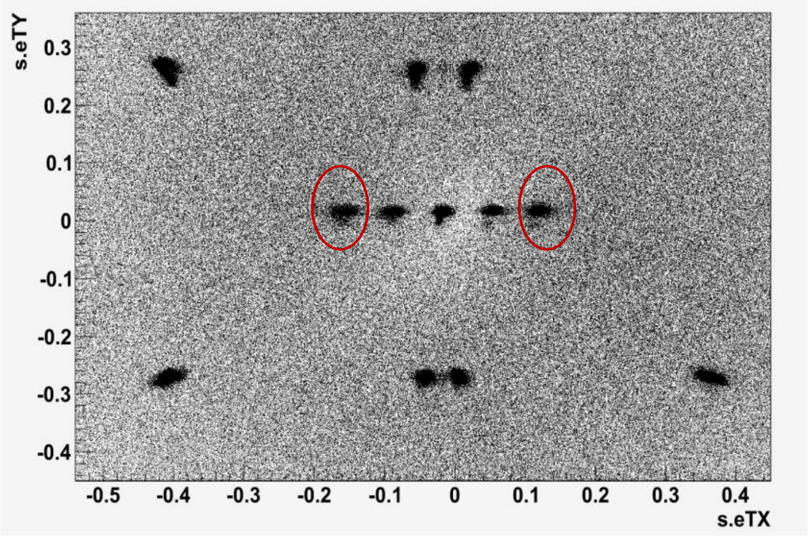

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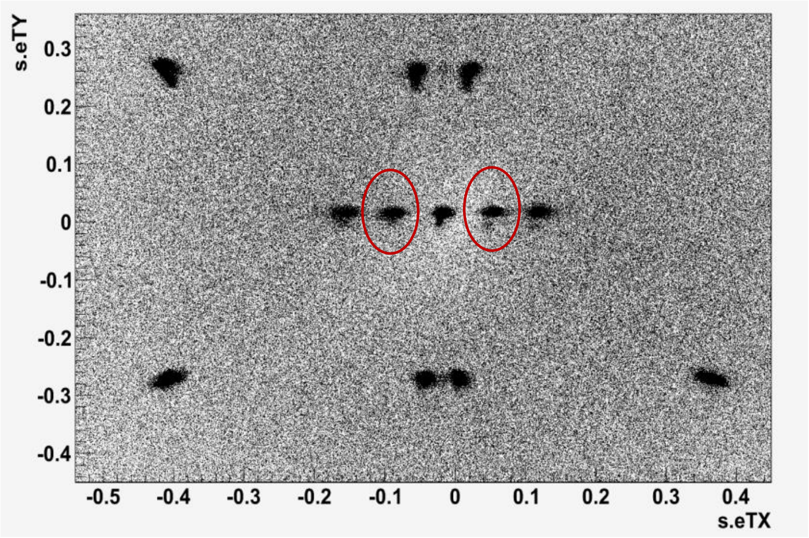

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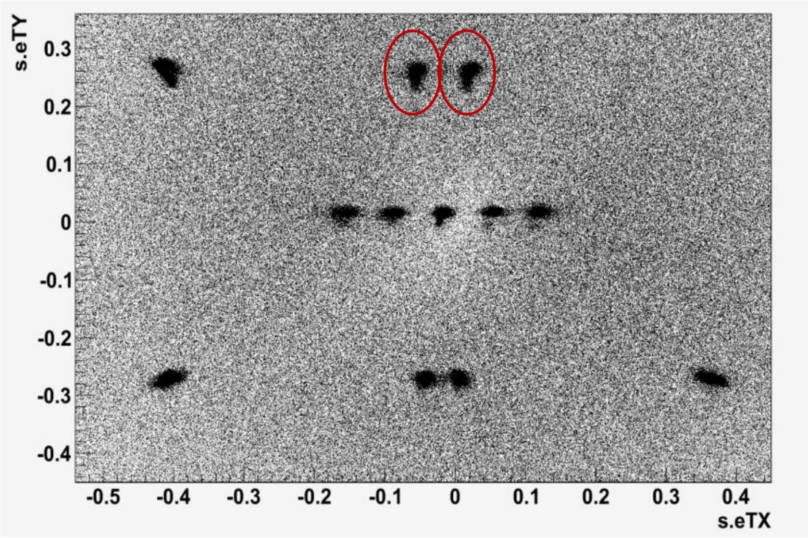

