dRICH Simulation Meeting : 23/07/2026

Understanding the time distribution of dRICH Hits

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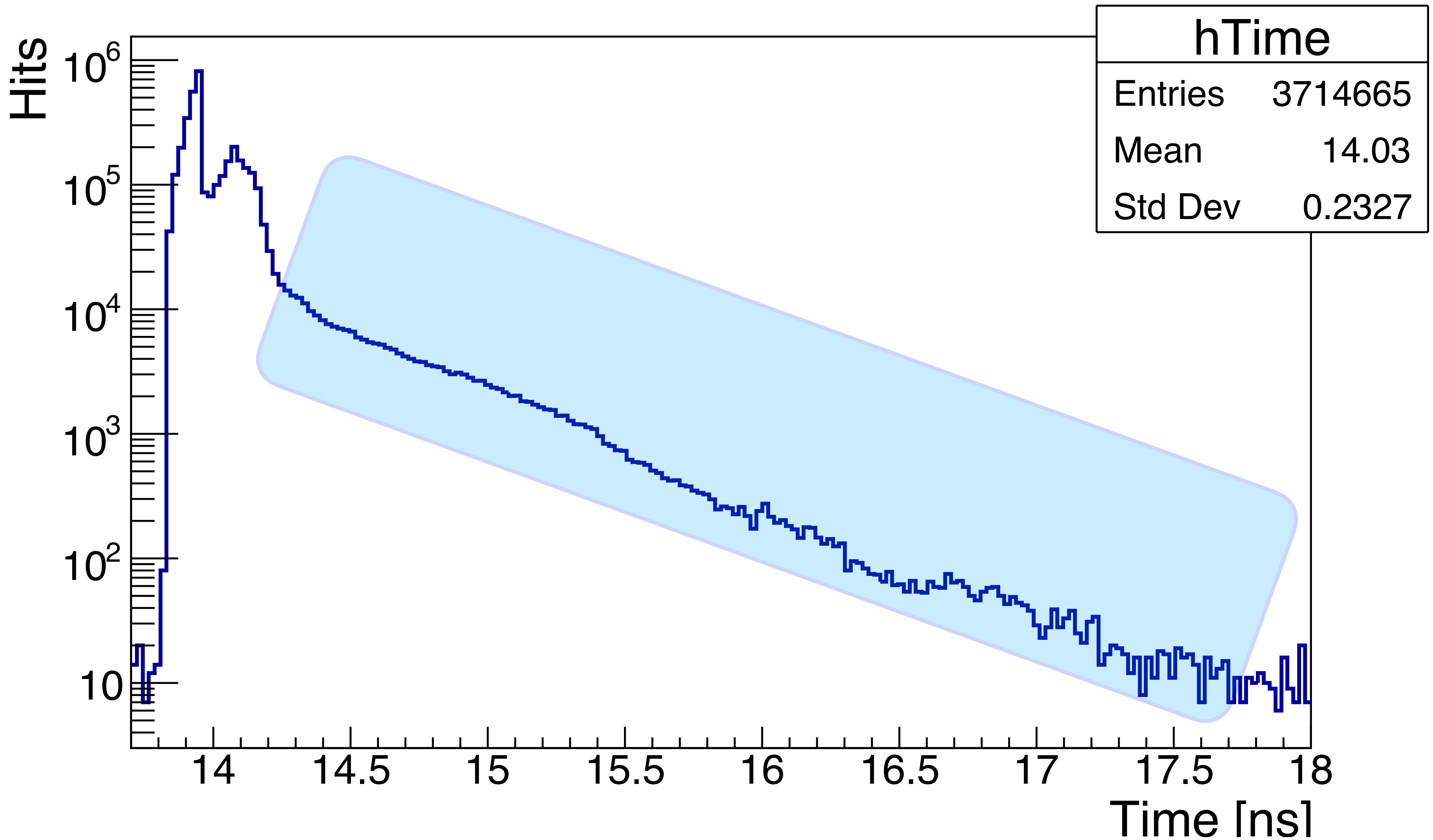
INFN Trieste

Beyond the Prompt Peaks: What Creates the Timing Tail?

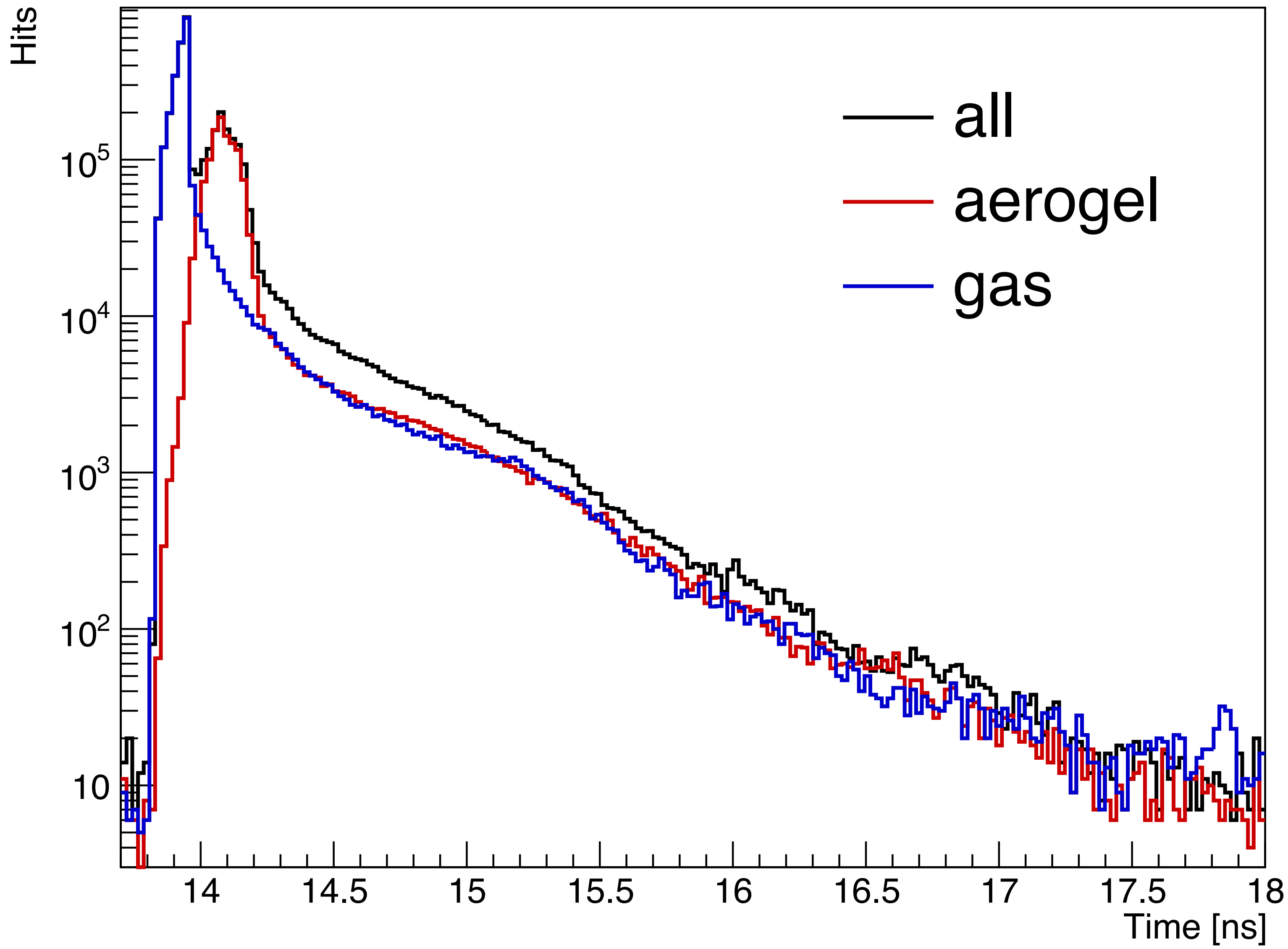
- The dRICH hit-time distribution contains a narrow prompt population followed by component extending to later times.



Bottom question:

Is the tail caused by photon transport, event generation, or secondary particles produced in detector material?

The Tail Is Not Exclusive to One Radiator



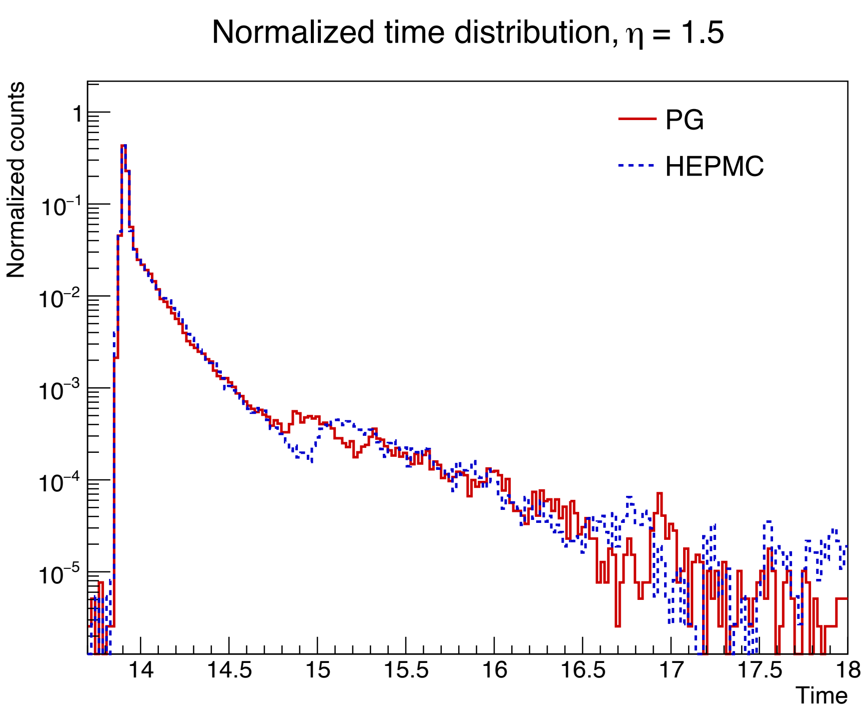
* legends' meaning :"all" means **aerogel and gas**;
:"gas" means **gas and vacuum**;
:"aerogel" means **vacuum and aerogel**;

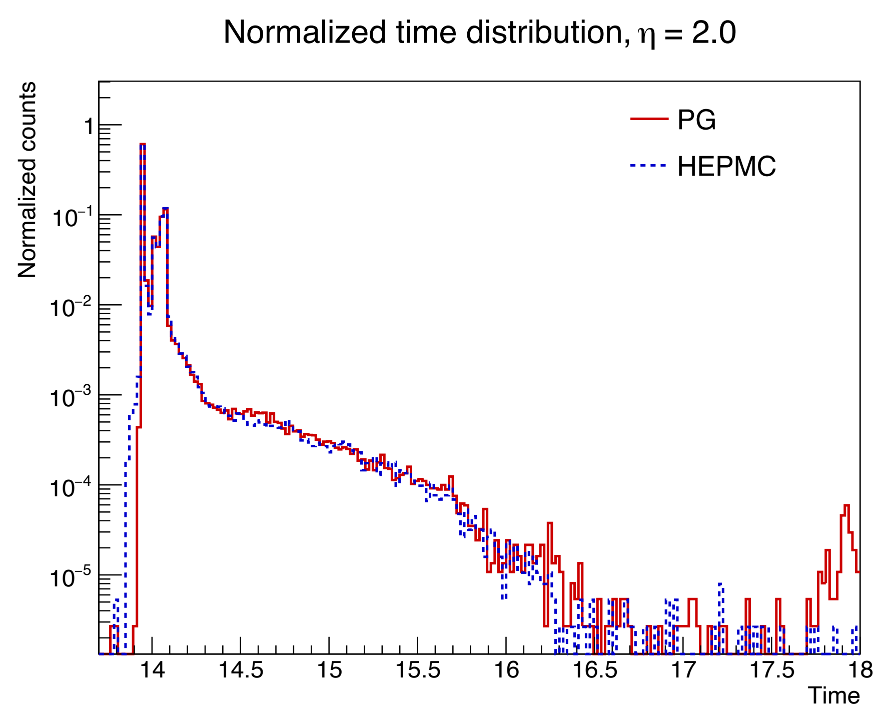
✤ Late hits remain when photons are generated separately in the aerogel and gas configurations.

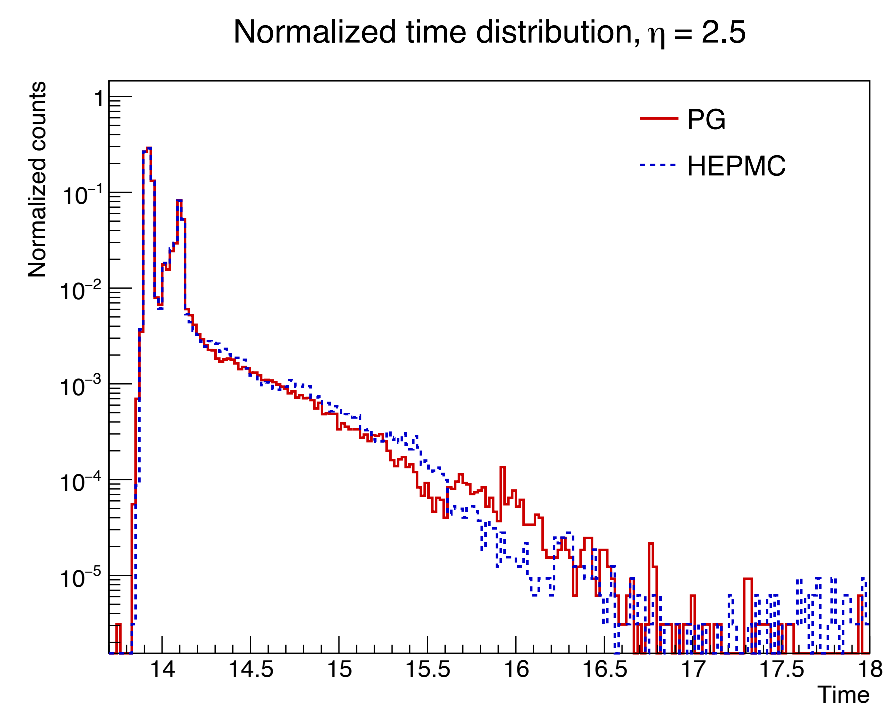
✤ Both radiator configurations contribute to the late-time region; neither radiator alone explains the complete tail.

