Multiplicities studies

Luisa Occhiuto*,

Annalisa De Caro, Chandradoy Chatterjee, Salvatore Fazio,

On behalf of the ePIC dRICH simulation team

From **Particle Gun** to Full Events with **Pythia**

Understanding the transition from idealized "Particle Gun" simulations to full Pythia events is critical for ePIC success:

- ✓ Environmental Background
- ✓ Occupancy Stress-Testing: Mapping high-energy DIS topologies to ensure SiPM arrays do not saturated
- ✓ PID Resolution Integrity
- ✓ Reconstruction Optimization

luisa.occhiuto@cern.ch

Strategy

✓ The analysis utilizes a full-chain simulation of Neutral Current DIS events
✓ Simulated 3000 events from this pythia event:
pythia8NCDIS_10x100_minQ2=1_beamEffects_xAngle=-0.025_hiDiv_vtxfix_1.hepmc, this means:

- Neutral Current Deep Inelastic Scattering events
- 10 GeV x100 GeV → beam energies
- minQ2=1 → cut on $Q^2 \geq 1$ (GeV^2)
- xAngle=-0.025 → crossing angle of beam on x axis

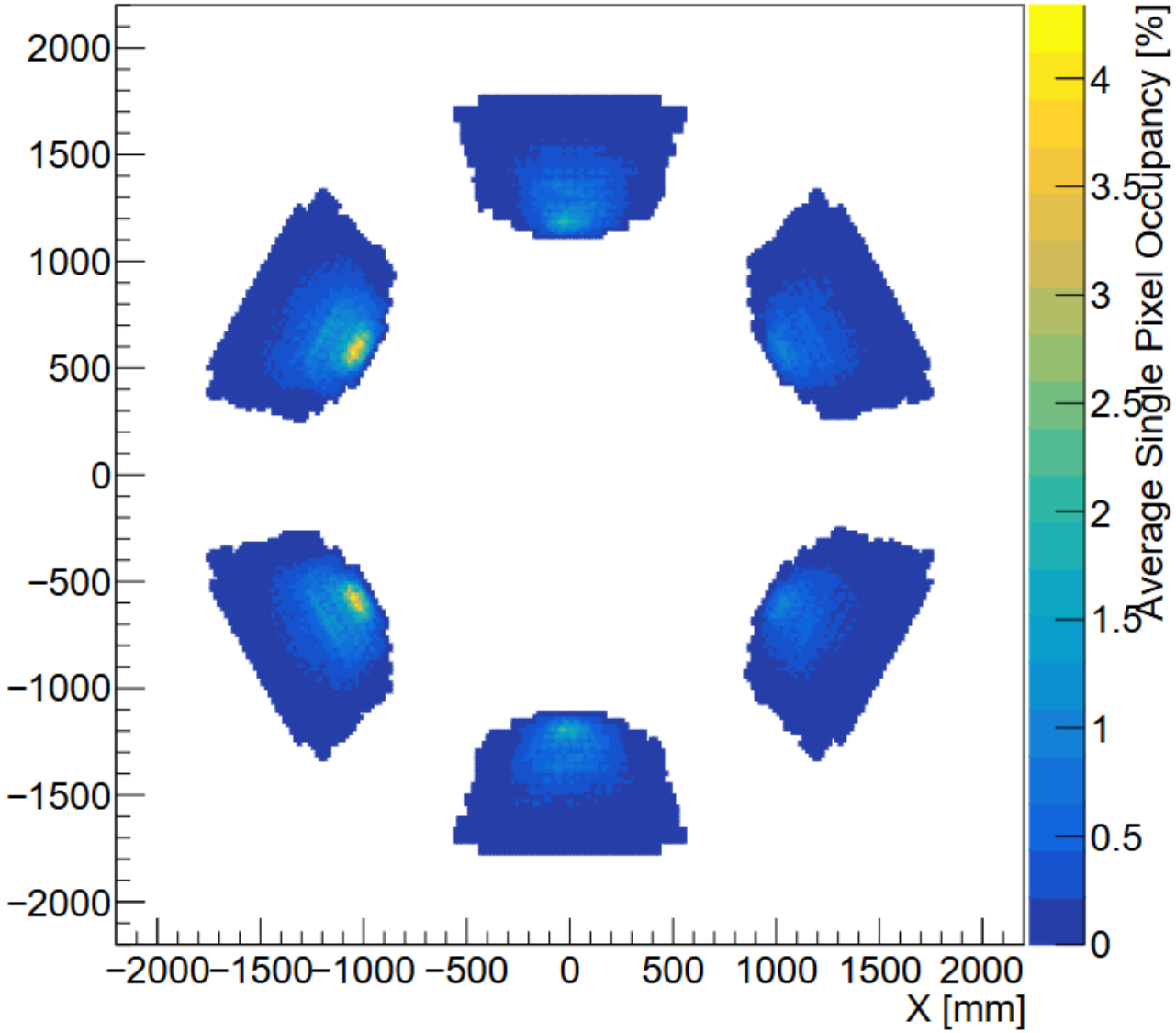
✓ How we select events?

- Take only pions generated to the primary vertex
- Select dRICH acceptance, $1.5 < \eta < 3.5$
- Select momentum range $1\ \mathrm{GeV} < p < 50\ GeV$
- Consider pion that enter into dRICH if they produce at least 1 photon (that we can detect on hits map)
- Consider real pion the one that can produce at least 3 photon.

Local occupancy

Occupancy: $\frac{\sum Hits\ in\ bin}{N.Events \times Pixel\ per\ bin} \times 100$

