# NUCLEAR EMULSIONS: STATUS OF THE ANALYSIS

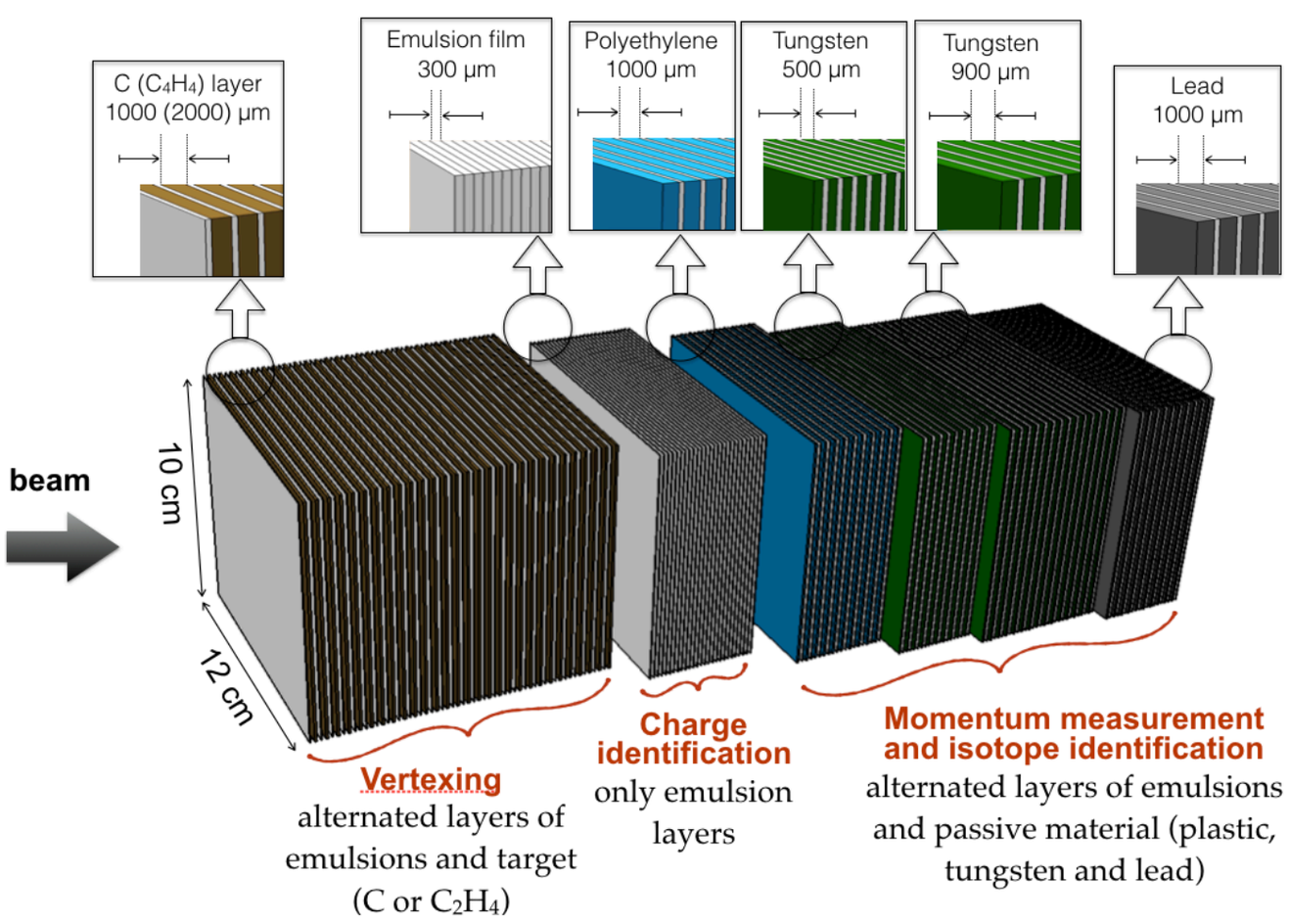
A. Alexandrov, B. Capone, A. Di Crescenzo, G. De Lellis, G. Galati,
A. Iuliano, A. Lauria, M. C. Montesi, A. Pastore, V. Tioukov

*Università di Napoli "Federico II", INFN Napoli, INFN Bari*

# GSI_2019: Scanning Progress

| Target \ Beam | Oxygen 200 MeV/n | Oxygen 400 MeV/n |
|---|---|---|
| Carbon | GSI1 | GSI3 |
| Polyethylene | GSI2 | GSI4 |

- Scanning completed for GSI2
- Scanning completed for GSI1. Some re-scan already done. Quality check on-going
- First scanning completed for GSI3 (quality check not done yet)
- Scanning on-going for GSI4



# ANALYSIS ON-GOING

**GSI_2019**

- Optimize tracking for each sections separately
- Merge different trackings
- Charge identification in S2

**GSI_2020**

- Comparison between Fluka2011 and Fluka2020 (back-up slides)
- Detector structure
- Test Refreshing
- Fluence evaluation

# ANALYSIS ON-GOING

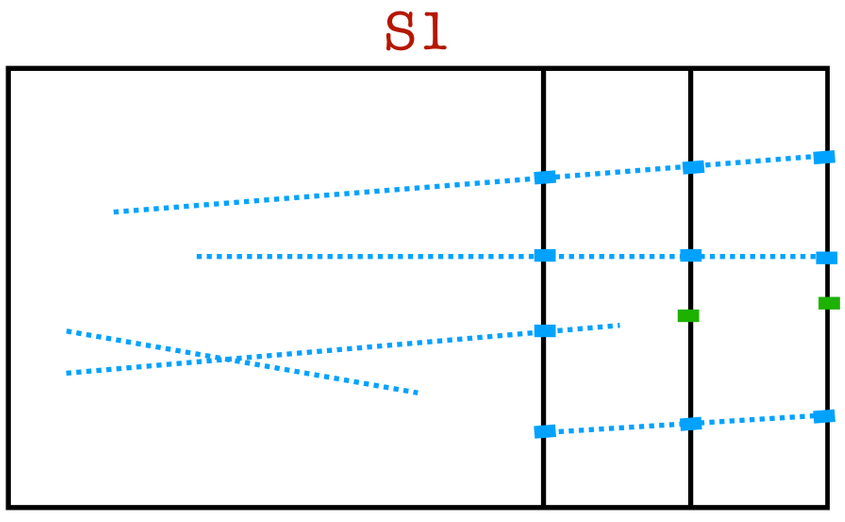
**GSI_2019**

- Optimize tracking for each sections separately
- **Merge different trackings**
- Charge identification in S2

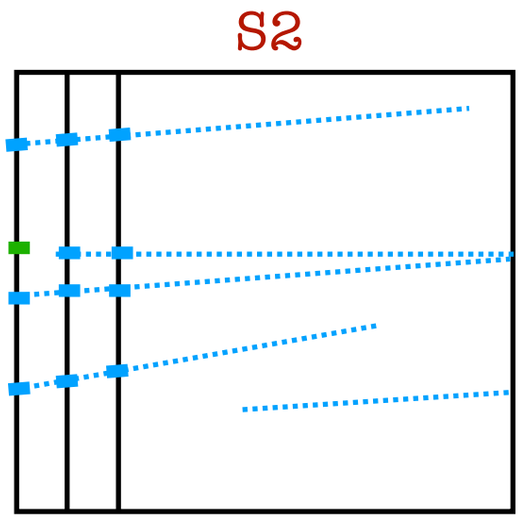
**GSI_2020**

- Comparison between Fluka2011 and Fluka2020 (back-up slides)
- Detector structure
- Test Refreshing
- Fluence evaluation

