

Digital Archives for Nuclear Emulsion Data

- past experiments in cosmic-ray and accelerator physics -

- HTS runs at $\sim 0.5\text{m}^2/\text{h}$ read-out speed.
- **All tracks in past experiments' emulsion can be read-out.**
for minimum bias re-analysis.
Share those emulsion data for educational use etc. → **Digital Archives**
- Emulsion plates read-out by HTS so far are ...
 - All two blocks of RUNJOB 1997 flight
 - Part of top 9 plates of JACEE-13 (Antarctic circumpolar flight in 1994)
 - **1 module of DONUT (neutrino experiment)**

This presentation

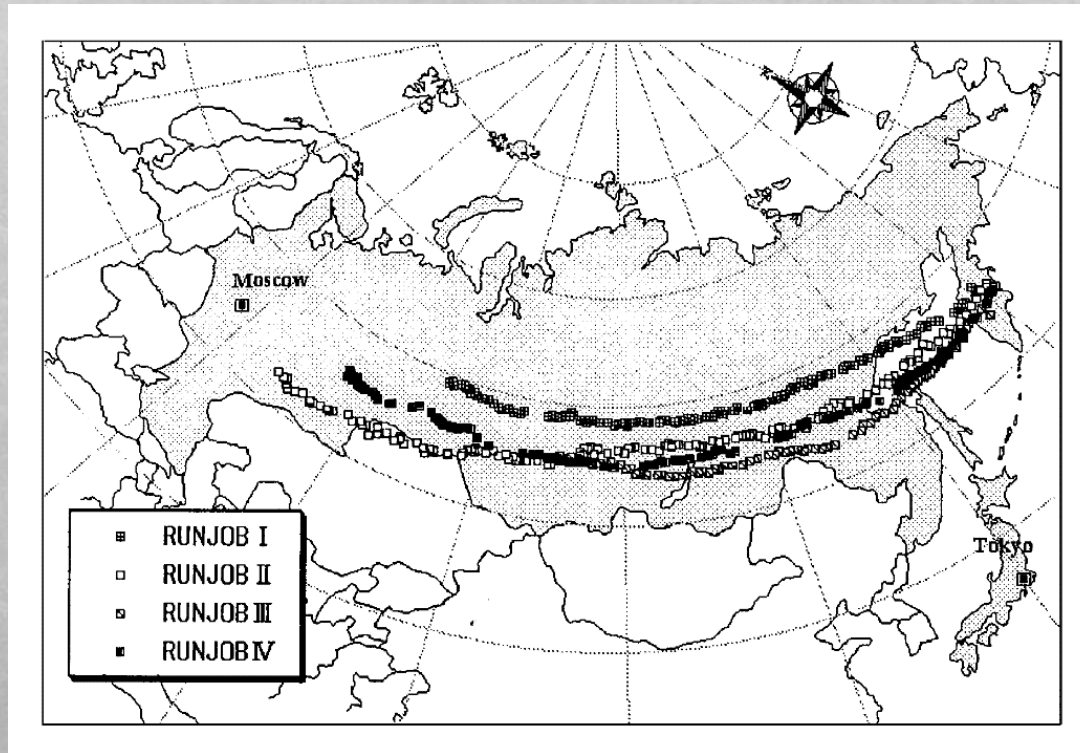
K. Kodama : Aichi Univ. of Education
M. Ichimura : Hirosaki Univ.
M. Nakamura : Nagoya Univ.

NETSCAN data obtained so far

- RUNJOB
 - Two blocks of 1997 flight (16.4 m²) were read-out.
 - Total 10 flight campaigns (20 blocks) had been done.
 - Slips among emulsion plates were observed.
- JACEE-13 (Antarctic flight)
 - 1/4 of upper 9 plates (0.45 m²) were read-out.
 - No slip observed.
- DONUT
 - Module #1 (11.5 m², largest ν Interactions expected) were read-out.
 - Total 7 modules were exposed to neutrino beam at Fermilab.