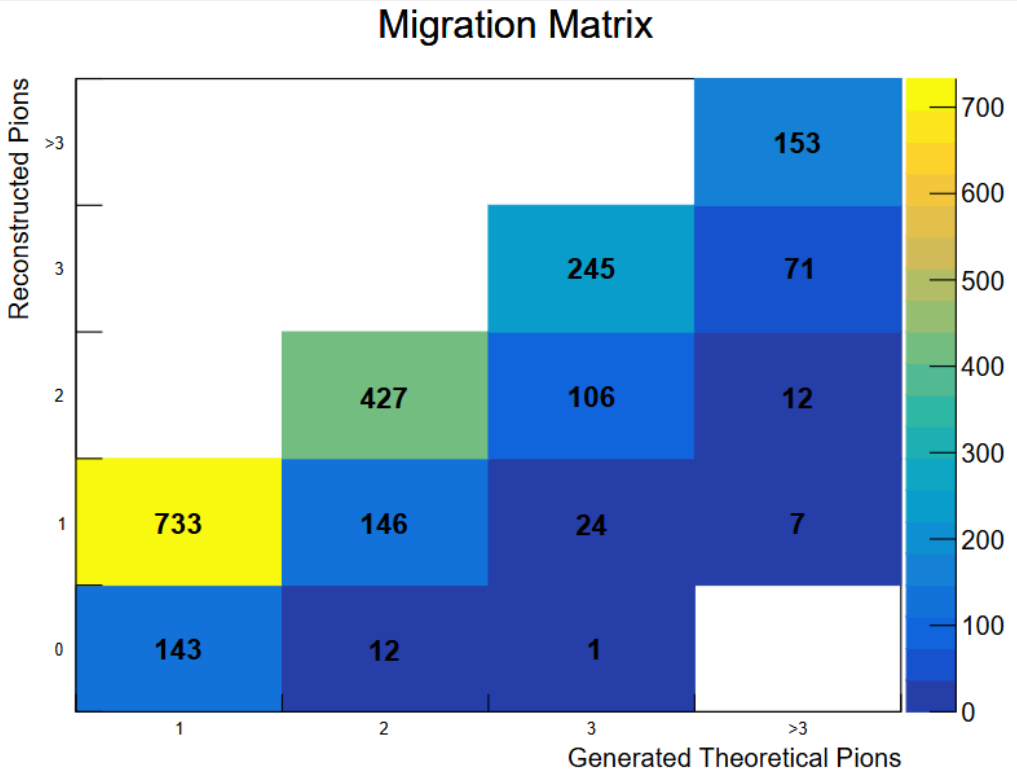
- ✓ Mapping of the average single-pixel hit probability.
- ✓ Strong spatial asymmetry reflecting the DIS collision kinematics (left-side hotspots).
- ✓ Maximum local occupancy safely peaks around **4%**.



luisa.occhiuto@cern.ch

Performance Matrix: Efficiency & Loss

- ✓ **Migration Matrix:** Compares the number of *generated* pions (at vertex) against the detected ones (≥3 hits) per event. Evaluates particle loss.
- ✓ **Acceptance Efficiency:** detected pions / Pions born at the vertex. Identifies geometrical losses (particles missing the detector).
- ✓ **Intrinsic Efficiency:** Detected pions / Pions physically entering the dRICH. Evaluates the pure tracking/PID performance.

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================================================================================
                    FINAL SUMMARY AND EFFICIENCY CALCULATION (PER PARTICLE)
================================================================================
Category   | Events | Born(Vertex)   | Arrived(dRICH)   | Seen(dRICH)   | Acceptance | Intrinsic
--------------------------------------------------------------------------------
1 Pion(s) |    876 |          876 |          738 |          733 |      83.7% |      99.3%
2 Pion(s) |    585 |         1170 |         1004 |         1000 |      85.5% |      99.6%
3 Pion(s) |    376 |         1128 |          971 |          971 |      86.1% |     100.0%
>3 Pions   |    243 |         1088 |          932 |          932 |      85.7% |     100.0%
--------------------------------------------------------------------------------
GLOBAL ACCEPTANCE EFFICIENCY (On pions born at vertex: 4262) :   85.3%
GLOBAL INTRINSIC EFFICIENCY (On physically arrived pions: 3645) :   99.8%
================================================================================
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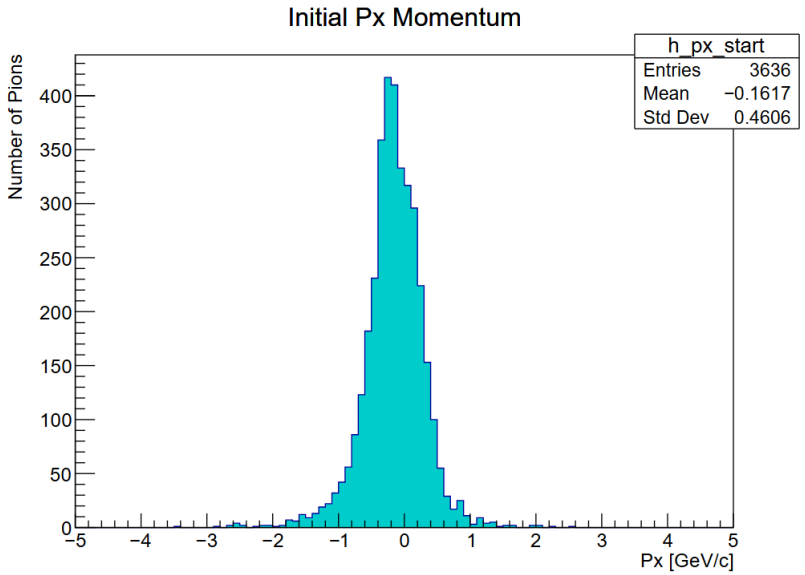
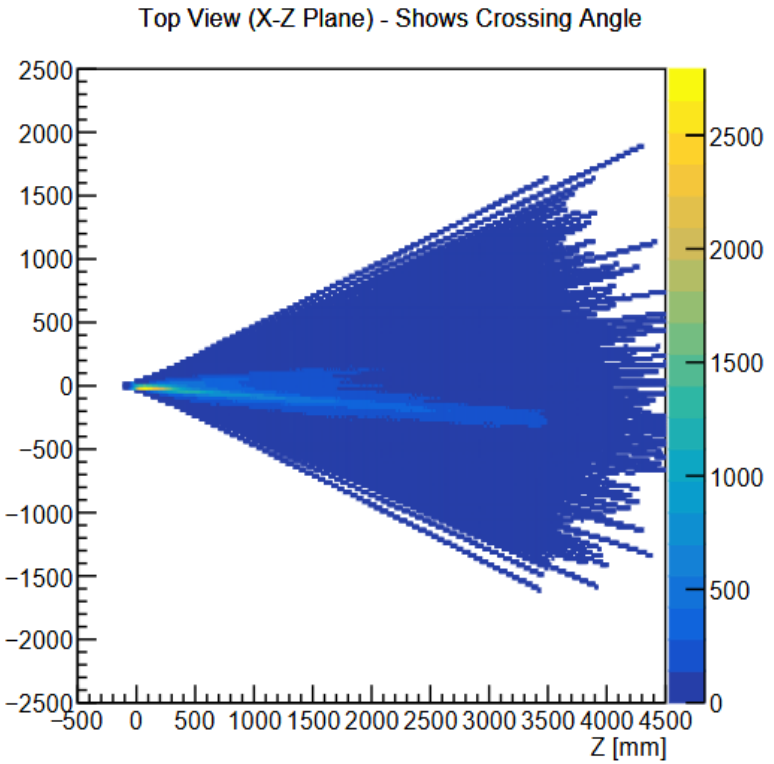
luisa.occhiuto@cern.ch