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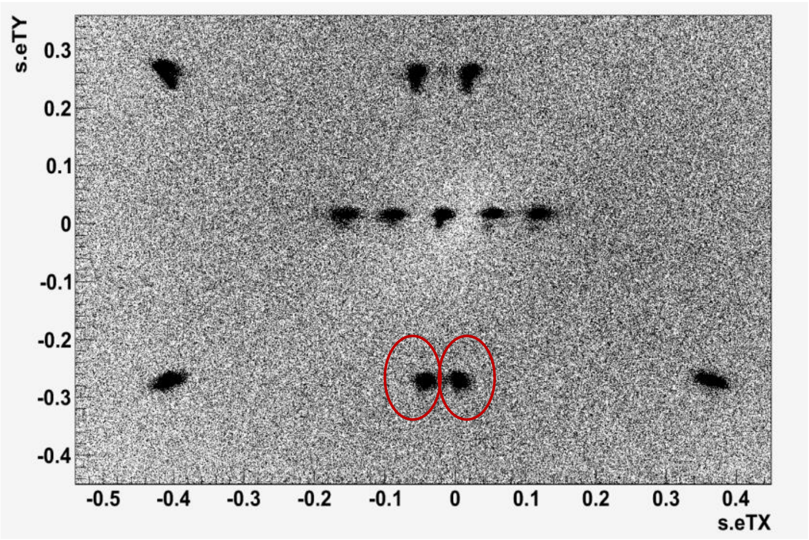

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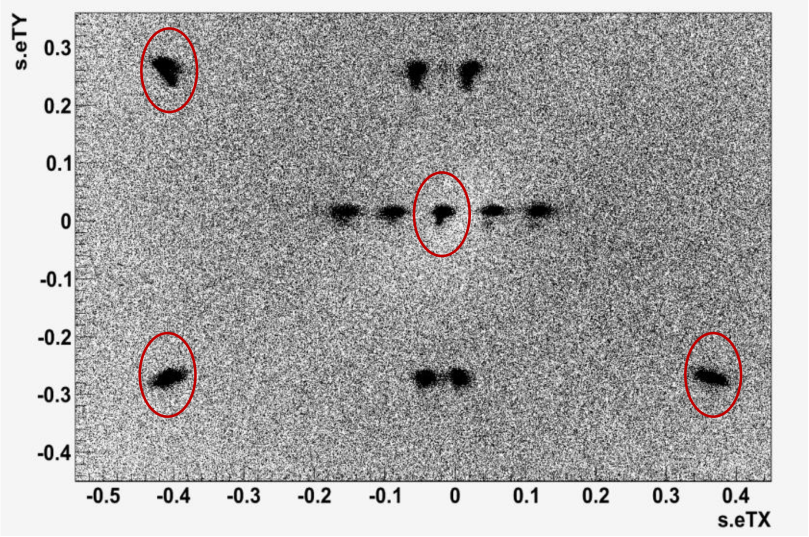