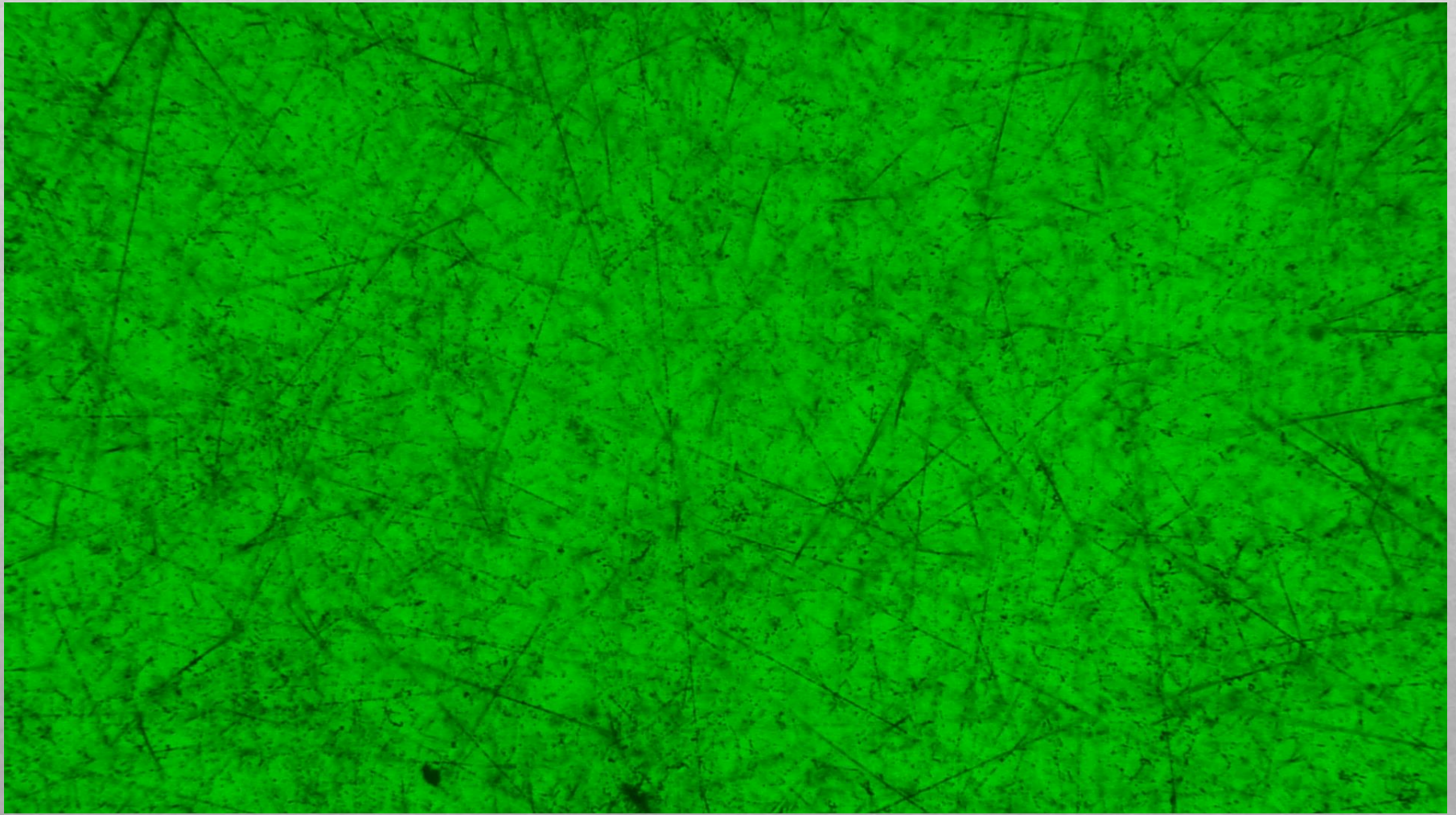
RUNJOB

RUssia-Nippon JOint Balloon-program



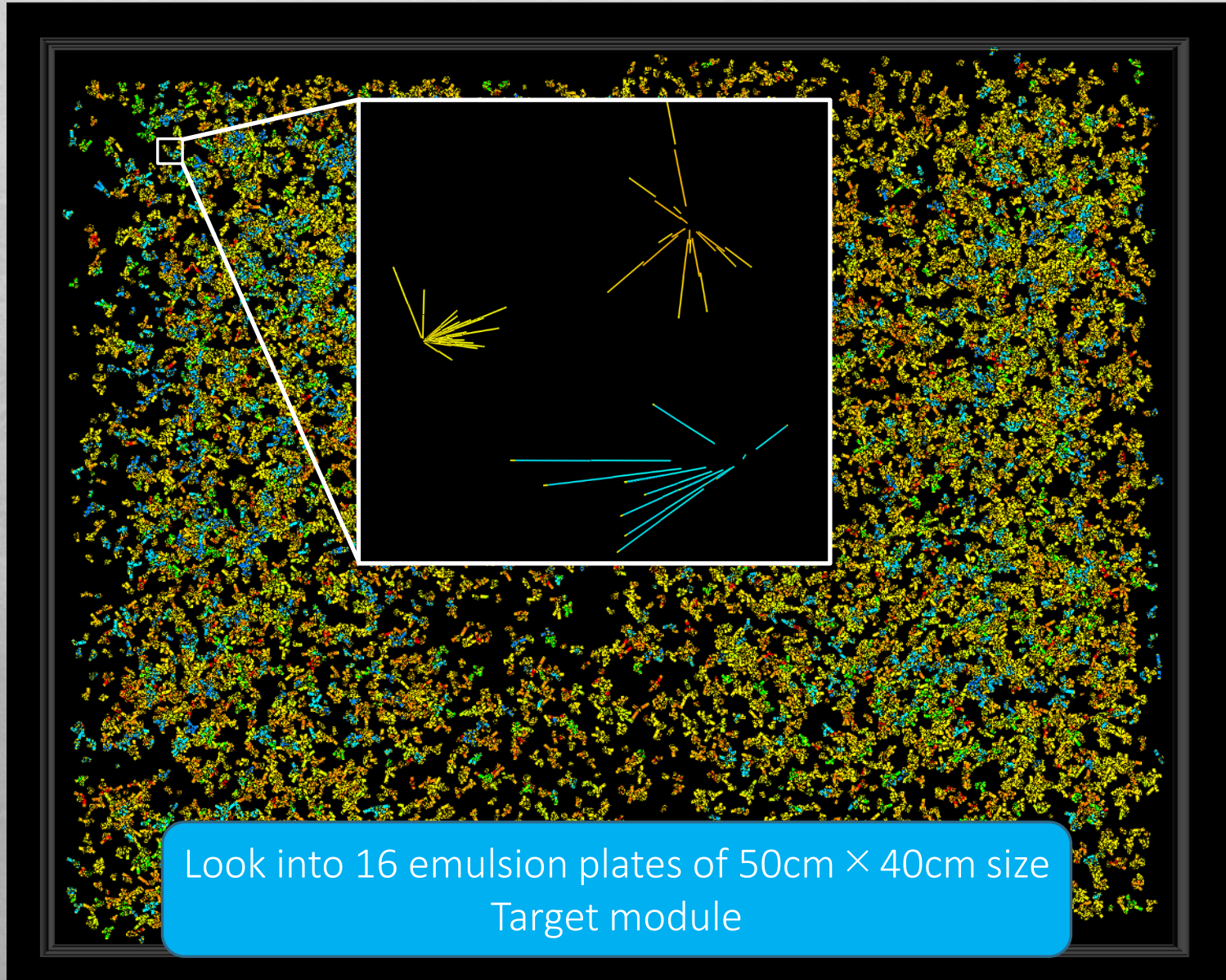
- 10 successful flights (1995~1997,1999)
 - Each flight was ~140 hours at mean altitude of $\sim 10\text{g/cm}^2$ (30~35km)
- HTS scanning done for 2 blocks of 1997 flight.

Microscope view of a RUNJOB emulsion plate



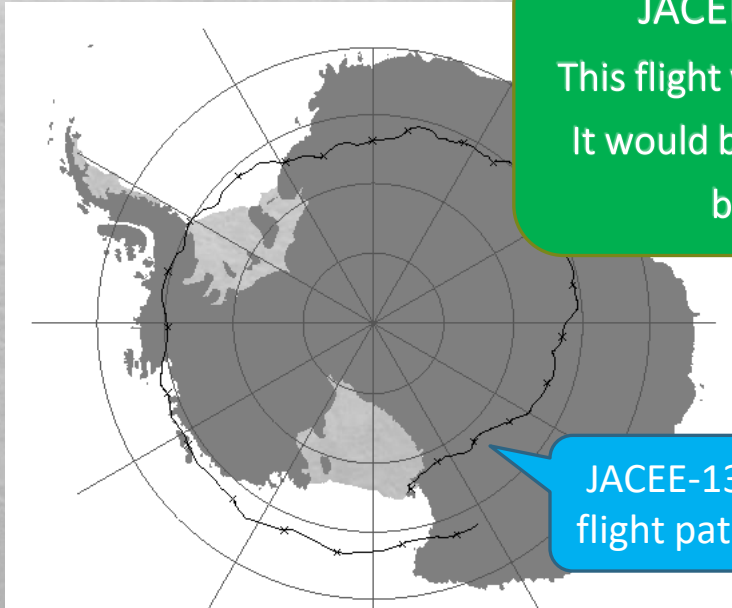
← ~0.7mm →

Selected vertices/interactions in RUNJOB target module



JACEE

Japanese-American Cooperative Emulsion Experiment



JACEE-13
flight path

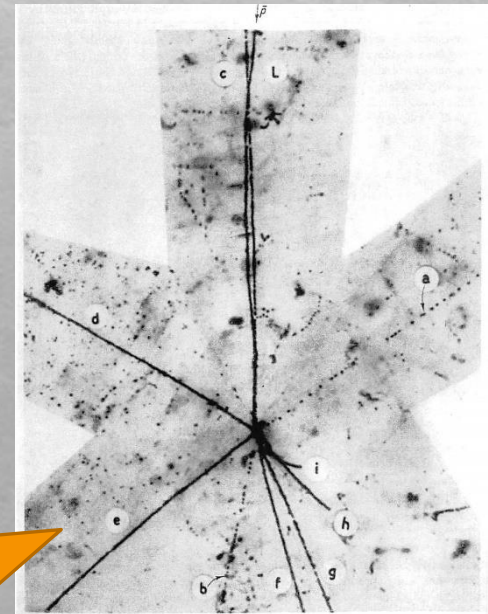
JACEE-13(1994) is Antarctic circumpolar flight
This flight was intended to study high energy cosmic ray flux.
It would be interesting to observe low energy anti-protons,
because of low rigidity cut off of this flight.

<https://stratocat.com.ar/fichas-e/1994/MCM-19941221.htm>

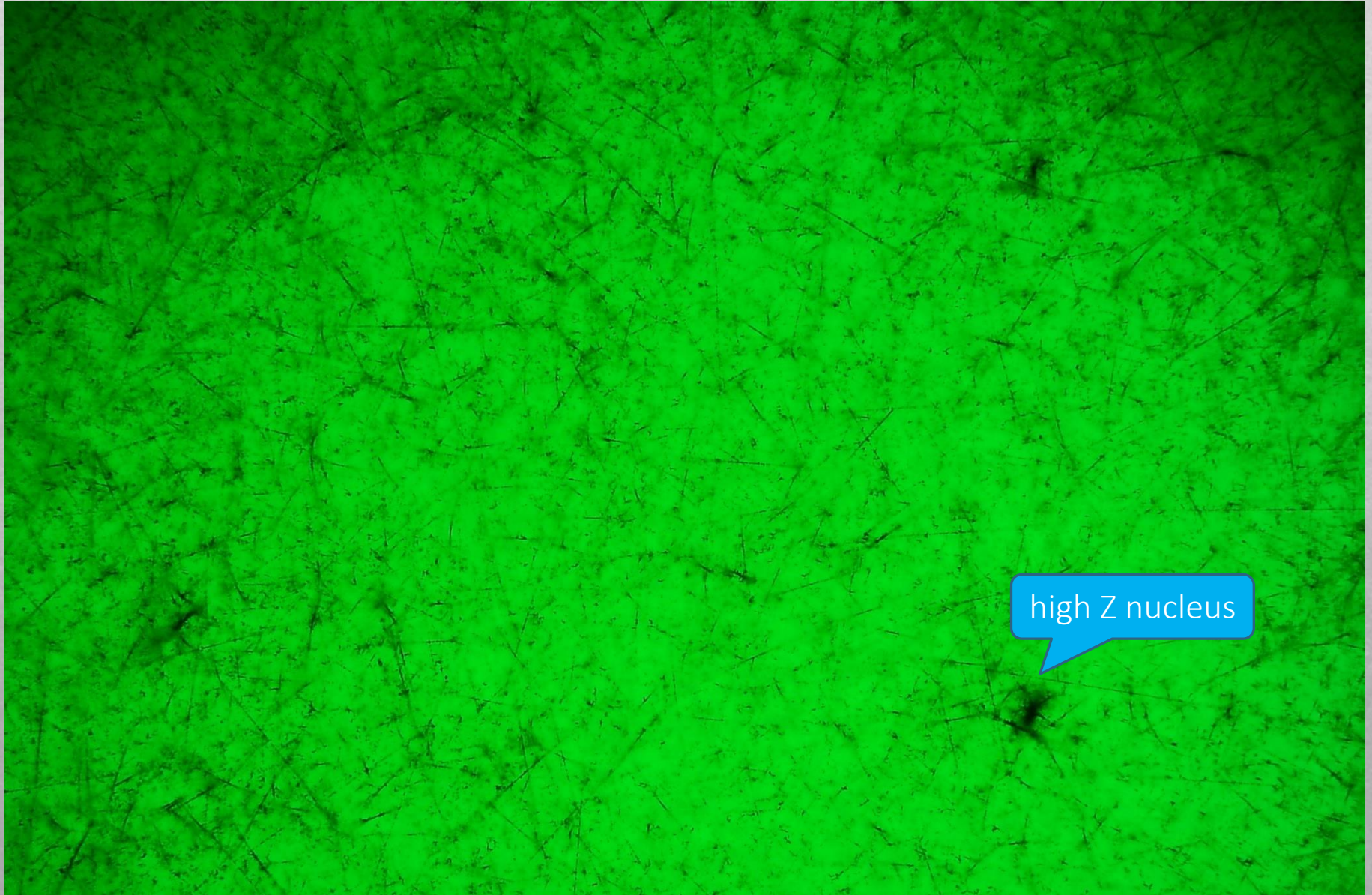
Anihilation of an anti-proton in emulsion