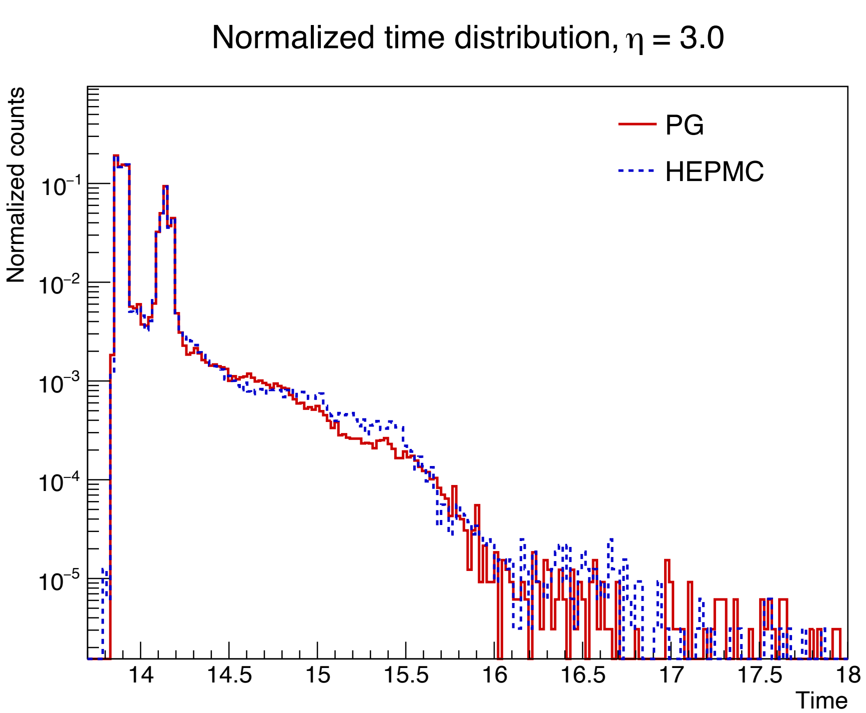
Different Event Inputs, Consistent Timing

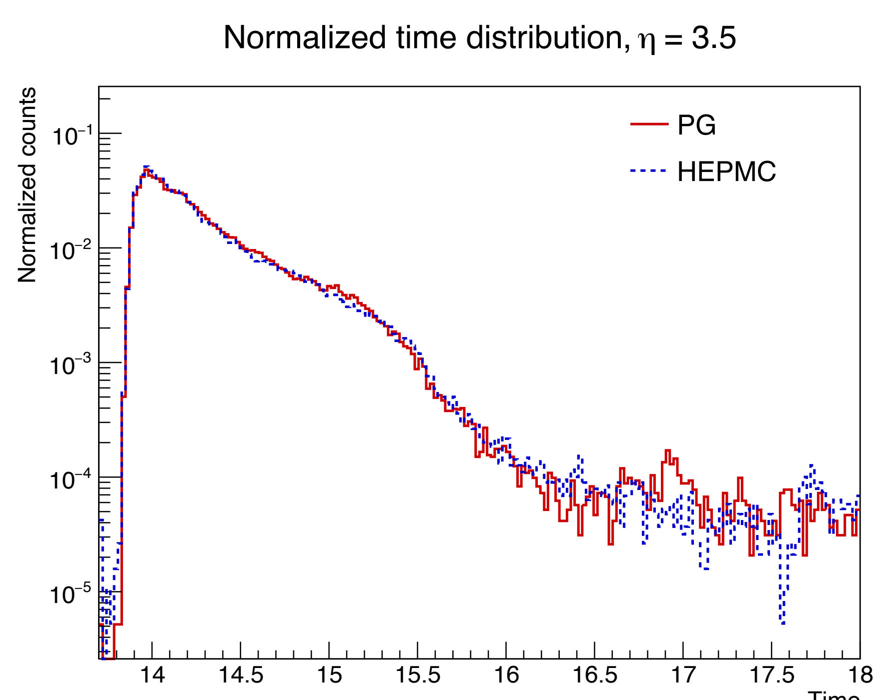
- Normalized time distribution for PION generated from *Particle Gun (PG) & HepMC* for different η (no. of events, p, ϕ are same) **Simulation : full detector setup**









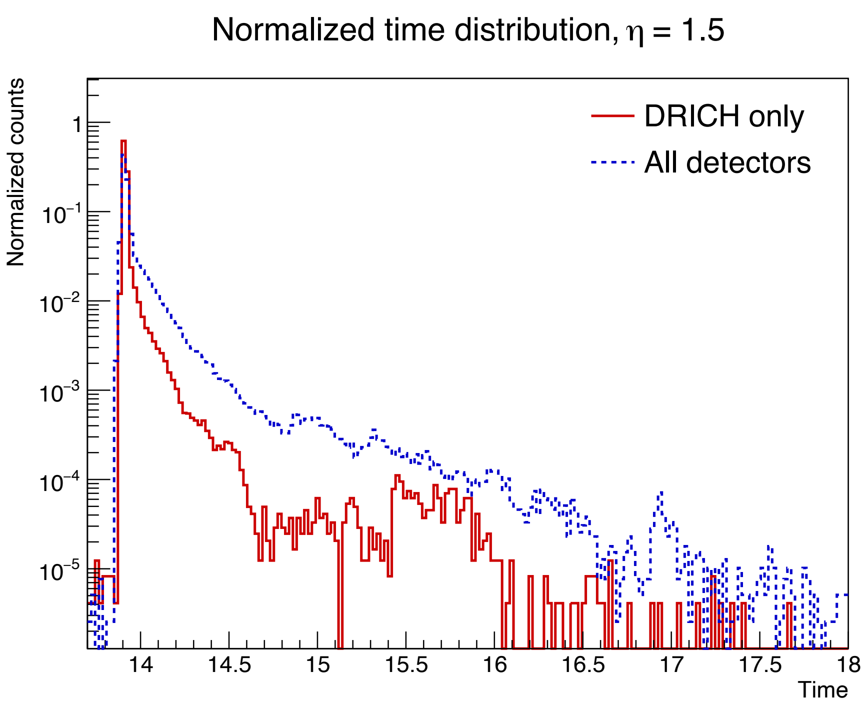


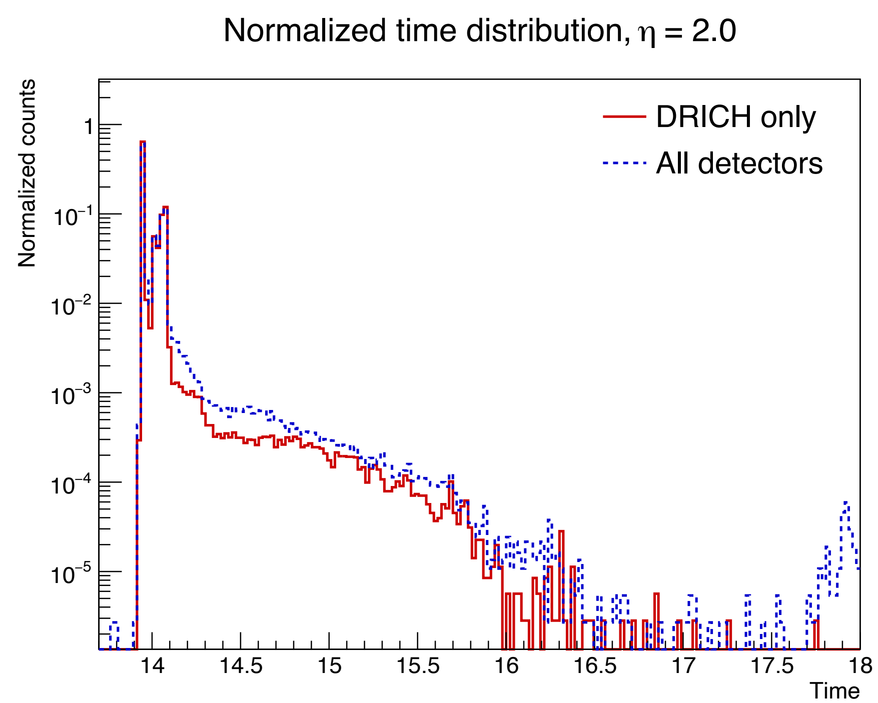
- For matched pion kinematics and identical detector geometry, PG and HepMC samples produce compatible hit-time distributions across the studied η range.

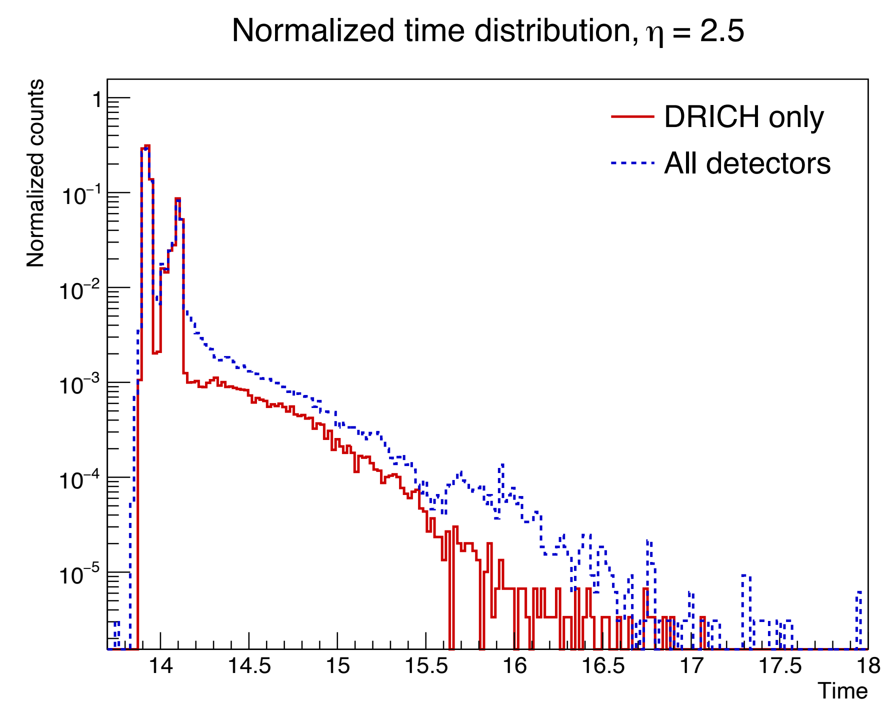
- The late component is not primarily an artifact of the event-input format.

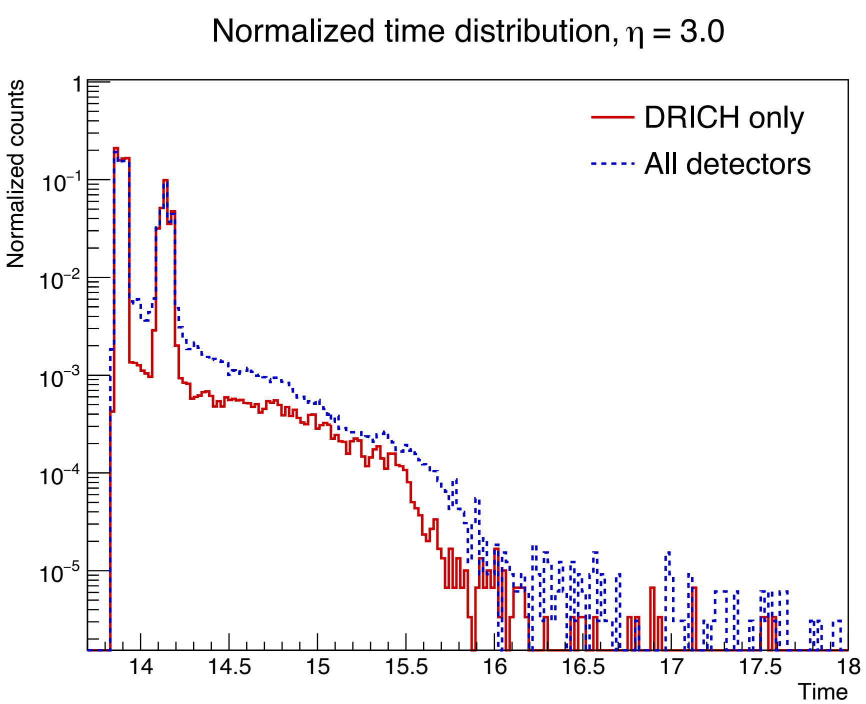
The Full Detector Amplifies the Late Population

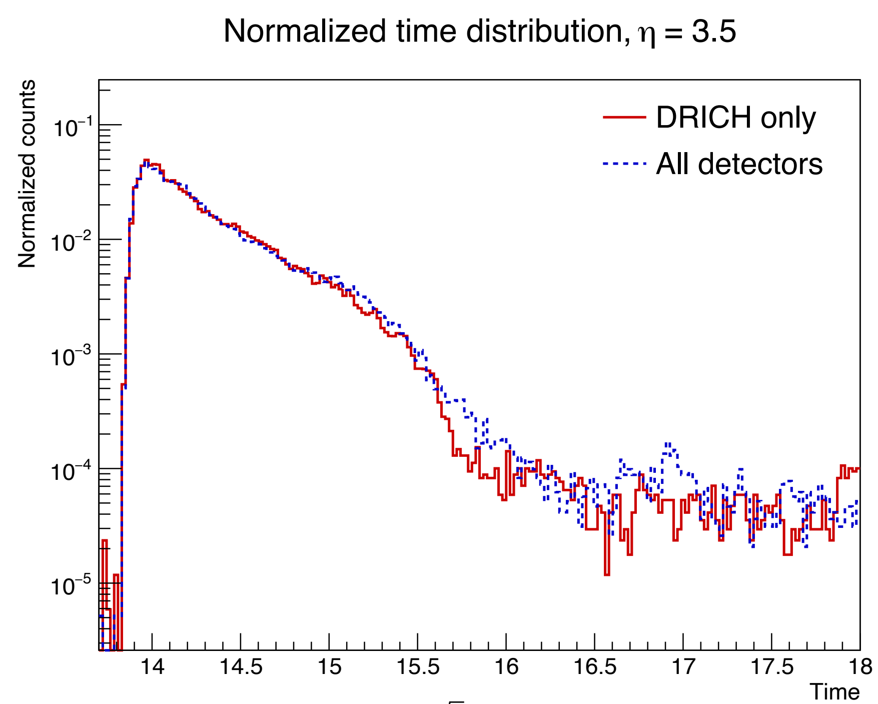
- Normalized time distribution for PION generated from *[Particle Gun for dRICH only & full detector](#)* sim setup for different η (no. of events, p, ϕ are same)