# MERGE TRACKINGS ALGORITHM



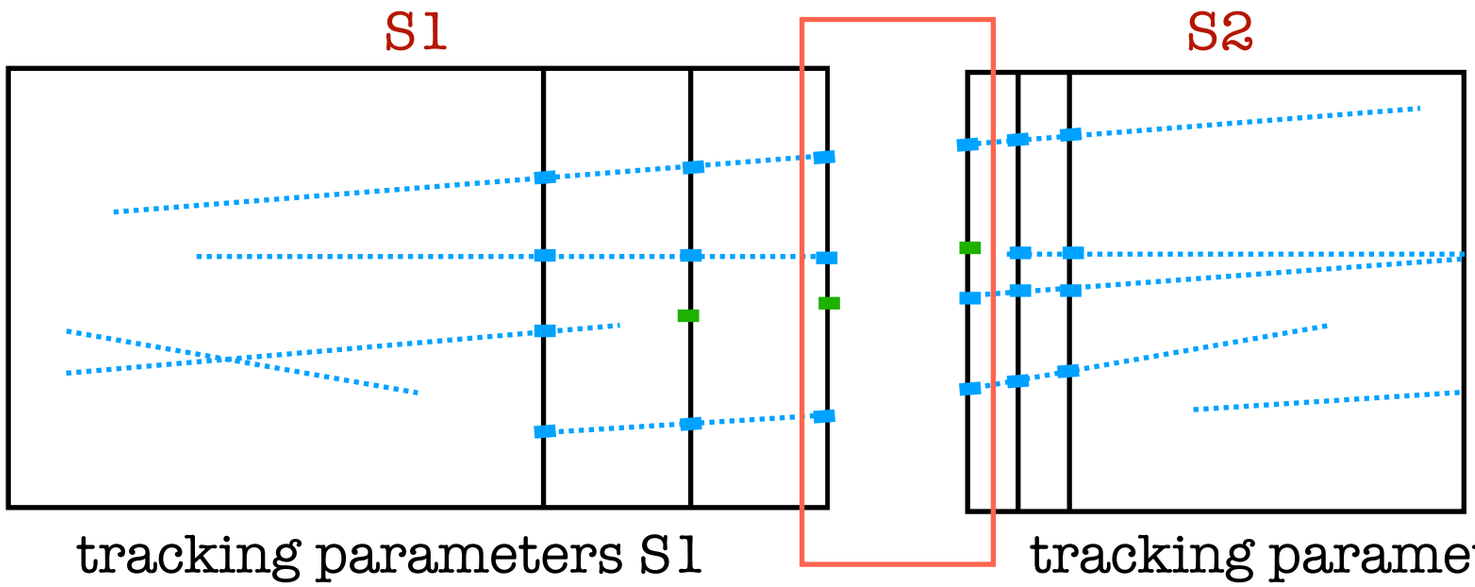

tracking parameters S1




tracking parameters S2

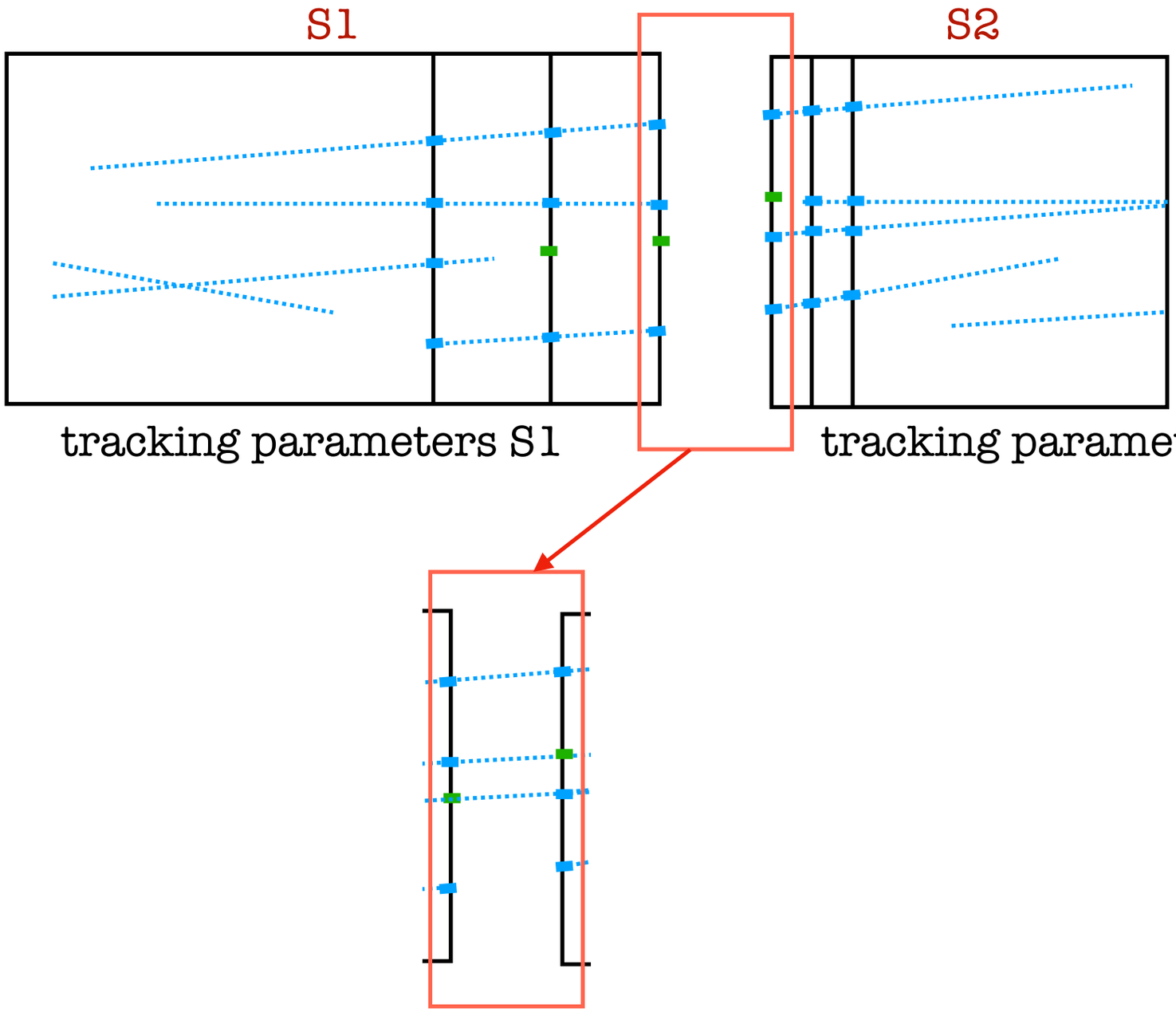
Projection of missing base tracks

# MERGE TRACKINGS ALGORITHM



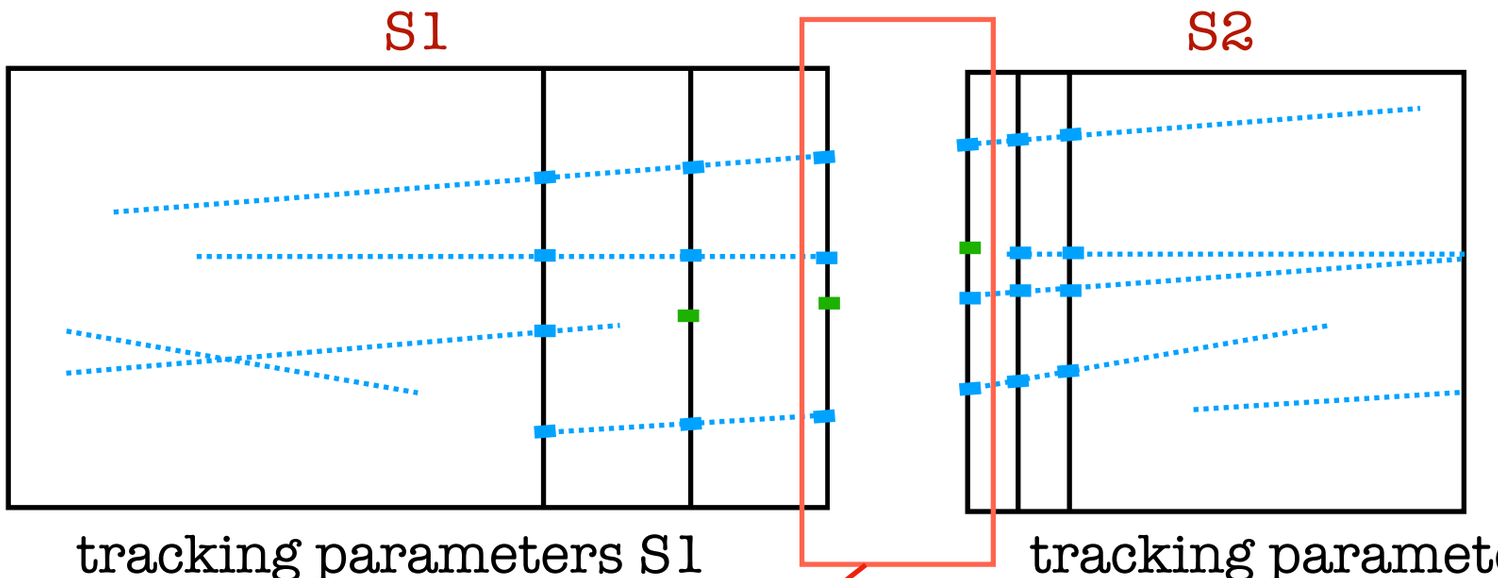

Projection of missing base tracks

# MERGE TRACKINGS ALGORITHM




Projection of missing base tracks

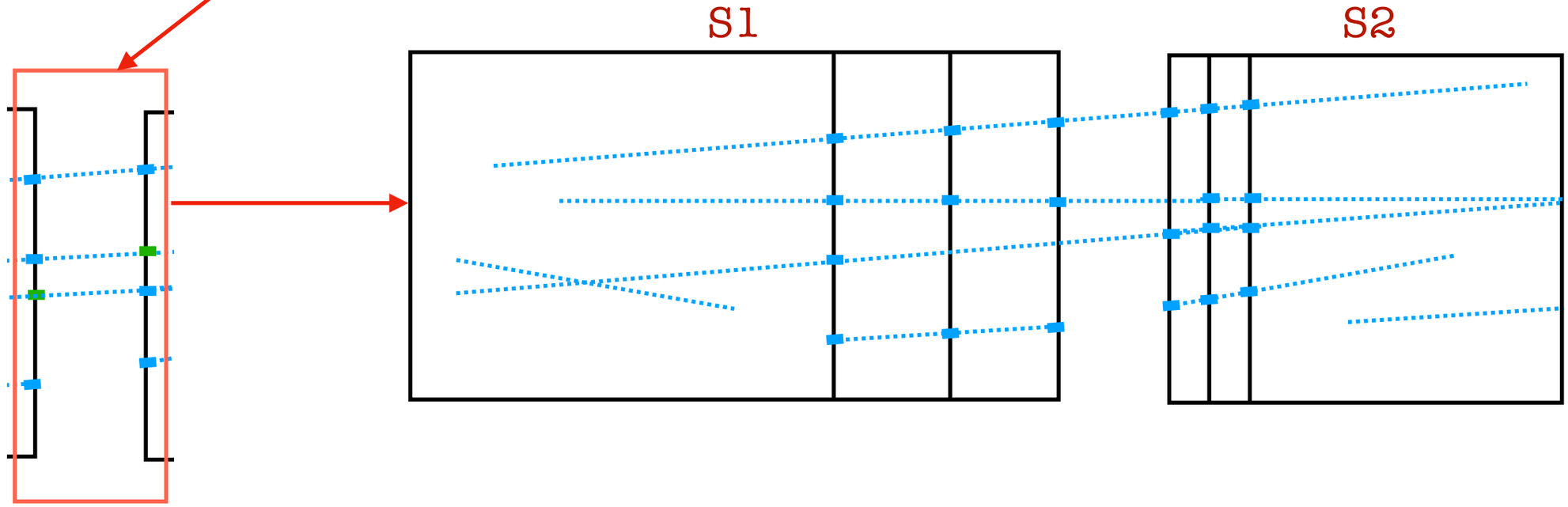
# MERGE TRACKINGS ALGORITHM




tracking parameters S1

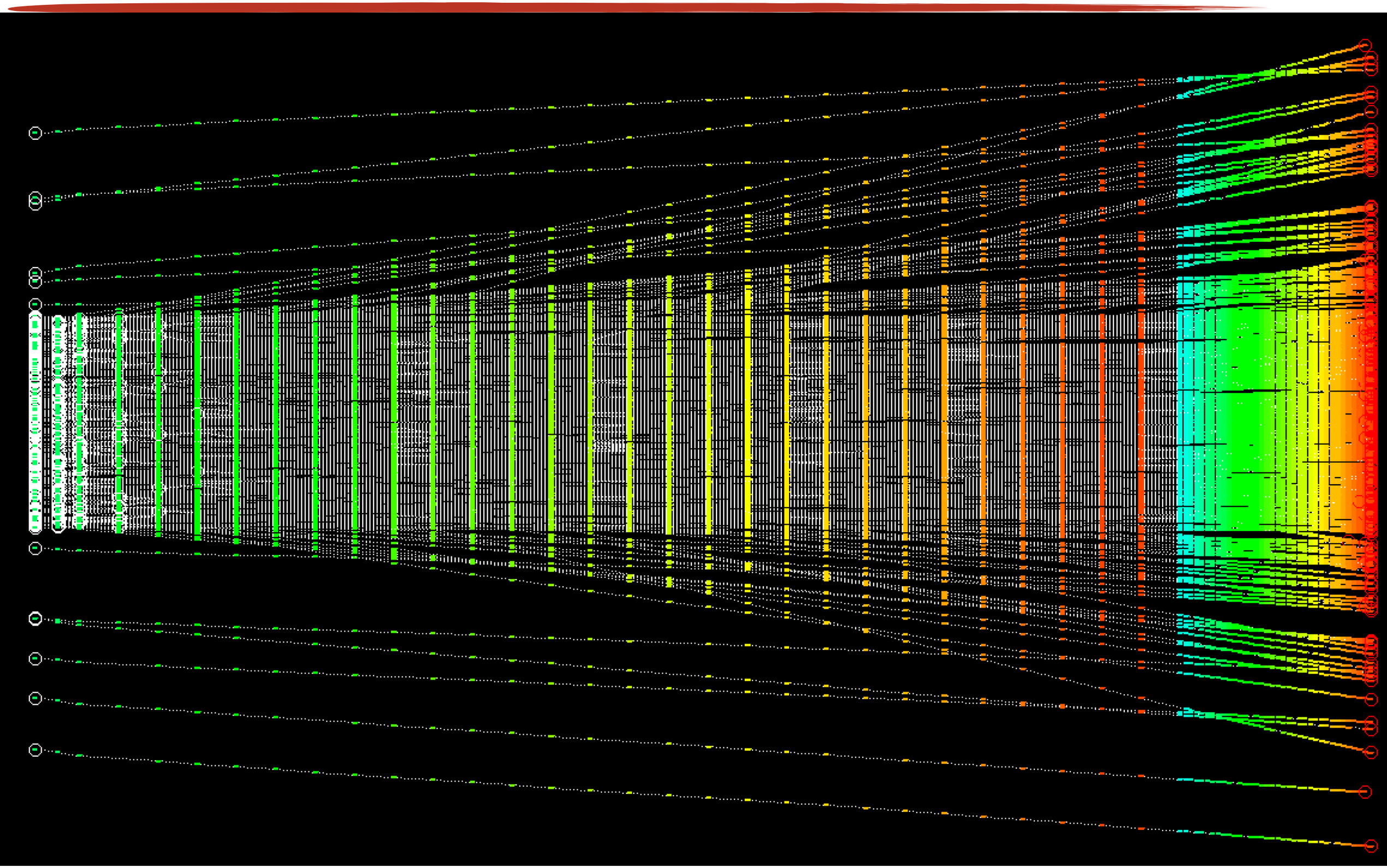
tracking parameters S2

Projection of missing base tracks




tracking parameters 1-2

# Merge Trackings Algorithm



## MonteCarlo Oxy 200MeV / n on C2H4

# ANALYSIS ON-GOING

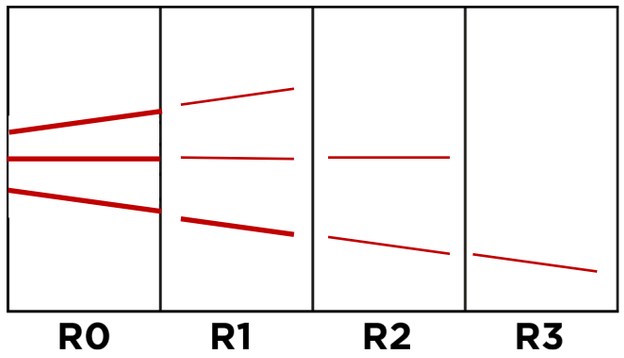
**GSI_2019**

- Optimize tracking for each sections separately
- Merge different trackings
- **Charge identification in S2**

**GSI_2020**

- Comparison between Fluka2011 and Fluka2020 (back-up slides)
- Detector structure
- Test Refreshing
- Fluence evaluation

# CHARGE IDENTIFICATION IN S2



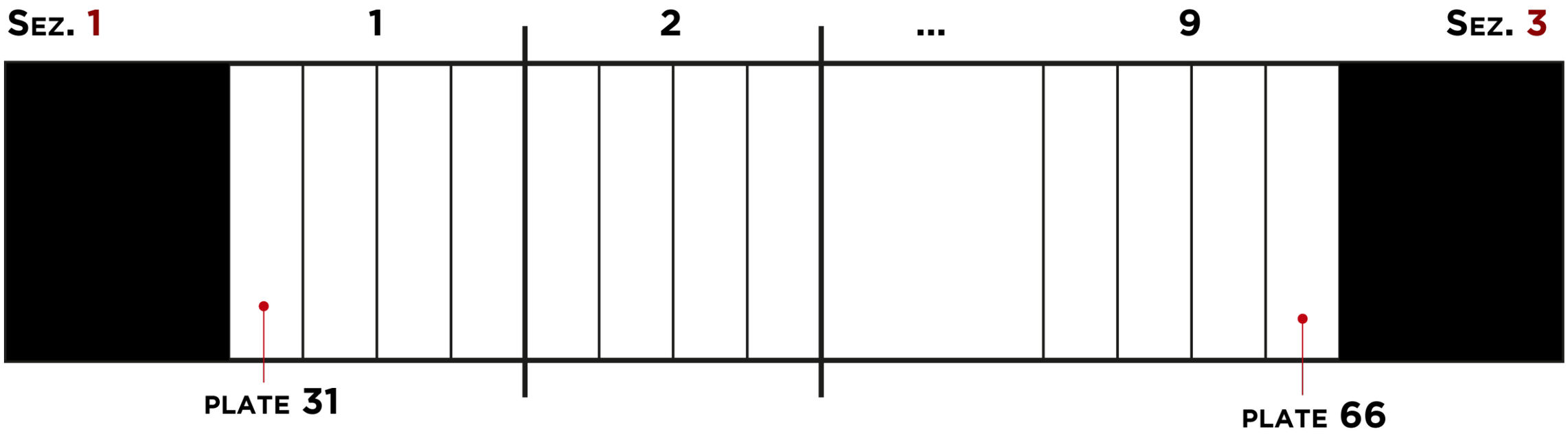

- **R0** not thermally treated;
- **R1** thermally treated at **28**°C and 95% relative humidity;
- **R2** thermally treated at **34**°C and 95% relative humidity;
- **R3** thermally treated at **36**°C and 95% relative humidity.