The Study of Elementary Particles by the Photographic Method

Powell, Fowler and Perkins



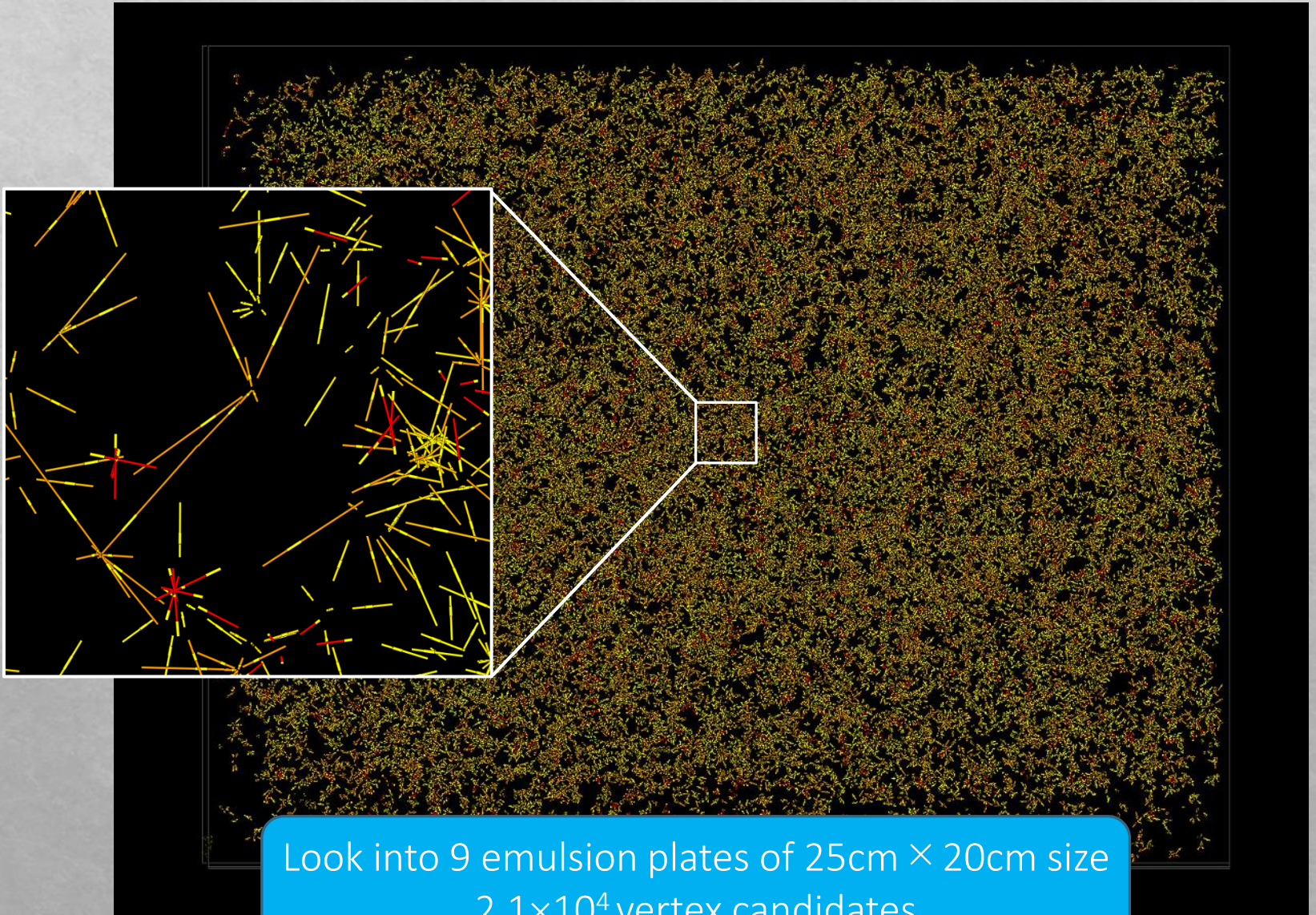
Microscope view of a JACEE-13 emulsion plate



high Z nucleus

← ~0.76mm →

Selected vertices in JACEE-13 data



Look into 9 emulsion plates of $25\text{cm} \times 20\text{cm}$ size
 2.1×10^4 vertex candidates

200 micron

tau decay vertex

NETSCAN method succeeded to identify tau neutrino charged current interactions.

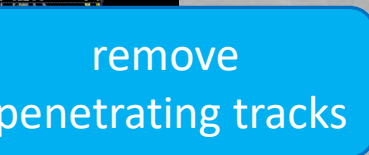
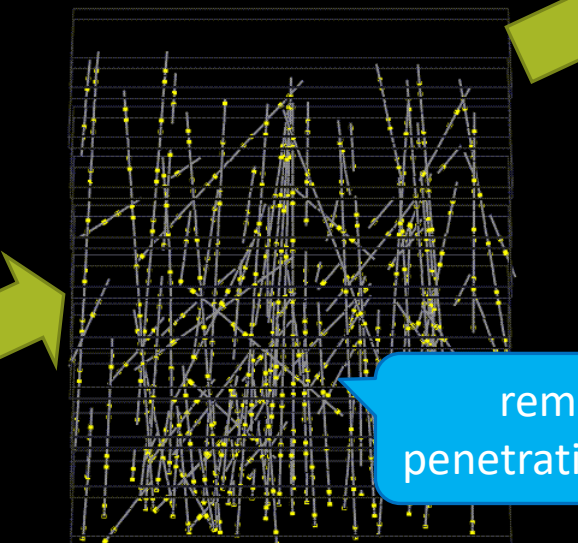
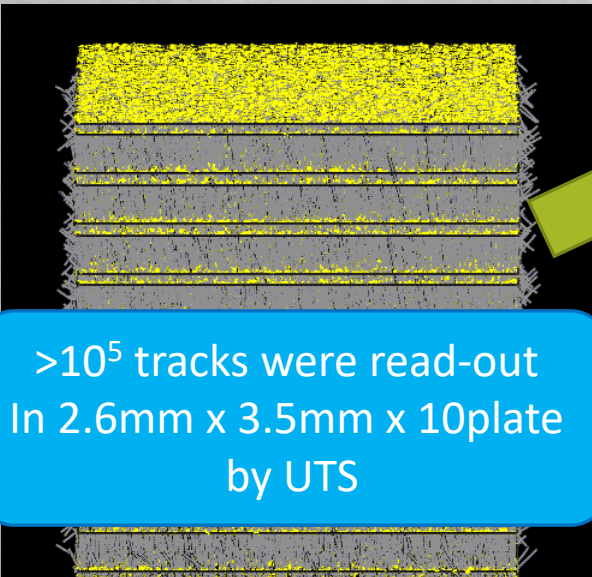
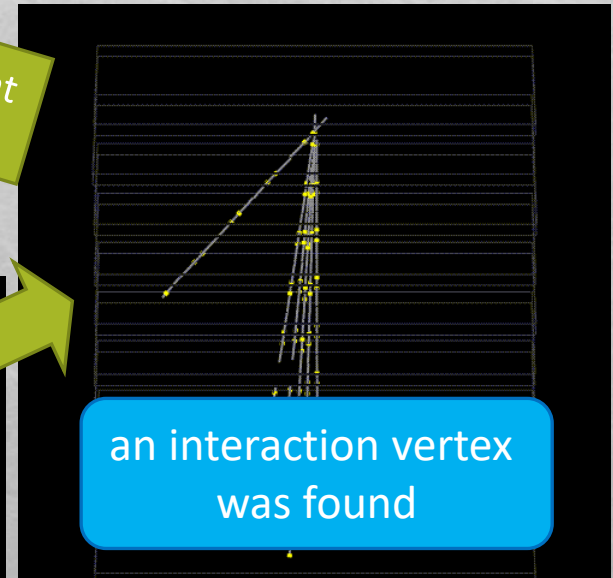
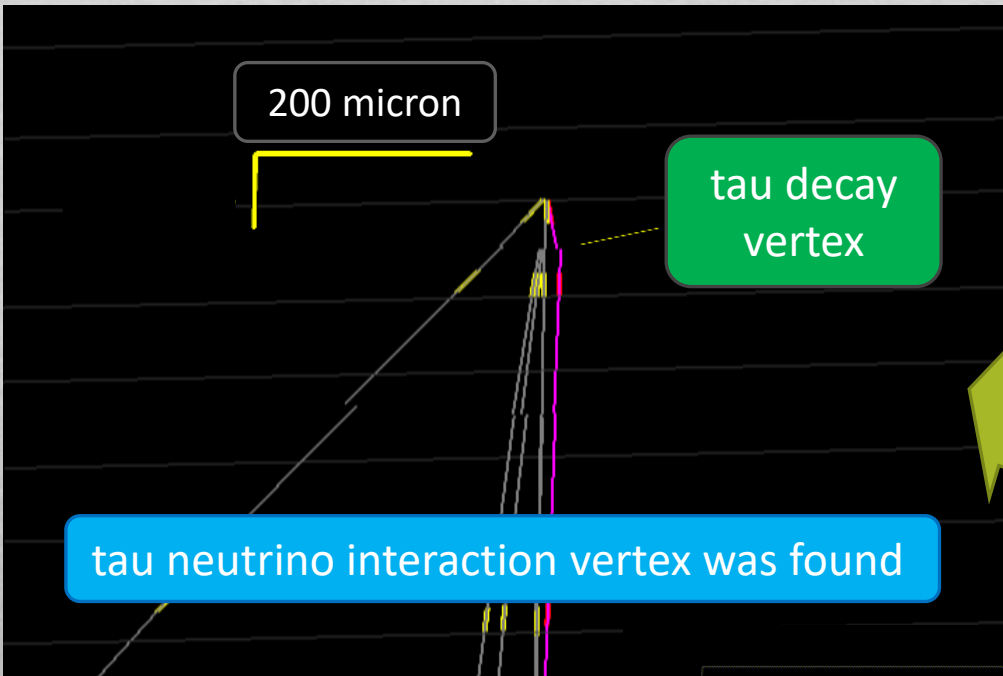
tau neutrino interaction vertex was found