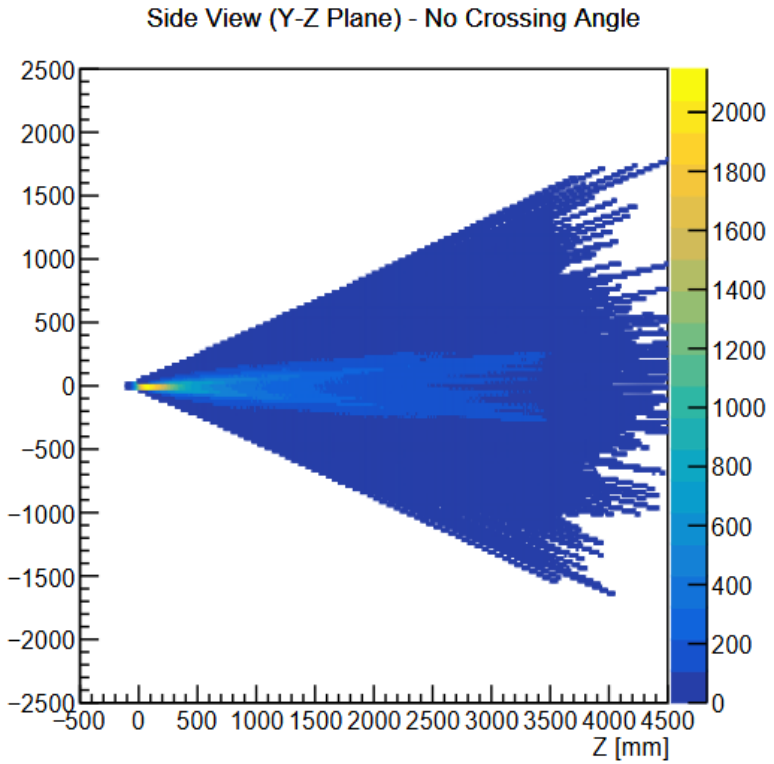
Left side asymmetry studies

- ✓ **Kinematic Shift:** The initial horizontal momentum (P_x) shows a systematic negative mean due to the beam crossing angle.



- ✓ **Horizontal Asymmetry (X-Z):** This momentum shift translates into a macroscopic spatial drift of the particle tracks towards the left side (-X).
- ✓ **Vertical Symmetry (Y-Z):** As expected, the vertical plane is unaffected by the horizontal crossing angle and remains perfectly symmetric.