# MEAN #SEGMENTS FOR EACH THERMAL CONDITION

| | R1 | R2 | R3 |
|---|---|---|---|
| **R0** | 8,5 | 8,0 | 8,0 |
| **R1** | / | **7,6** | **7,7** |
| **R2** | / | / | **6,9** |

mean #segments in $R_X$ evaluated for the tracks that have at least 8 segments in $R_{X+1}$

# TRACKS SELECTION CRITERIA



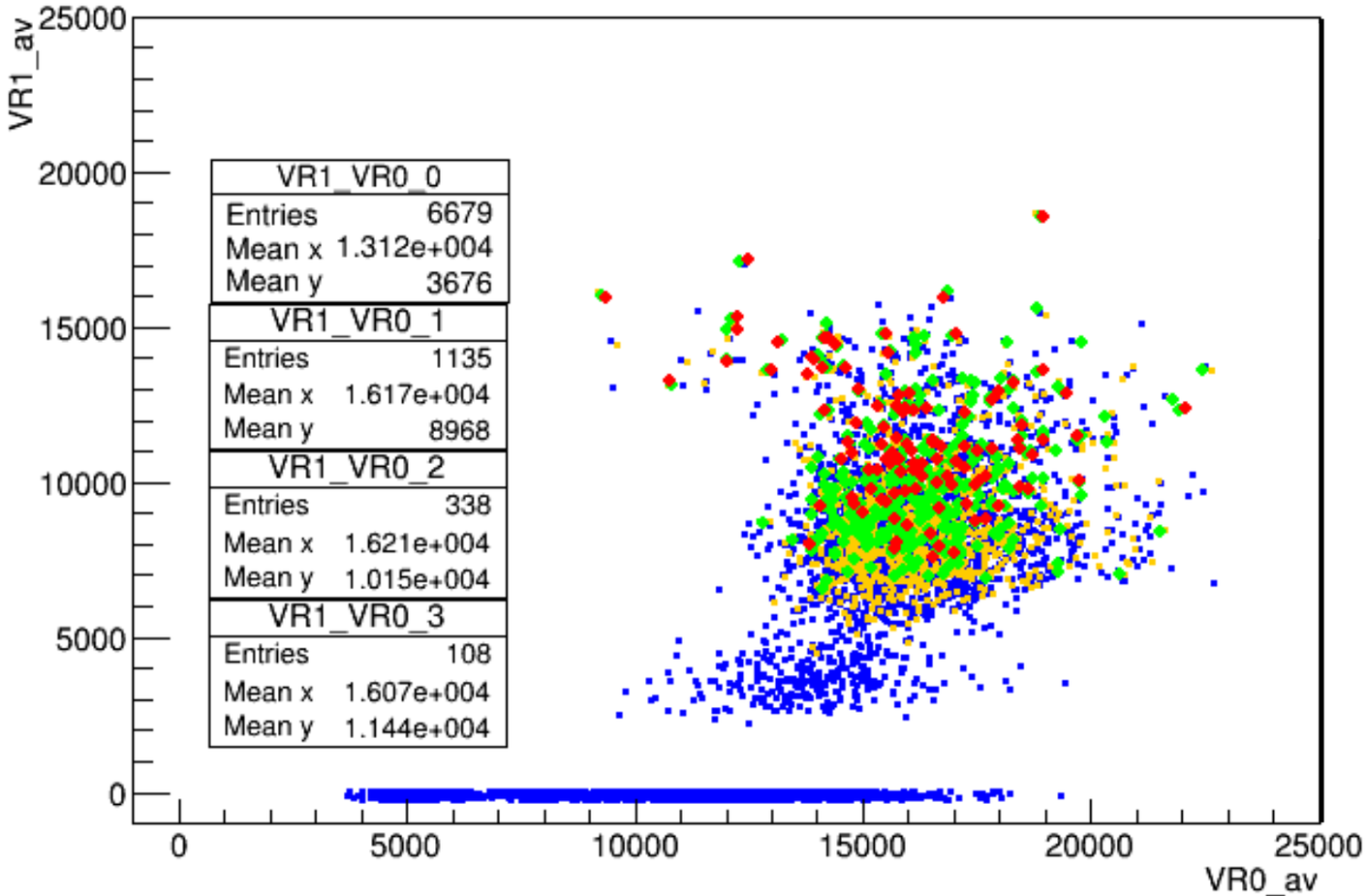

## Old Criteria

First segment in one of the first four cells and last segment in one of the last four cells

## New Criteria

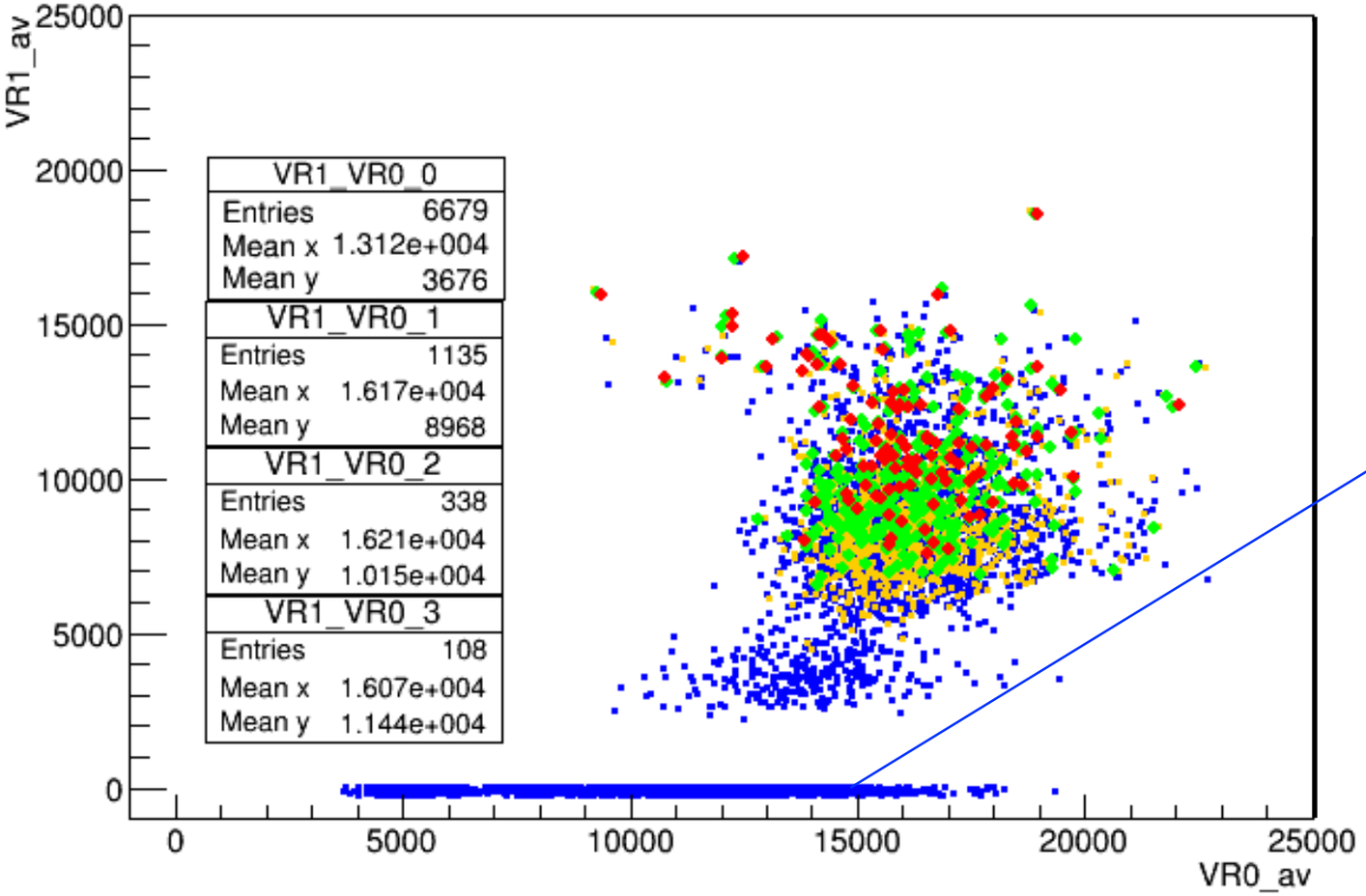
- 1st cut: **8** R0 required
- 2nd cut: **8** R0 - **8** R1 required
- 3rd cut: **8** R0 - **8** R1 - **7** R2 required
- 4th cut: **8** R0 - **8** R1- **7** R2- **7** R3 required

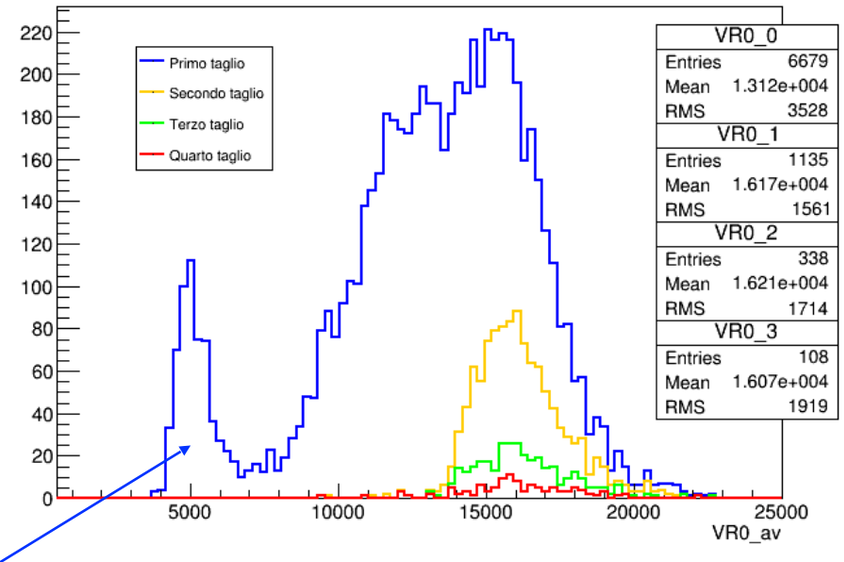
# AVERAGE VOLUME VR1 - VR0 COMPARISON



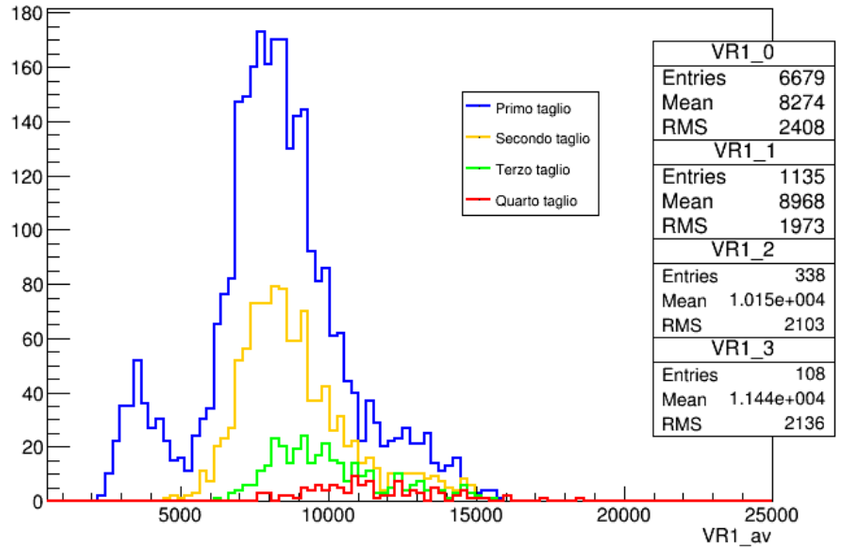

- **1st cut: 8 R0 required**
- **2nd cut: 8 R0 - 8 R1 required**
- **3rd cut: 8 R0 - 8 R1 - 7 R2 required**
- **4th cut: 8 R0 - 8 R1- 7 R2- 7 R3 required**