close look at the vertex

an interaction vertex was found

remove penetrating tracks

$>10^5$ tracks were read-out
In 2.6mm x 3.5mm x 10plate
by UTS



Summary of ν beam exposures in DONUT

3.54×10^{17} protons of 800GeV/c were used to create neutrino beam and exposed to emulsion targets

Table 1
Information about the exposed emulsion modules

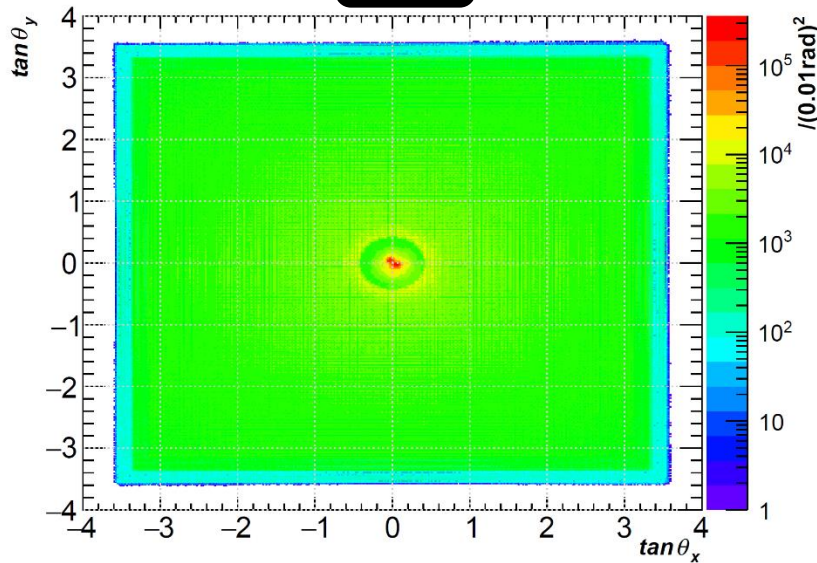
Module	Composition	Mass (kg)	$n_{\text{POT}} \times 10^{16}$	Expected ν events
mod 1	ECC200 \times 47	104	20.1	236
mod 2	ECC800 \times 19 + Bulk \times 38	70	25.8	203
mod 3	ECC200 \times 47	104	9.8	115
mod 4	ECC200 \times 2 + ECC800 \times 7 + Bulk \times 47	70	14.7	115
mod 5	ECC800 \times 21 + Bulk \times 30	71	15.5	124
mod 7	ECC800 \times 20 + Bulk \times 32	70	25.8	203
mod 8	Bulk \times 87	60	15.5	105
Total				1100

Here n_{POT} is the number of 800 GeV protons on target.

Module #1 were read-out.
No swelling (i.e. expand emulsion layer)
not to damage emulsion plates

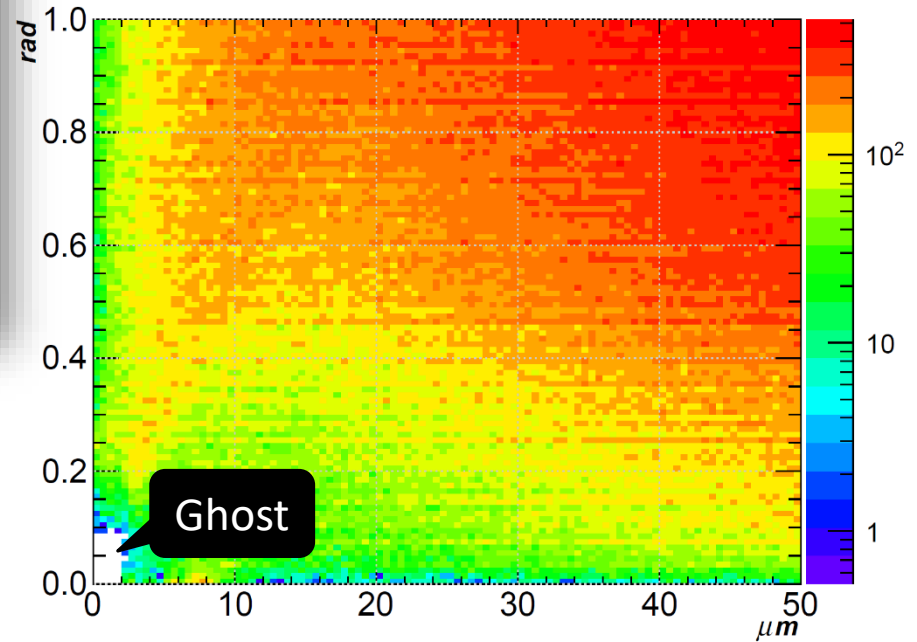
MicroTrack Read-out

$\tan\vartheta$



MicroTrack density = $1.6 \times 10^6/\text{cm}^2$

Position and angle difference
of any two MicroTracks



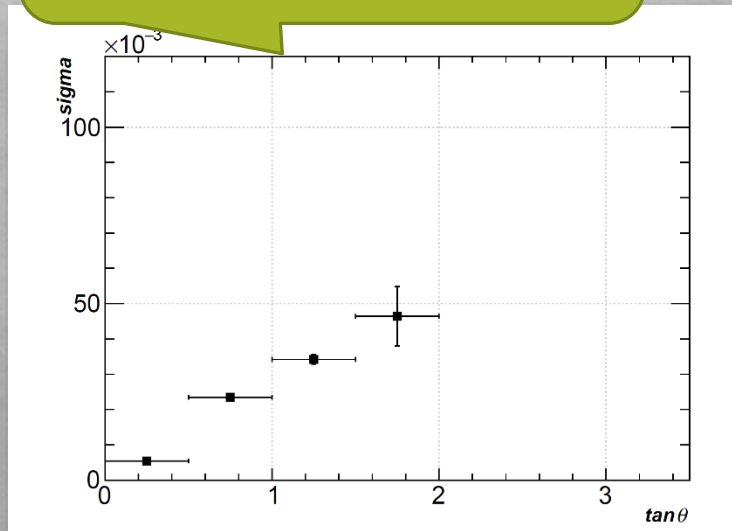
MicroTrack, DONUT mod-01 pl048 face=1 ph \geq 7 (test scan)

BaseTrack production

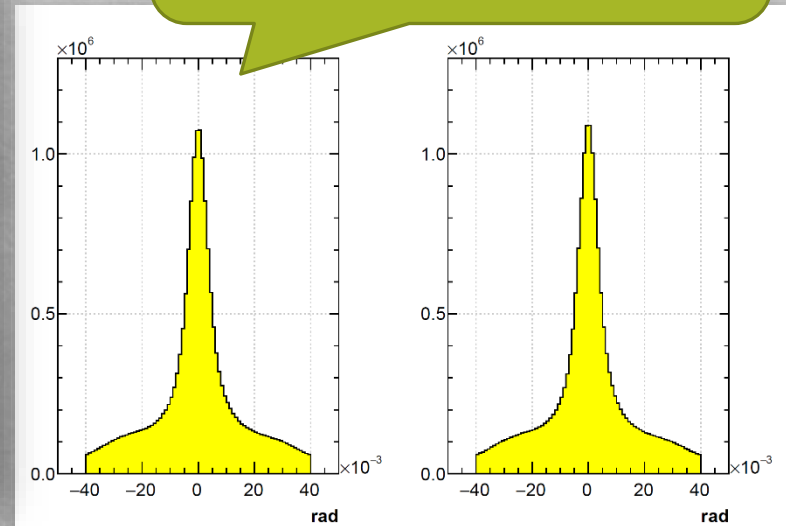
BaseTrack condition

$$\Delta\theta \leq 0.06 + 0.01 \times \theta_{base} \text{ where } \Delta\theta = \text{abs}(\theta_{micro} - \theta_{base})$$