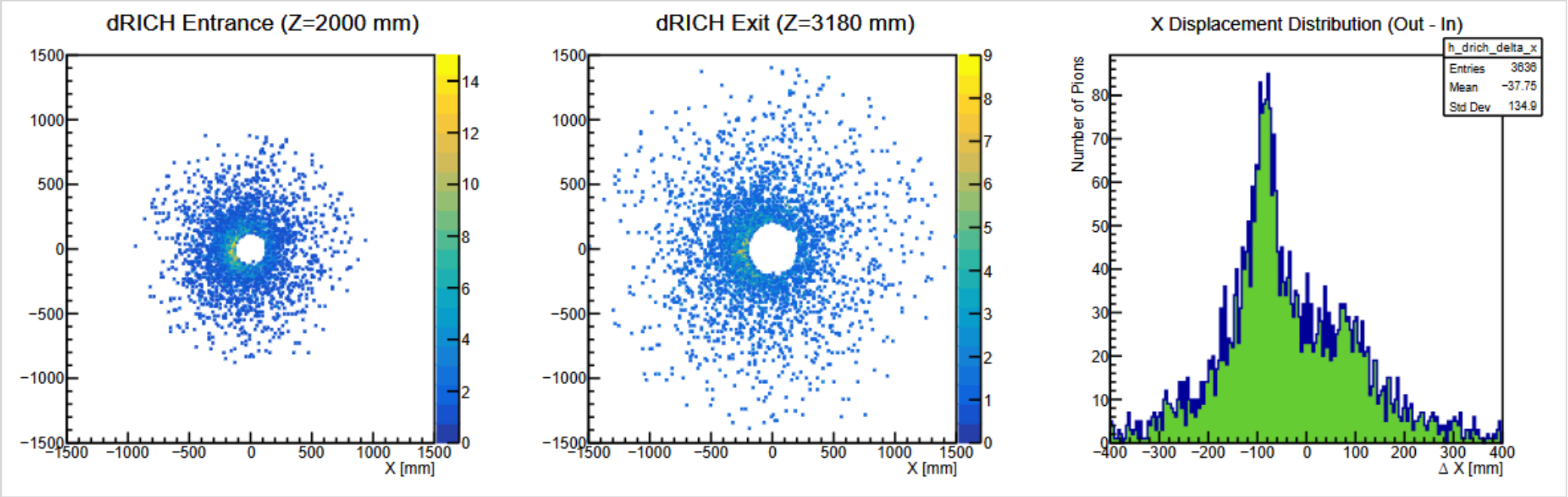




luisa.occhiuto@cern.ch

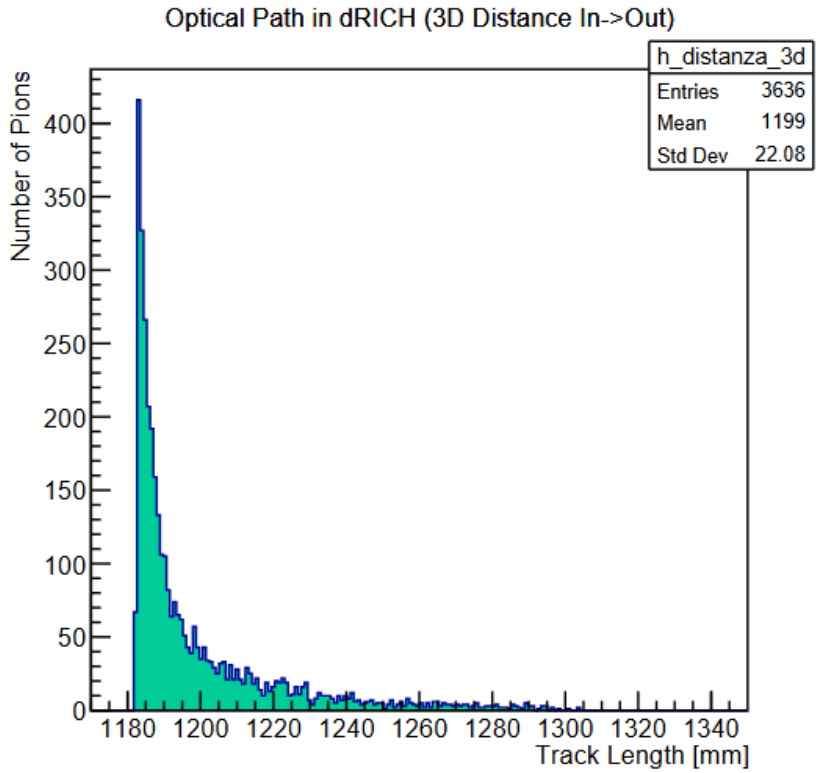
Left side asymmetry studies

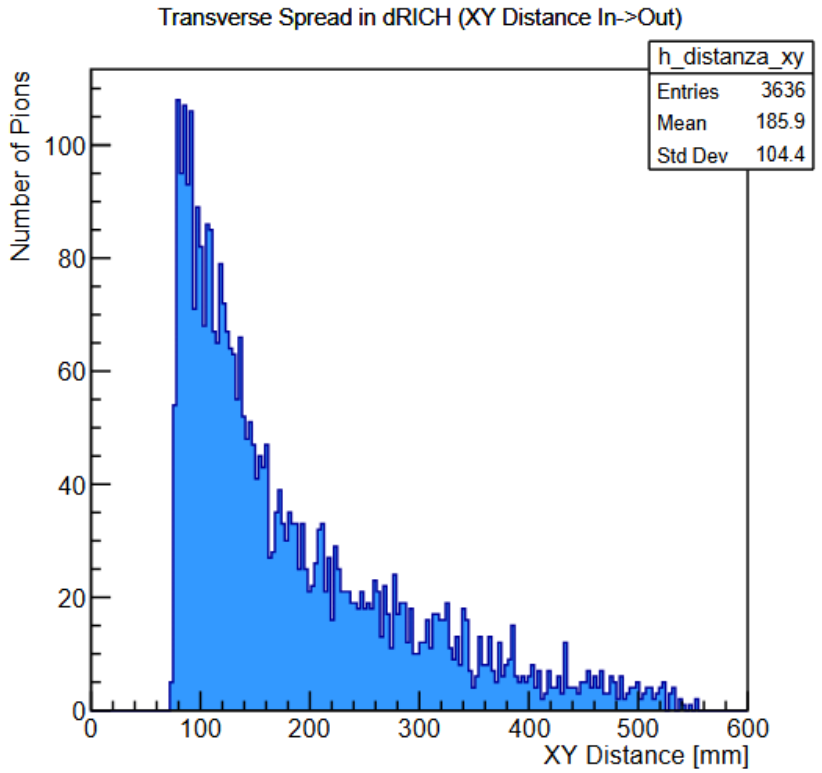
- ✓ **Geometric Projection:** 2D mapping of pion spatial coordinates at the dRICH entrance (Z = 2000 mm) and exit window (Z = 3180 mm).
- ✓ Measurement of the horizontal displacement ΔX along the optical path.
- ✓ The clear negative mean confirms the physical drift towards the -X sectors induced by the beam crossing angle



Left side asymmetry studies

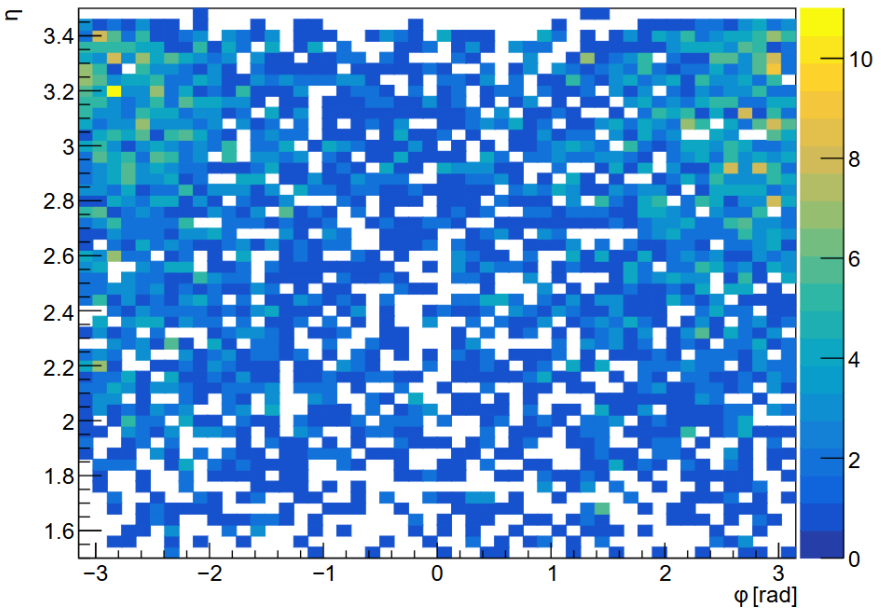
- ✓ **3D Optical Path (Left):** Total distance traveled by pions inside the dRICH gas volume.
  The sharp peak at 1180 mm corresponds to tracks moving perfectly parallel to the beam axis.
- ✓ **XY Spread (right):** Quantifies the radial divergence of the tracks from entrance to exit