# AVERAGE VOLUME VR1 - VR0 COMPARISON



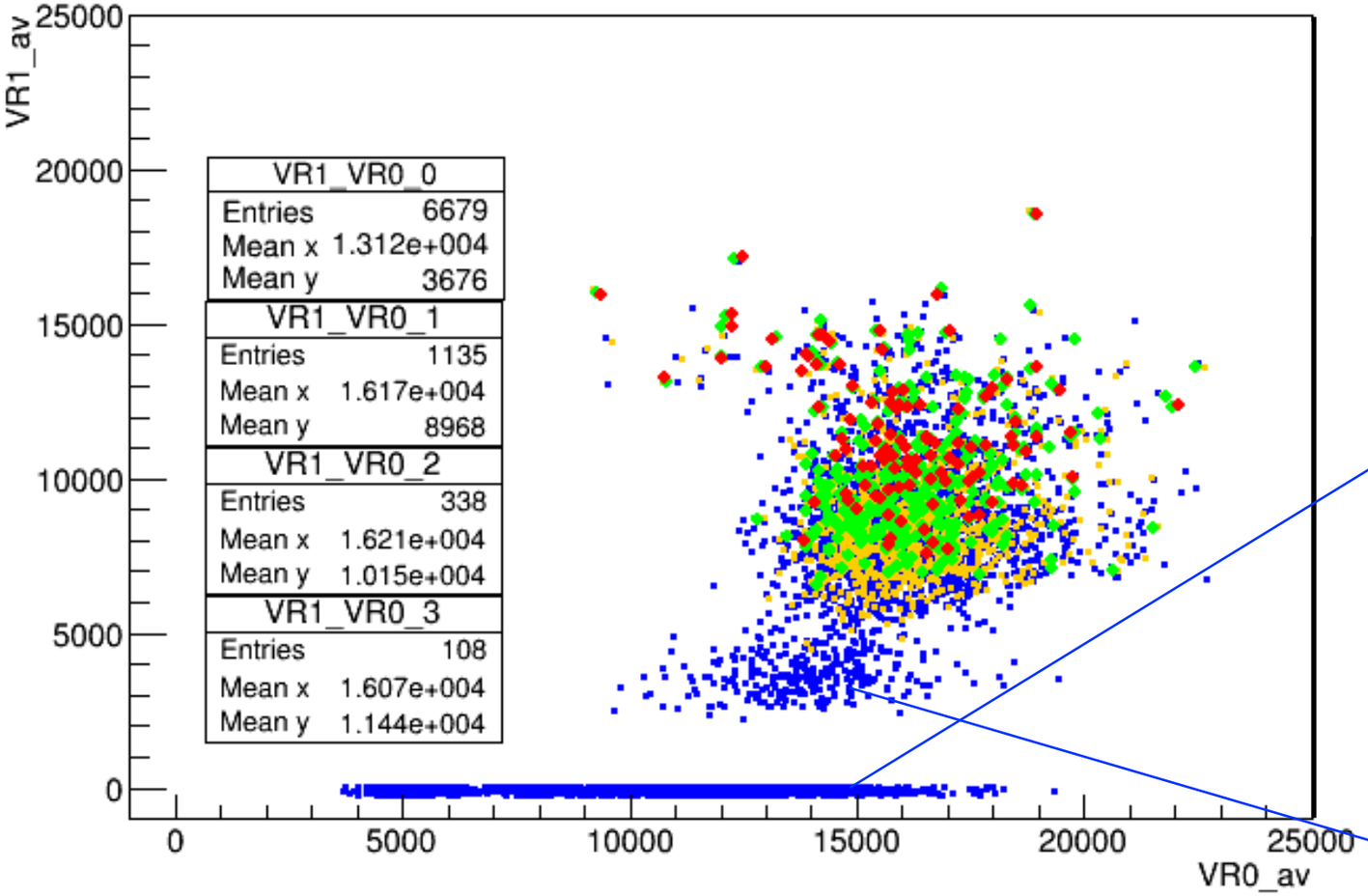

**VR0**

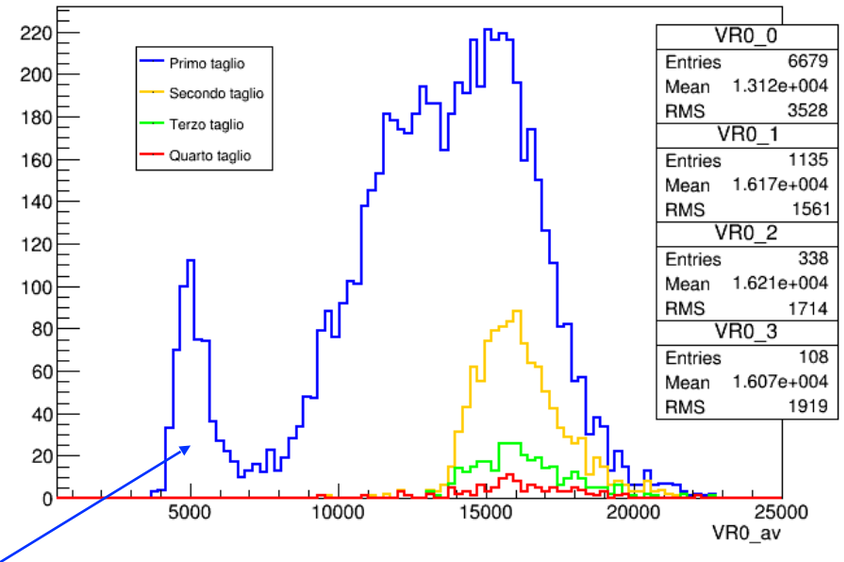



**VR1**

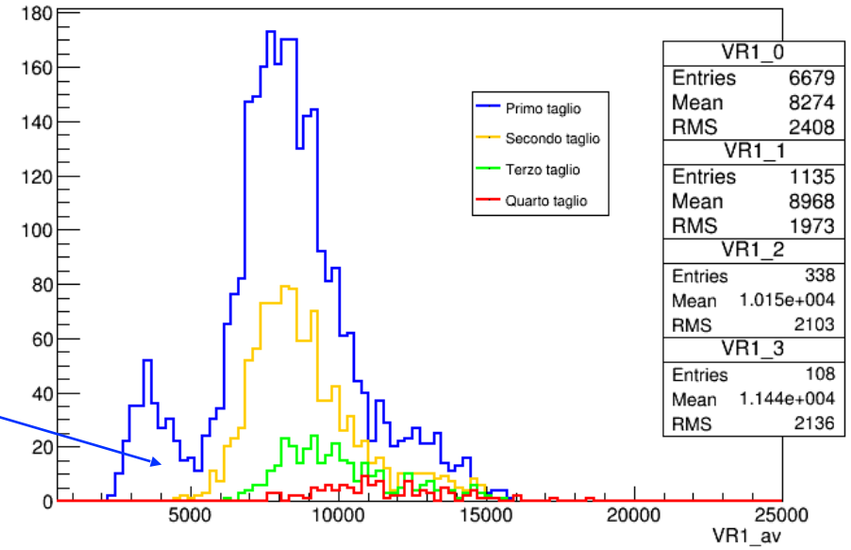
- **1st cut: 8 R0 required**
- **2nd cut: 8 R0 - 8 R1 required**
- **3rd cut: 8 R0 - 8 R1 - 7 R2 required**
- **4th cut: 8 R0 - 8 R1- 7 R2- 7 R3 required**

# AVERAGE VOLUME VR1 - VR0 COMPARISON




**VR0**




**VR1**

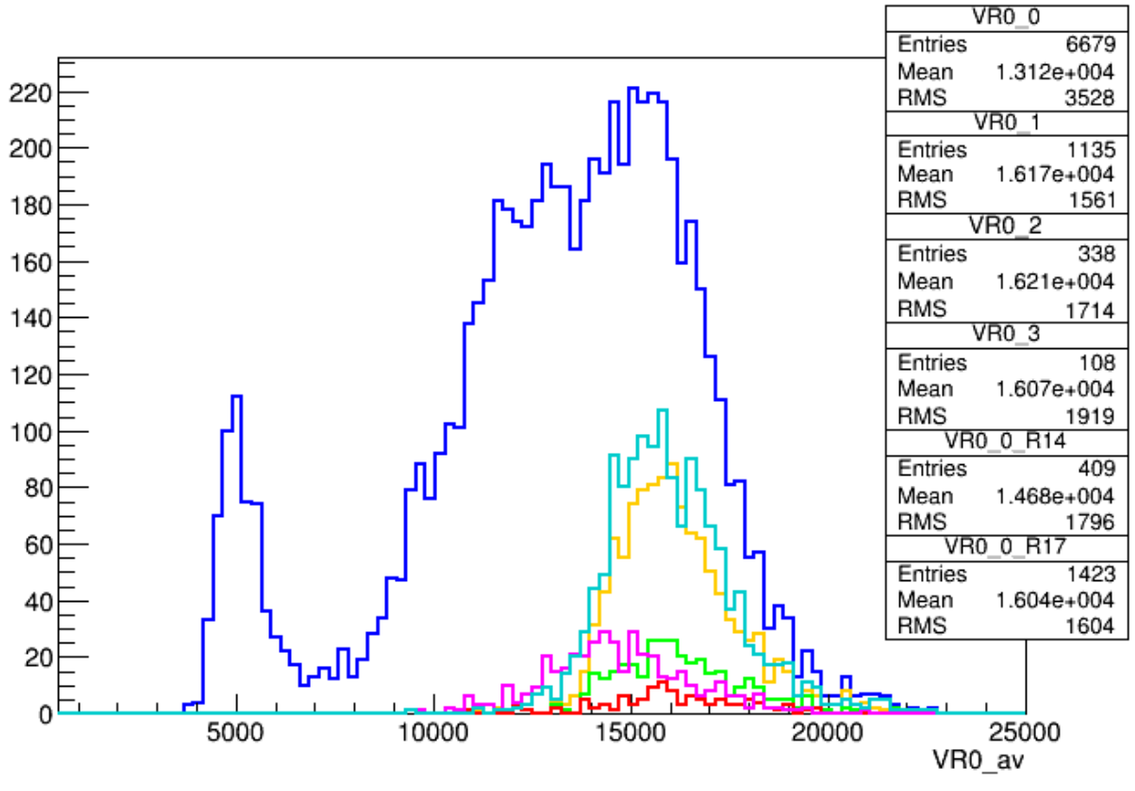
- **1st cut: 8 R0 required**
- **2nd cut: 8 R0 - 8 R1 required**
- **3rd cut: 8 R0 - 8 R1 - 7 R2 required**
- **4th cut: 8 R0 - 8 R1- 7 R2- 7 R3 required**

# CHECK ON R1 SEGMENT DISTRIBUTION FOR BLUE TRACKS

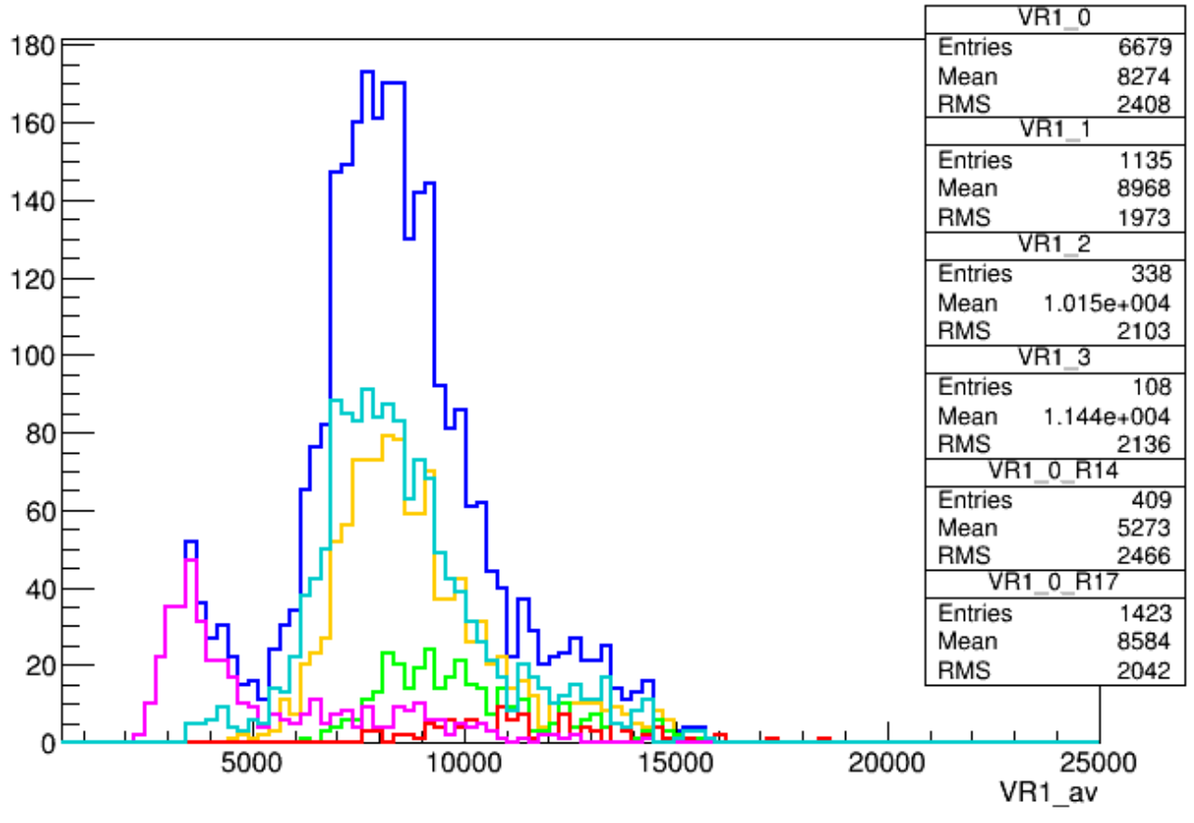
**MAGENTA**: $2 \leq R1 \leq 4$
**LIGHT BLUE**: $5 \leq R1 \leq 7$
**YELLOW**: $R1 \geq 8$

- **1st cut: 8 R0 required**
- **2nd cut: 8 R0 - 8 R1 required**
- **3rd cut: 8 R0 - 8 R1 - 7 R2 required**
- **4th cut: 8 R0 - 8 R1- 7 R2- 7 R3 required**

