

The nuclear emulsion approach to the muon radiography



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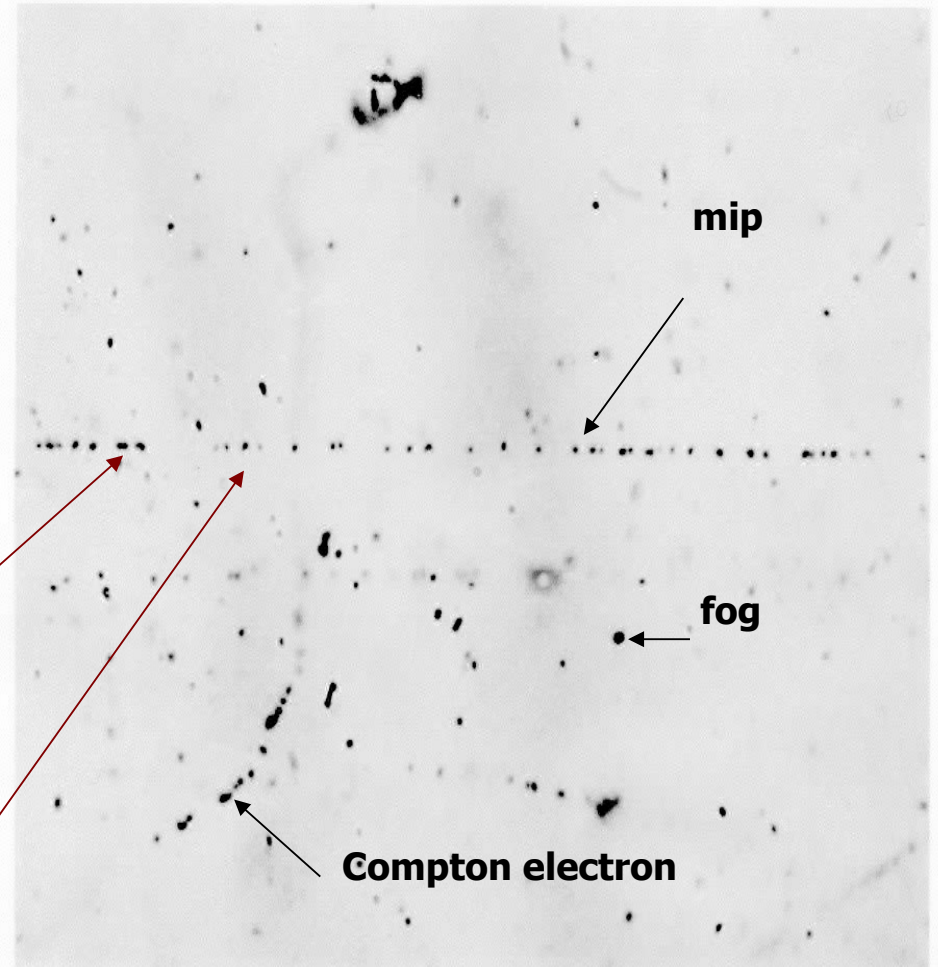
Nuclear emulsion films

Made of **AgBr crystals** poured
in an organic gelatine.

Passage of charged particles
can be recorded with accuracy
better than 1 micrometer

charged particles crossing emulsions
ionize AgBr crystals. *Fixing* and
development turn ionization points
into **black grains**

A track is defined as a sequence of
aligned black grains



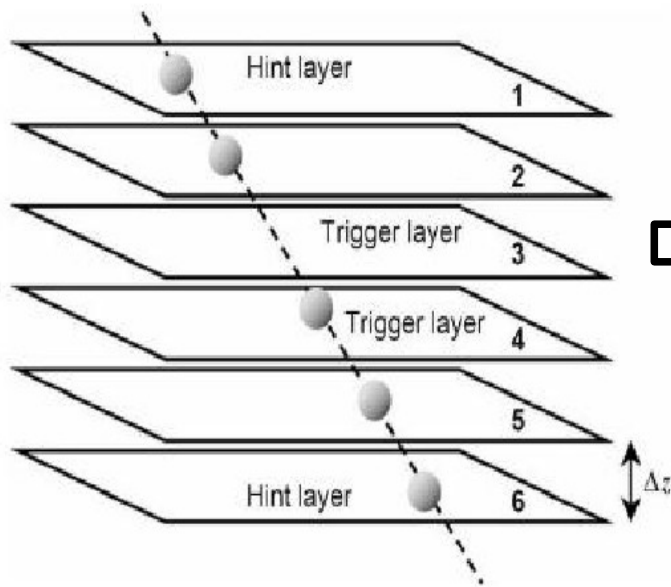
About 35 grains/100 microns

on OPERA-like emulsions

(optimized for detection of m.i.p. particles)

