Angle Calibration of emulsion read-out system for gamma-ray telescope by test beam

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Abstract

In our laboratory we use Hyper Track Selector (HTS) which is the world's fastest emulsion read-out system. HTS has an optical systematic error in angular measurement caused by difference of refractive index between emulsion and base film, and it makes 3% uncertainty in absolute angle. Such kind of error is a factor which makes imaging performance of gamma-ray telescope worse at larger angle. I conducted calibration by a beam test with 400 GeV proton beam at SPS/CERN to reduce that uncertainty to 1% or less.

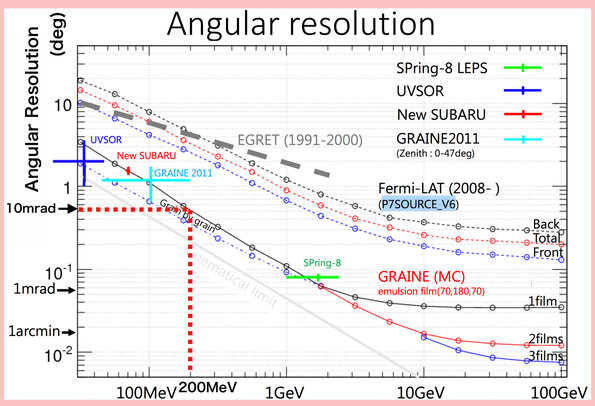
Application of emulsion is expanding

Emulsion is 3D track detector with sub-micron accuracy. Recently application of emulsion is expanding into imaging fields (cosmic gamma-ray observation, muon-radiography).

GRAINE

Gamma-**R**ay **A**stro-**I**mager with **N**uclear **E**mulsion

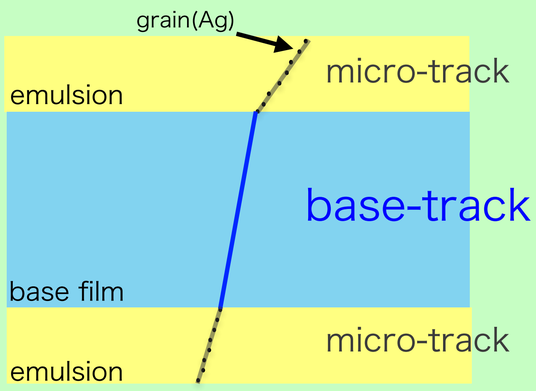
GRAINE is gamma-ray telescope experiment with nuclear emulsion. A demonstration test was performed with a balloon-borne emulsion telescope in 2015. The aim is to detect Vela pulsar at 200MeV energy region. Angular resolution is expected to be 10mrad at 200MeV with MC.

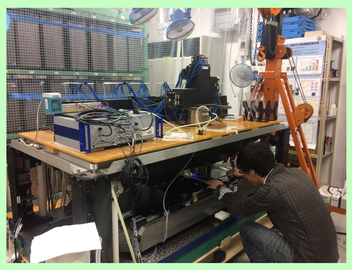


HTS has an optical systematic error

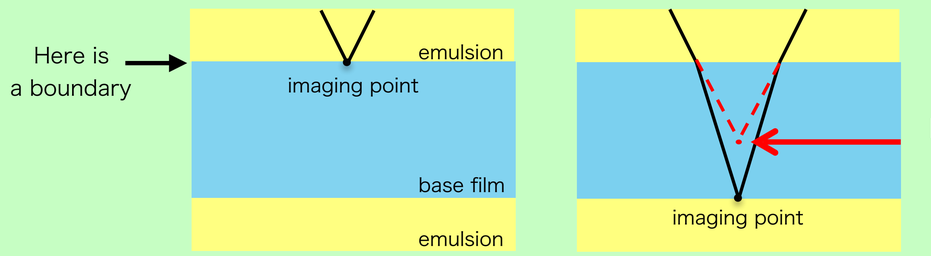
base track

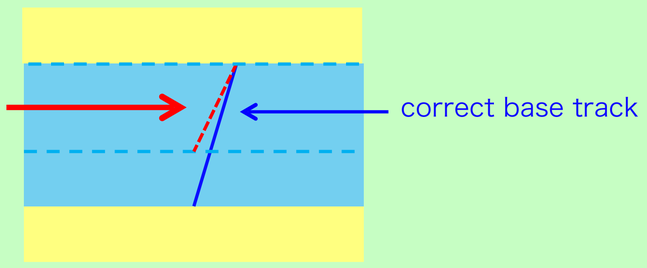
We scan grains in emulsion and make micro-tracks. Micro-tracks are visible tracks, but their angle is incorrect because they are influenced by shrink and distortion. So we make virtual tracks in base film called **base-track**. Base tracks are not so influenced by such things and their angles more resemble real tracks.