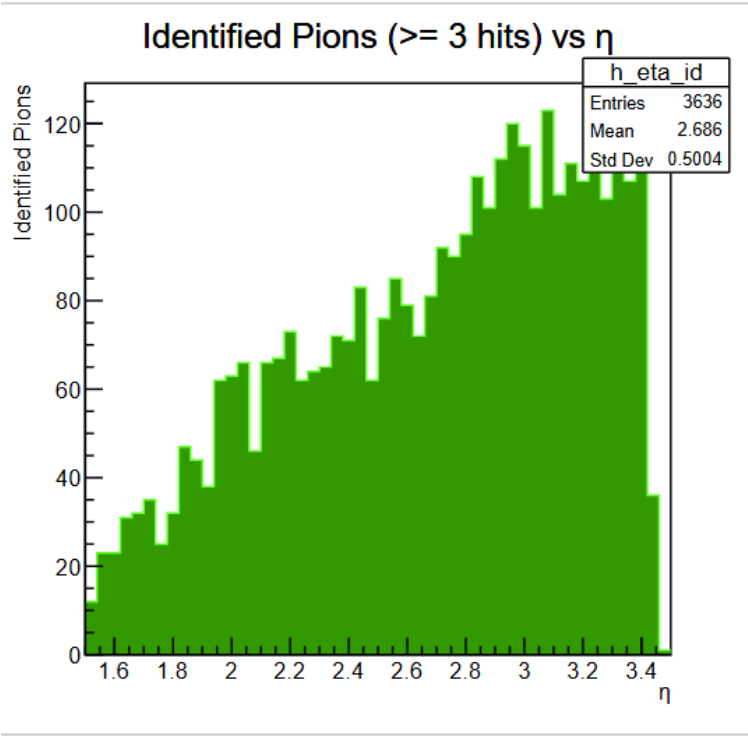


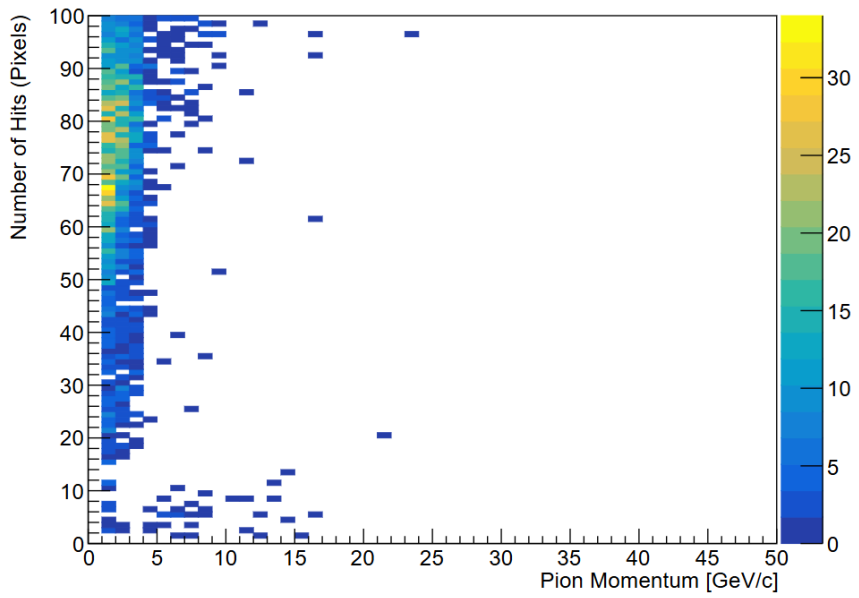


Eta vs phi maps

- ✓ **Angular Coverage (Left):** Azimuthal ϕ distribution is roughly uniform
- ✓ **Forward Kinematics (Center):** Pion density strongly peaks at higher pseudorapidity
- ✓ **Detector Response (Right):** Correlation between pion momentum and the number of generated hits (Cherenkov photons).



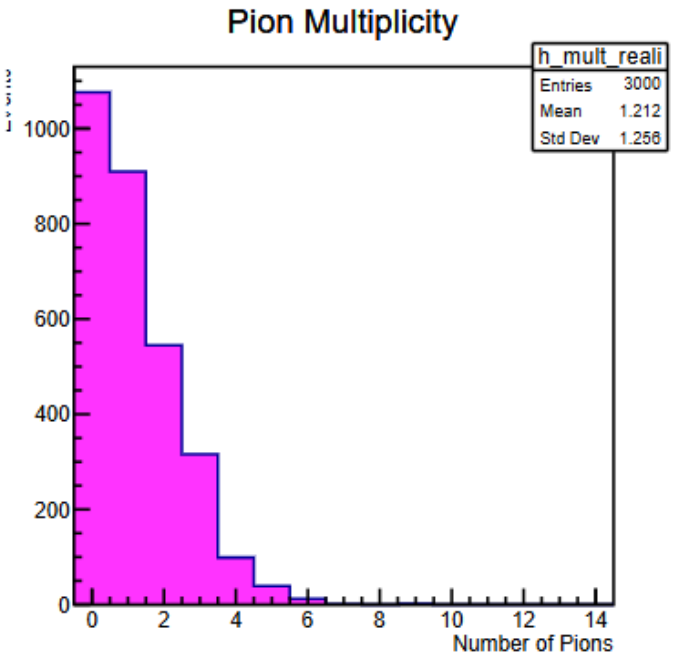


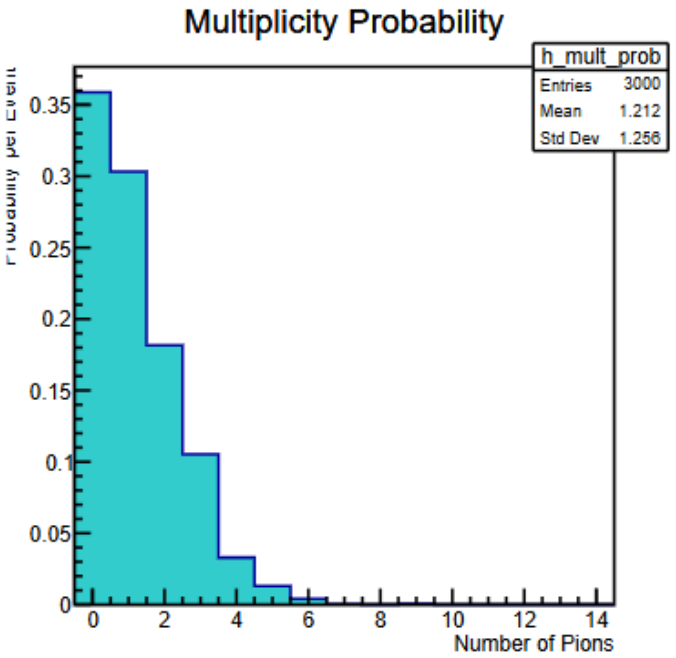


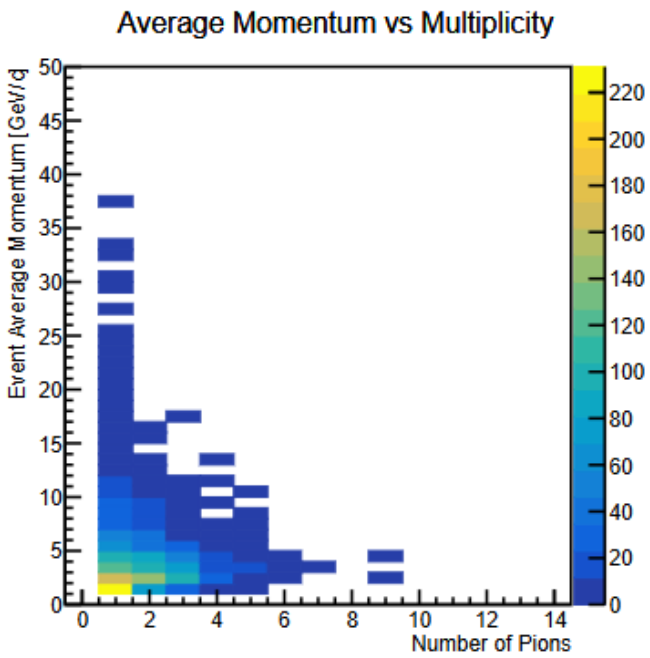
luisa.occhiuto@cern.ch

Multiplicities studies

- ✓ **Pion Multiplicity (Left):** Absolute number of events vs the number of detected primary pions. Zero and single-pion events are the most frequent topologies.
- ✓ **Multiplicity Probability (Center):** The same distribution normalized by the total number of events.
- ✓ **Average Momentum vs Multiplicity (Right):** Reveals a strong inverse correlation. Events with higher pion multiplicity exhibit a significantly lower average momentum per particle

