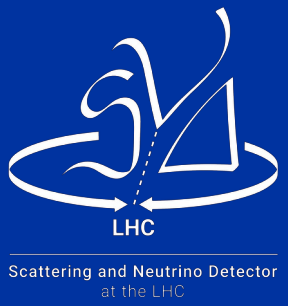


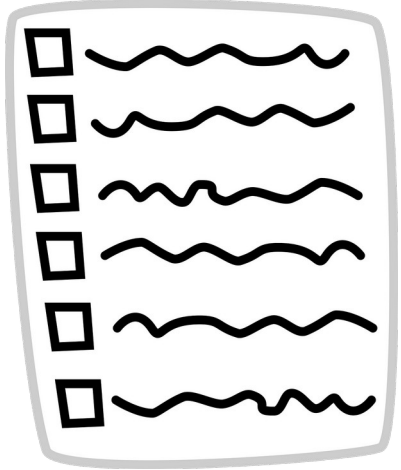
Analysis of SND@LHC emulsion films

A. Iuliano (Università di Napoli and INFN)

INFN Napoli Gr1 Meeting

12th January 2023

Introduction



- **Reporting results of Target 0 analysis: first SND@LHC emulsion target, exposed at the beginning of LHC RUN3**
- **Muon density and performance of track reconstruction in emulsion**
- **Next steps and analysis of higher luminosity data**

Target composition

Target 0 installed in the TI18 tunnel on May 7th and extracted on July 26th

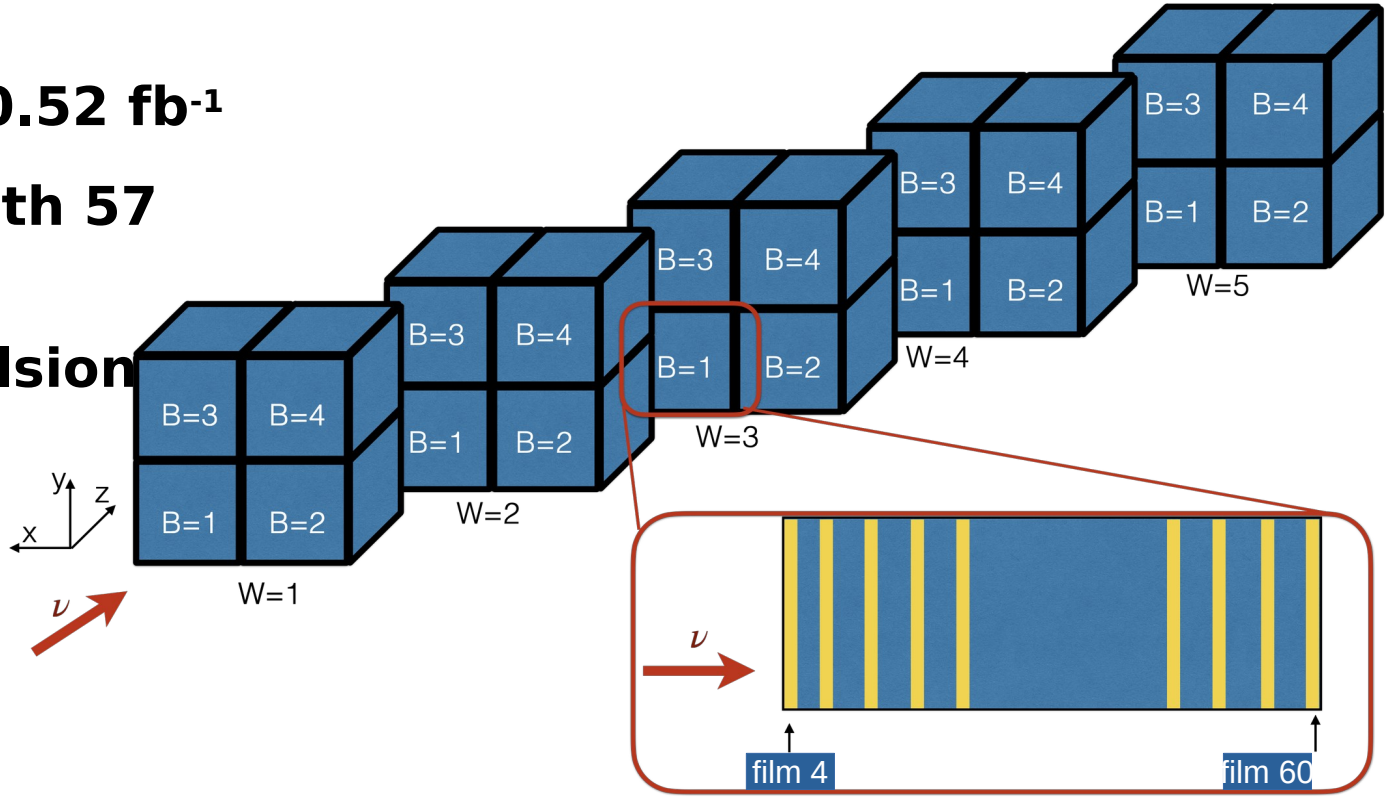
Integrated luminosity: 0.52 fb^{-1}

1 brick instrumented with 57 emulsion films

Reference for next emulsion target analyses

Target 1 and following:

20 bricks each



Emulsion processing

Emulsions developed in a dedicated facility at CERN

Scanning rate: 1 emulsion per day per microscope

Emulsion films the distributed between scanning stations:

- **Bologna**
- **CERN**
- **Lebedev**
- **Napoli**
- **Zurich**

Responsible of data sharing and analysis training/development

Naples scanning station

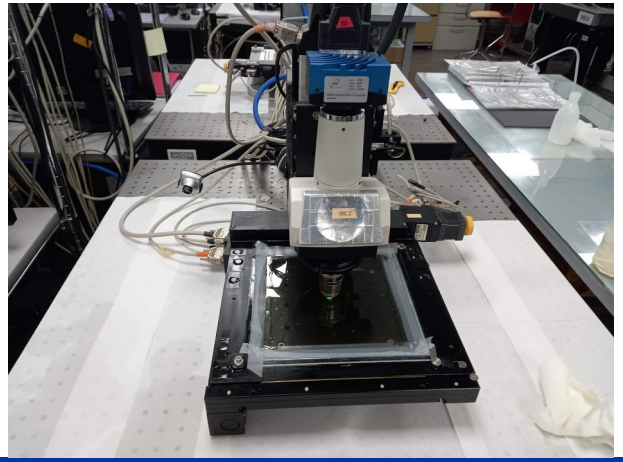
Located in 1H25 laboratory

Controlled humidity and temperature

Scanning SND@LHC emulsion data continuosly since august

1 microscope upgraded and in operation → now scanning Target 1

1 microscope under upgrade, partially funded by Napoli INFN section



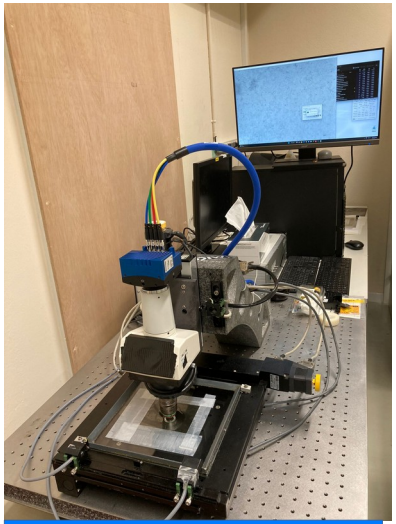
Microscope installation at CERN

Additional scanning station at CERN, allowing to perform scanning already immediately after emulsion development.

Personally involved into the assembly, upgrade and calibration within June-November 2022

Operation and development within a dedicated CERN-INFN project starting 1st March

June 2022



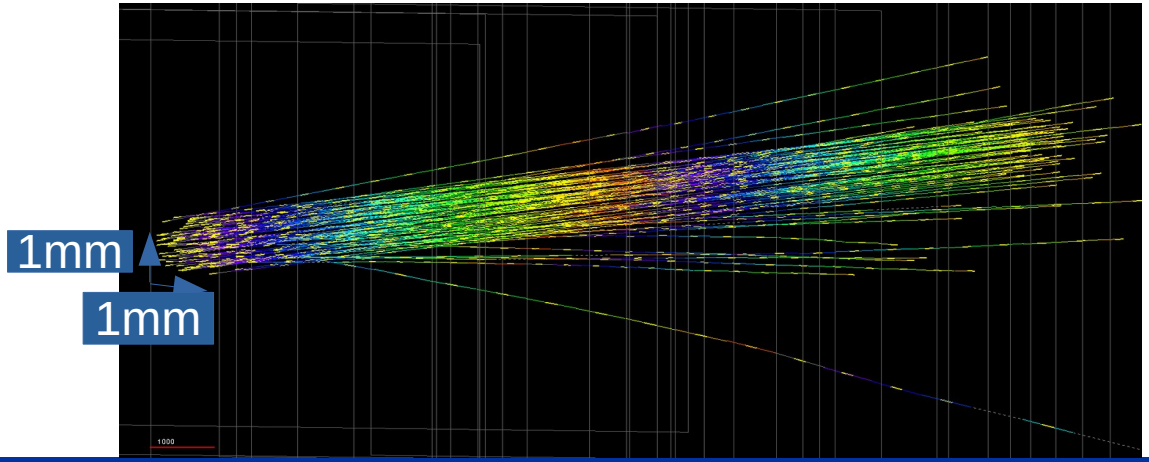
November 2022

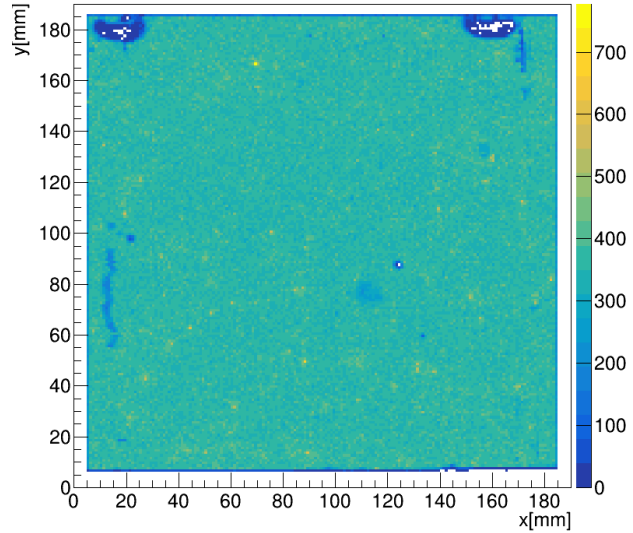
Emulsion data reconstruction

SND@LHC emulsions exposed to high luminosity

In each film, density of 10^2-10^4 segments/mm^2 (depending on target unit)

Optimizing scanning and reconstruction algorithms to cope with integrated luminosity and replacement rate