## VR0

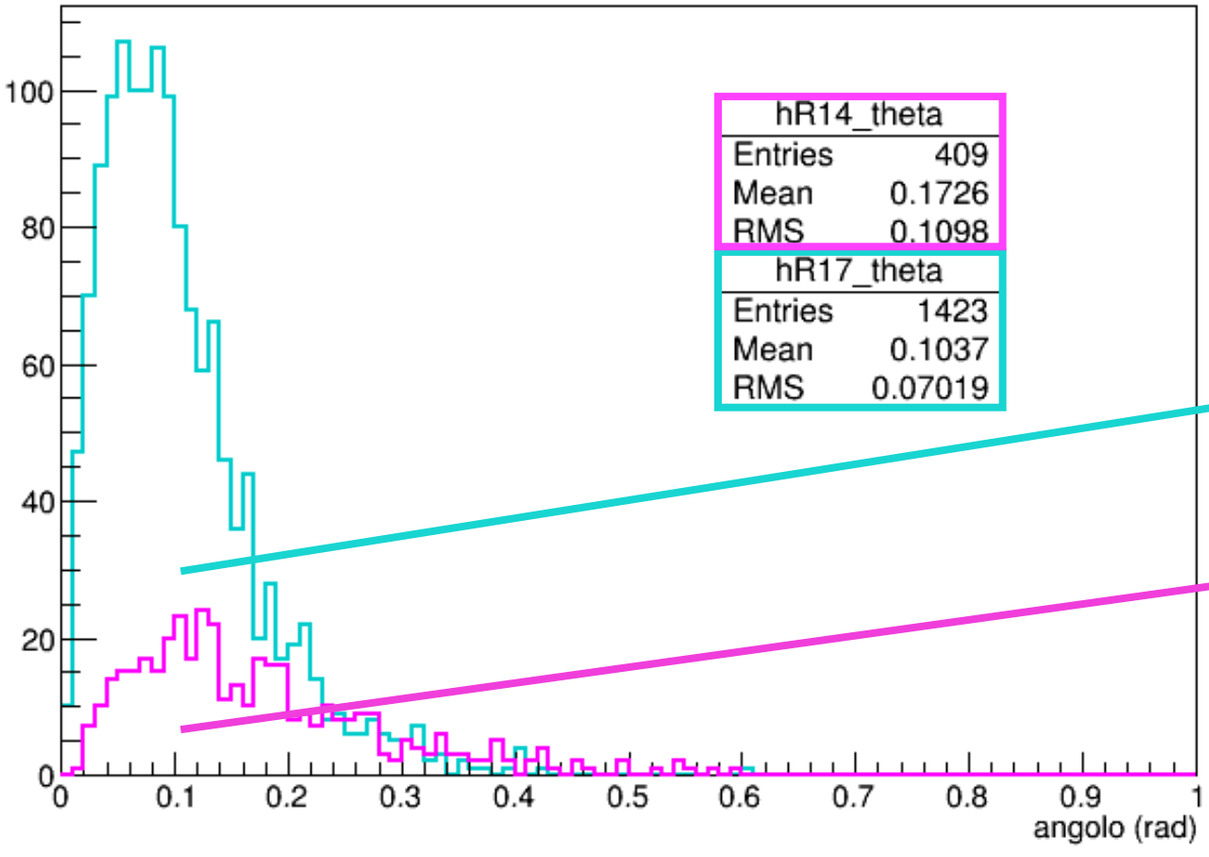



## VR1



# ANGULAR DISTRIBUTION FOR TRACKS WITH R1 ≤ 7

**MAGENTA**: $2 \leq R1 \leq 4$
**LIGHT BLUE**: $5 \leq R1 \leq 7$




Preliminary Hypothesis

**HELIUM**

protons not completely erased in R1:
**LOW ENERGY PROTONS**

# Analysis on-Going

**GSI_2019**

- Optimize tracking for each sections separately
- Merge different trackings
- Charge identification in S2

**GSI_2020**

- Comparison between Fluka2011 and Fluka2020 (back-up slides)
- **Detector structure**
- Test Refreshing
- Fluence evaluation

# Detector Structure

| | Carbon 700 MeV/n | | | |
|---|---|---|---|---|
| S | Material | #Passive Layers | #Emu | Tot |
| S1 | C(1mm) or C2H4(2mm) | 40 | 40 | 40 |
| S2 | Emu (1R0+9x4cells R0R1R2R3R4) | 0 | 37 | 77 |
| S3 | Lexan (1mm) | 10 | 10 | 87 |
| S4 | W (0.5mm) | 14 | 14 | 101 |
| S5 | W (0.9mm) | 14 | 14 | 115 |
| S6_1 | Pb (1mm) | 40 | 40 | 155 |
| S6_2 | Pb (2mm) | 10 | 10 | 165 |

# Analysis on-Going

**GSI_2019**

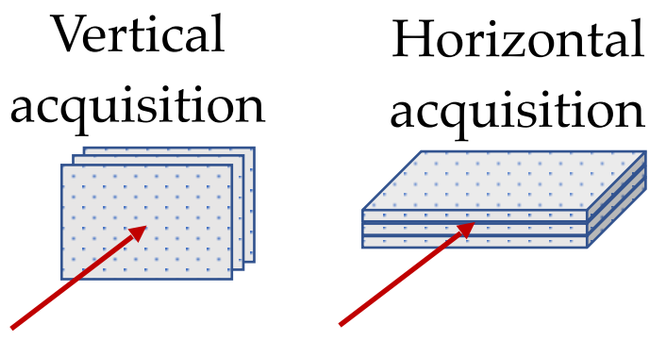
- Optimize tracking for each sections separately
- Merge different trackings
- Charge identification in S2

**GSI_2020**

- Comparison between Fluka2011 and Fluka2020 (back-up slides)
- Detector structure
- **Test Refreshing**
- Fluence evaluation

# SET-UP

**Proton Therapy center in Trento**


| E (MeV) | FWHM (cm) | # particles required (1000p/cm²) | # particles counted by scintillator (vertical acquisition) | # particles counted by scintillator (horizontal acquisition) |
|---|---|---|---|---|
| 70 | 1.62 | 4200 | 4304 | 6361 |
| 90 | 1.46 | 3400 | 3492 | 3557 |
| 200 | 0.8 | 2000 | 1933 | 2078 |

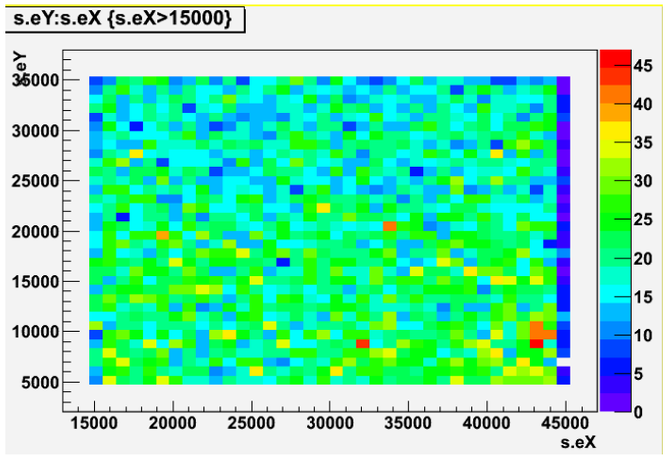
# THERMAL TREATMENTS CONDITIONS

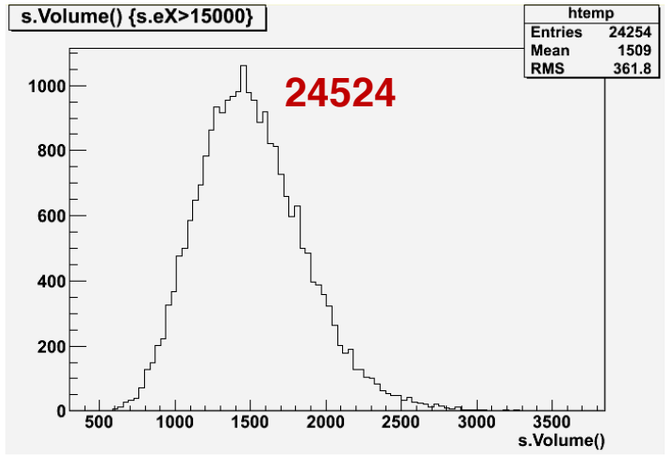
| time (h) | T (°C) | | |
|---|---|---|---|
| | 28 | 32 | Jolly |
| 12 | ✔ | ✔ | ? |
| 24 | ✔ | ✔ | ? |
| 36 | ✔ | ✔ | ? |

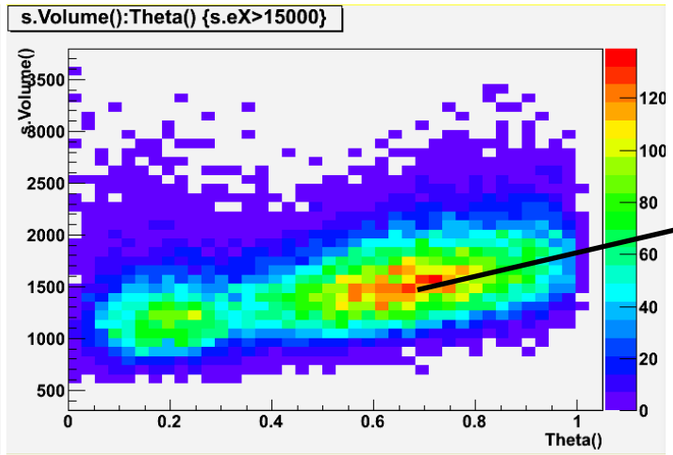
- Thermal treatments concluded for all energies
- Emulsions development completed for all energies
- Scanning and analysis completed for 70MeV

# PRELIMINARY RESULTS PROTONS@70MEV

No thermal treatment



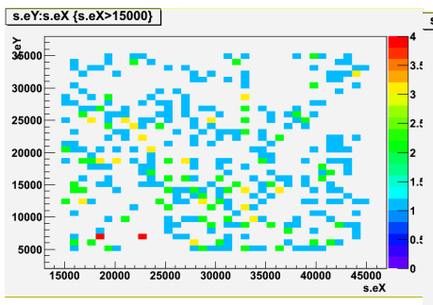



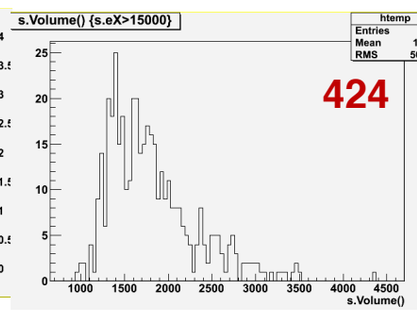

Cosmic rays

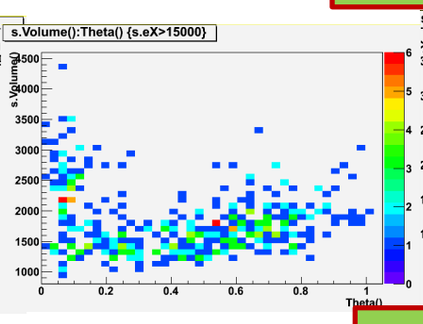
T=28°C

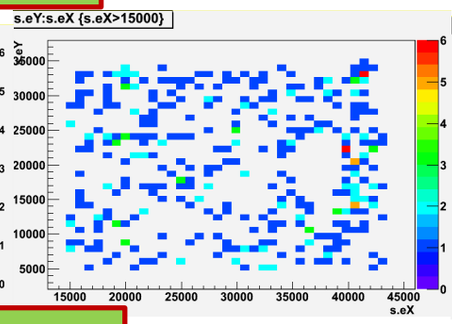
T=32°C

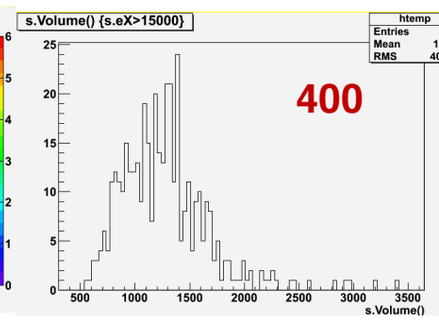
**12 h**

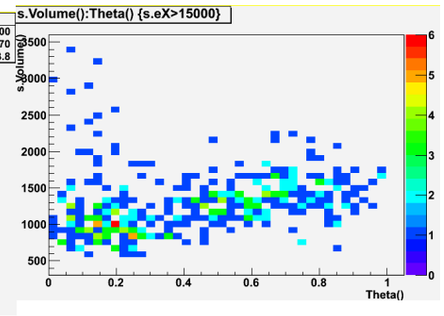


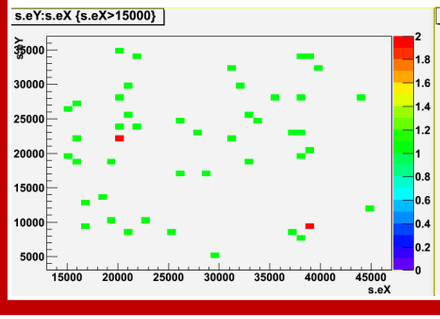



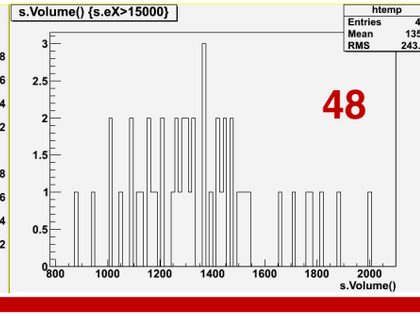



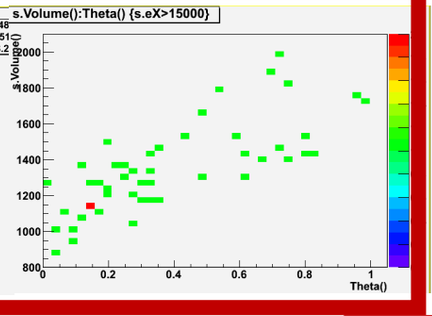



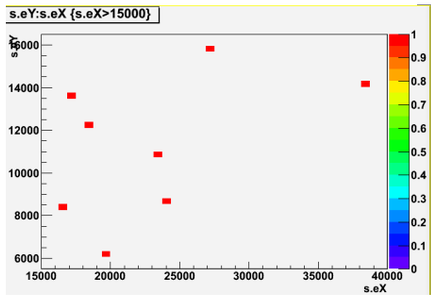



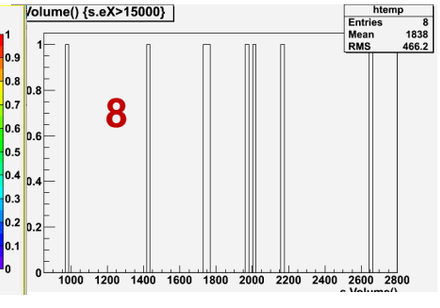

**24 h**



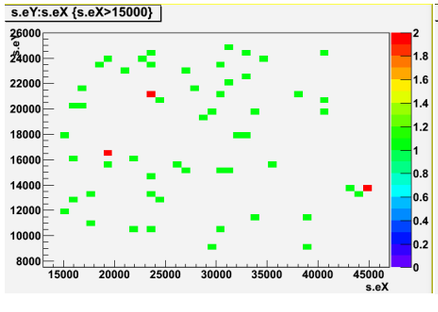



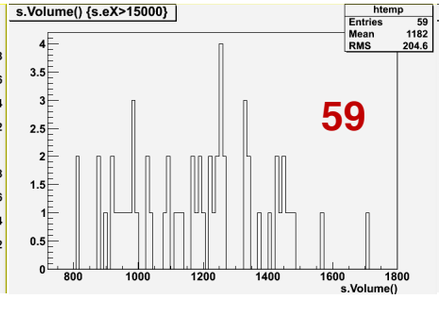



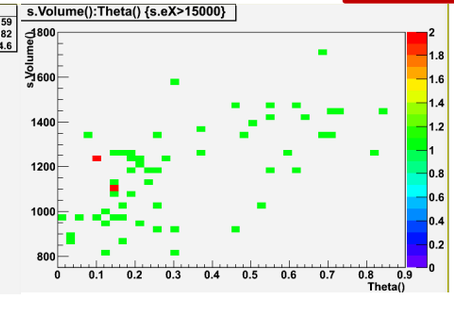




**36 h**



# PRELIMINARY RESULTS

| E (MeV) | time (h) | T (°C) 28 | T (°C) 32 |
|---|---|---|---|
| 70 | 12 | partial | total |
| 70 | 24 | total | partial |
| 90* | 12 | to be done | to be done |
| 90* | 24 | to be done | to be done |
| 200 | 12 | to be done | to be done |
| 200 | 24 | to be done | to be done |