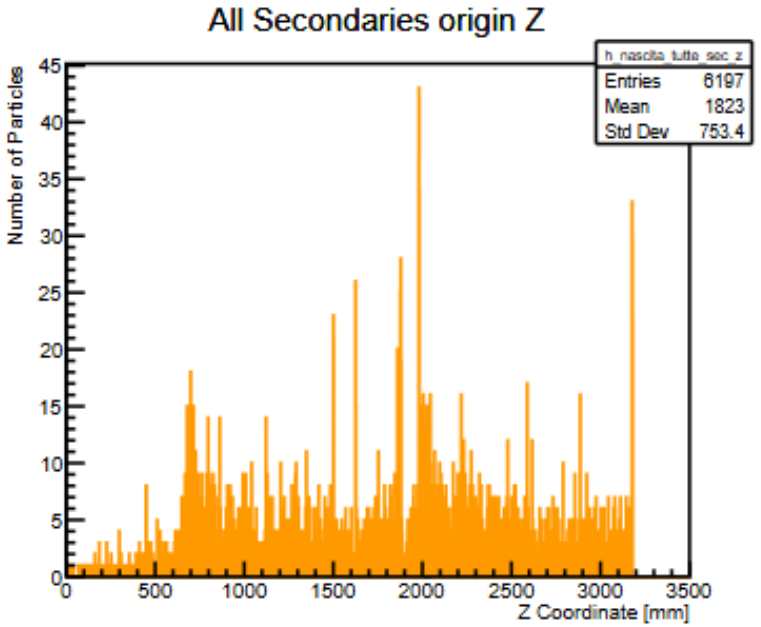


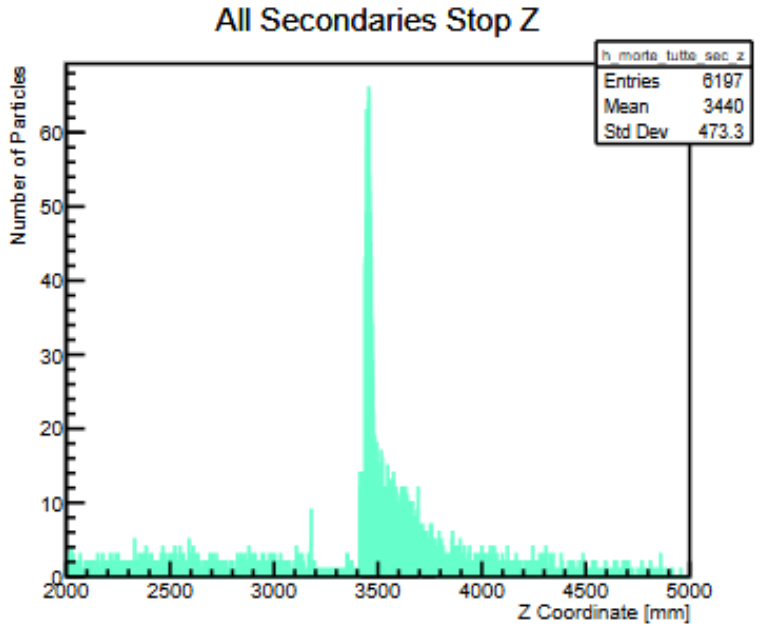


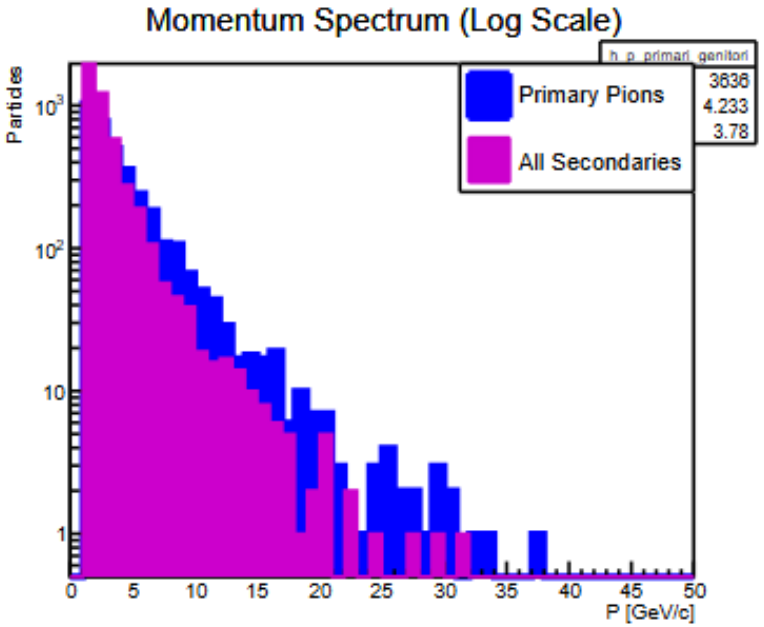


Secondary particles studies

- ✓ **Spatial origin:** secondary particles origin also before the dRICH entrance
- ✓ **Stopping point:** most secondary particles do not stop inside dRICH volume
- ✓ **Energy profile:** momentum distribution of primary and secondary particles