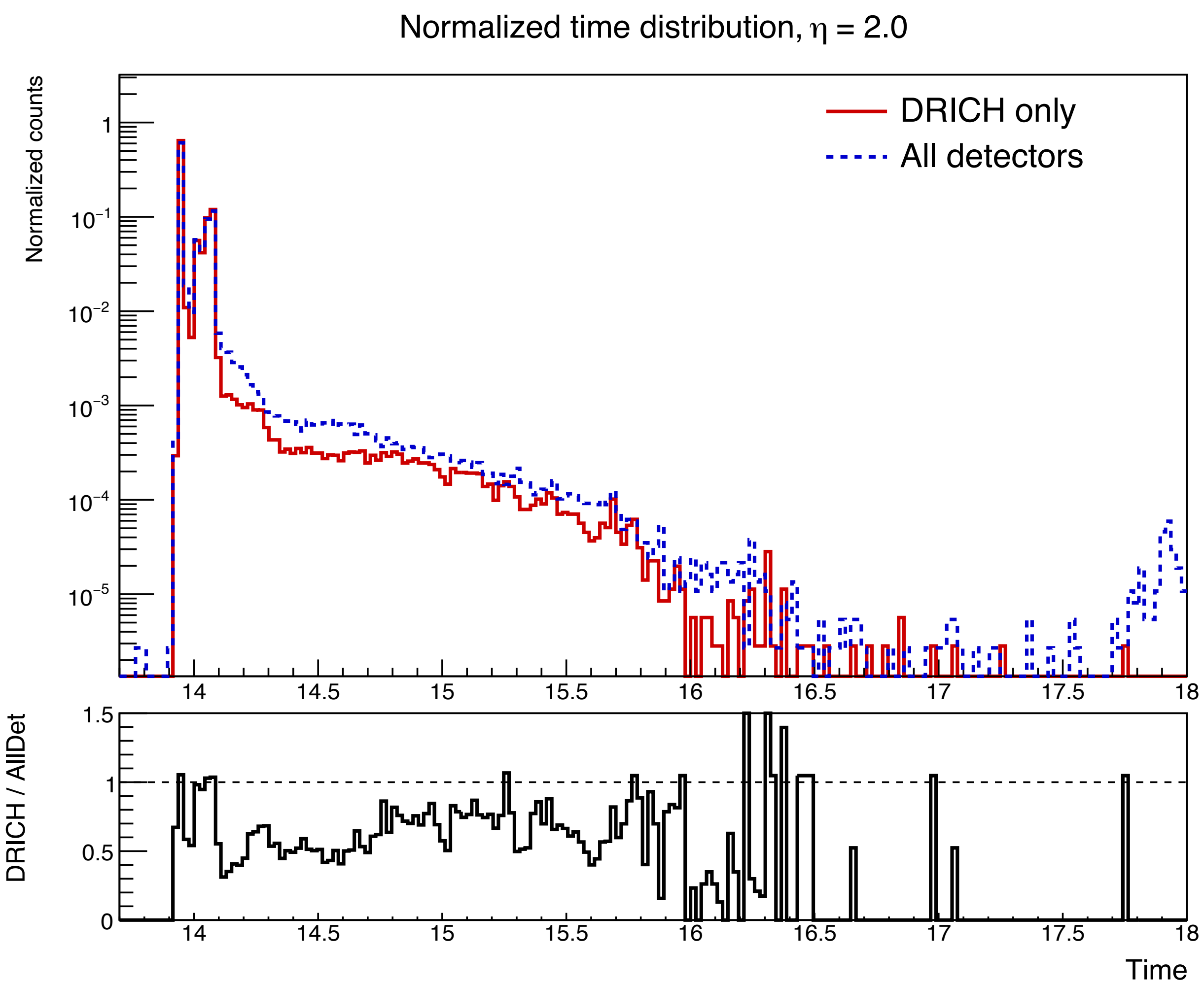


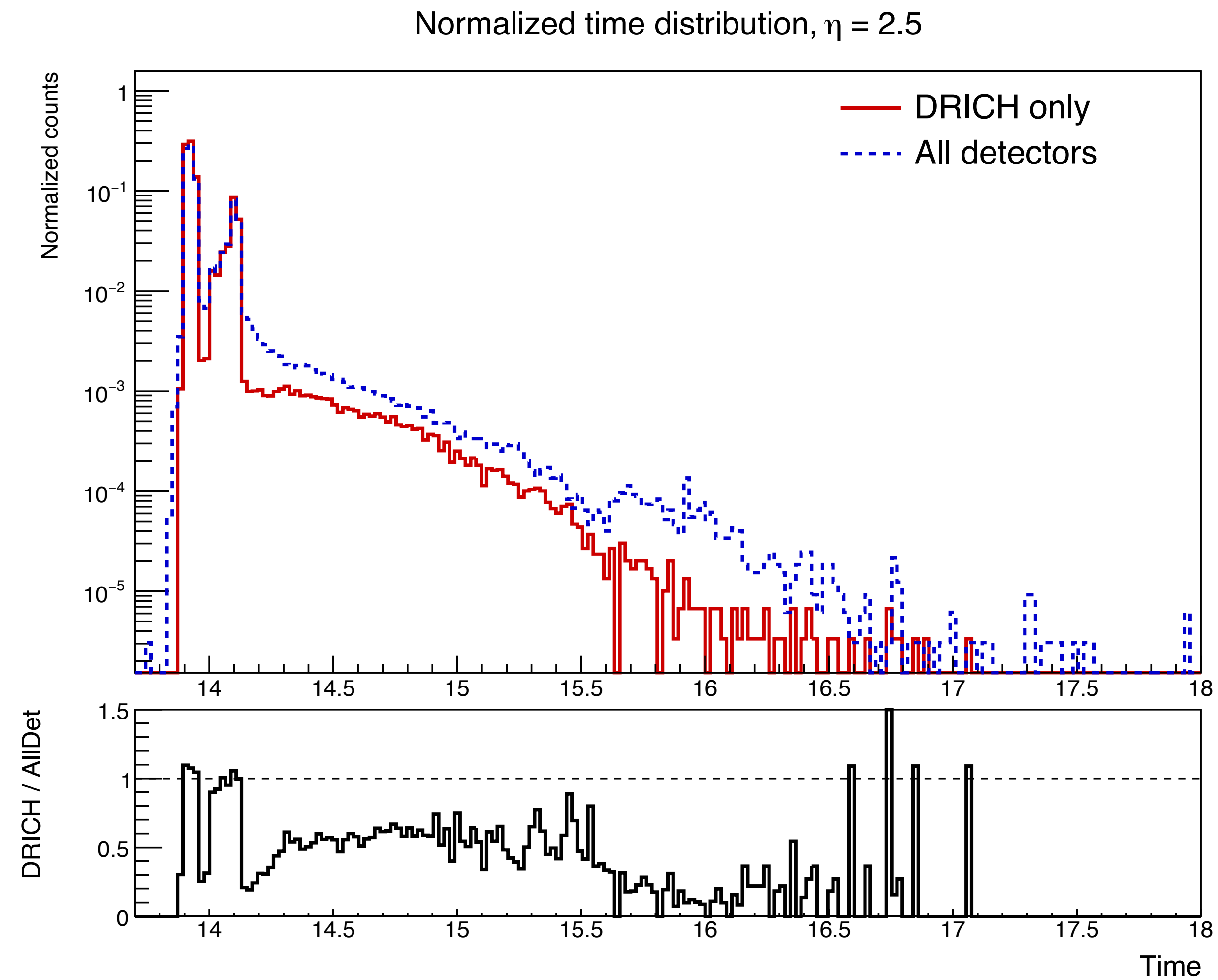


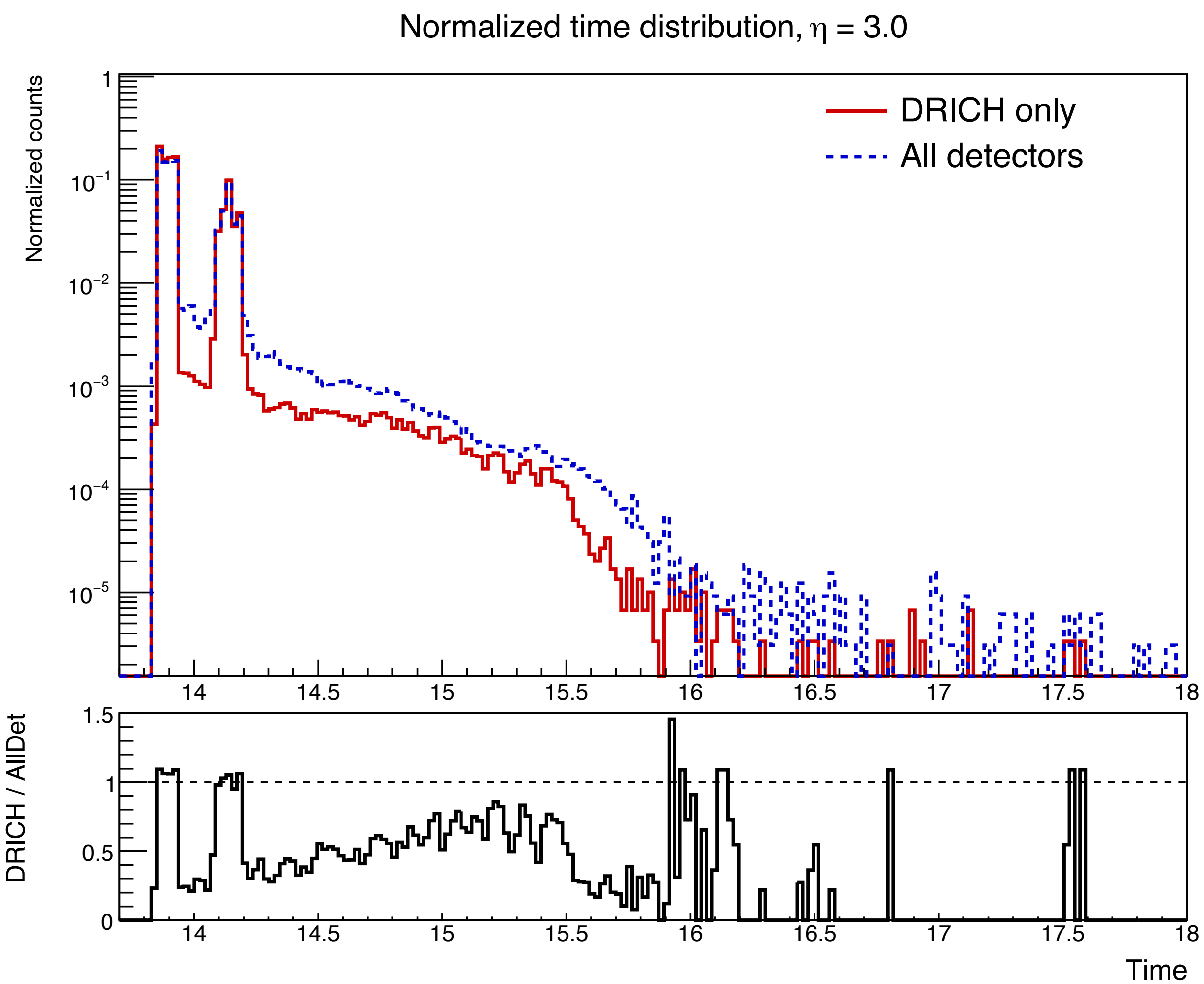




- Relative to the standalone dRICH geometry, the full-detector simulation produces a larger late-time photon-hit population.
- Material outside the standalone dRICH geometry influences the timing distribution.

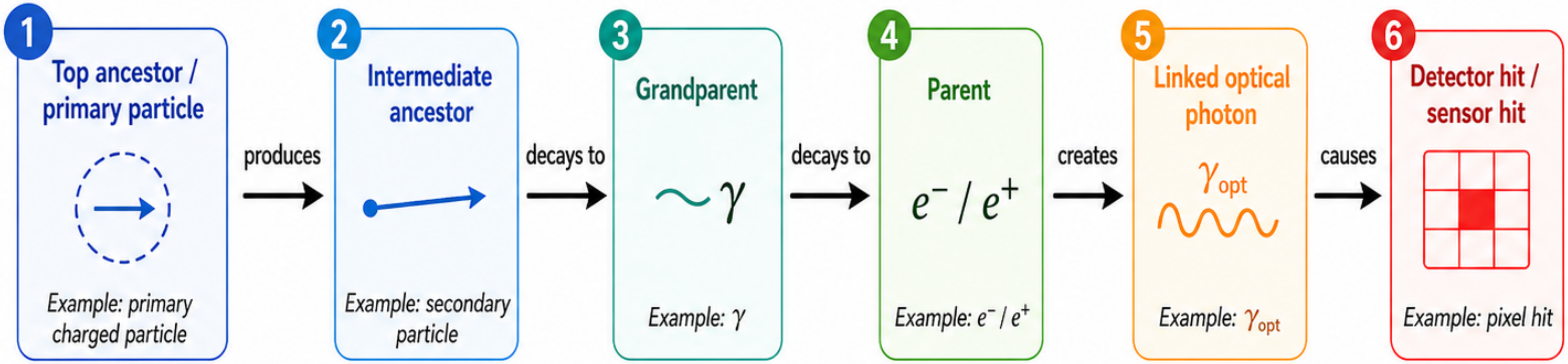






- Ratio panels show that the largest difference between the two configurations occurs beyond the prompt timing region.
- Full-detector material likely increases secondary production.
- Therefore, we study the **parent**, **grandparent**, and **production vertex** of photons linked to dRICH hits.