*same ionization as He@700 MeV/n

# Analysis on-Going

**GSI_2019**

- Optimize tracking for each sections separately
- Merge different trackings
- Charge identification in S2

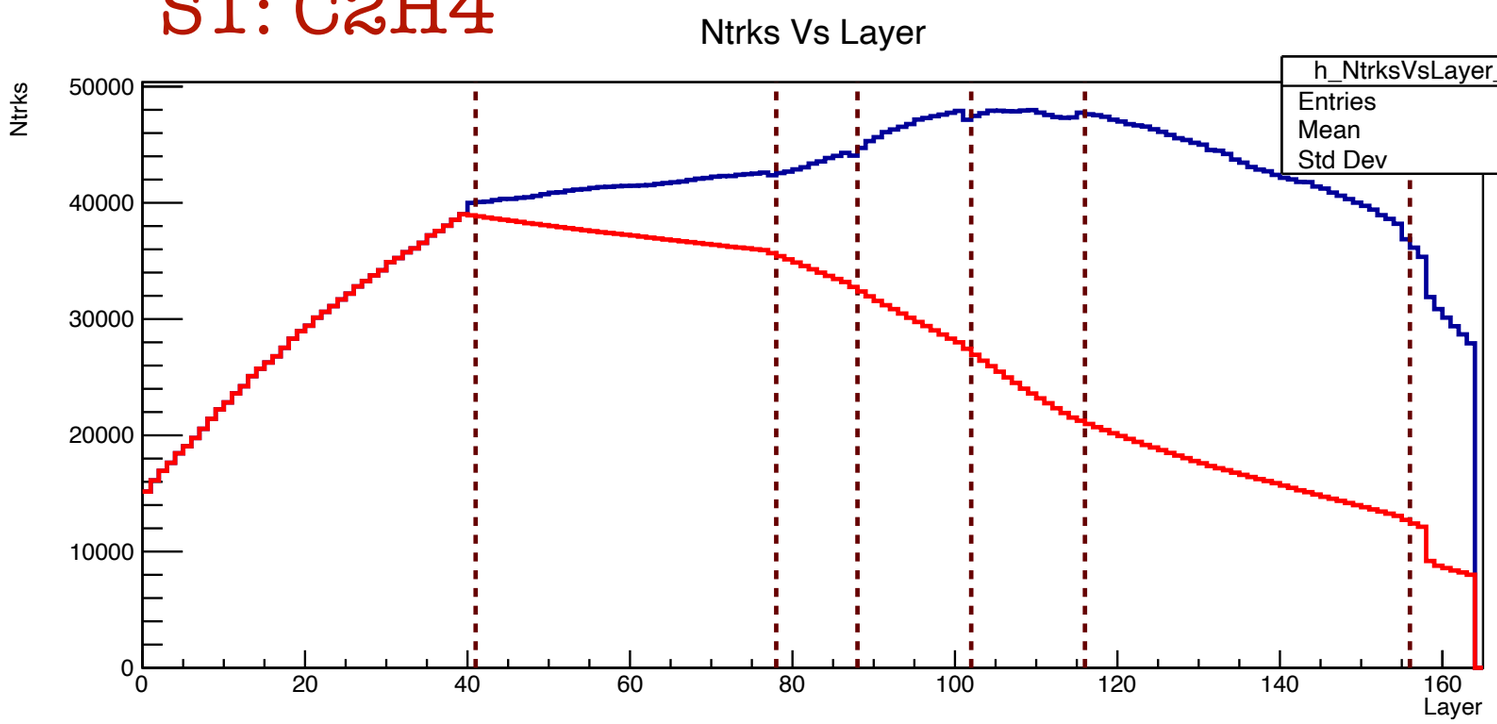
**GSI_2020**

- Comparison between Fluka2011 and Fluka2020 (back-up slides)
- Detector structure
- Test Refreshing
- **Fluence evaluation**

# Fluence Evaluation

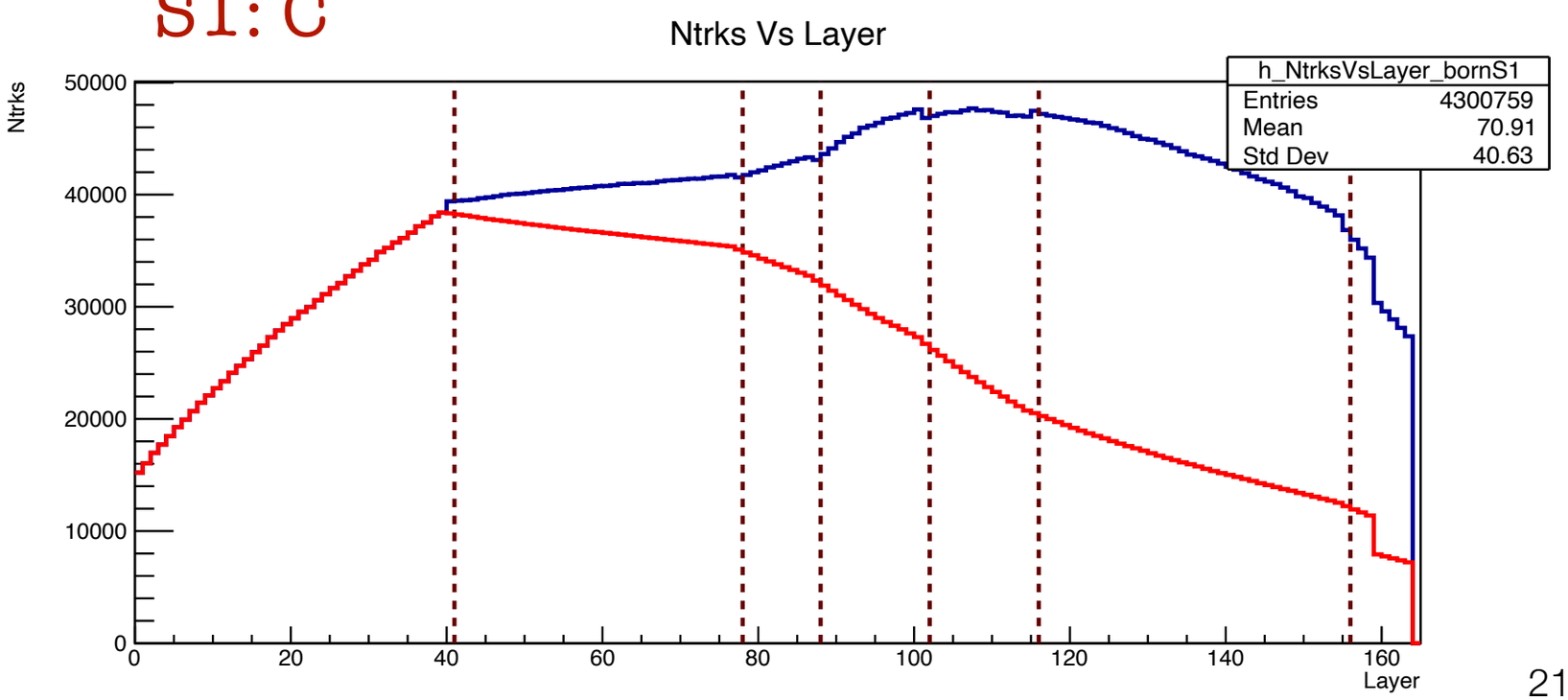
Max occupancy allowed: 10000 particles/cm²

## S1: C2H4




- MC Beam: 15000 particles
- Max occupancy: 3639 particles/cm² on layer 109
- Fluence: 40000

## S1: C




- MC Beam: 15000 particles
- Max occupancy: 3753 particles/cm² on layer 107
- Fluence: 40000

BACK-UP SLIDES

# COMPARISON BETWEEN FLUKA 2011 AND FLUKA 2020

## CARBON@700MEV/N
## TARGET: S1 POLYETHYLENE

# Beam Characteristics

- Carbon @ 700 MeV/n
- Rectangular Shape
- Isotropic distribution
- @-30cm in z
- Aluminium box between beam and emulsion
- 5000 events with Fluka 2011
- 5000 events with Fluka 2020

# INTERACTIONS

| TARGET | 2019 | 2020 |
|---|---|---|
| Beam particles | 5000 | |
| VTX in S1 | 39.2% | 39.3% |

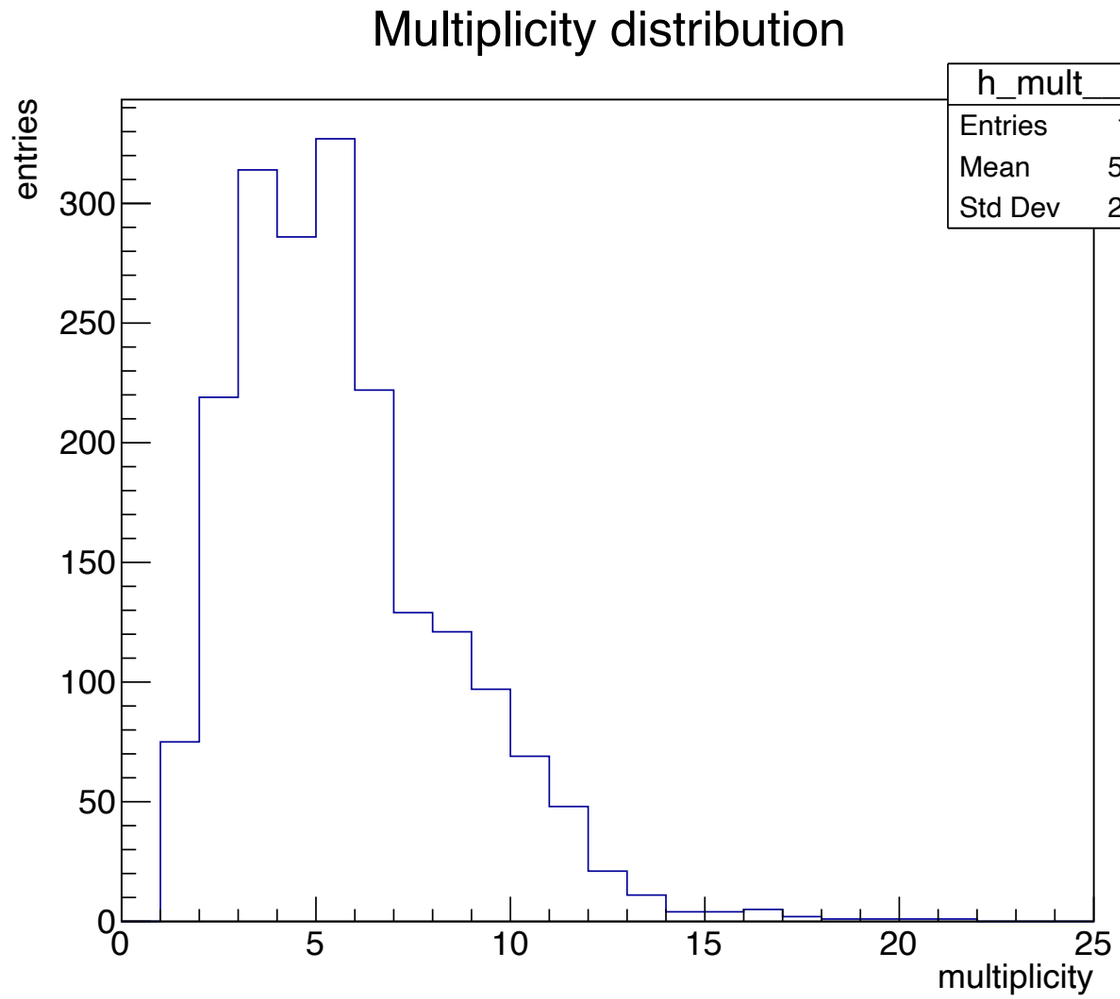
Beam: Carbon@700MeV/n - Target: S1 Polyethylene