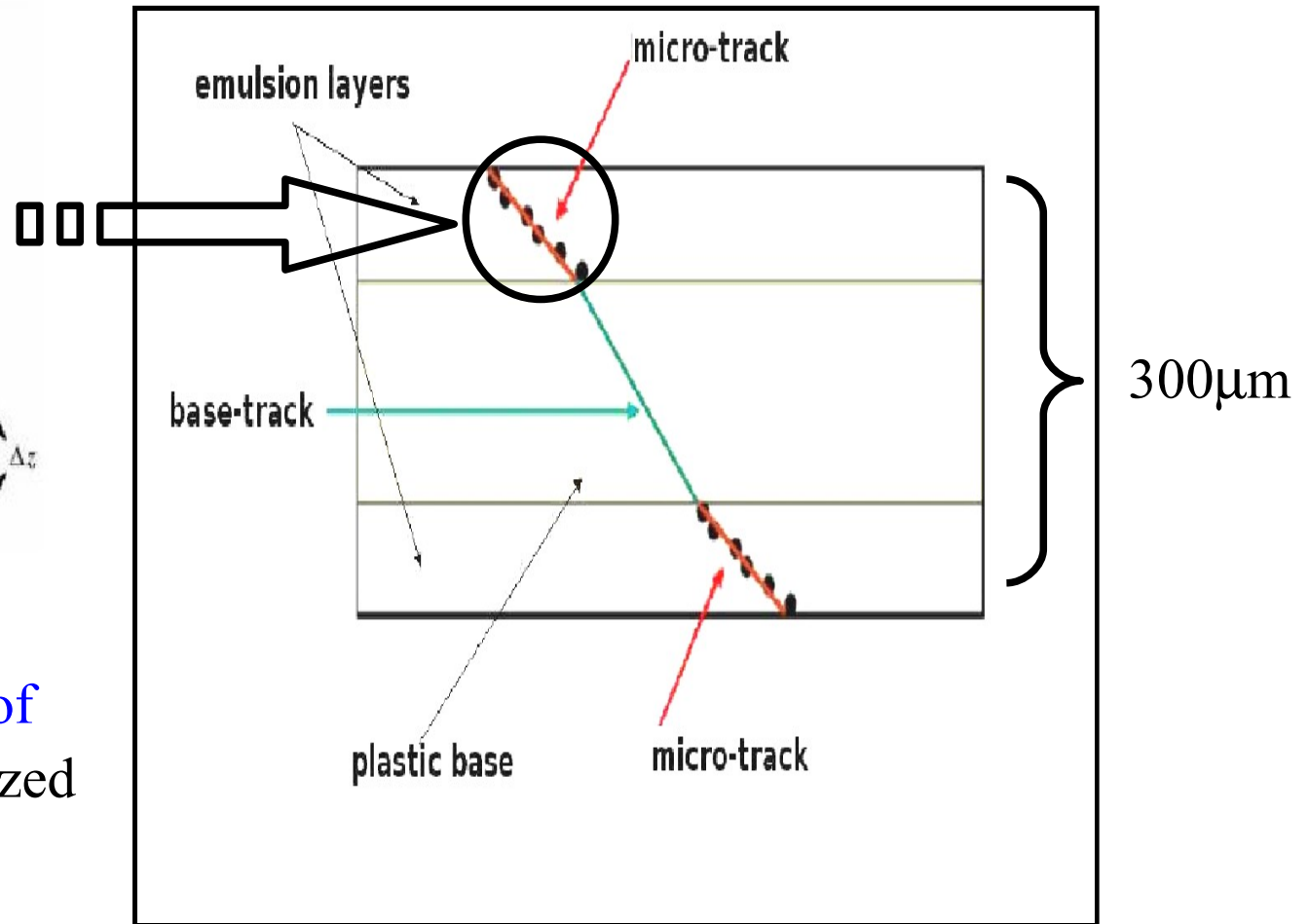
Emulsion Scanning Principle

Tracking in emulsion layer



Tomographic scanning of emulsion to identify ionized grains \rightarrow processed to identify 3d tracks