HTS reads grains and identifies a boundary between emulsion and base film, and we make base-tracks by micro-tracks. But now a boundary is recognized incorrectly because of difference of refractive index between emulsion and base film. It makes a systematic error of base-track angle.

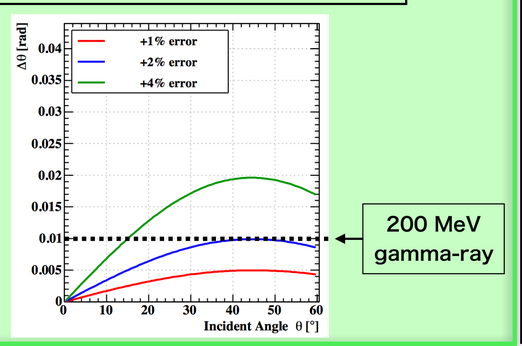




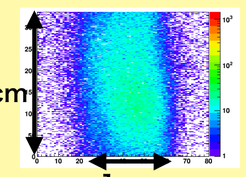
HTS scanned angle - Absolute track angle
= **k** × Absolute track angle

If we can understand **k**
we can correct this angle gap

for GRAINE . . .
I aim to reduce error of **k** within 1% because we want to reduce angle difference caused by it to 5mrad or less.

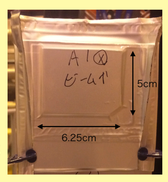


Beam Test @SPS/CERN

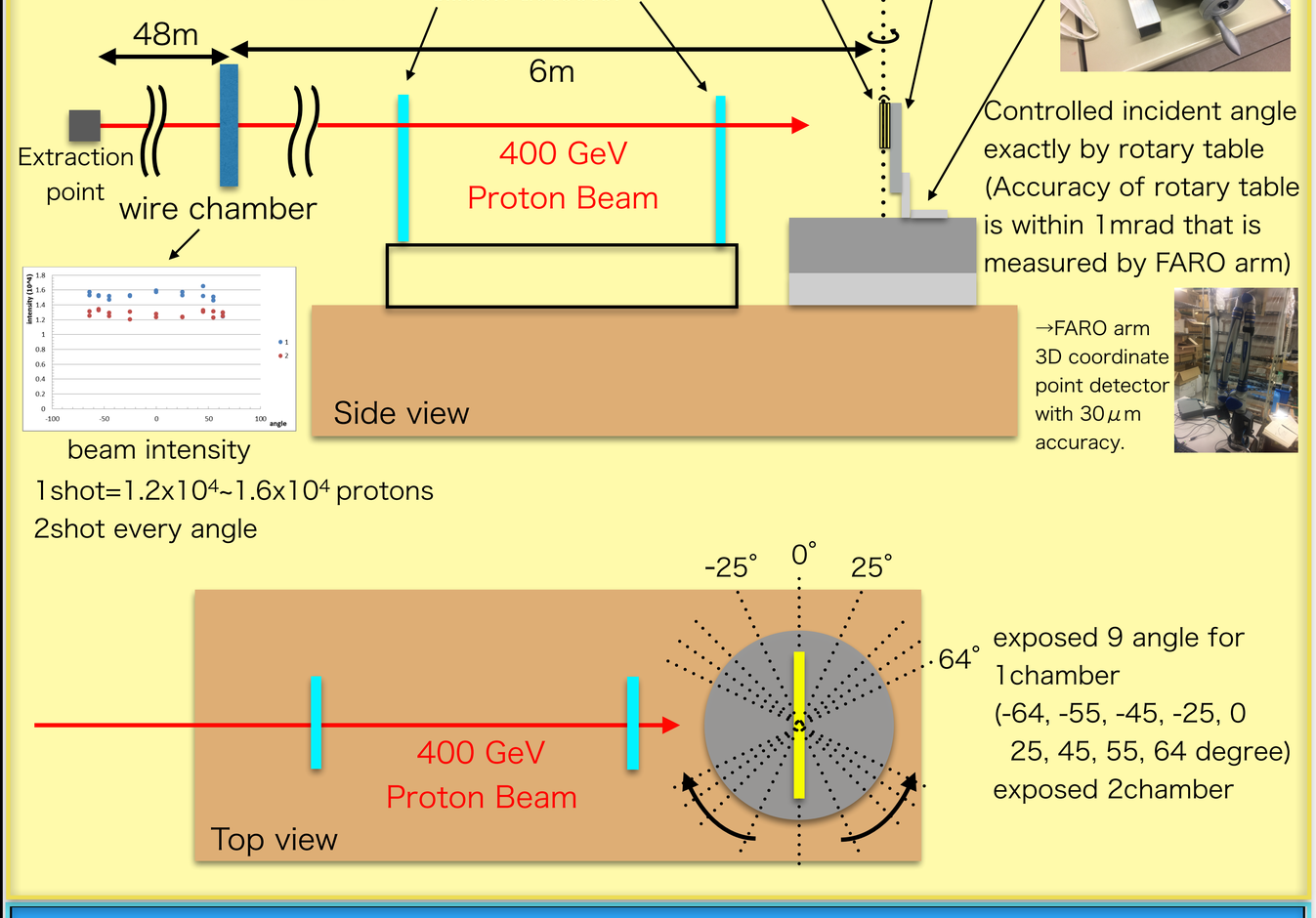


beam profile by silicon detector

1 chamber
= stack 3 films

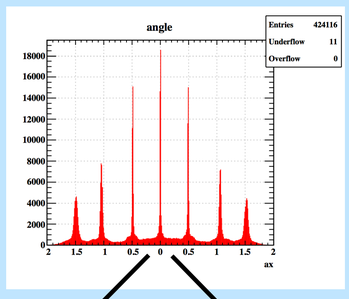


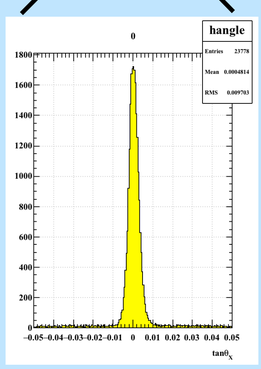
5mm-thick Al plate for flatness



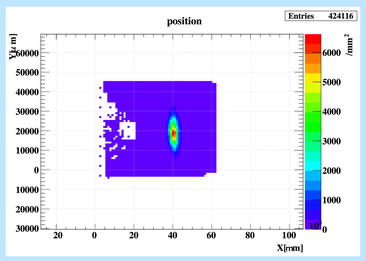
Analysis

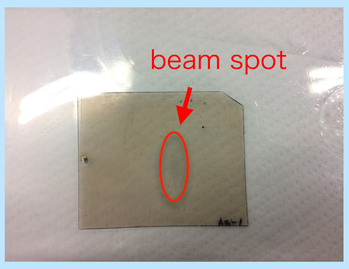