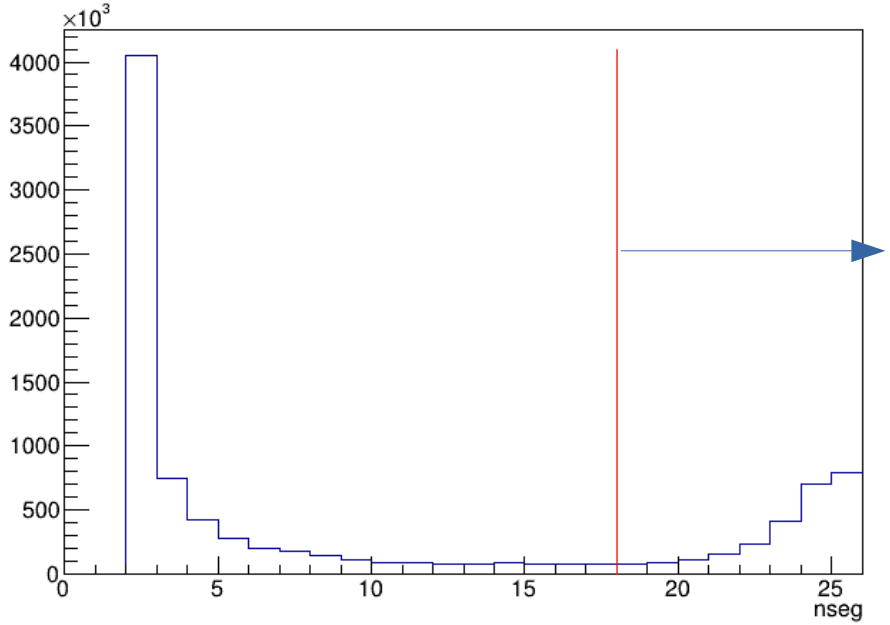


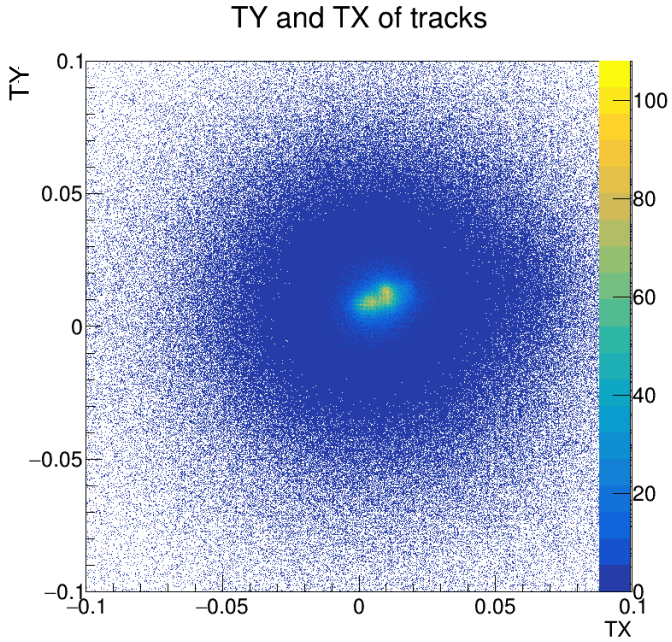


Track reconstruction

Performing rate measurement by considering tracks with at least 18 segments in 25 emulsion films

Studying angular structure and measuring resolutions





Muon rate over the surface

Track density in emulsion target, corrected for reconstruction efficiency

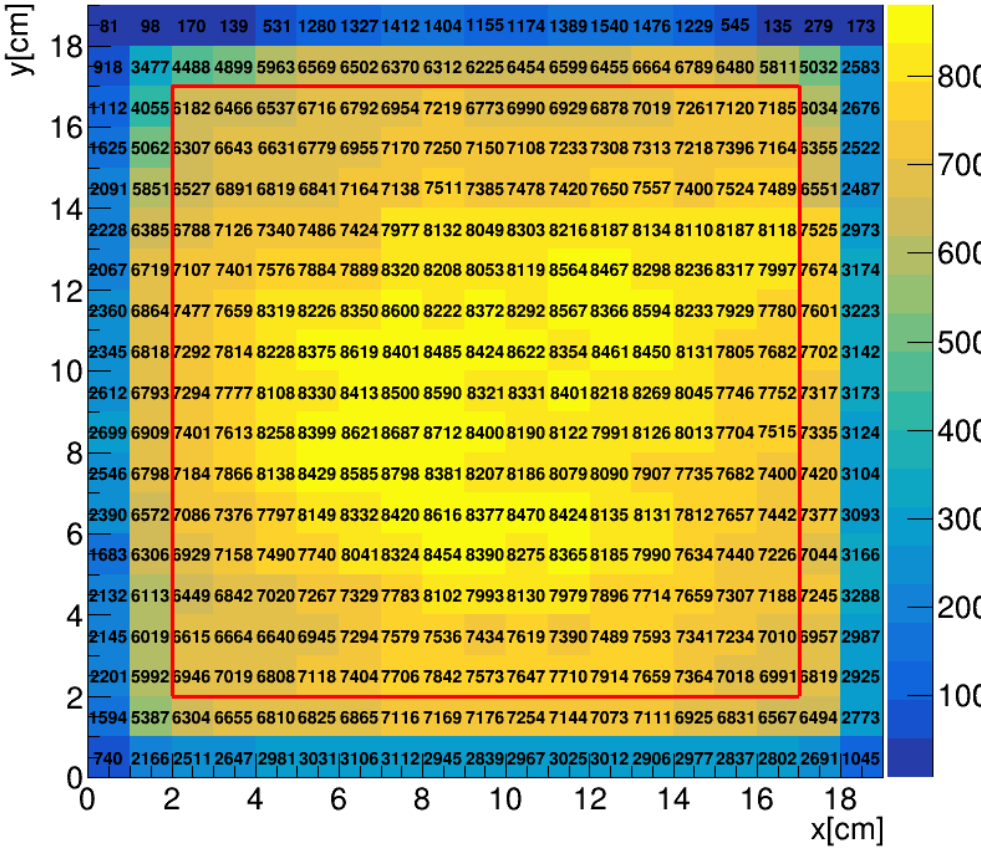
Measured density:

$(7.7 \pm 0.6) \times 10^3$ /cm²

Considering Target 0 luminosity: 0.52 fb^{-1}

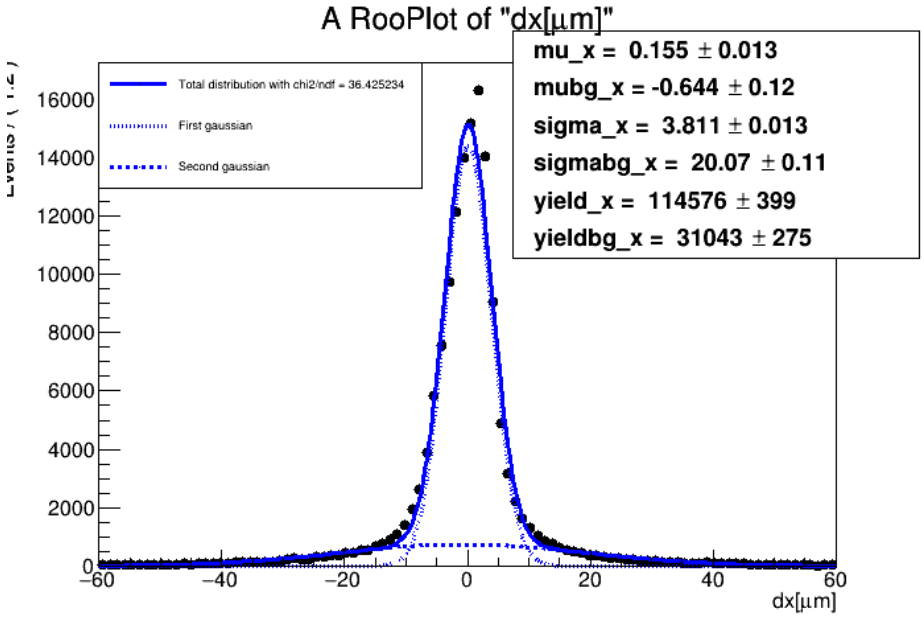
Measured rate:

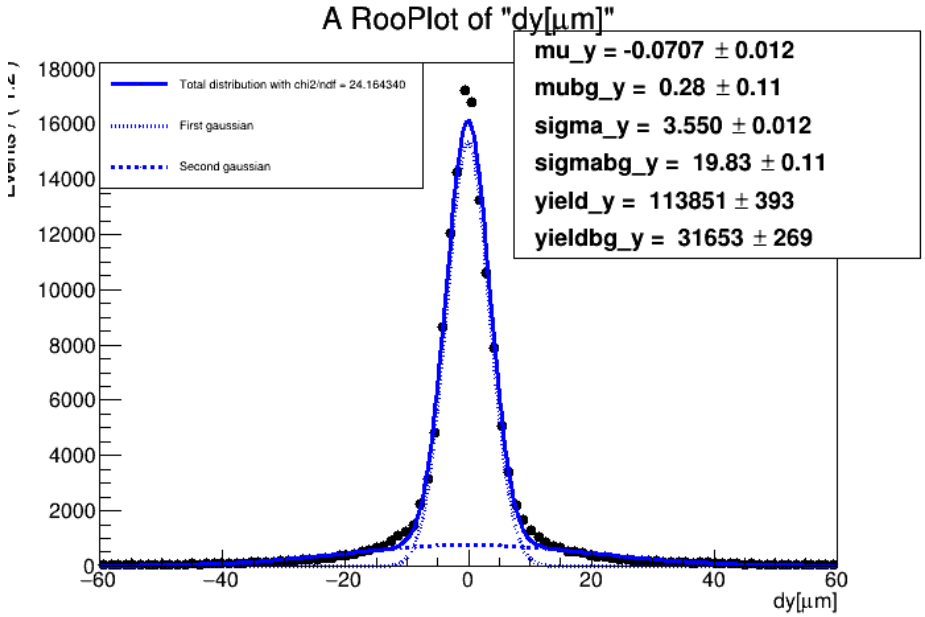
$(1.5 \pm 0.1) \times 10^4$ fb/cm²



Position resolution

Resolution computed as residual between linear fit and positions of segments



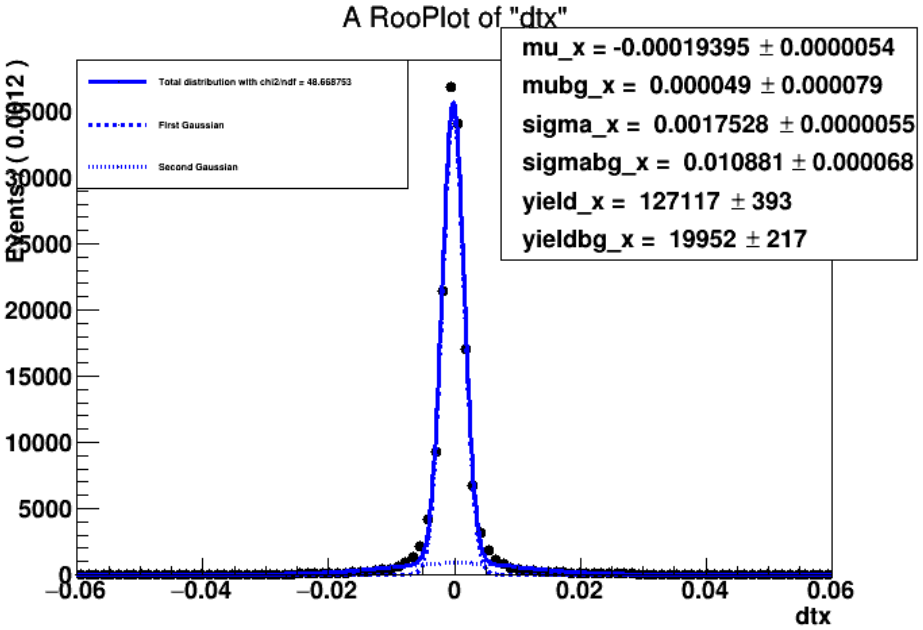


σ_x =3.8 µm

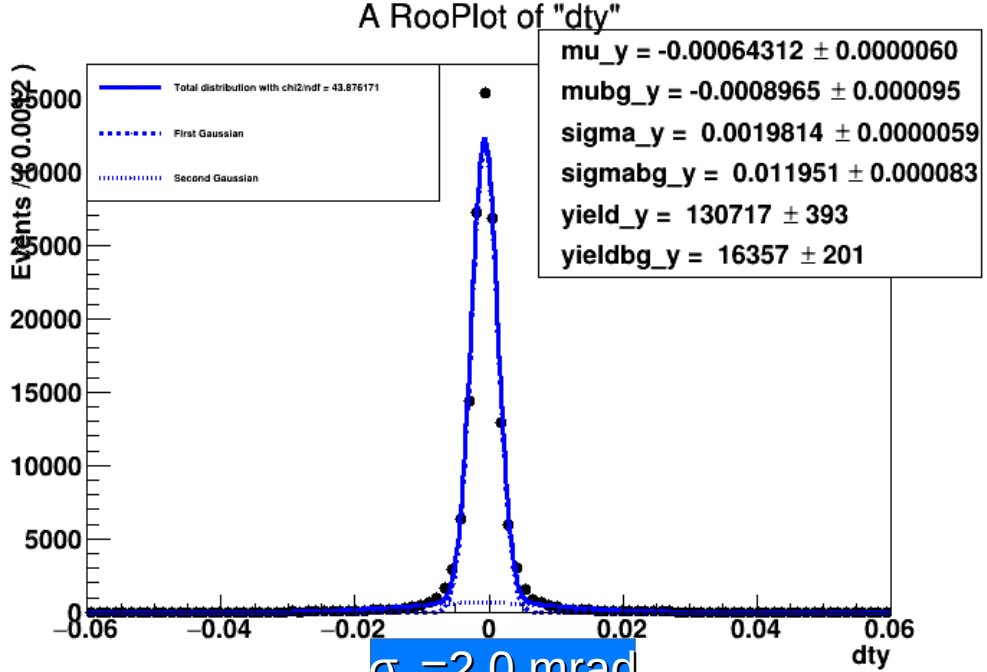
σ_y =3.6 µm

Angular resolution

Resolution computed as residual between linear fit and angles of segments



σ_{tx} =1.8 mrad

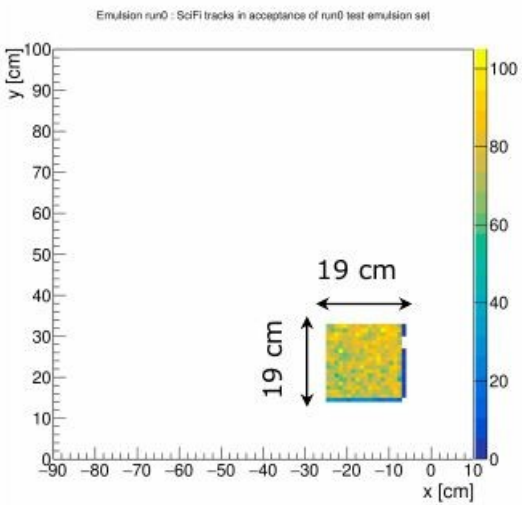


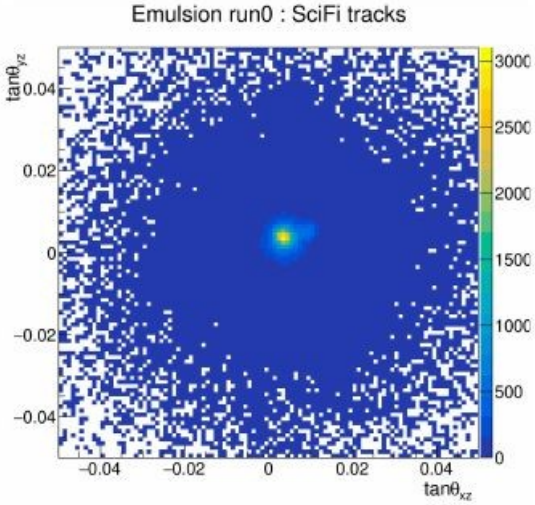
σ_{ty} =2.0 mrad

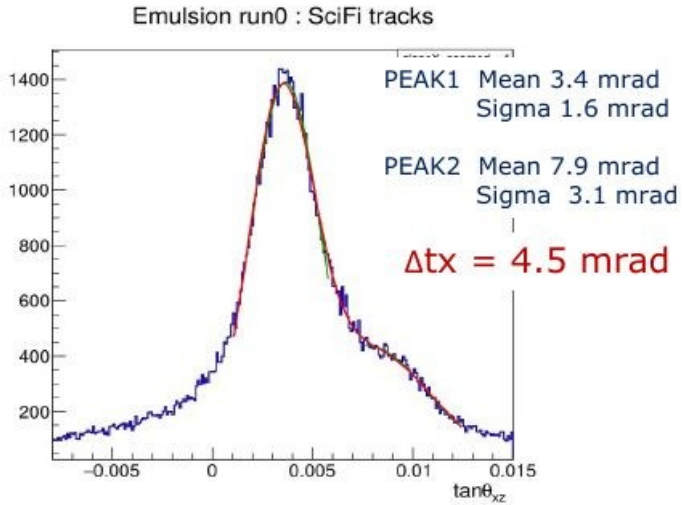
Emulsion and SciFi comparison