Test Beam Summary 2016

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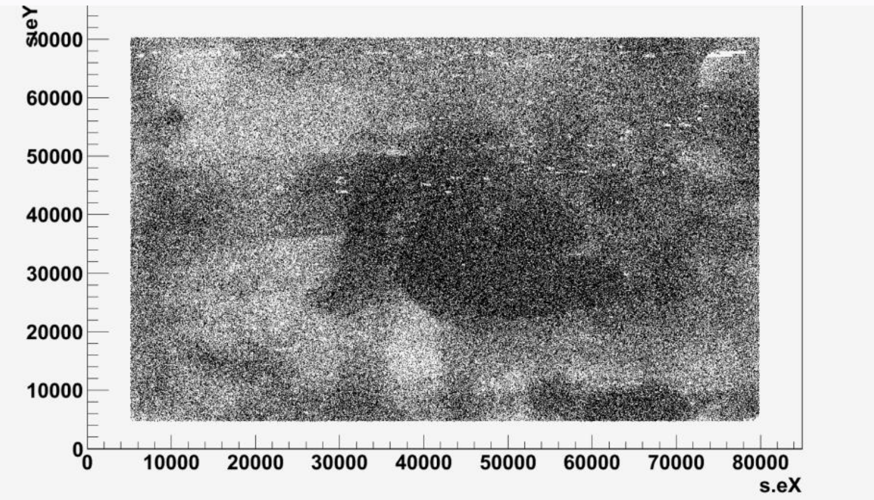
    - Necessary to modify the standard OPERA reconstruction software to implement:
        - Local correction to emulsion distortion

Position of tracks in one films



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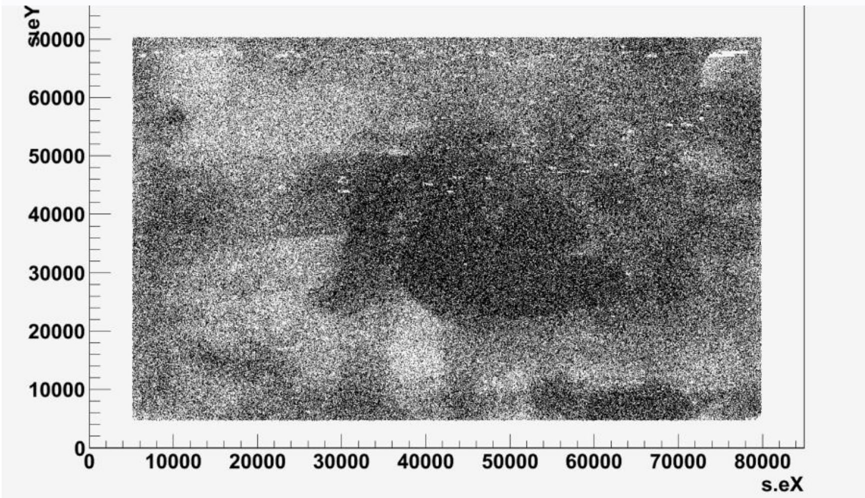

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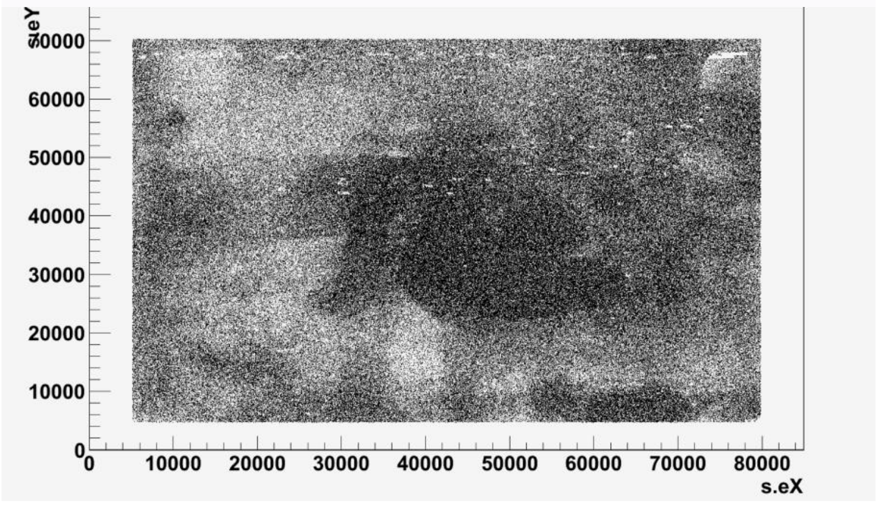