Angle distribution





Track Position distribution

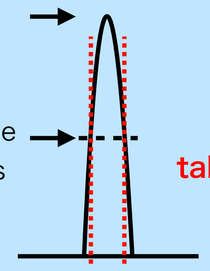




determination of Angle Mean

get the number of entries at the top

cut the angle at the half of the entries



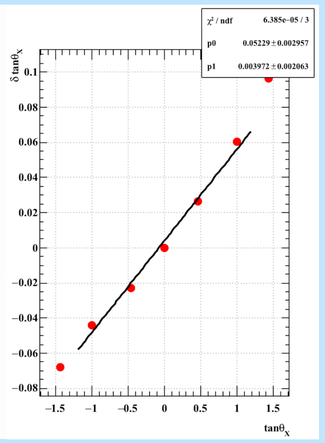
take the average in this range

Result

After performing some correction I made a plot of absolute angle vs a difference between absolute angle and HTS scanned angle, and fitted by linearly approximating. This slope of the straight line is just **k** that I showed.

Vertical axis =
HTS scanned angle
- Absolute track angle

Horizontal axis =
Absolute track angle



tan θ = -1.5, 1.5 are not used for fitting because scan parameters are not fixed exactly for large angle yet and angle mean is not decided well.

The slope **k** is
0.0523±0.0030

It means that if a particle enter emulsion as incident angle is tan θ = 1.00 HTS show its base track angle is about 1.05!

Error of the **k** I showed is only fitting error but it seems that the error is within 1%,