SciFi

Measured rates on BRICK1 surface
1.4×10^4 fb/cm^2

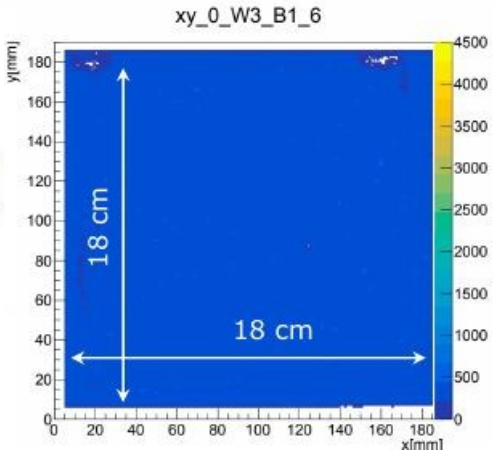


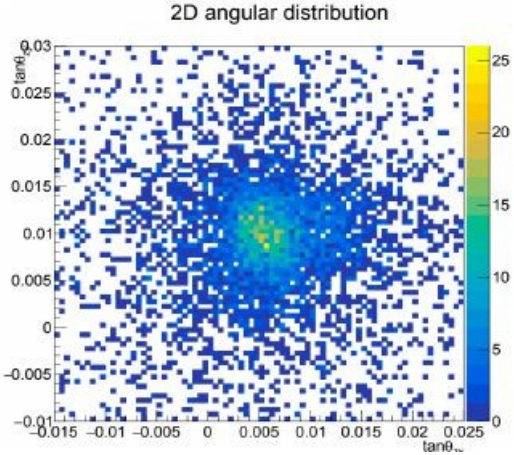


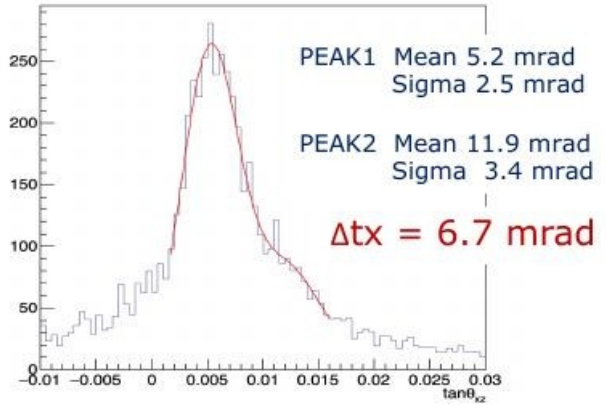


EMULSIONS

Measured rates in BRICK1
1.5×10^4 fb/cm^2







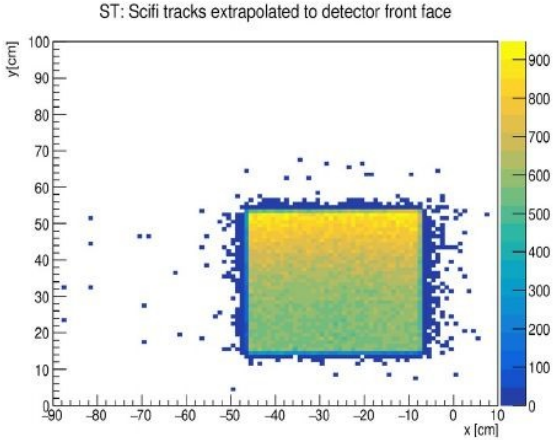
Scanning of Target 1 emulsion films

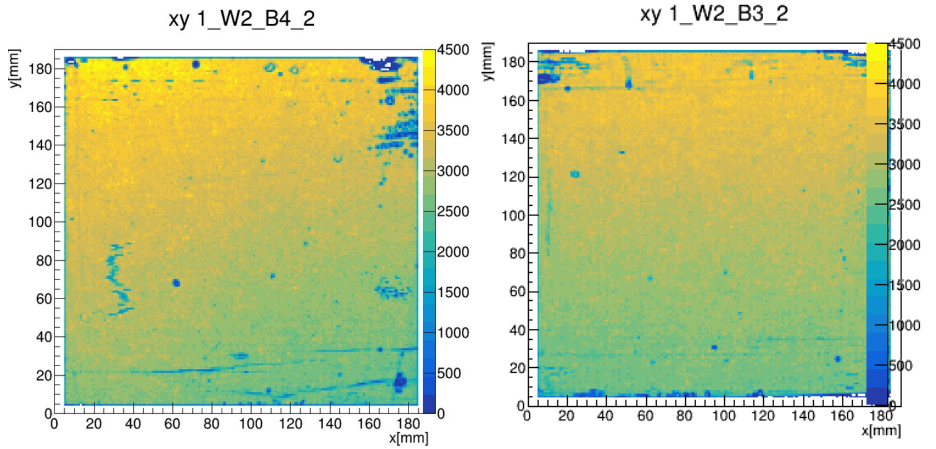
Integrated luminosity: 10.5 fb^{-1}

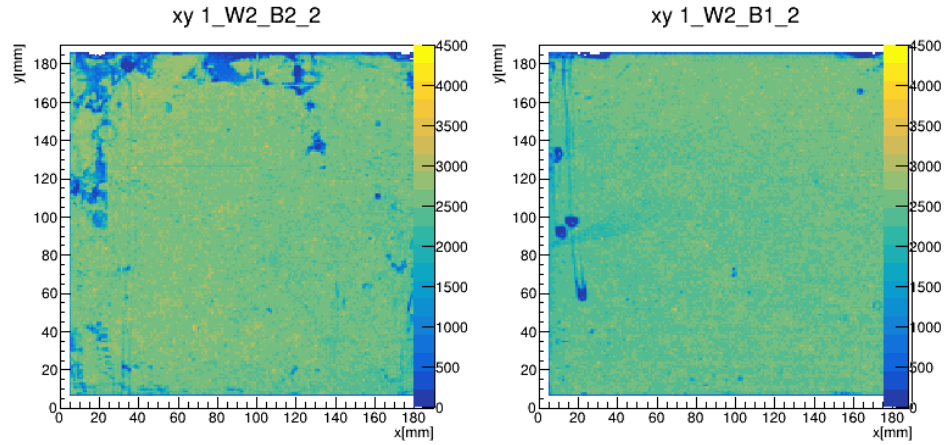
Comparing same film number from different bricks from the same wall

Observed increase of muon rate at larger distance from the beam axis