MicroTrack angle resolution evaluated with BaseTracks. BaseTrack angle dependent

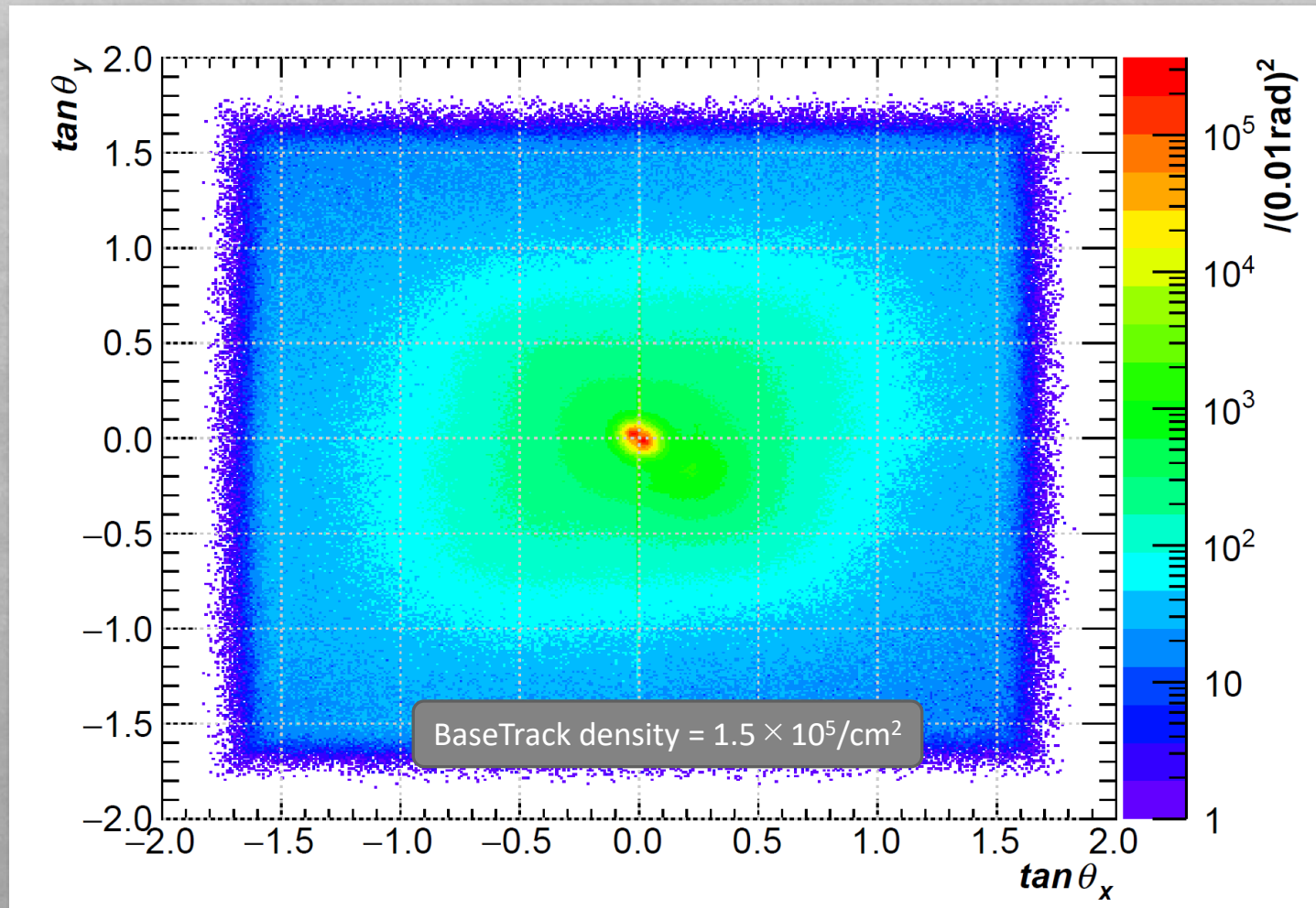


Tight cut ($\Delta\theta \leq 0.04$) in lateral angle difference to increase BaseTrack purity.



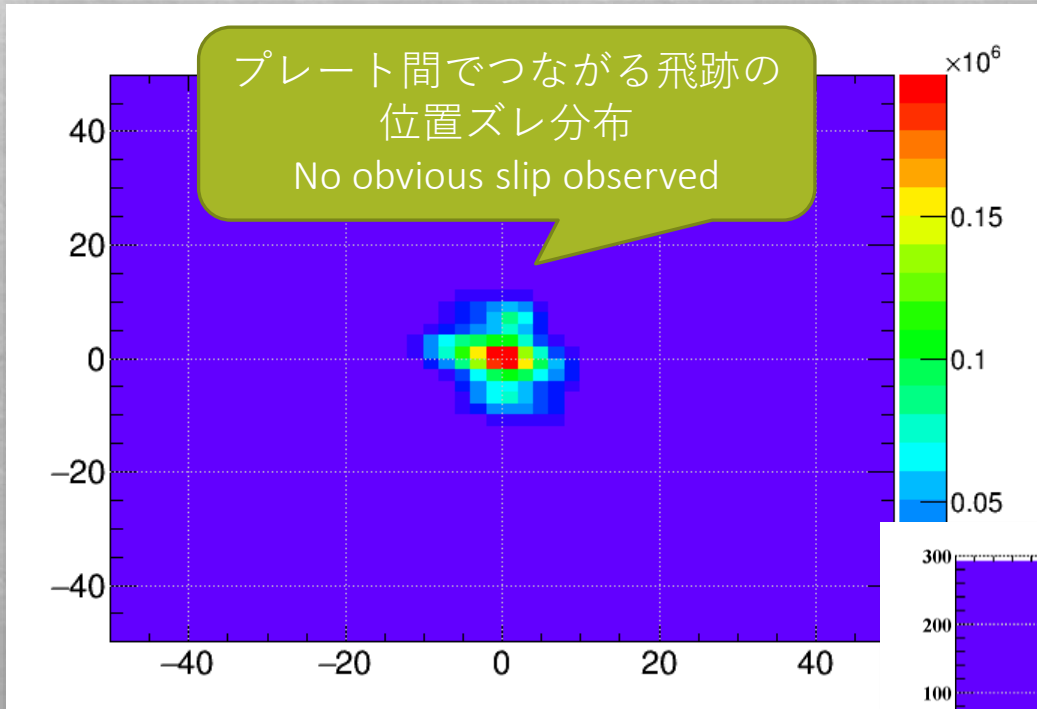
BaseTrack, DONUT mod-01 p1048 ph \geq 7 (test scan)

BaseTrack angle distribution

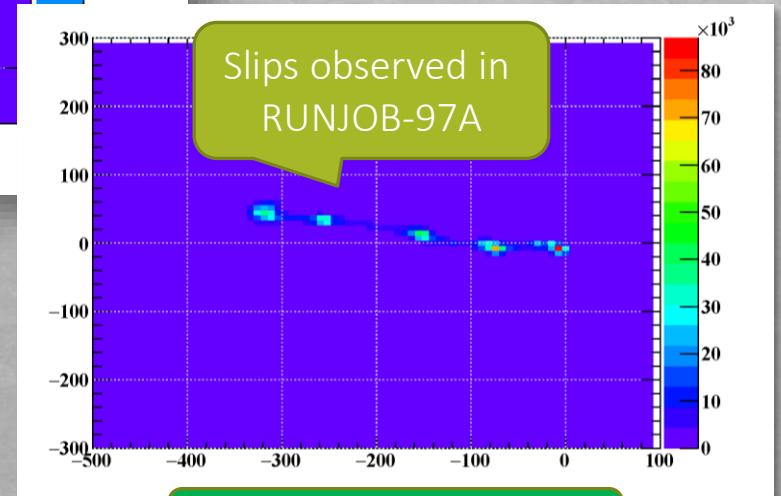


BaseTrack, DONUT mod-01 pl048 ph \geq 7 (test scan)