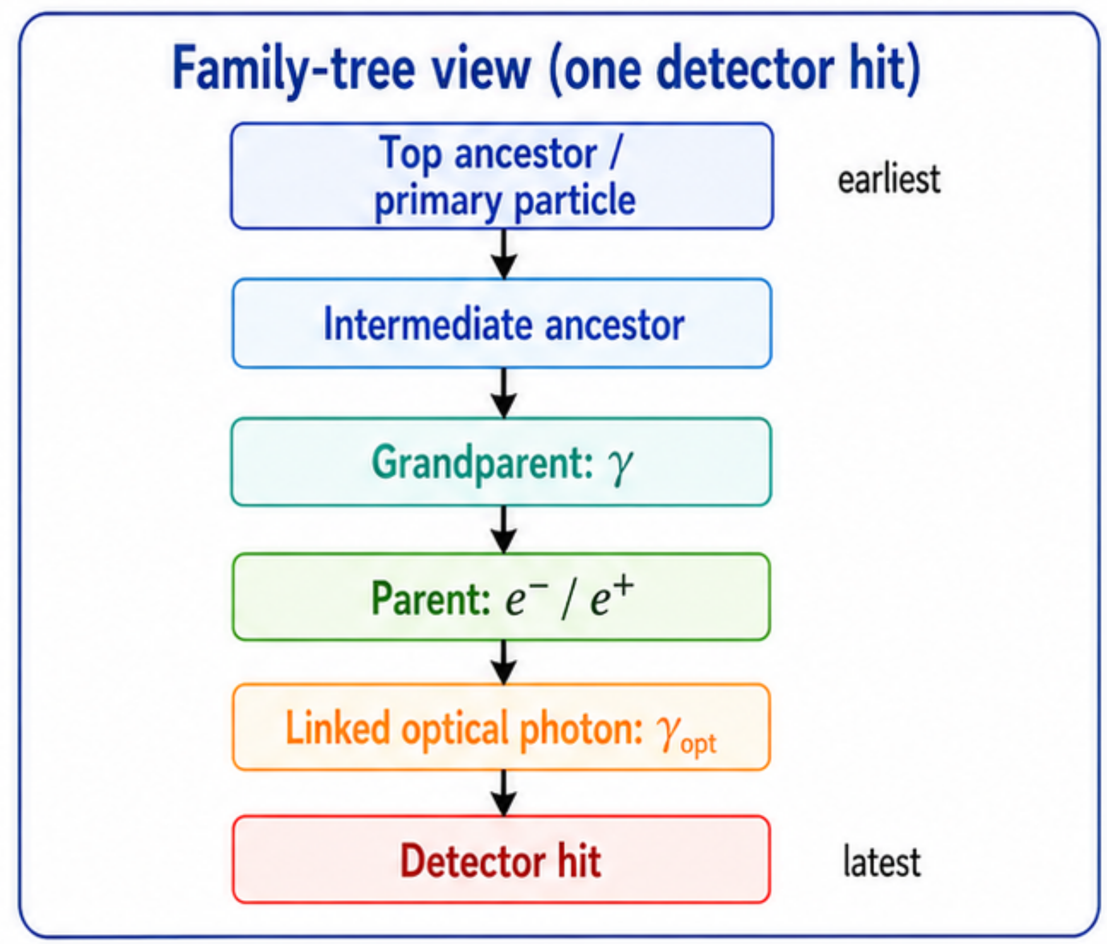
Understanding Parent, Grandparent, and Ancestor Relations



What these terms mean

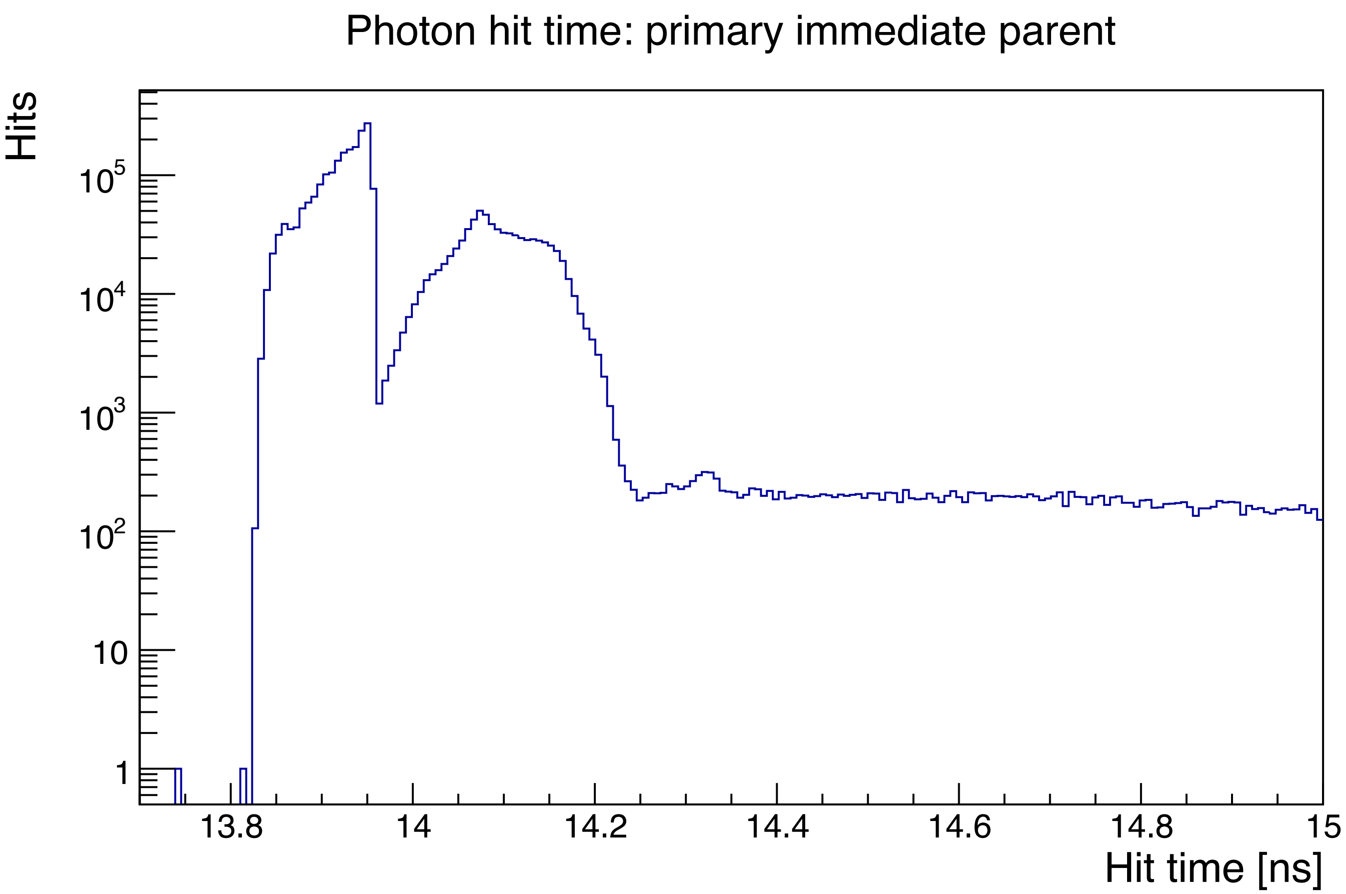
- **Parent:** the particle directly responsible for the current particle.
- **Grandparent:** the parent of the parent.
- **Ancestor / top ancestor:** an earlier particle upstream in the chain.

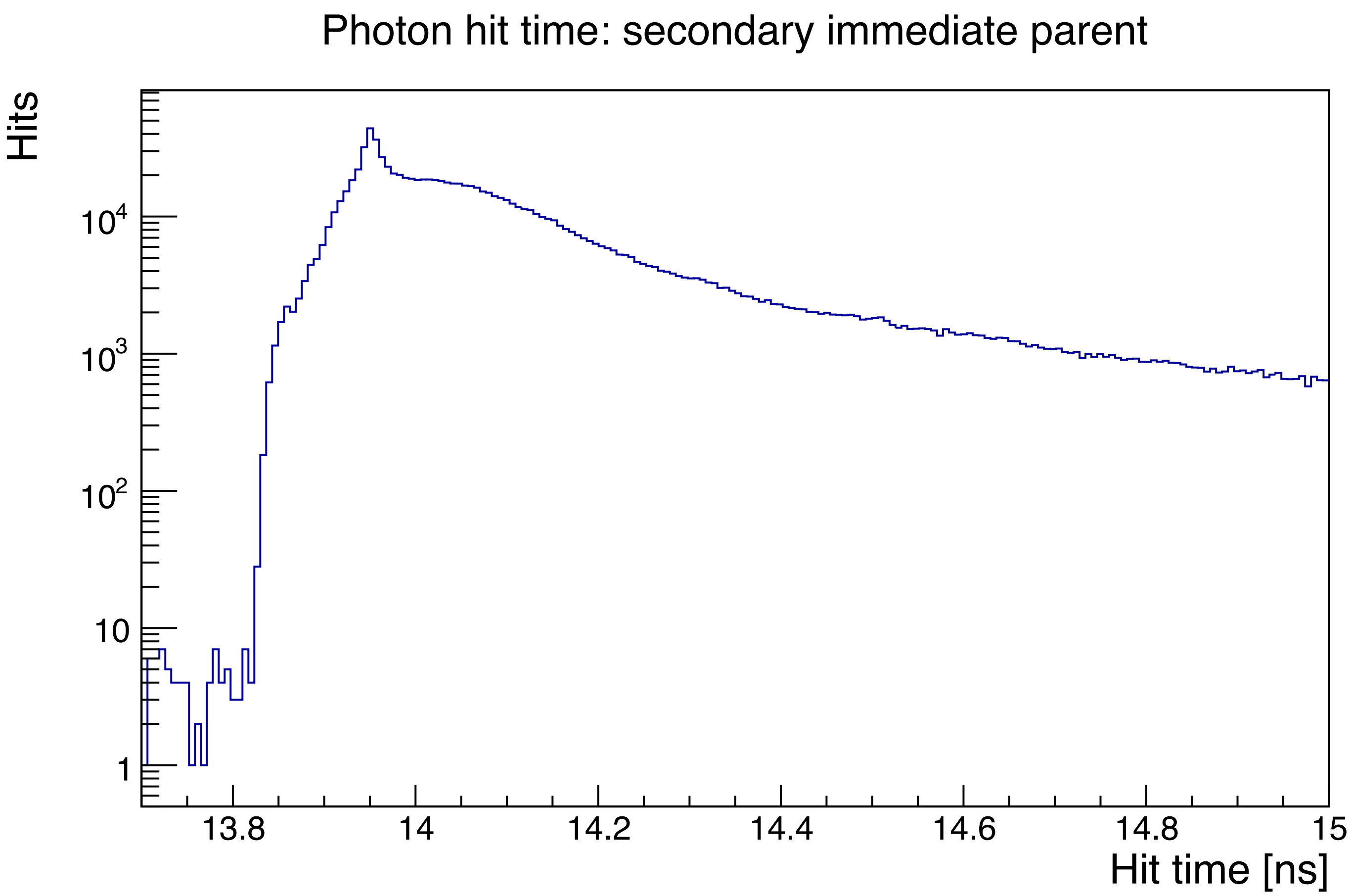
For a detector hit, the linked optical photon is the direct particle associated with the hit.



*Co-created with ChatGPT

TAIL : Primary vs Secondary parent contribution ?





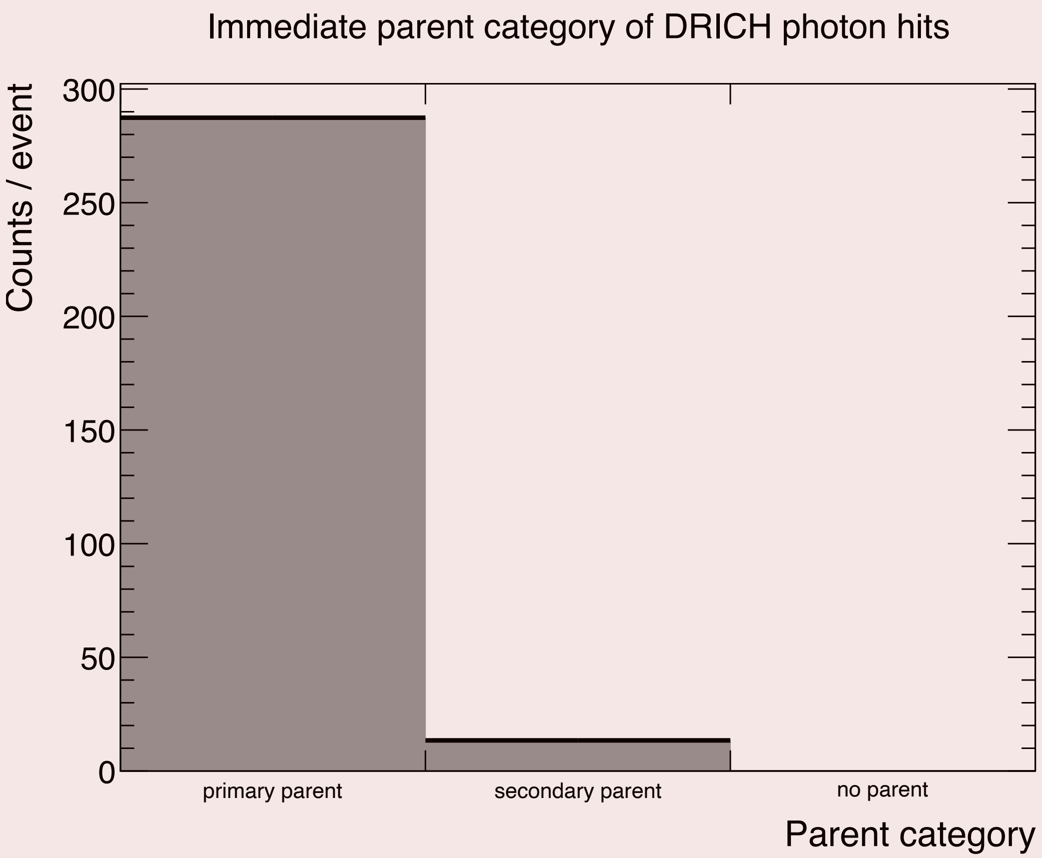
◉ Photon-hits time distribution: whose **Parent is Primary** particle.

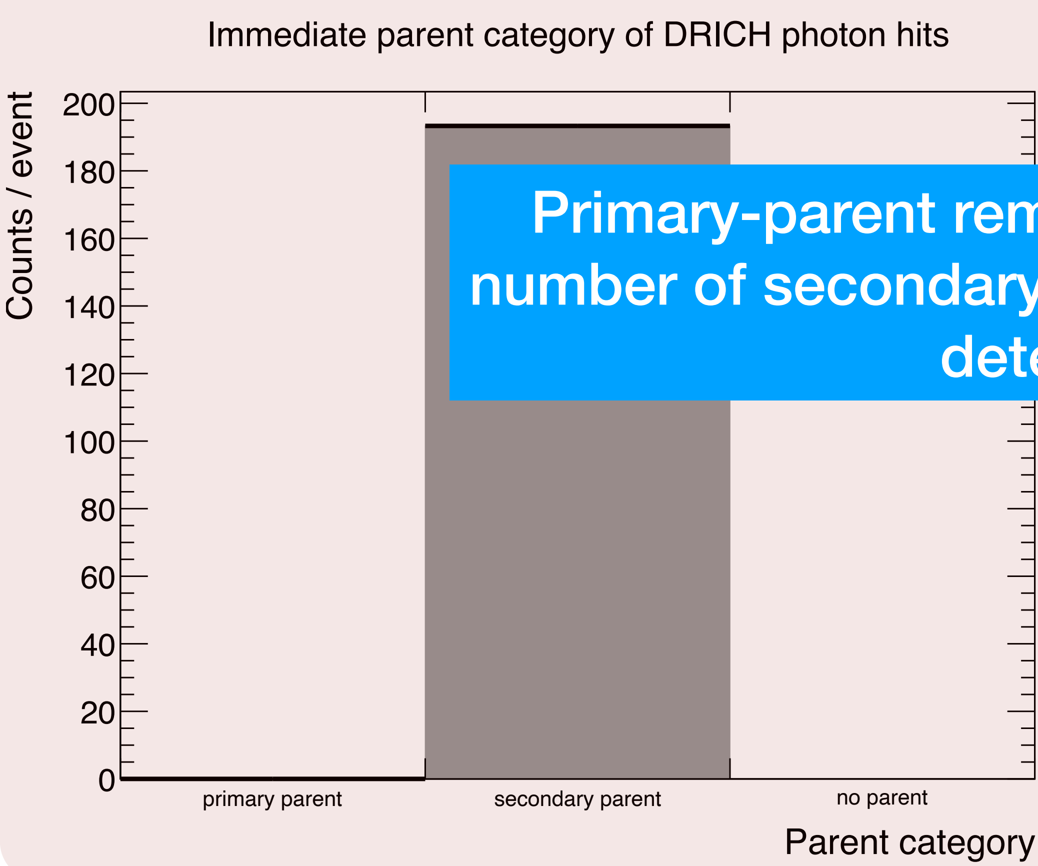
◉ Photon-hits time distribution: whose **Parent is Secondary** particle.