Confirmed by electronic detectors







Conclusions

- **Measured muon rate from LHC in nuclear emulsion target**
- **Evaluation of tracking resolution in position and angles**
- **Currently scanning and analyzing high luminosity data**
- **Installed a new scanning station at CERN, under operation starting this year**
- **Personally responsible for sharing scanning and analysis procedure among scanning stations**

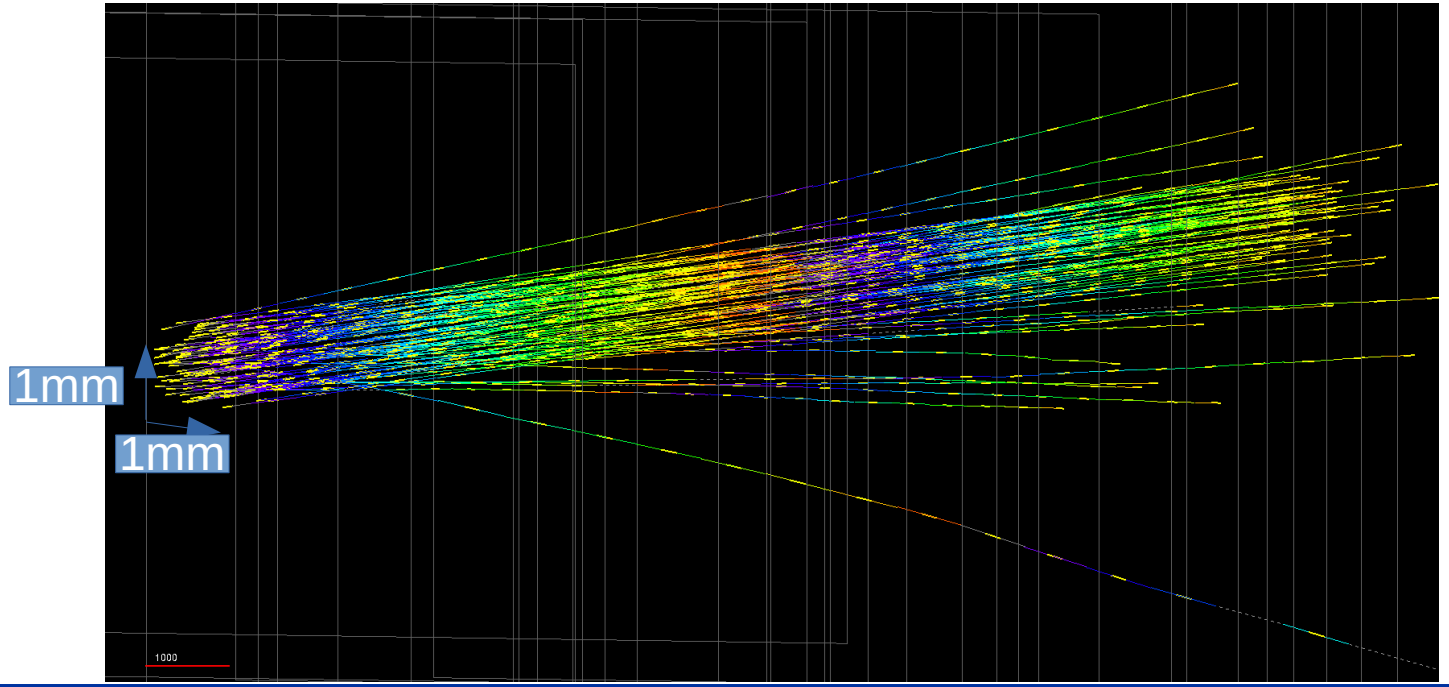
home.cern

Track display with colour by Plate

Tracks starting from 1 mm² area, around center (96 mm, 96 mm)