Position alignment between plates

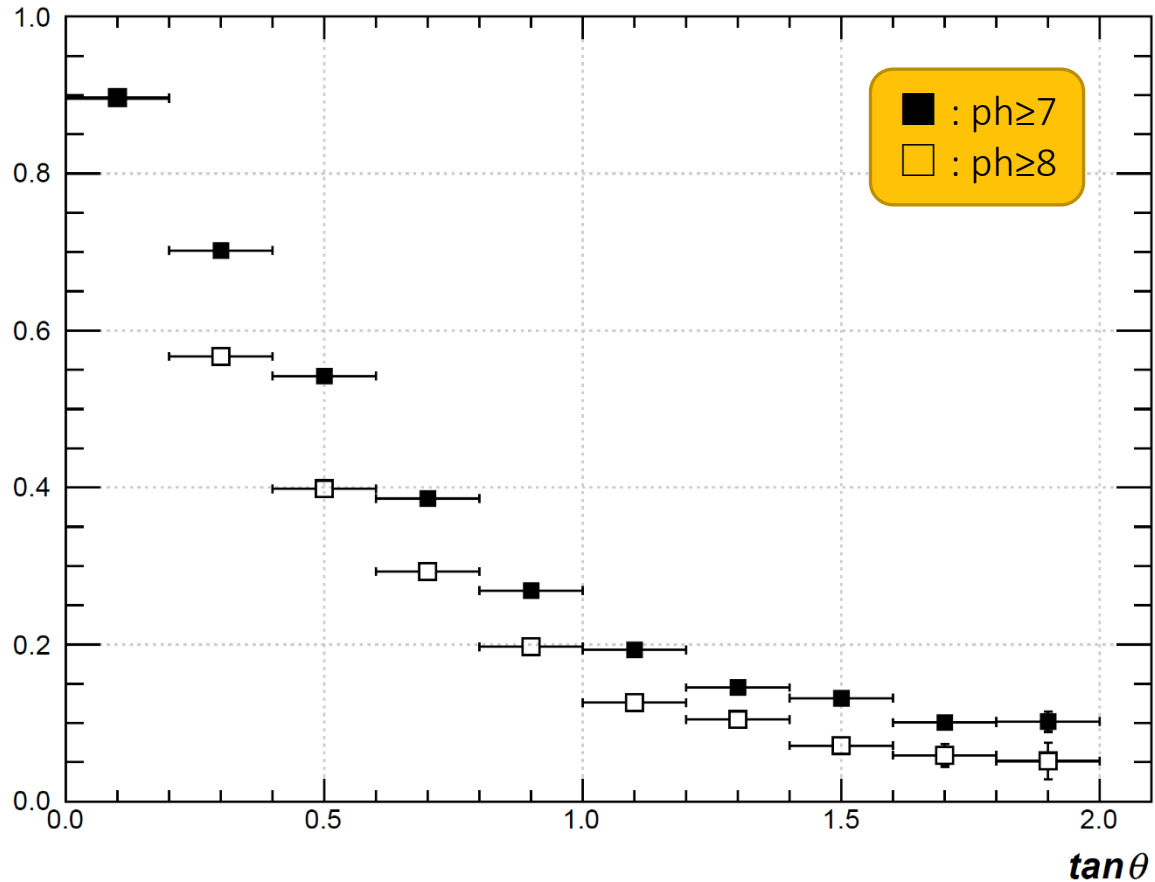


DONUT mod-01 pl46-pl47 ph \geq 7
(test scan)



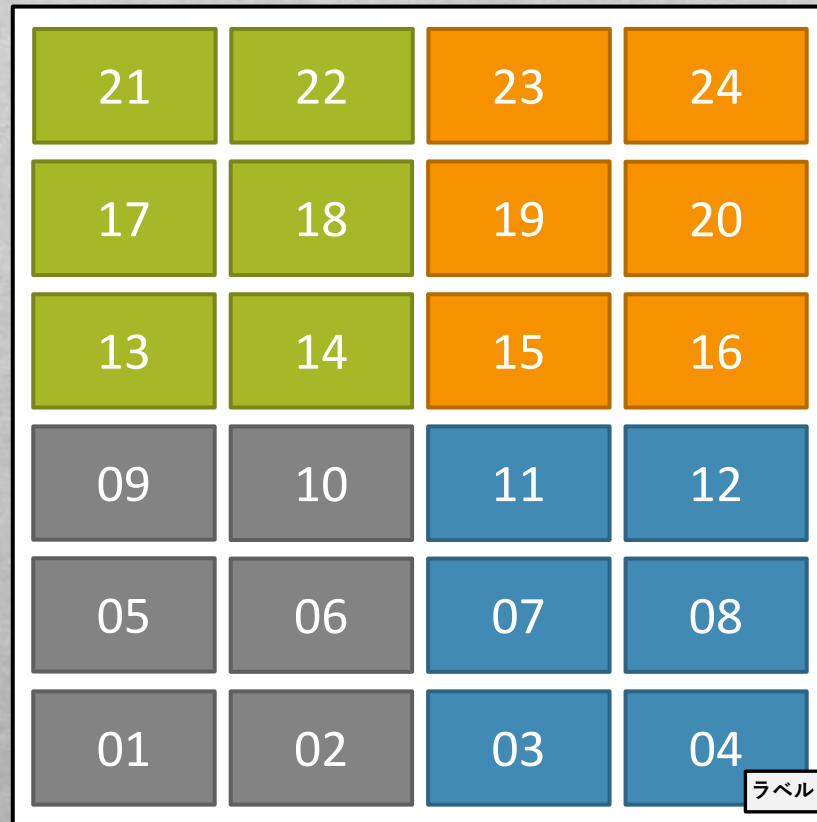
RUNJOB-97A pl02-pl03

BaseTrack recognition efficiency



DONUT mod-01 pl47 (test scan)

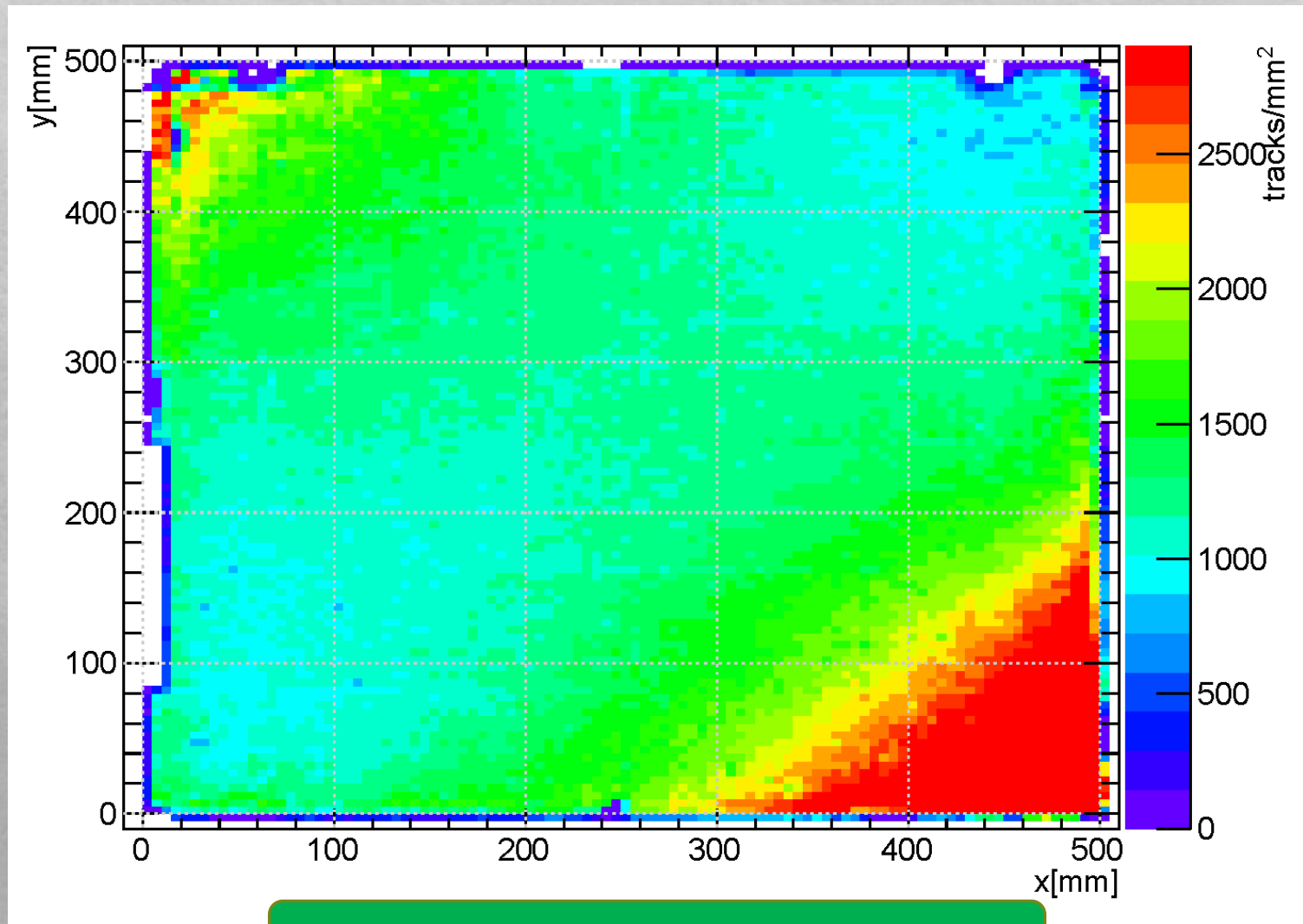
24 HTS scan data were joined to read-out one plate