✤ Photons emitted by the primary particle dominate the prompt structure, while photons emitted by secondary particles form a much broader time distribution.

Immediate parent category of dRICH hits:

dRICH Only



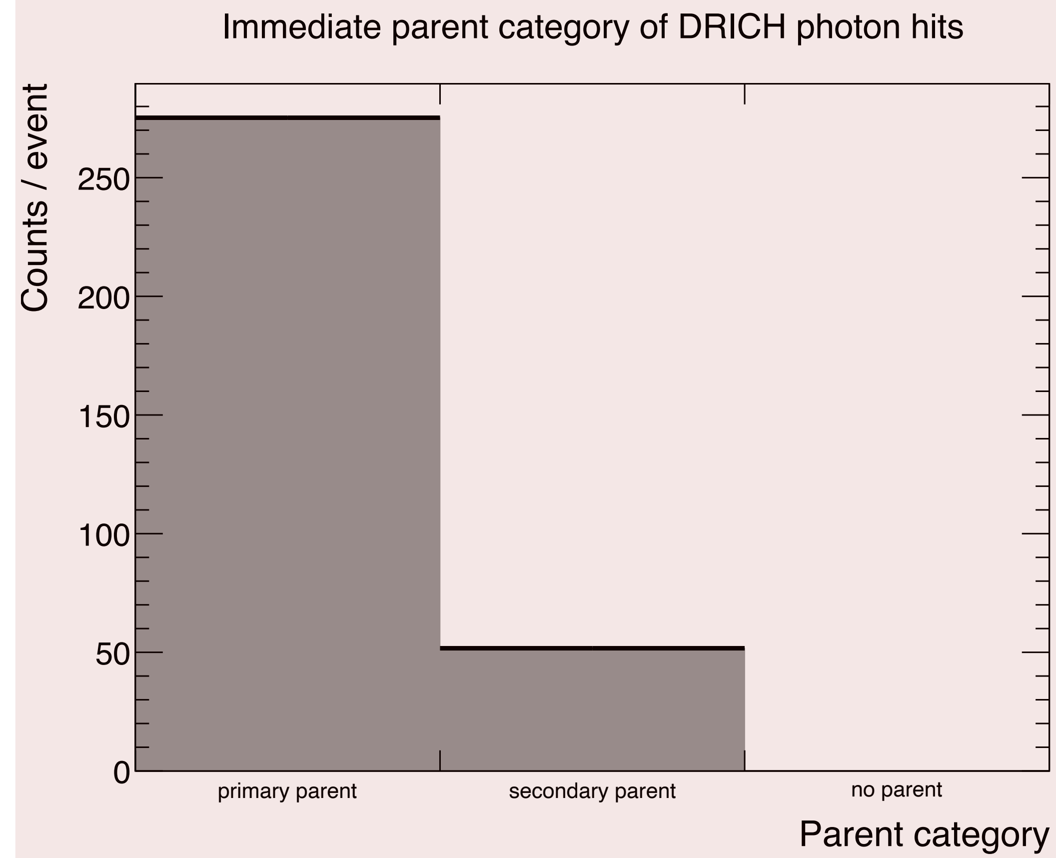


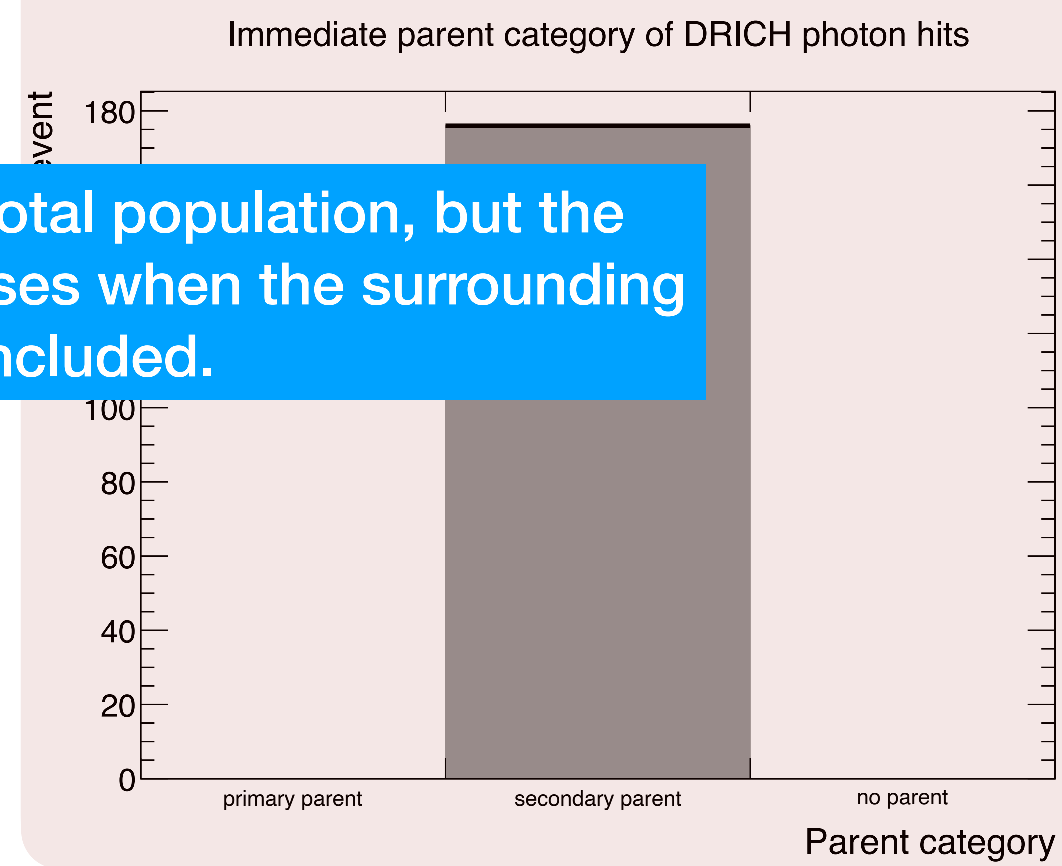
eta=2.5

eta=3.5

Primary-parent remain the dominant total population, but the number of secondary-parent hits increases when the surrounding detector geometry is included.

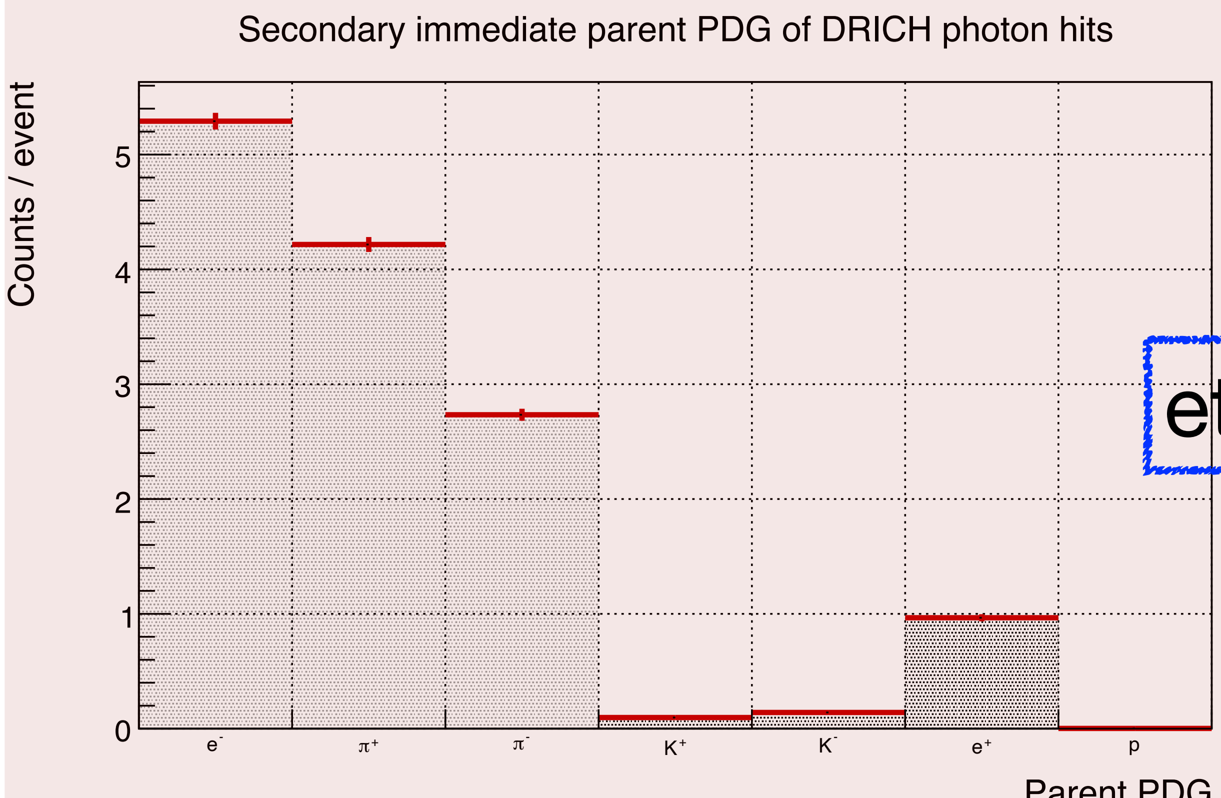
Full Detector



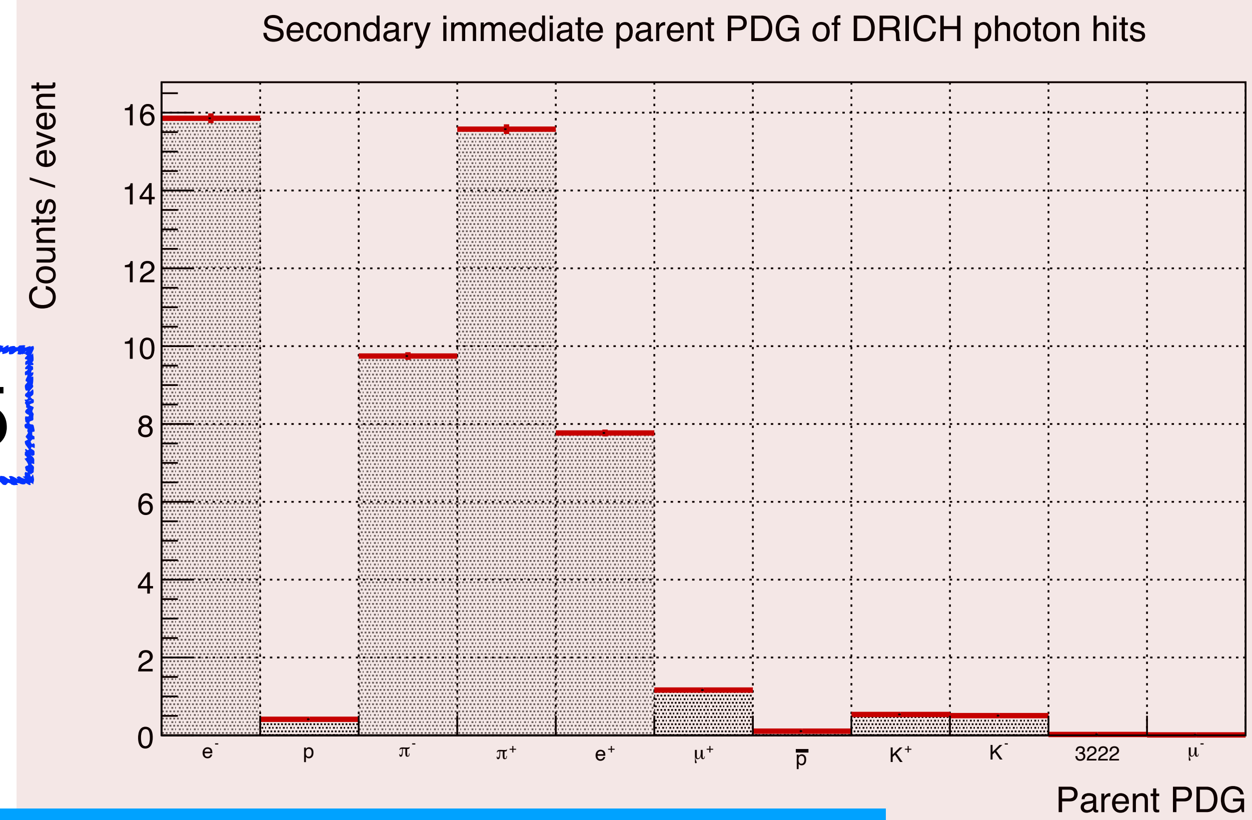


Secondary-parent PDGs of dRICH hits:

dRICH Only

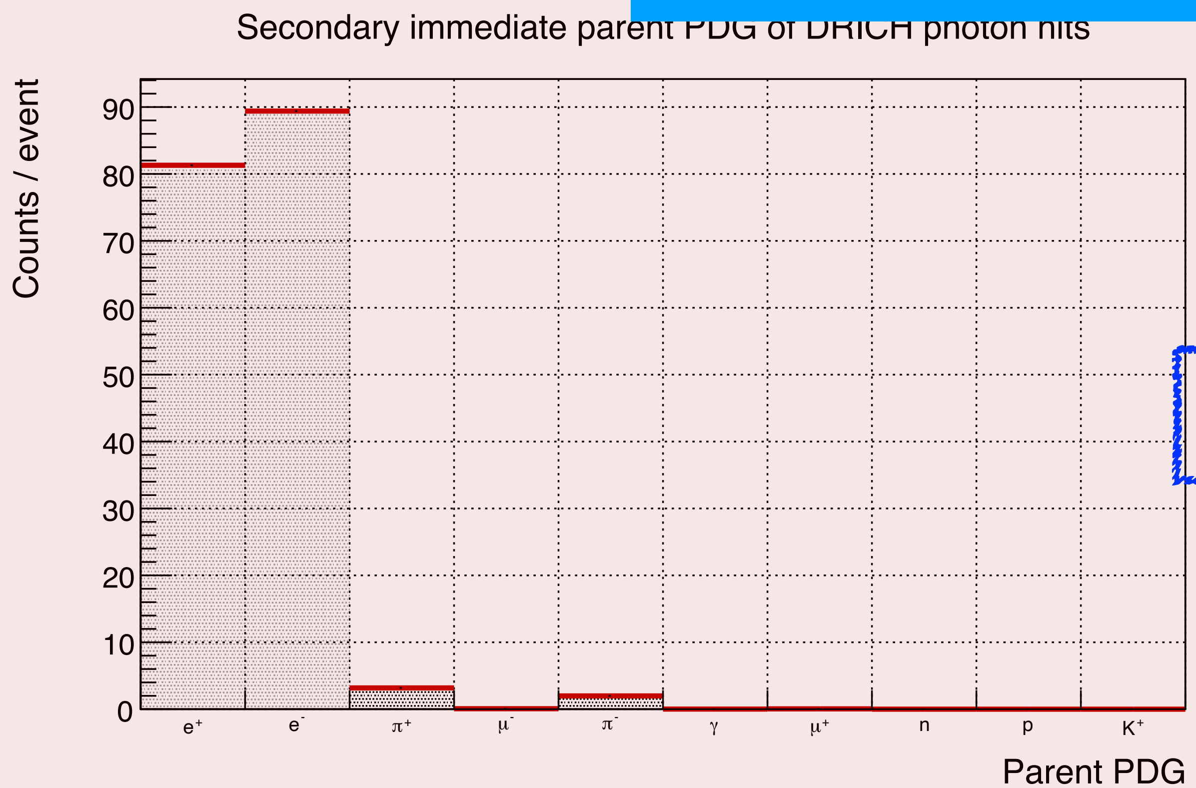


Full Detector

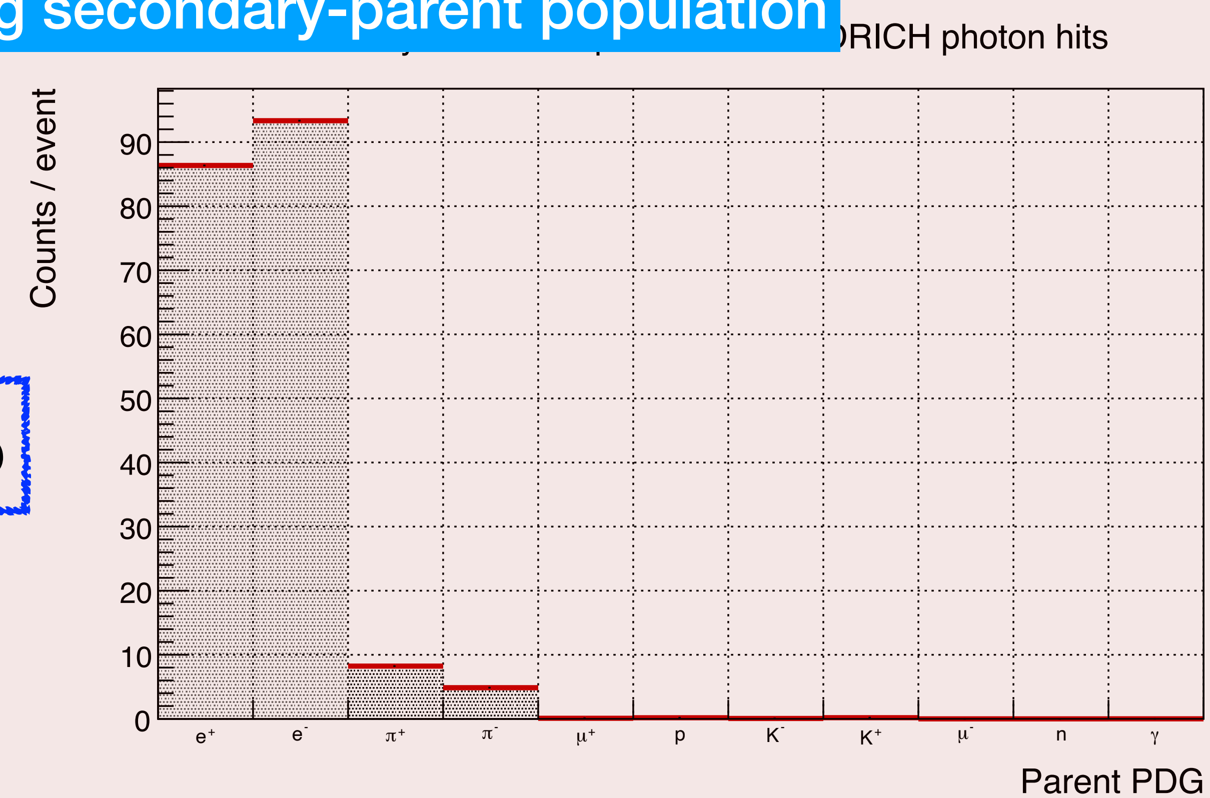


eta=2.5

Electrons constitute the leading secondary-parent population

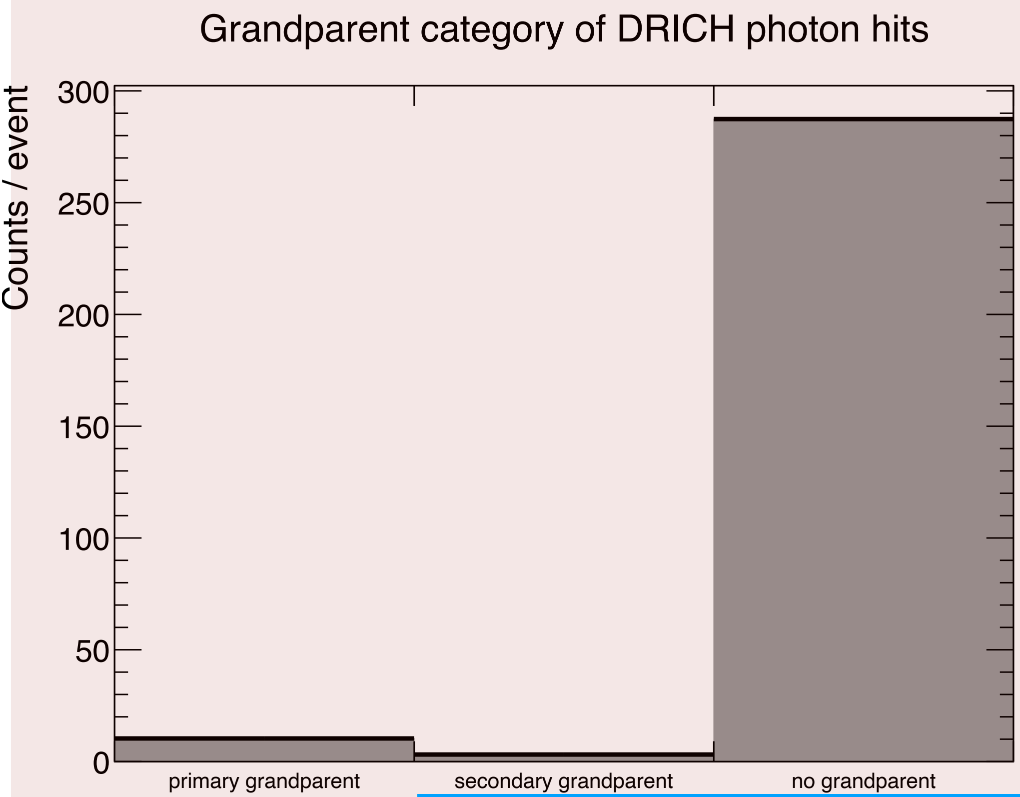


eta=3.5

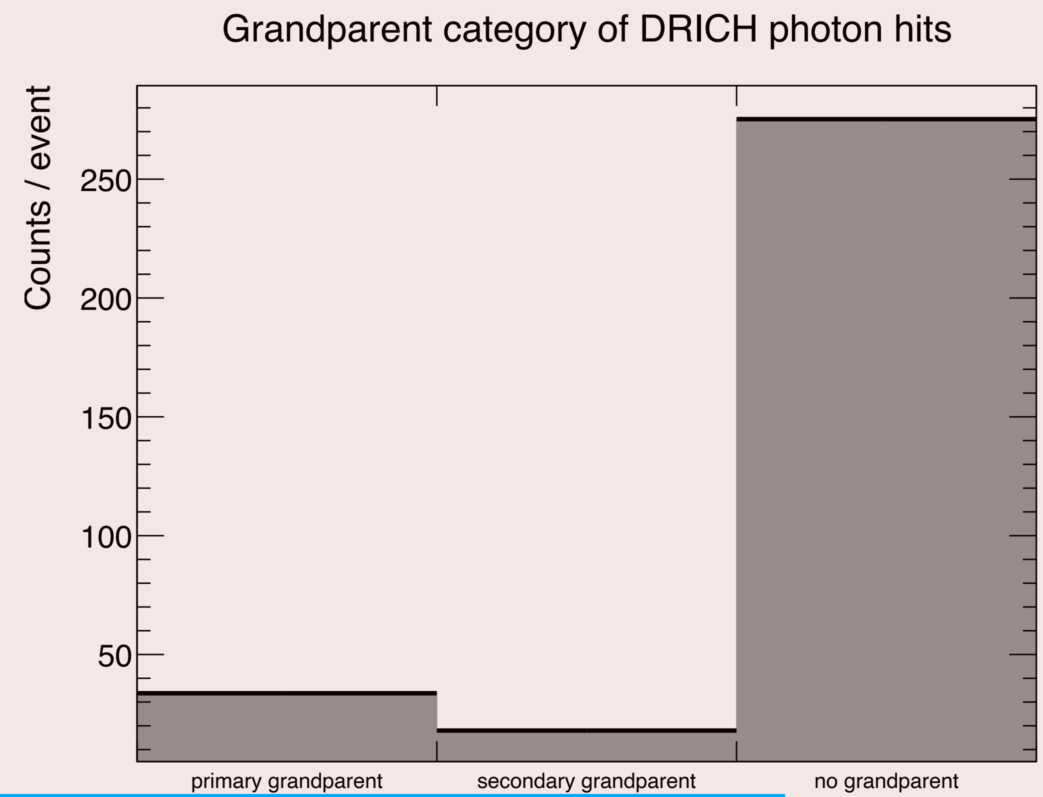


Grand-parent category of dRICH hits:

dRICH Only

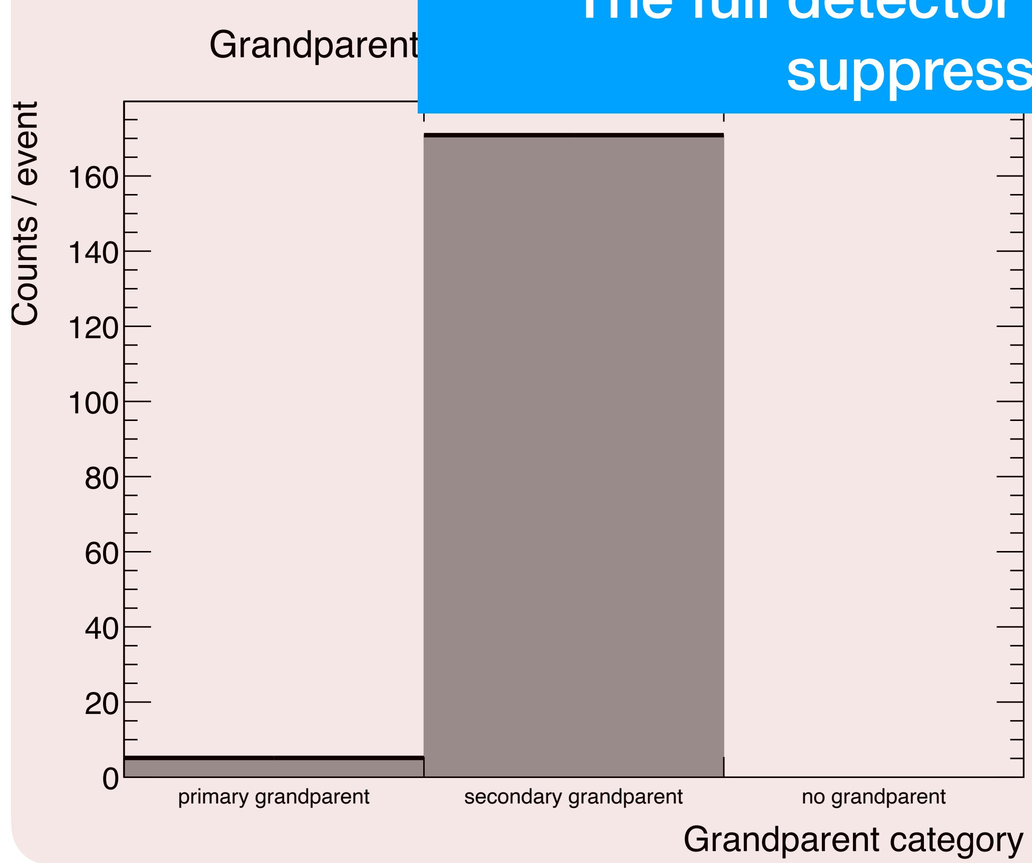


Full Detector

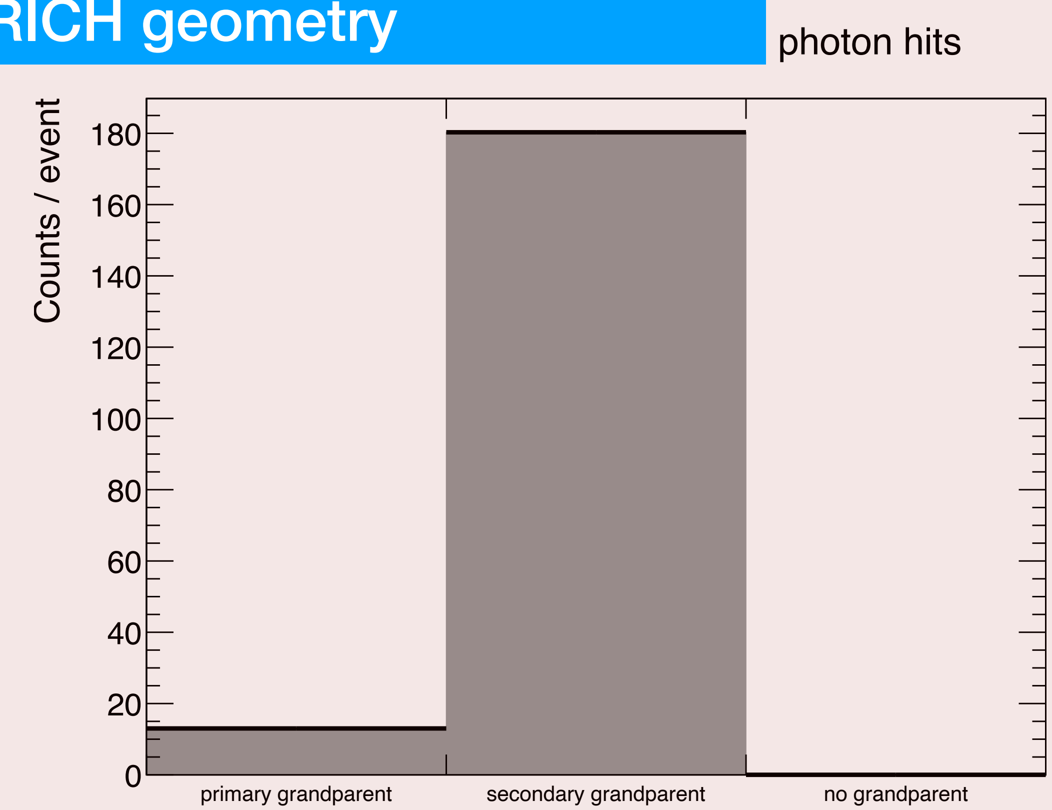


eta=2.5

The full detector introduces additional ancestry chains that are suppressed in the standalone dRICH geometry