OPERA-like emulsion



High speed automated emulsion scanning

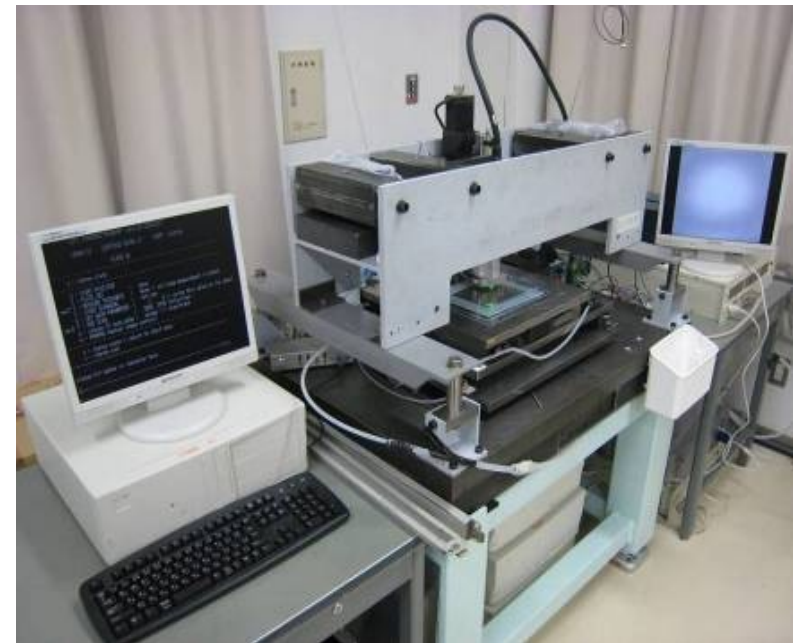
Two approaches

ESS (European Scanning System)



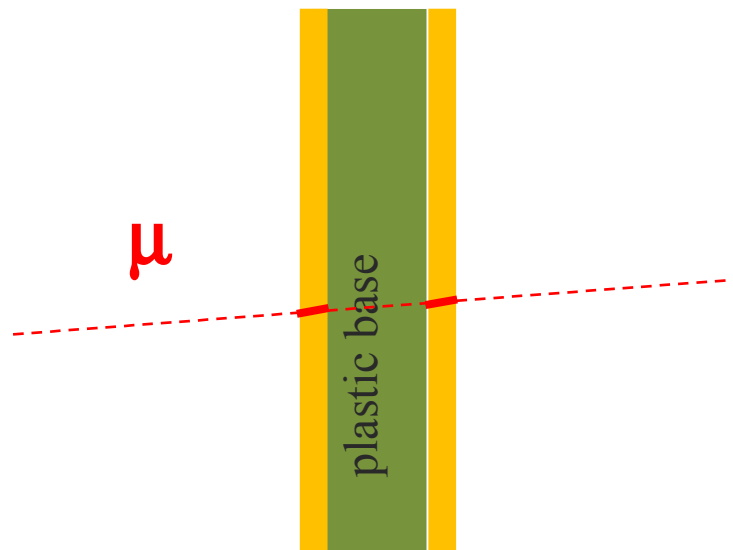
- Customized commercial optics and mechanics
- Asynchronous DAQ software

SUTS (Super Ultra Track Selector)



- High speed CCD camera (3 kHz), Piezo-controlled objective lens
- FPGA Hard-coded algorithms