DONUT plate
500mm x 500mm

24 HTS scan areas were needed to read-out one emulsion plate.
~5mm overlap between scan areas

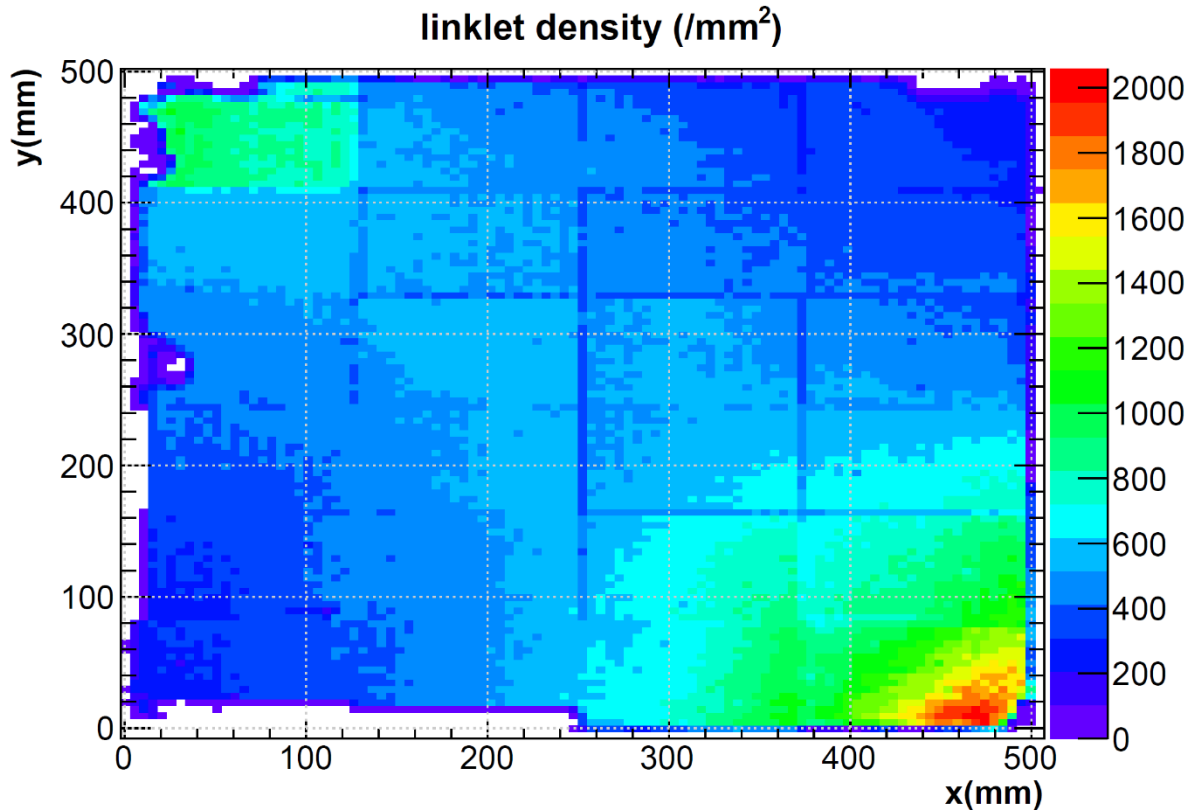
BaseTrack position distribution of one emulsion plate (50cm x 50cm in DONUT)



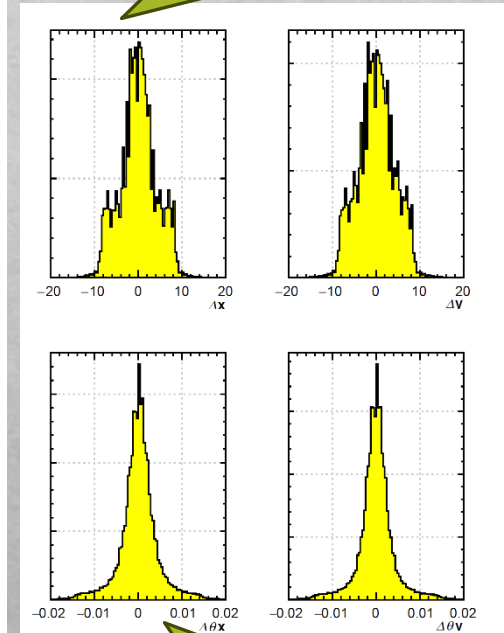
BaseTrack, DONUT mod-01 pl045 $ph \geq 7$