82 tracks in this region

Colour represents emulsion film plate number

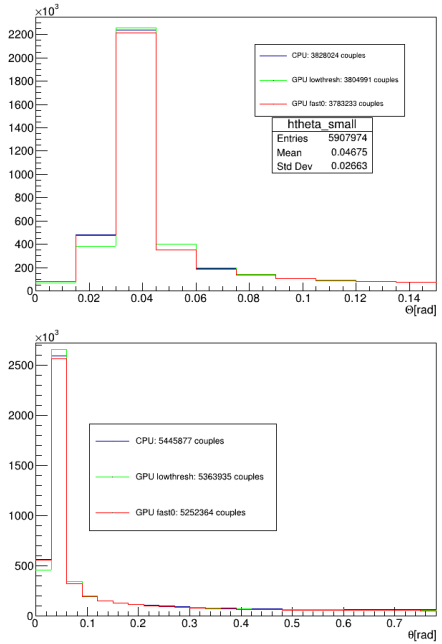


Processing for Target 1

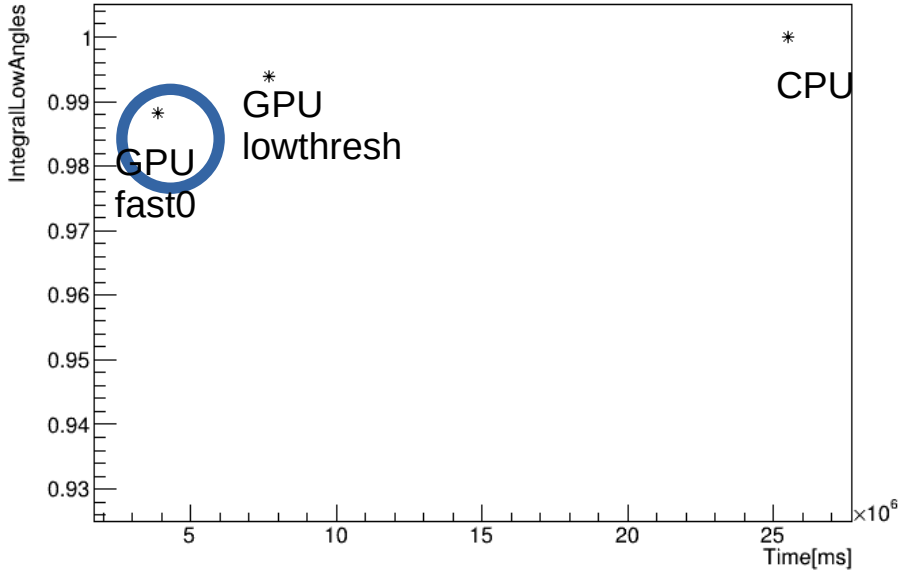
Compared processing parameters in small area offline scans

Optimization according to time and base-track efficiency

Maximum scanning time of 26 hours for Wall2_B4 films



Comparing number of base-tracks within 150 mrad

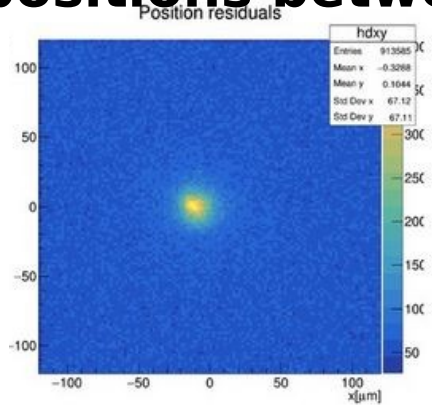


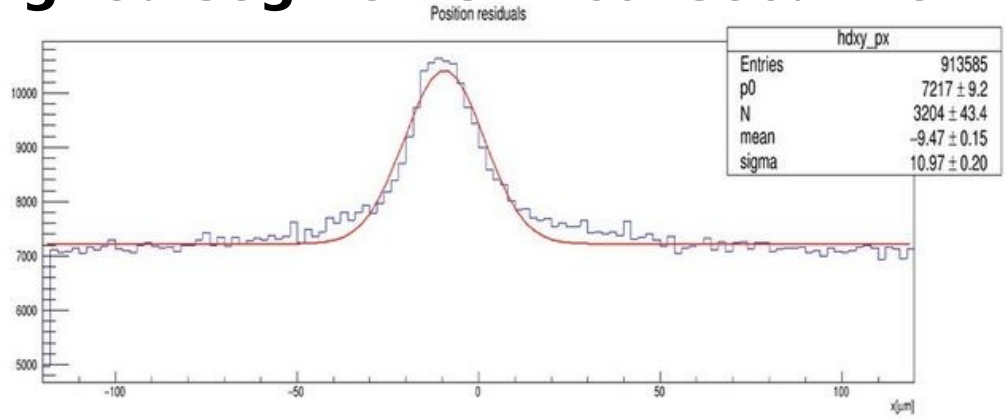
Local alignment tests for Target 1

Compared alignment on the whole surface with a local alignment

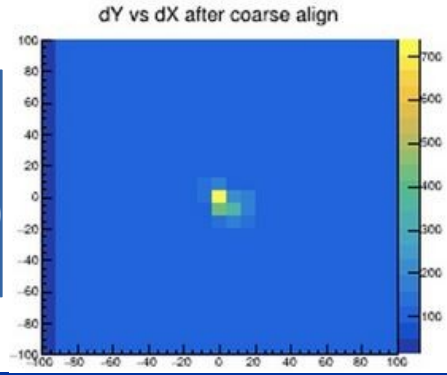
Residuals in positions between aligned segments in consecutive films

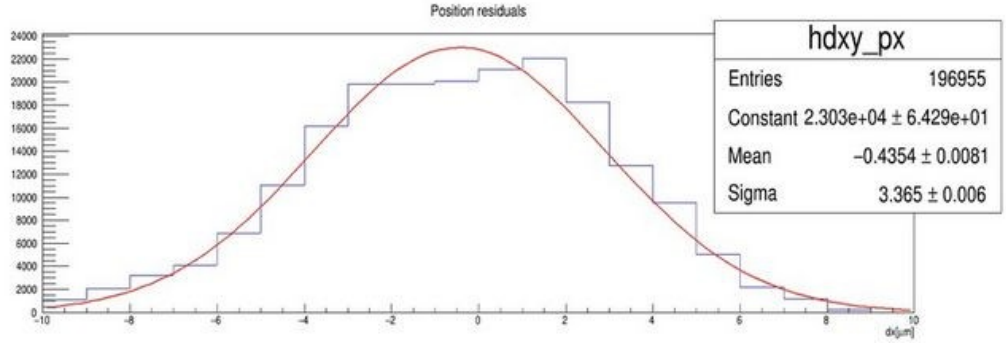
Standard “global” alignment





“Local” alignment (under development)