# CHARGED PARTICLES PRODUCED IN S1

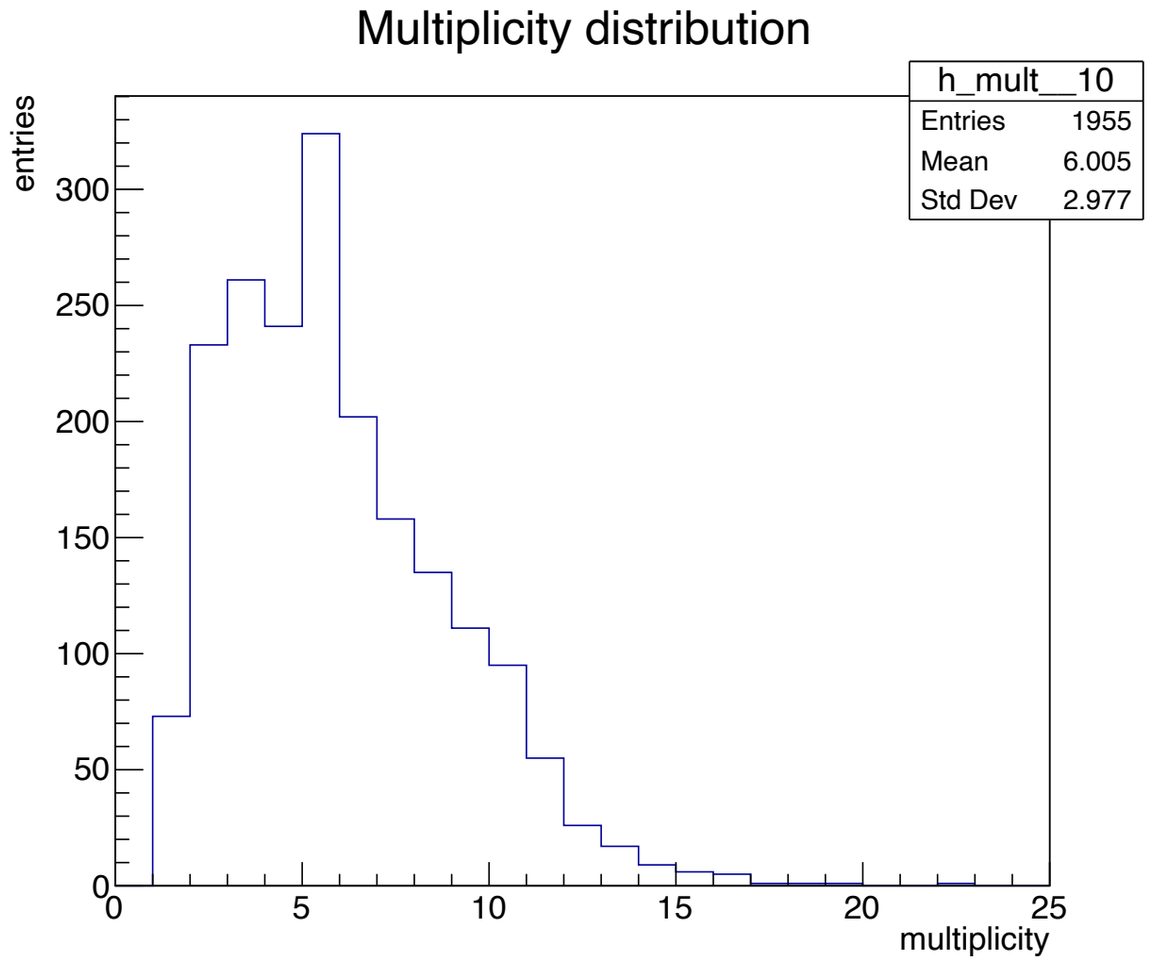
| | 2011 | 2020 |
|---|---|---|
| Total products | 10763 | 10231 |
| Exit lateral | 20.6% | 21.3% |
| Exit at the end | 21.2% | 20.8% |
| Contained | 58.9% | 58.9% |
| Absorbed in S1 | 23.1% | 23.2% |
| Charge measured | 75.9% | 75.7% |
| P measured | 68.7% | 69.0% |
| Silver | 68.7% | 69.0% |
| Golden | 37.4% | 37.5% |

- EXIT LATERAL = last segment coordinates at 0.5 cm from the edge
- EXIT AT THE END = end point in the last 2 plates
- CONTAINED = not exiting laterally nor at the end
- CHARGE MEASURED = at least 6 segments in S2
- P MEASURED = at least 5 segments in S3+S4+S5+S6
- SILVER = charge and p measured
- GOLDEN = contained + charge and p measured

# MULTIPLICITY DISTRIBUTIONS




2011: mean multiplicity = 5.7




2020: mean multiplicity = 6.0

# Charged Particles Produced in S1

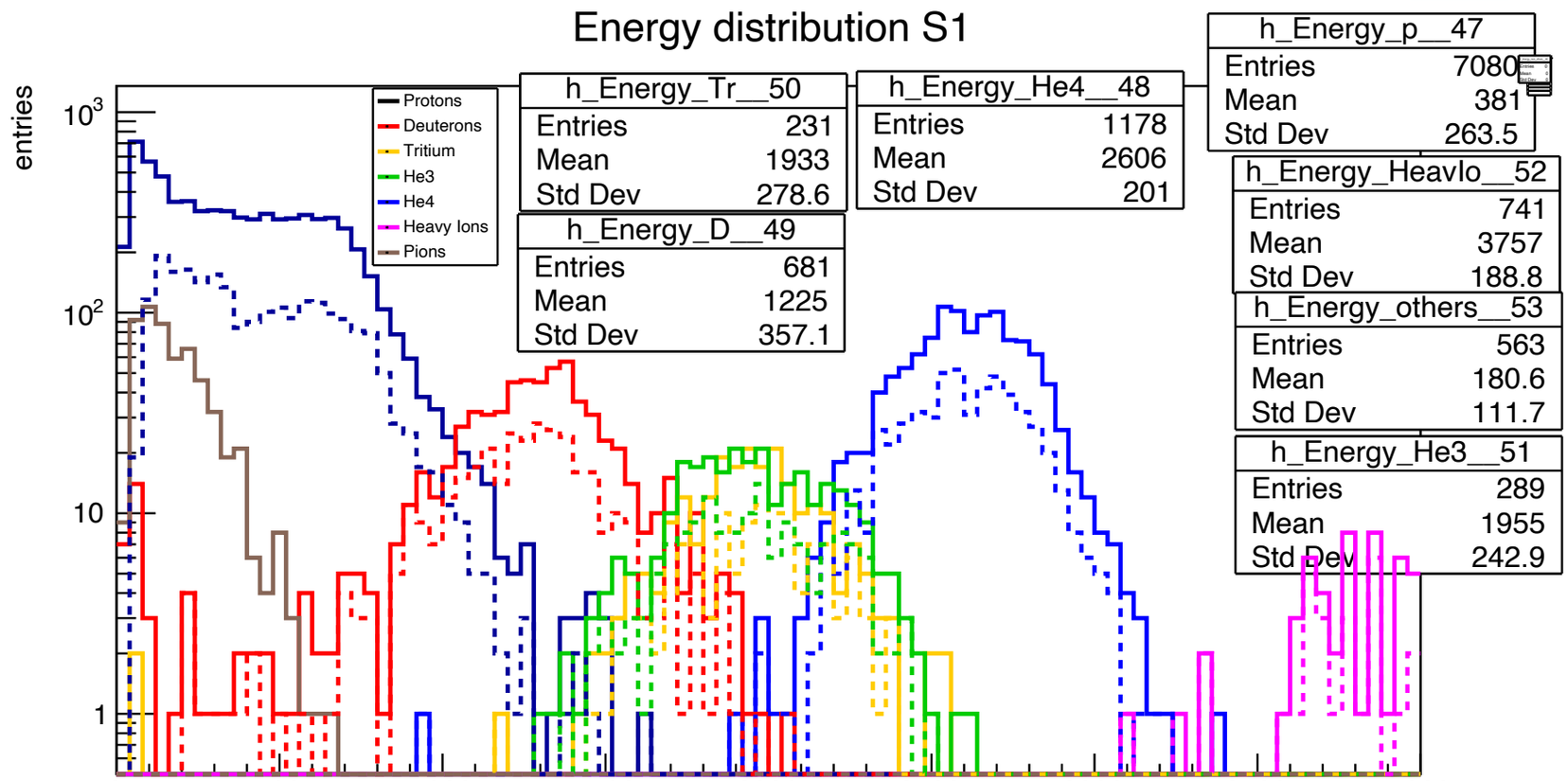
| | 2011 | | 2020 | |
|---|---|---|---|---|
| | #tot | % | #tot | % |
| Total | 10763 | | 10231 | |
| Protons | 7080 | 65.8% | 6292 | 61.5% |
| Deuteros | 681 | 6.3% | 694 | 6.8% |
| Tritium | 231 | 2.2% | 281 | 2.8% |
| He3 | 289 | 2.7% | 312 | 3.1% |
| He4 | 1178 | 10.9% | 1304 | 12.7% |
| Heavy Ions | 741 | 6.9% | 799 | 7.8% |
| others | 563 | 5.2% | 549 | 5.4% |