Emulsion films as tracking detectors

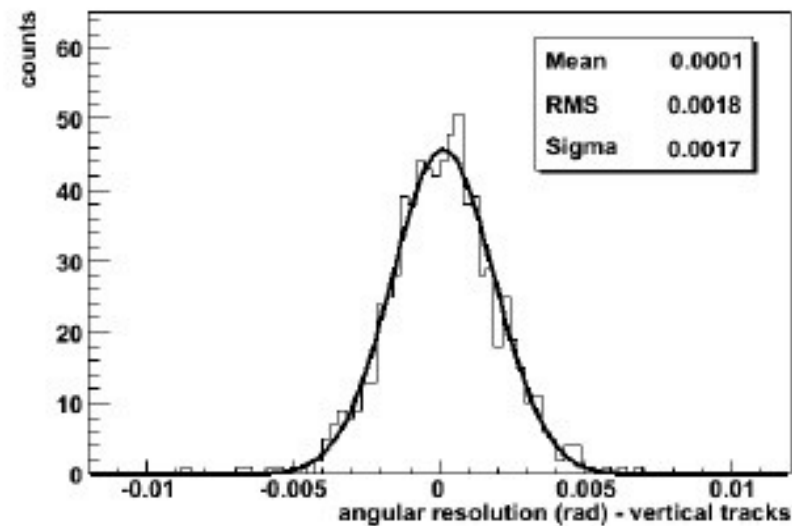


emulsion film
300 μm

Micrometric position resolution

Films exposed **orthogonal**
to the beam

Angular resolution:
from $\cong 2$ to a few mrad
depending on track angle

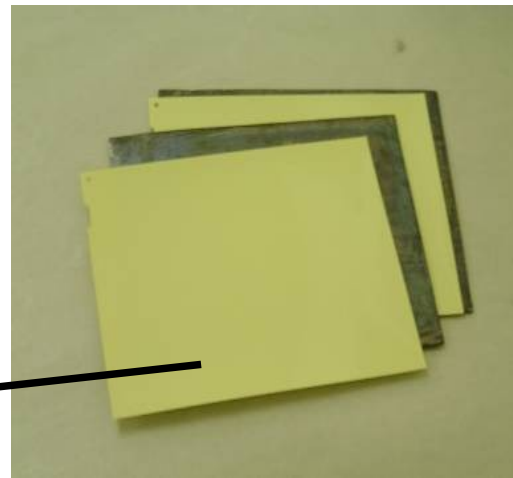
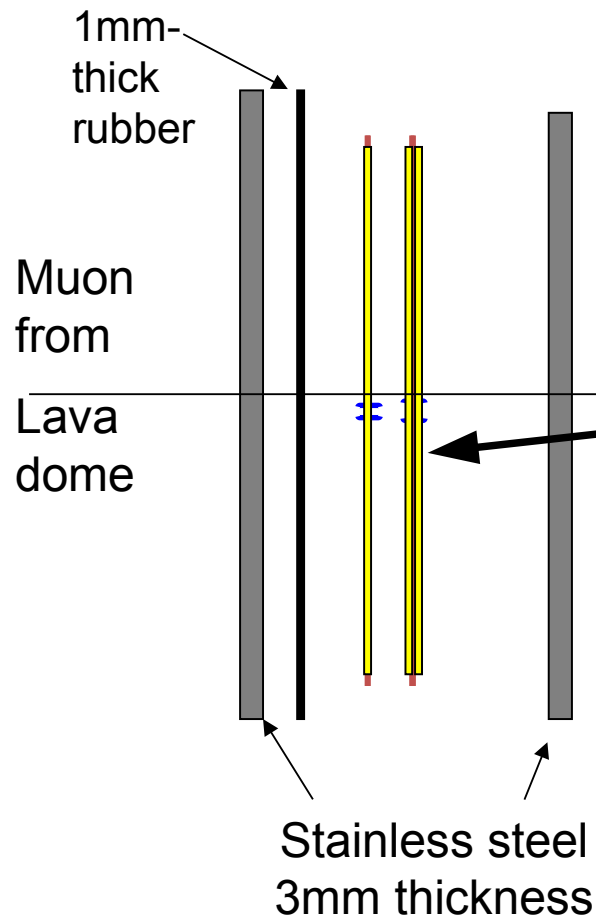


Track angular resolution (mrad)

Emulsion films as tracking detectors (2)

Highly modular structure: detection surface easily scaled to fit requirements, flexible detector geometry