Linklet

- a pair of BaseTracks connected on two plates -



Position difference

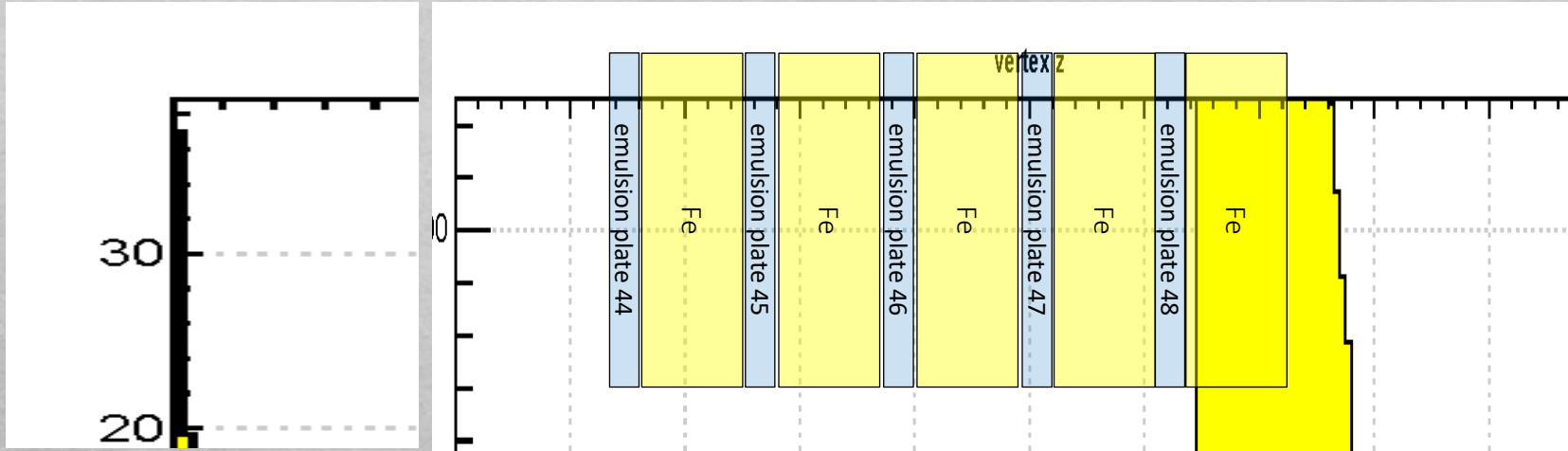


Angle difference

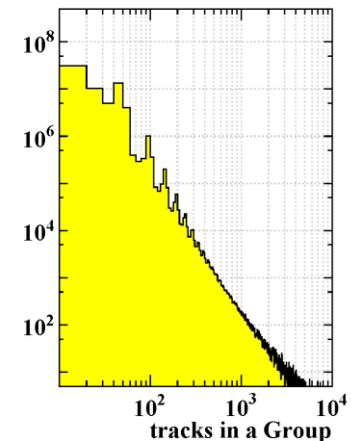
Linklet between pl045 and pl046

Track reconstruction and vertex search

group \Rightarrow chain \Rightarrow m-file \Rightarrow vertex

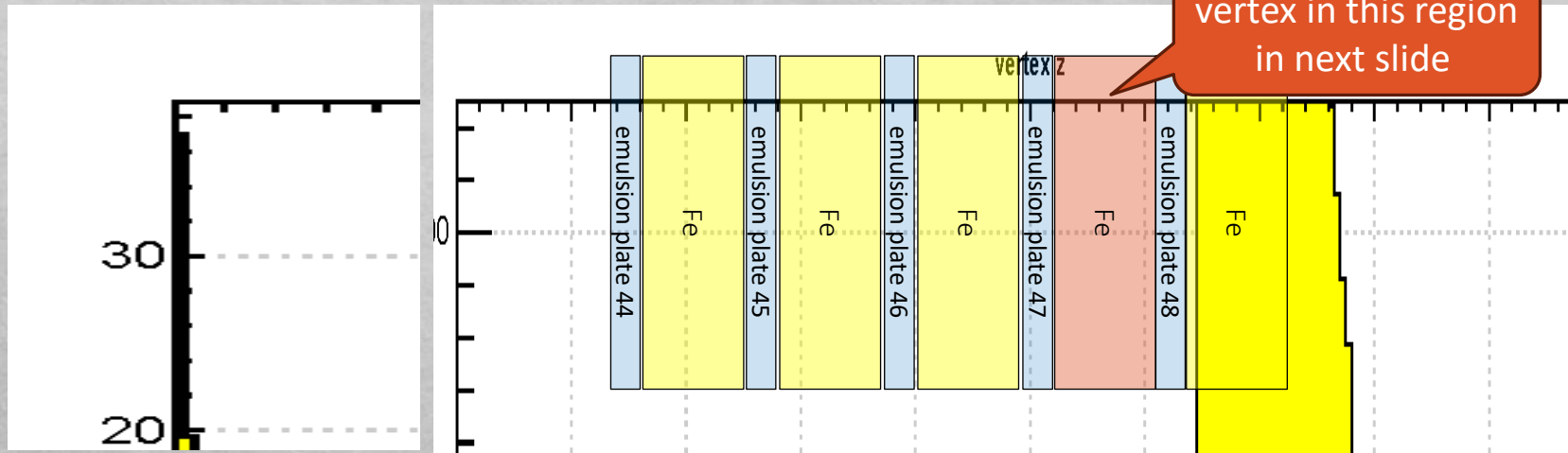


1. BaseTrack : $1.5 \times 10^3 / \text{mm}^2$, 3.6×10^8 tracks/plate
2. Linklet : $0.5 \times 10^3 / \text{mm}^2$, 1.3×10^8 linklets/plate-pair (1x)
3. Group : total 0.45×10^6 Groups, 14.8 tracks/Group
4. Chain : 13.2 chains/group, total 6.0×10^9 Chains
 - make Chains for Groups with $< 1 \times 10^6$ tracks
5. M-file of largest chains in each Group only.
 - Reject passed-through (tusukinuke) tracks.
 - definition : $dxy = 100 \mu\text{m}$, $dz = 1 \text{plate}$
6. Pickup vertex candidates.
 - ttv : same-plate, $dr < 3 \mu\text{m}$, $dt > 20 \text{mrad}$, $0 < dz < 2.3 \text{mm}$
 - vtx : bin-volume = $20 \times 20 \times 100 \mu\text{m}$, #-of-ttv > 10

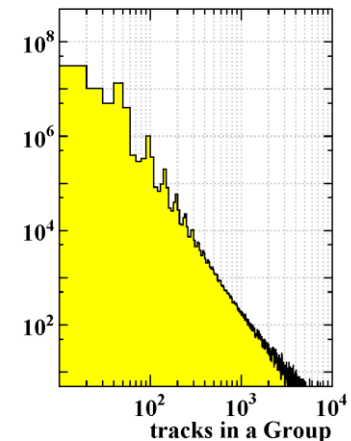


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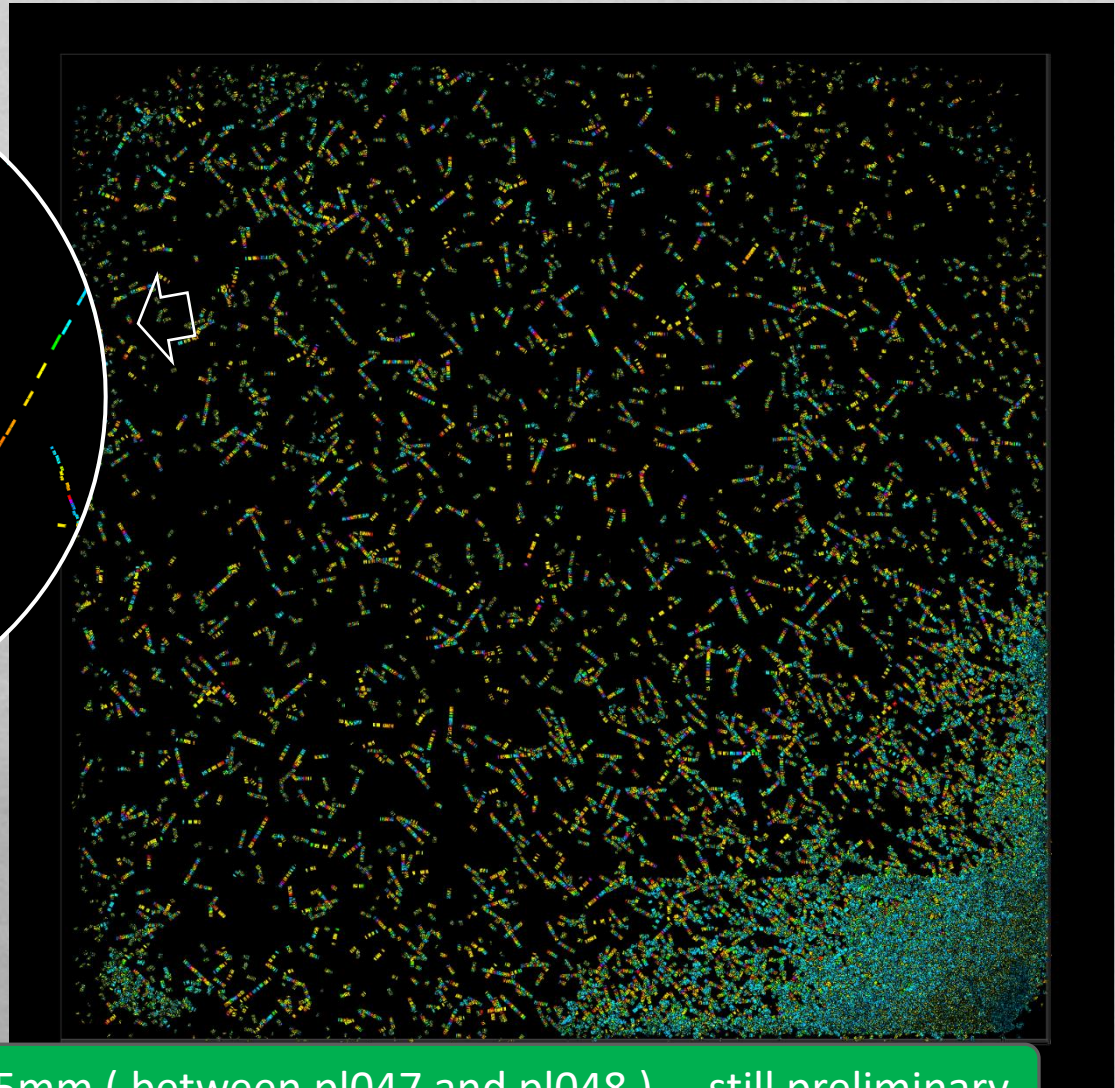
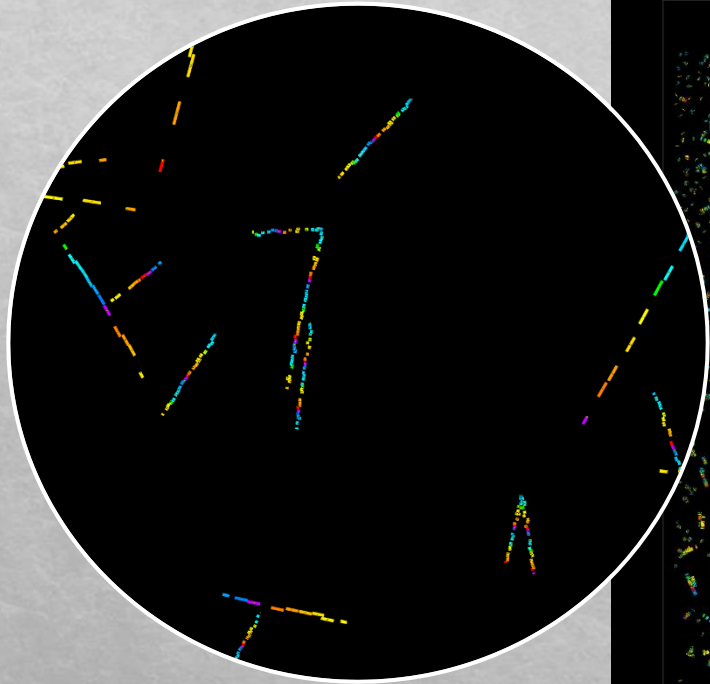
group \Rightarrow chain \Rightarrow m-file \Rightarrow vertex



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Selected vertex candidates



62.1mm < v_z < 63.5mm (between p1047 and p1048) ... still preliminary

Summary

- Full surface read-out of all emulsions in past experiments is being possible.
- It will be valuable to read out emulsions in past experiments and make them public in some way, such as a **Digital Archives** of emulsion data.
 - Minimum bias re-analysis for **physics purpose**.
 - Real data for **educational use**.
- Data obtained so far ...
 - All two blocks of RUNJOB 1997 flight (16.4 m²)
 - Part of JACEE-13 flight (0.45 m²)
 - 1 module of DONUT (11.5 m²)