- SILVER = charge and p measured
- GOLDEN = contained + charge and p measured

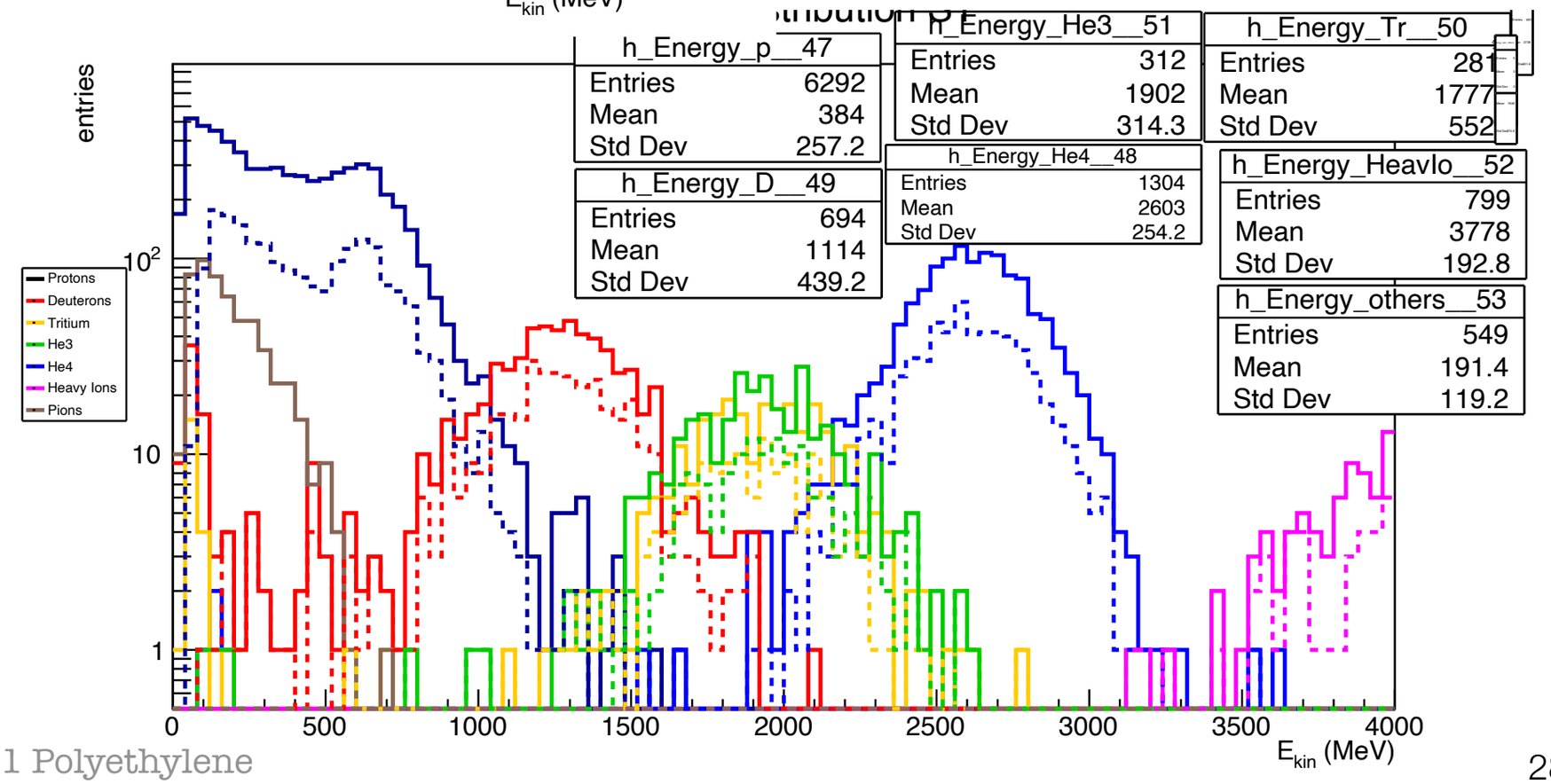
# ENERGY DISTRIBUTION

solid line = all tracks
dotted line = GOLDEN

2011




2020

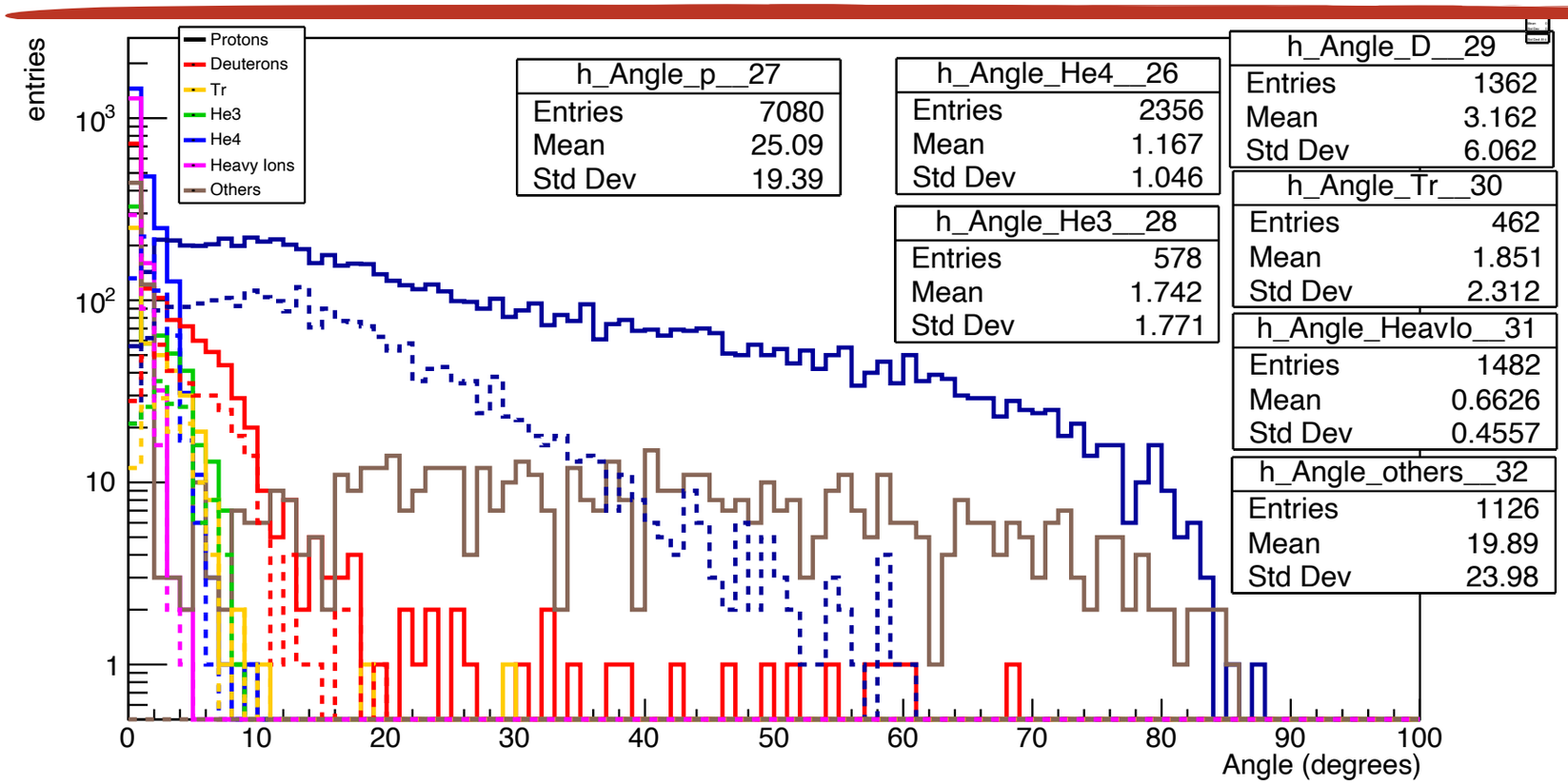



Beam: Carbon@700MeV/n - Target: S1 Polyethylene

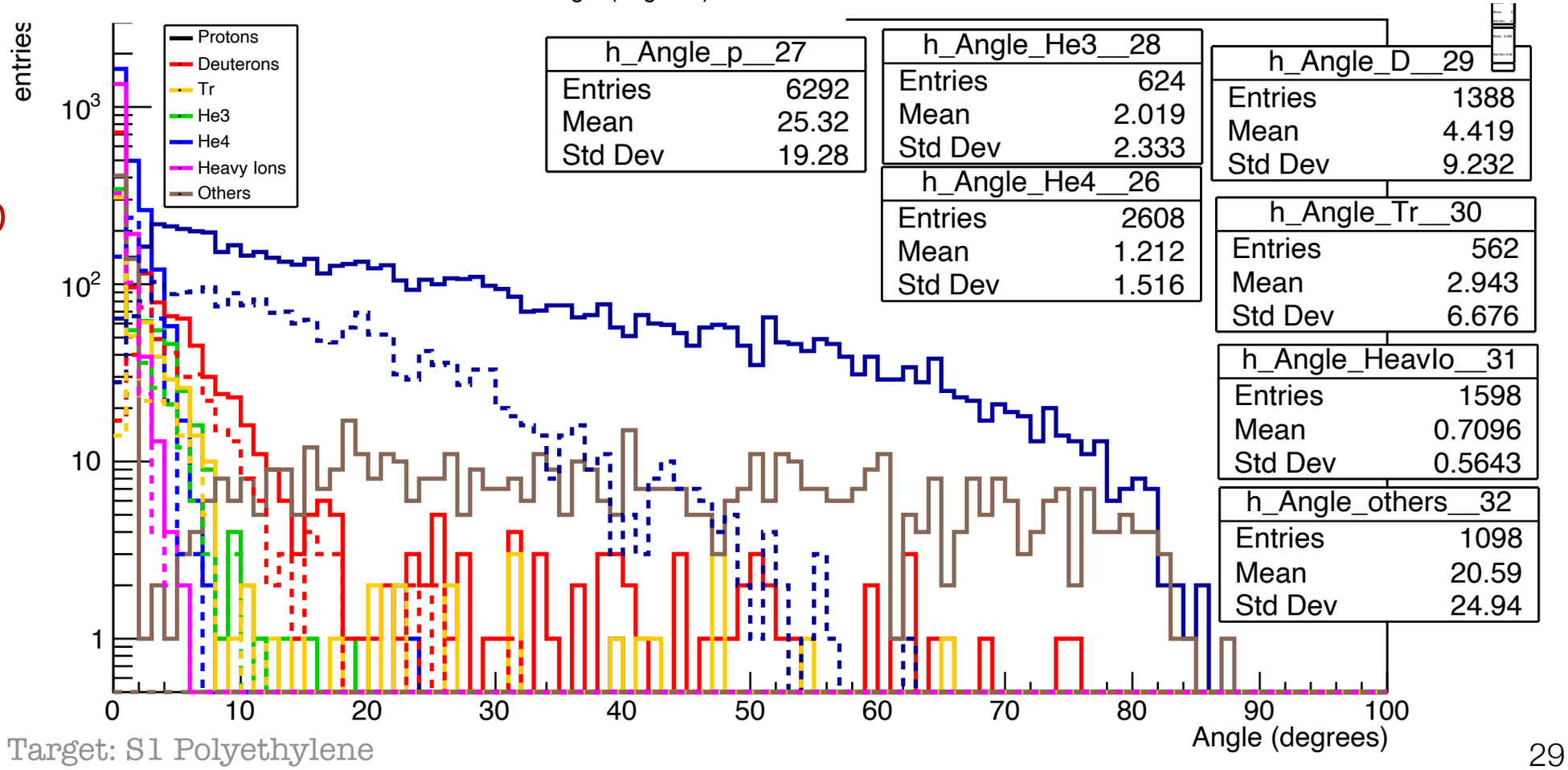
# ANGLE DISTRIBUTION

solid line = all tracks
dotted line = GOLDEN

2011

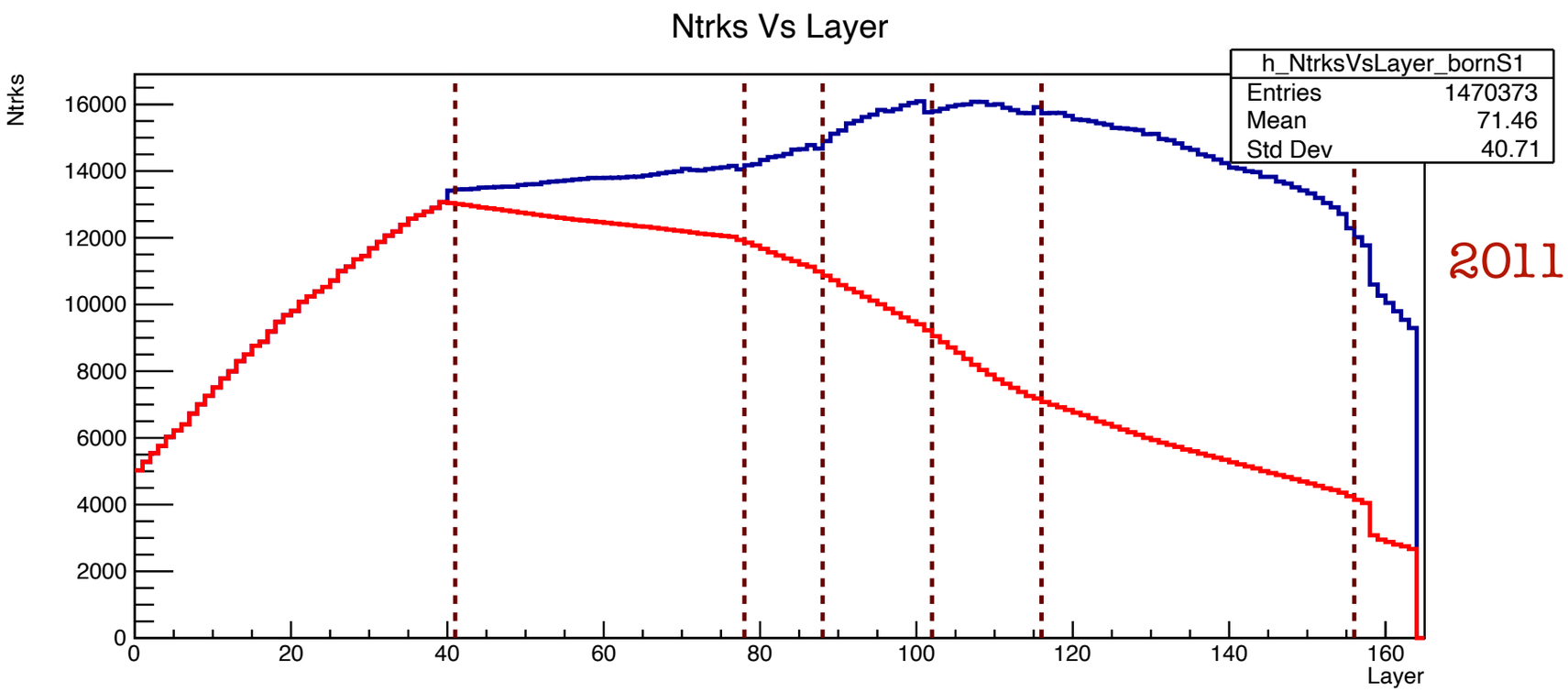



2020

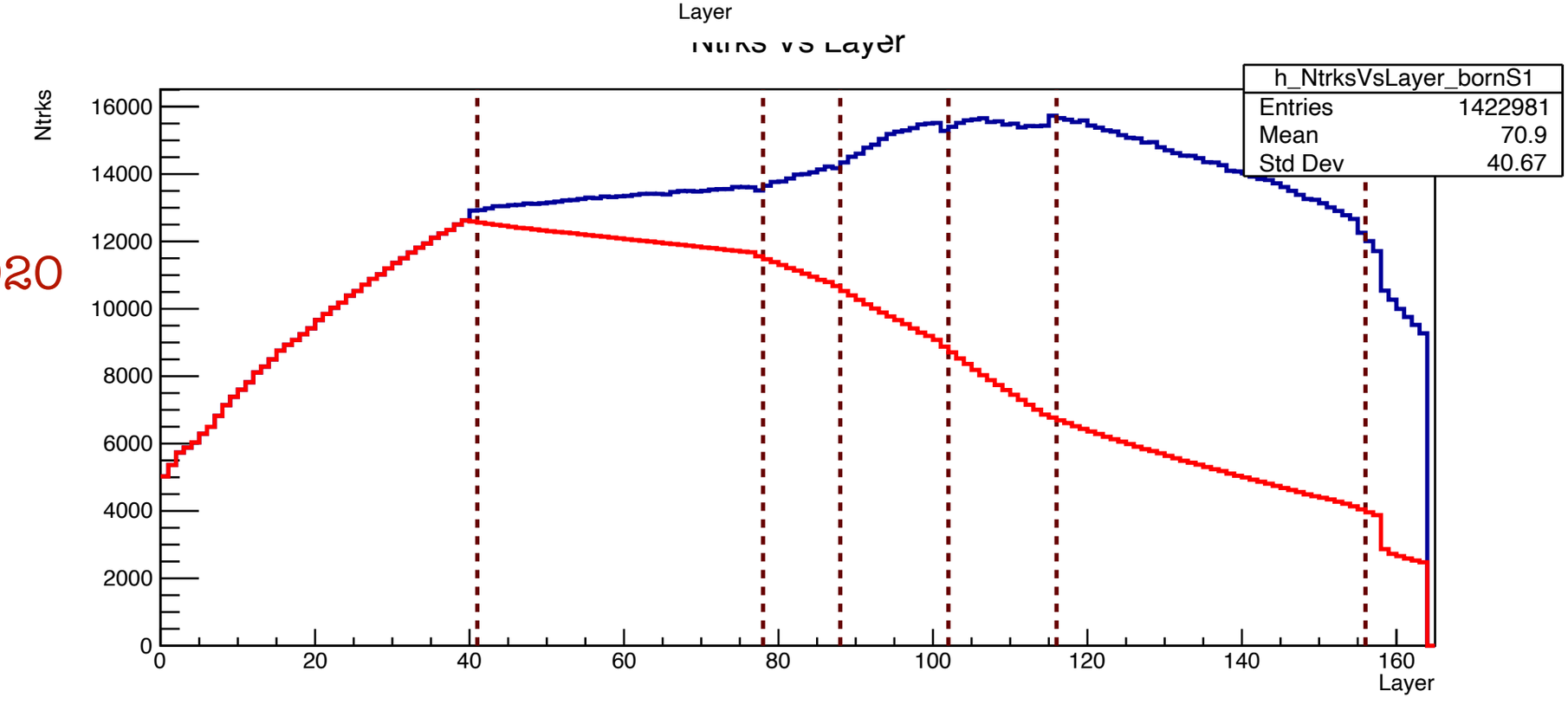



Beam: Carbon@700MeV/n - Target: S1 Polyethylene

# OCCUPANCY (ALL TRKS)




2011




2020