Emulsion detector at Unzen volcano

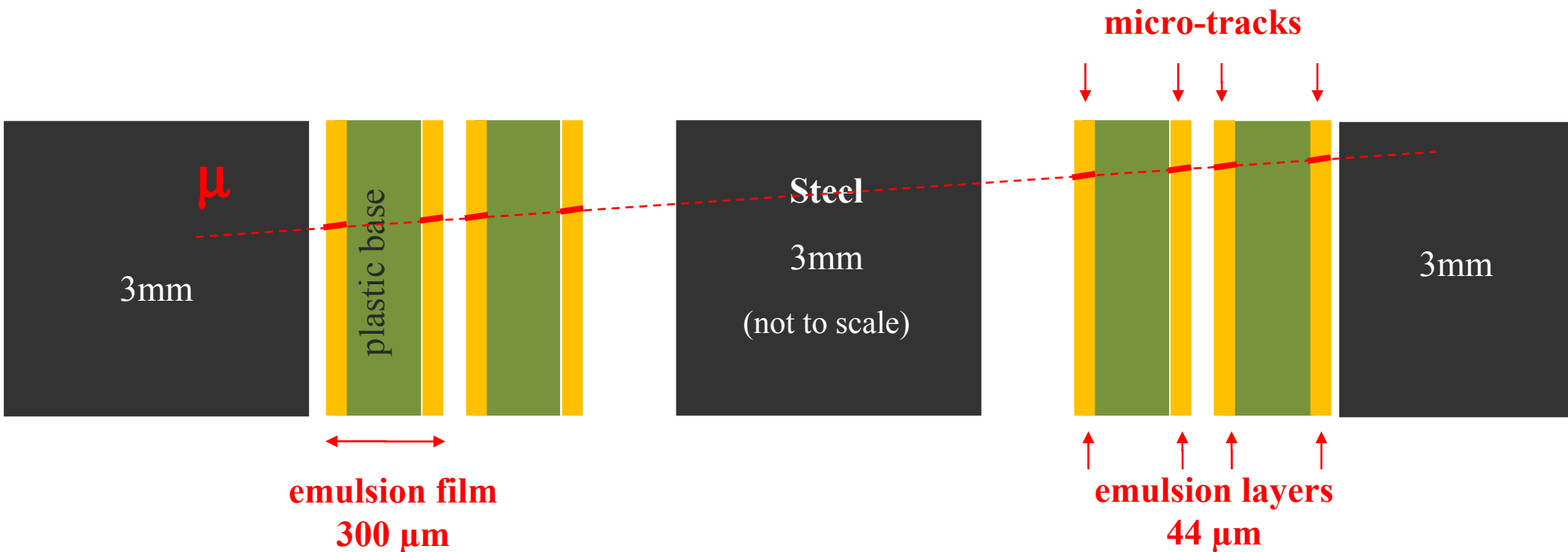


Basic module:
emulsion film
 $12.5 \cdot 10.0 \text{ cm}^2$
300 micron thick

Easily portable
No need for electric power supply

Suited for outdoor sites

Emulsion telescope at Stromboli



4 emulsion films / 8 emulsion layers / 8 micro-tracks

→ Few mrad resolution

→ Redundant tracking for background rejection

→ Low momentum particle rejection by multiple scattering analysis

Issues in emulsion film analysis

Detector surface issue:

Detection surface limited by scanning power:
present limits: $\cong 0.02 \text{ m}^2/\text{day}/\text{microscope}$ (ESS system)

New generation microscope (10 times faster) under development

Timing issue:

Emulsion integrate ionizing radiation *anytime* from production to development, *no timing information* available:

- dedicated analysis to *separate “transportation background”* from exposure signal
- need for *shielding* from radioactive background to *keep emulsion films “clean”*

Issues in emulsion film analysis

Temperature issue:

Ionizing radiation creates a *latent image* in emulsion films, fixed and developed by chemical treatment.

Latent image rapidly fades away **before development at temperature above $\cong 20^\circ$**



Thermic insulation at Stromboli site.

Emulsion exposure done in **autumn-winter**

SPARES

High speed automated emulsion scanning

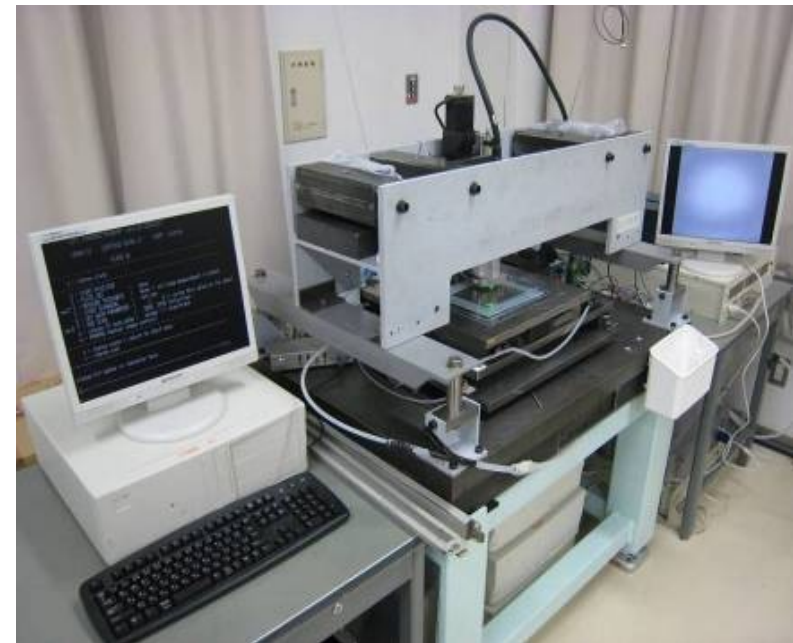
Two approaches

EU: ESS (European Scanning System)

Japan: SUTS (Super Ultra Track Selector)



- Scanning speed/system: 20cm²/h
- Customized commercial optics and mechanics
- Asynchronous DAQ software



- Scanning speed/system: 75cm²/h
- High speed CCD camera (3 kHz), Piezo-controlled objective lens
- FPGA Hard-coded algorithms