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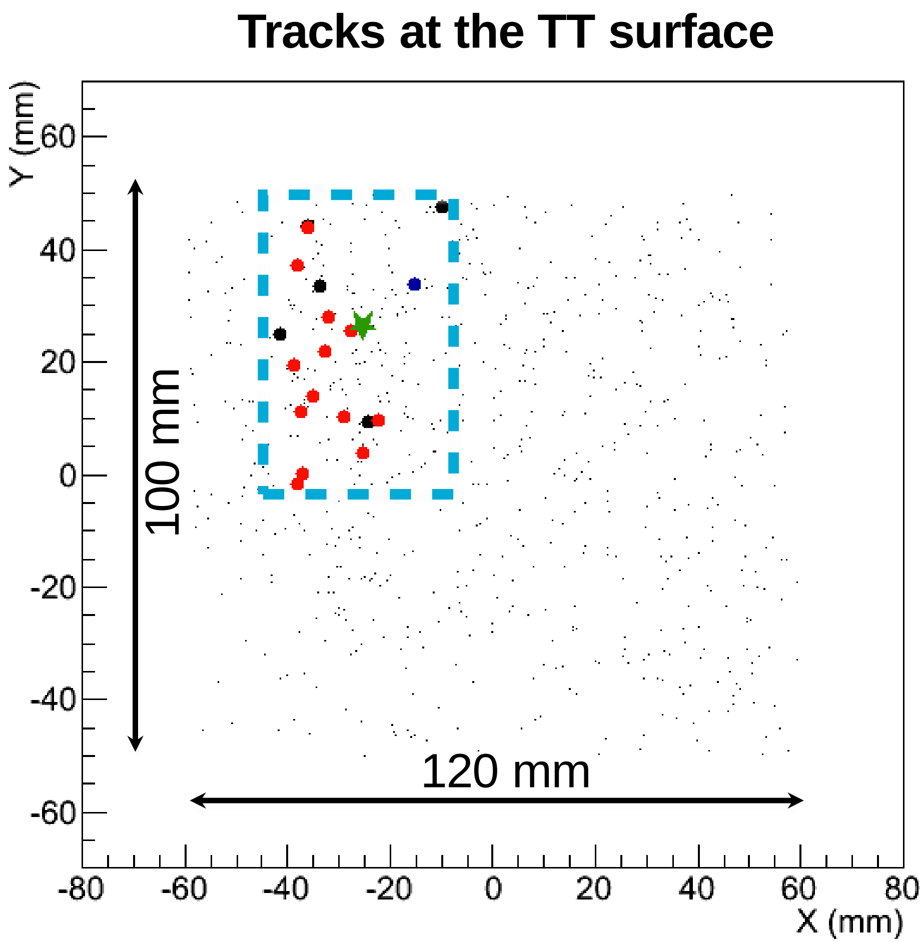
Updates foreseen for next collaboration meeting.

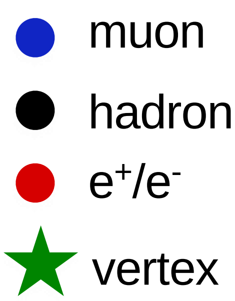
Back -up

Neutrino events in Target Trackers (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

Resolution of Target Trackers

Simple geometrical assumptions on muon flux

- For 1000 μ/mm² => average track distance: 30 μm
- For 100 μ/mm² => average track distance: 100 μm
- For 10 μ/mm² => average track distance: 300 μm

→ Defines Max acceptable TT resolution

From pattern matching analysis (A. Di Crescenzo Dec 2014)

- Requiring:
  - TT-Emulsion alignment with high (>98%) purity and (>90%) efficiency
  - 100 GeV muons at zero angle uniformly distributed on the surface
  - 2 mm gap between CES and TT
- Needed resolution:
  - For 100 μ/mm² => 20 μm
  - For 10 μ/mm² => 60 μm

→ Defines Minimum needed TT resolution