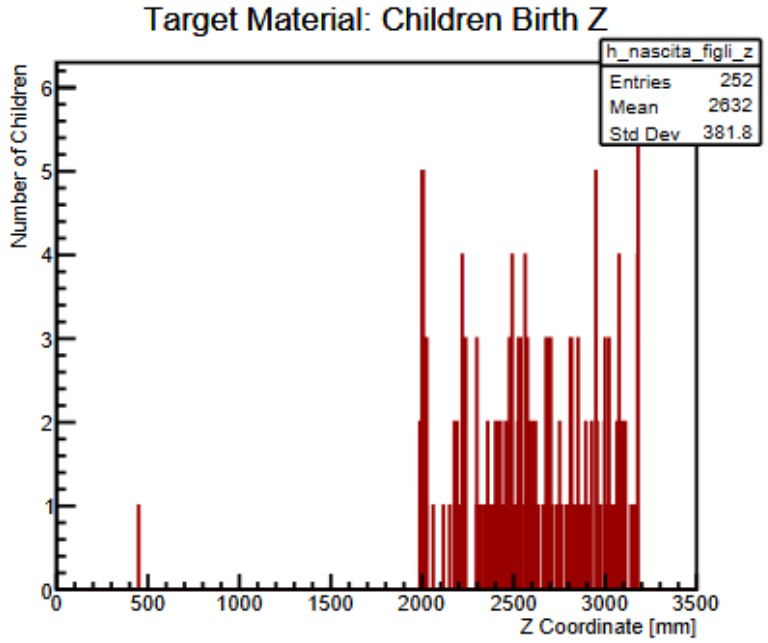


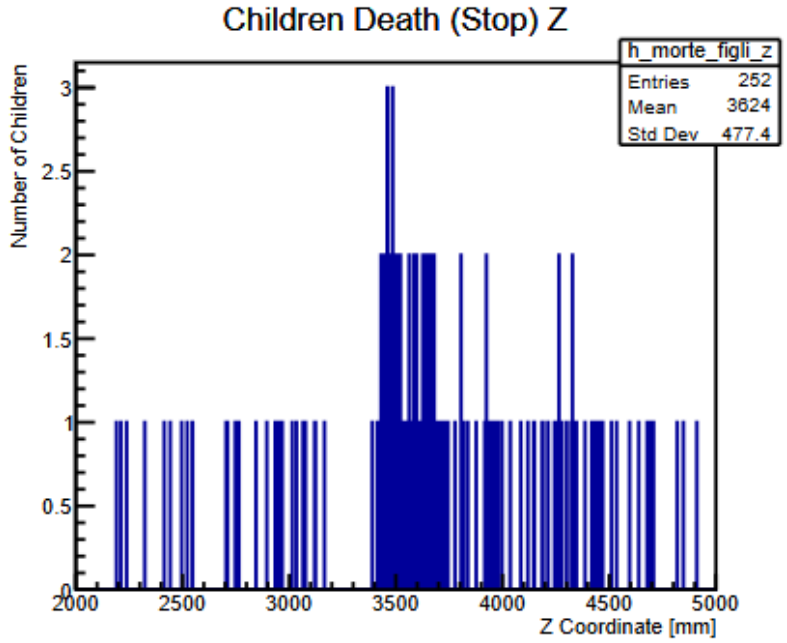


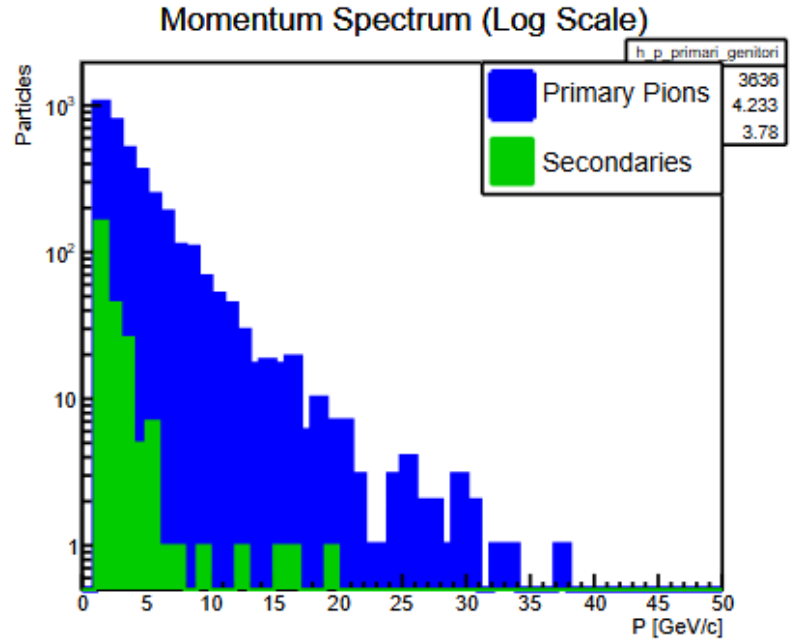
Secondary particles studies

The same strategy is applied for children of the primary pions

- ✓ **Spatial origin:** interactions are mainly localized at the dRICH entrance (aerogel/window)
- ✓ **Stopping point:** most secondary particles do not stop inside the gas but exit the dRICH volume
- ✓ **Energy profile:** generated secondaries exhibit a very soft momentum spectrum compared to parent pions