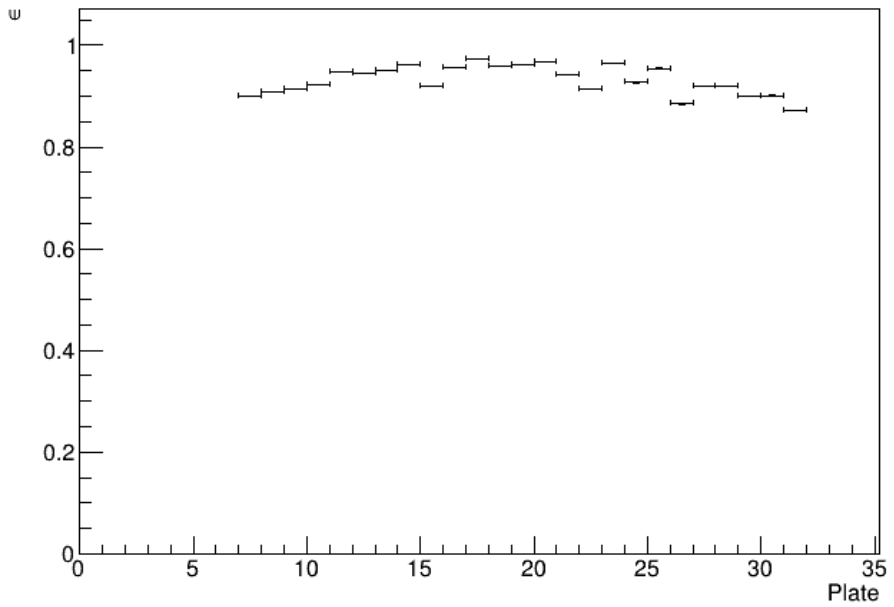
Tracking efficiency

Base-track efficiency computed for each plate as ratio between

- **number of segments associated to a track in this plate**
- **Number of segments expected from long reconstructed tracks passing through this plate**

Average plate efficiency of 93%

Combine multiple films for volume track efficiency, requiring at least 18 segments in 25 films



From base-track efficiency to volume track efficiency

Assuming all films have similar base-track efficiency

Probability of having at least k segments in n films

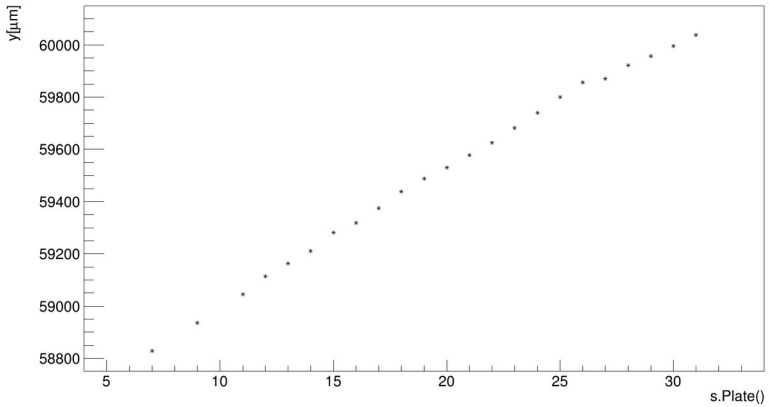
Sum of binomial distributions in k over n

(automatically implemented in ROOT Tmath::BinomialI, or more precise for large n TMath::BetaIncomplete)

$$P = \sum_{j=k}^{n} \binom{n}{j} p^j (1-p)^{(n-j)}$$

From base-track efficiency to volume track efficiency

Example track
(trid 3226, first quarter)



With large variation of film efficiency binomial assumption not accurate anymore

Need to replace single p with array p[nfilms]

Looping over all combinations of k segments in n films, multiplying for p[ifilm] or (1-p) [ifilm] accordingly.

Obtaining probabilities for each combination, then summed to obtain total volume track probability

Example: a combination of 23 plates over 25:

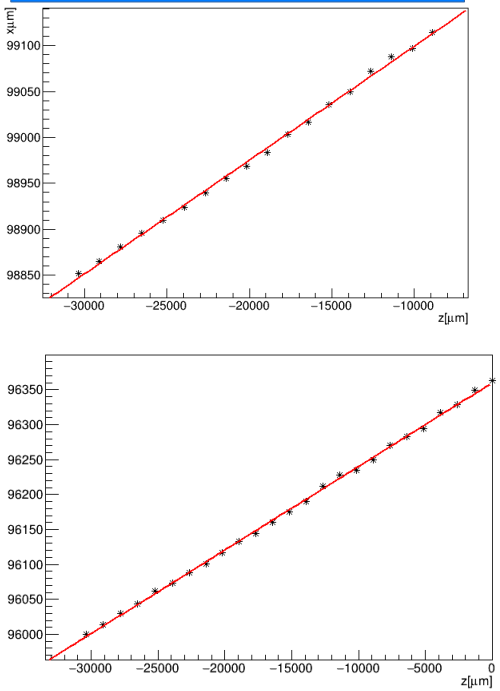
[7 9 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31] prob 0.00144073

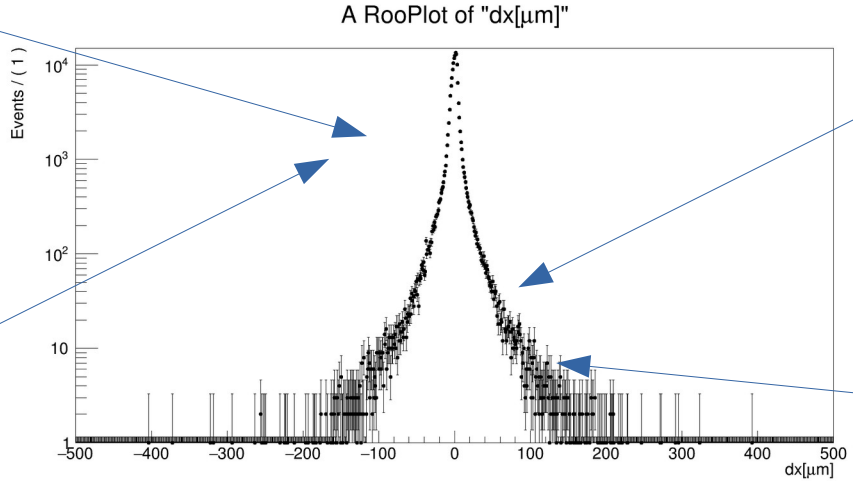
P(7) * (1-P(8))*P(9)*(1-P(10))*P(11)*.....P(31)

Measurement of tracking resolution

Comparing position and angles of tracked segments in the single films, with a linear fit

Example of good fits





Example of bad fits