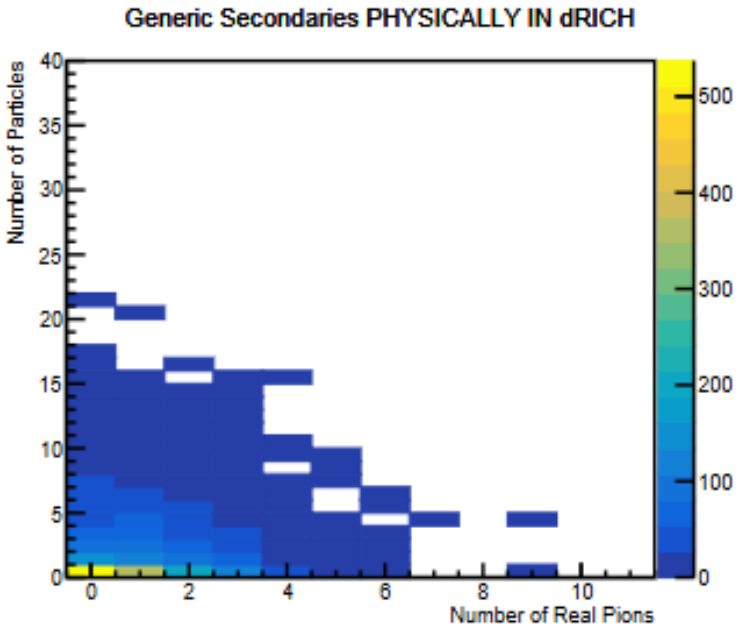


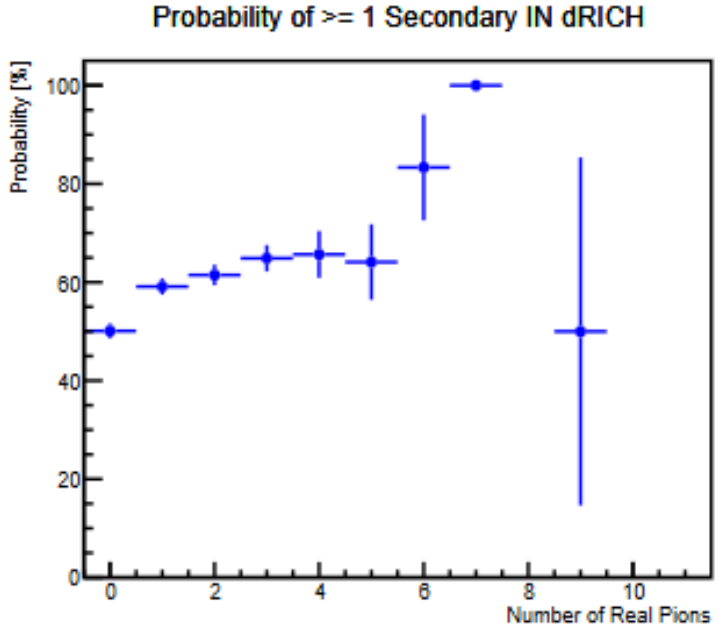


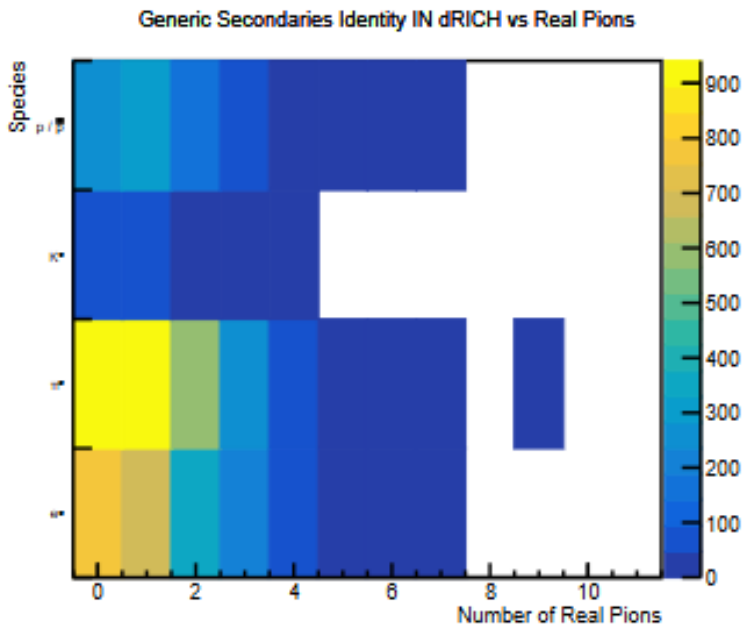


Secondary particles studies

- ✓ Characterization of generic secondary particles inside the dRICH volume.
- ✓ **Baseline background:** secondary particles are present even in events without primary pions.
- ✓ **Background composition:** Secondary yield dominated by pions, electrons and positrons

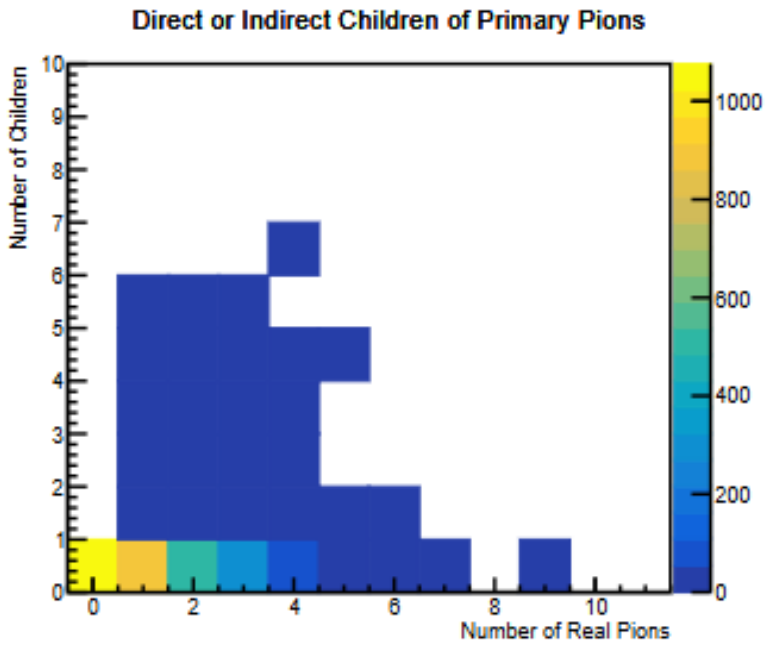


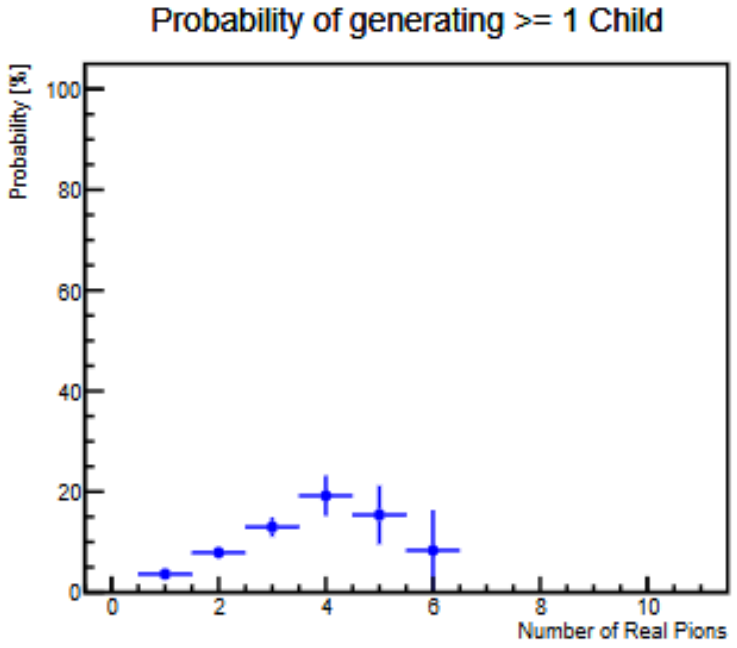


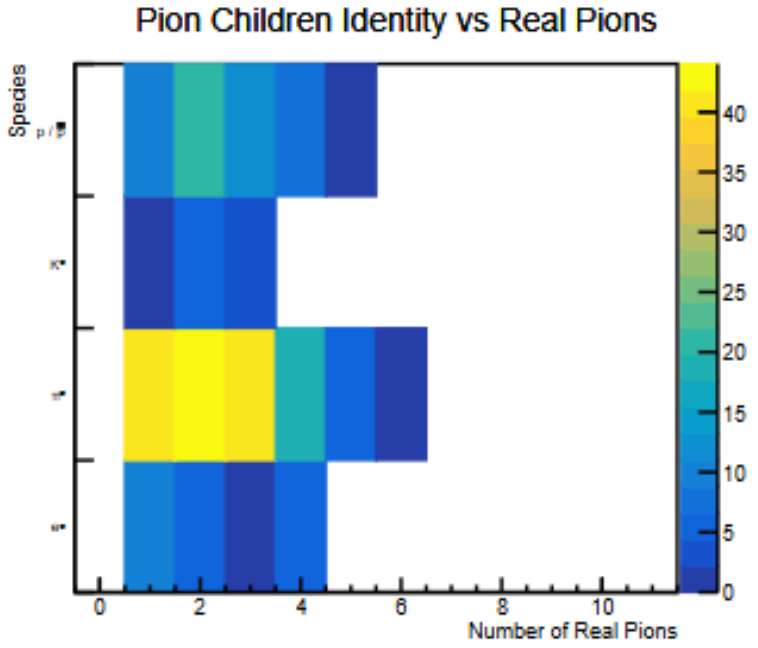


Secondary particles studies: Primary pion's children studies

- ✓ The same strategy is applied to children of the primary pions
- ✓ **Minimal generation of secondary particles** from primary pions.
- ✓ Low probability of generating daughter particles
- ✓ Secondary yield dominated by pions ⍰ Hadronic inelastic scattering







THANKS!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