eta=3.5

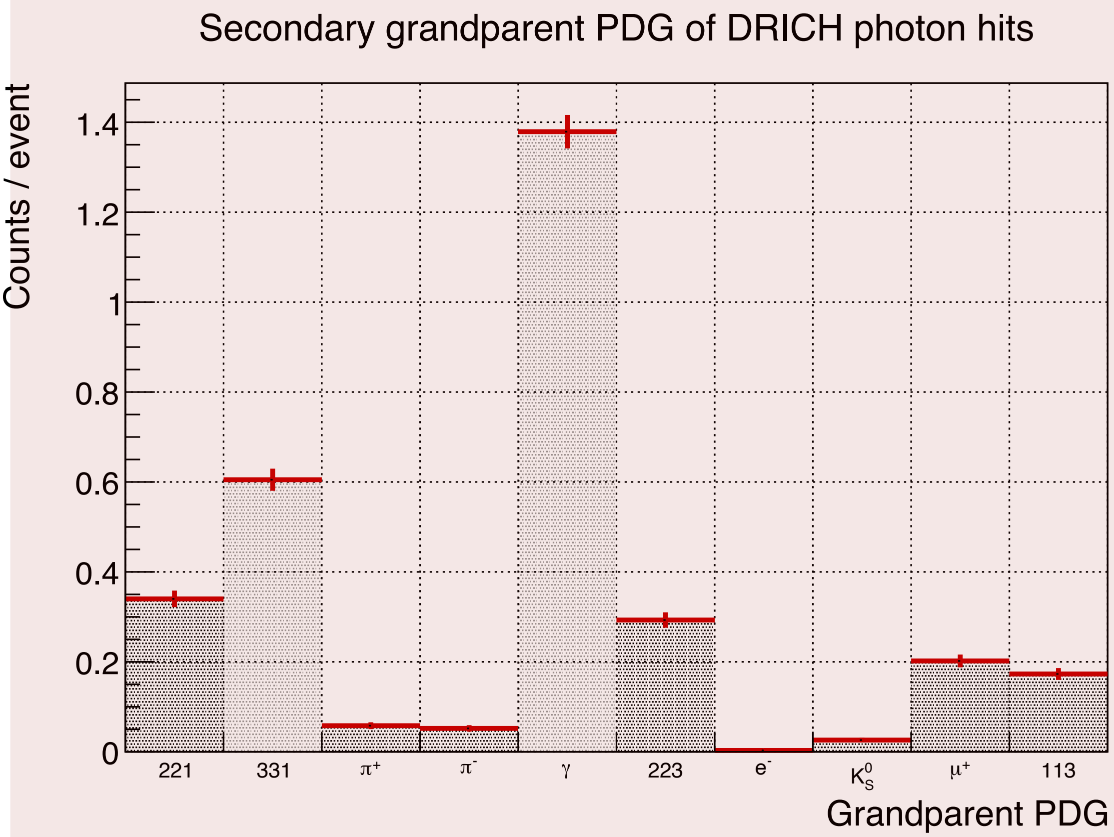


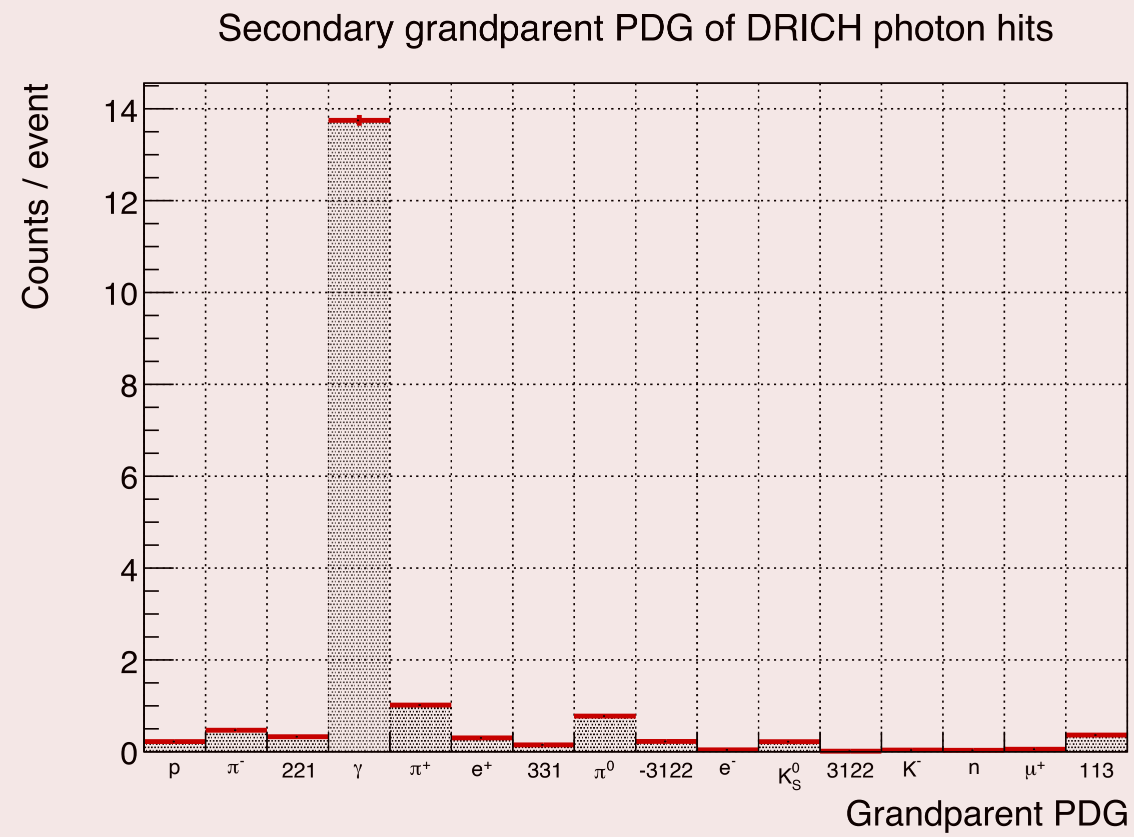
Secondary-Grandparent PDGs of dRICH hits:

dRICH Only

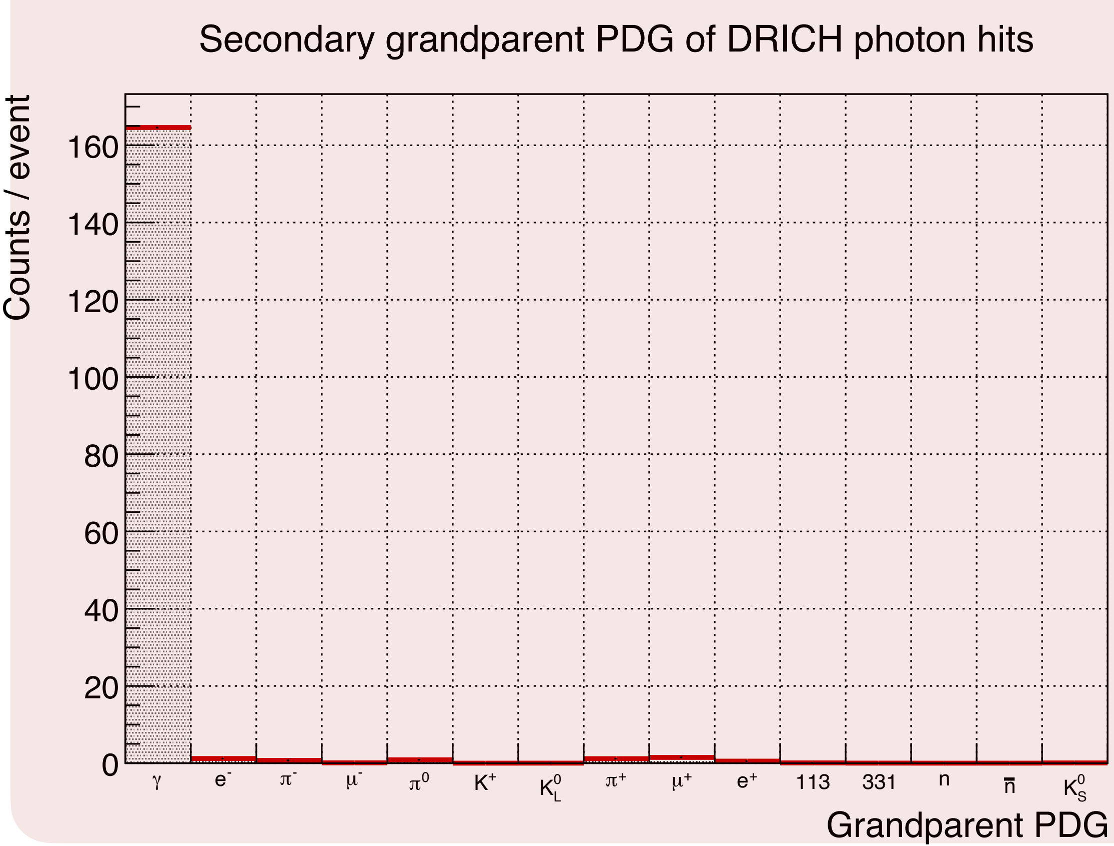
Full Detector

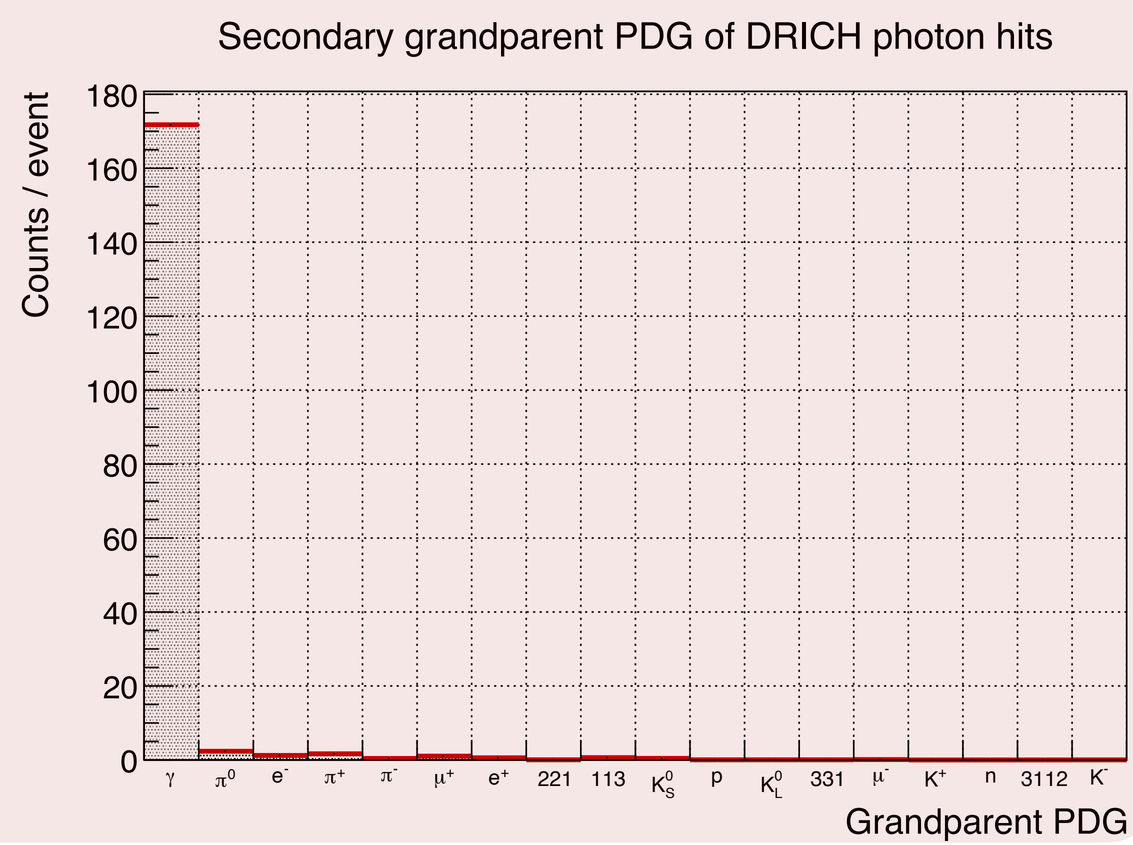
eta=2.5

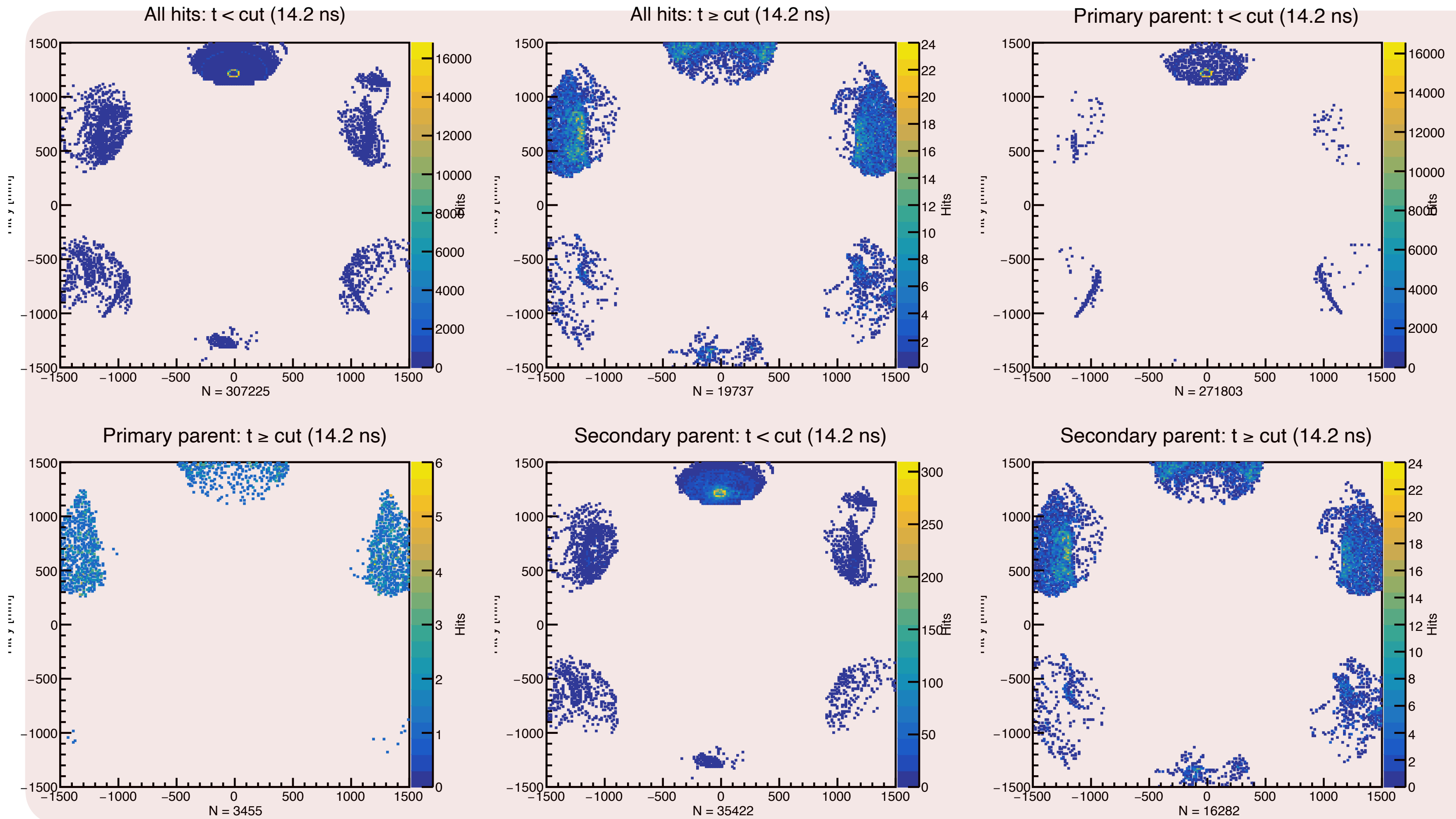




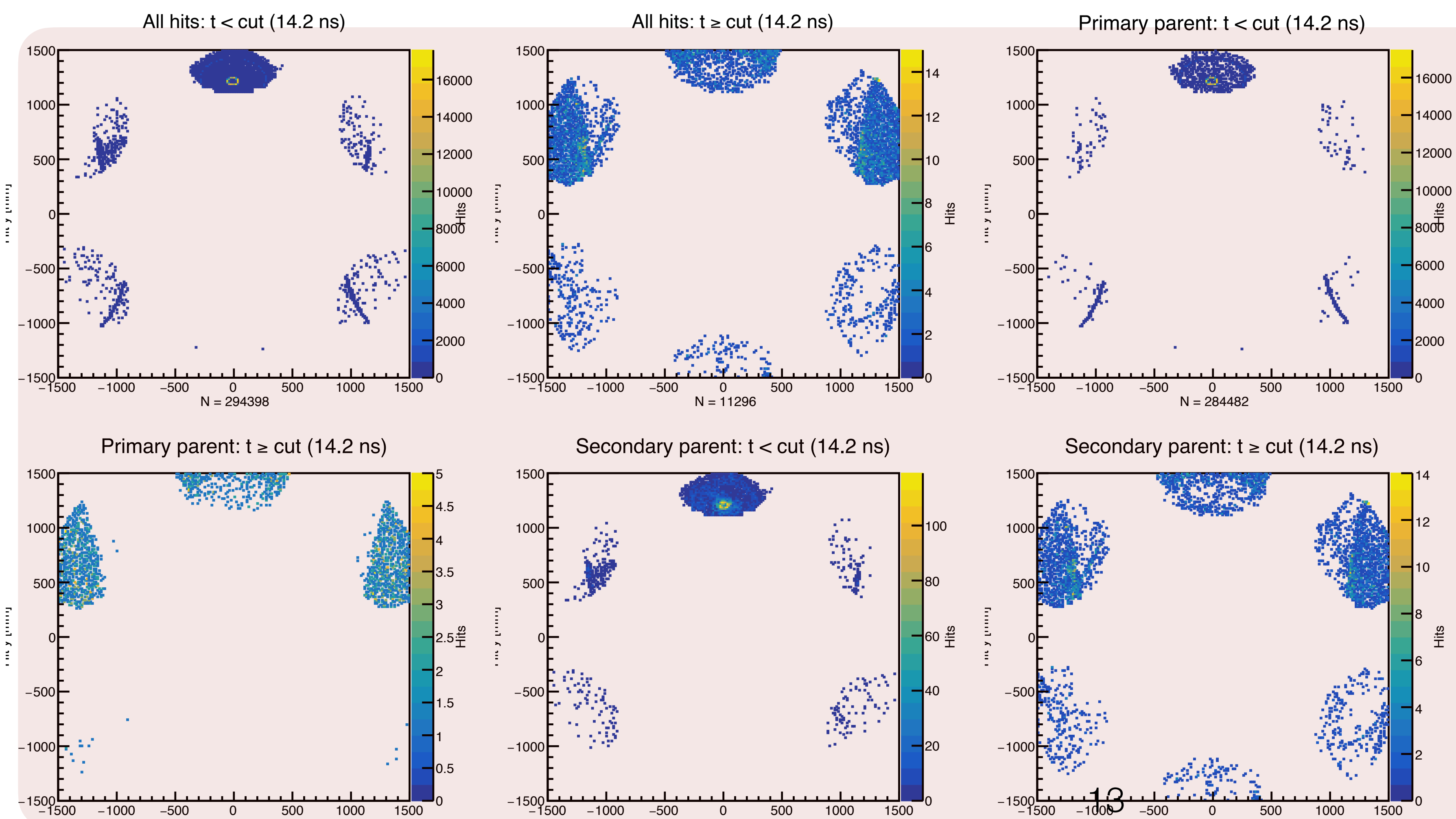
eta=3.5







Full Detector

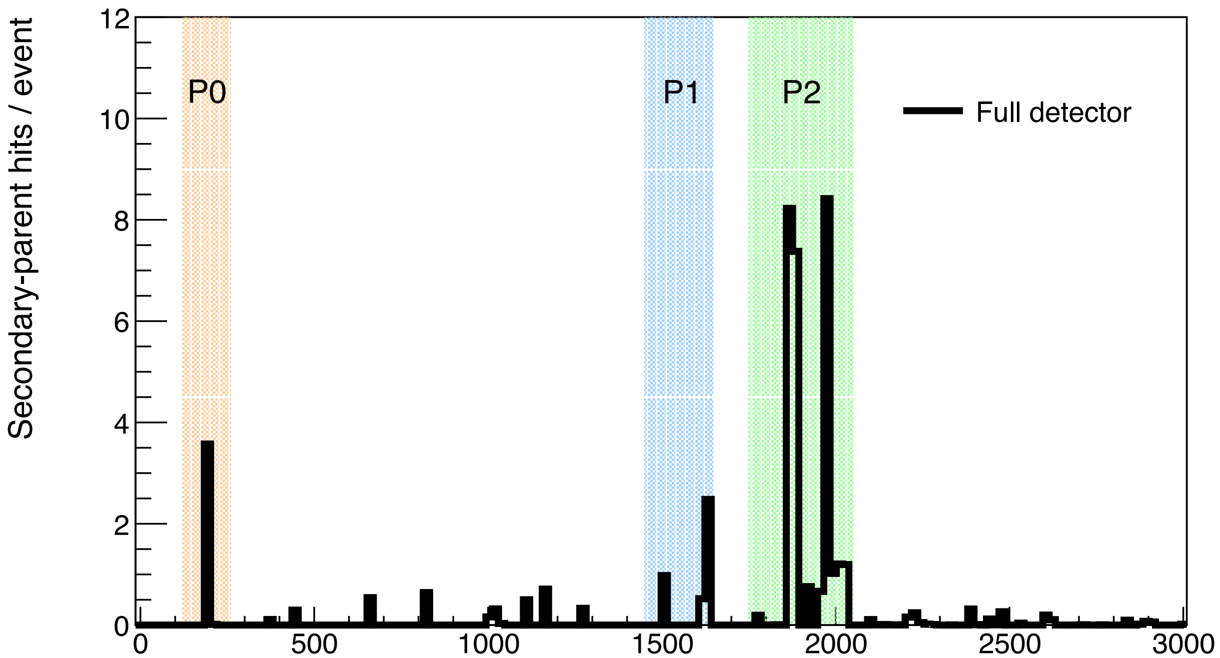


dRICH Only

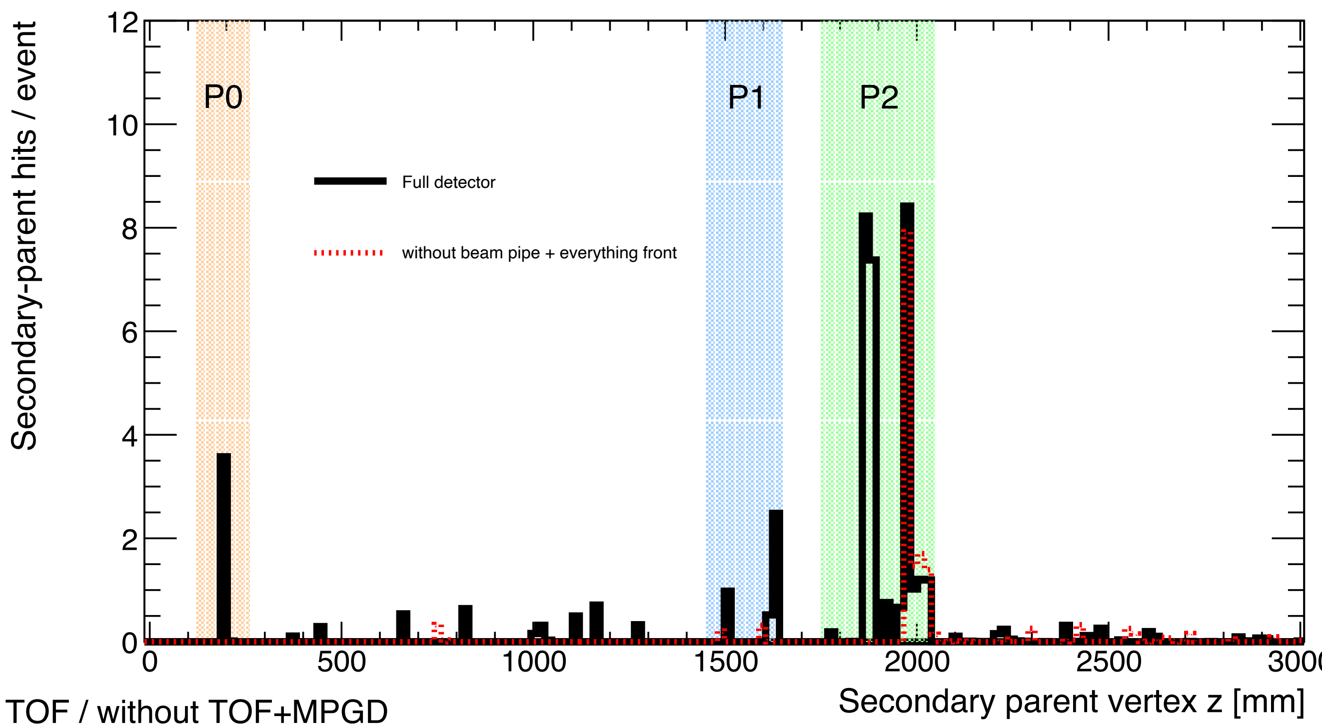
Secondary Production Is Localized, Not Uniform

Baseline: full-detector secondary-parent vertex-z distribution

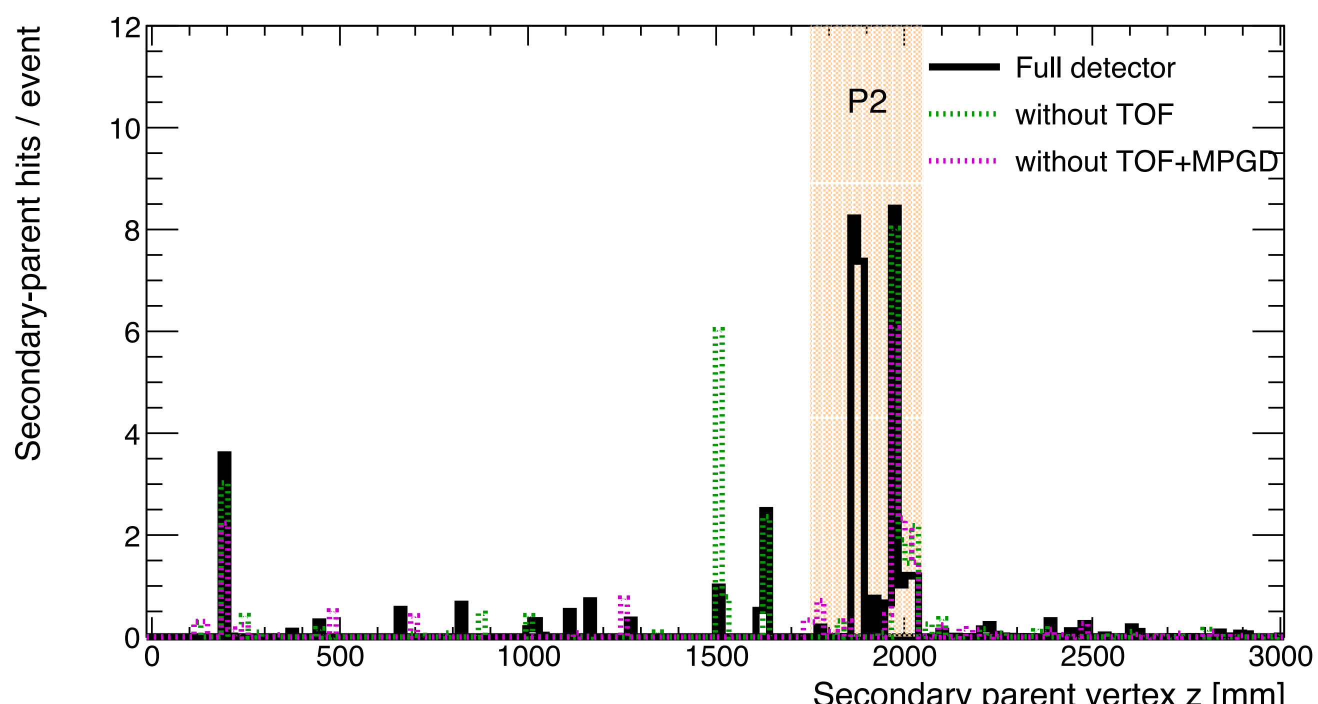
Secondary parent vertex Z: Full detector



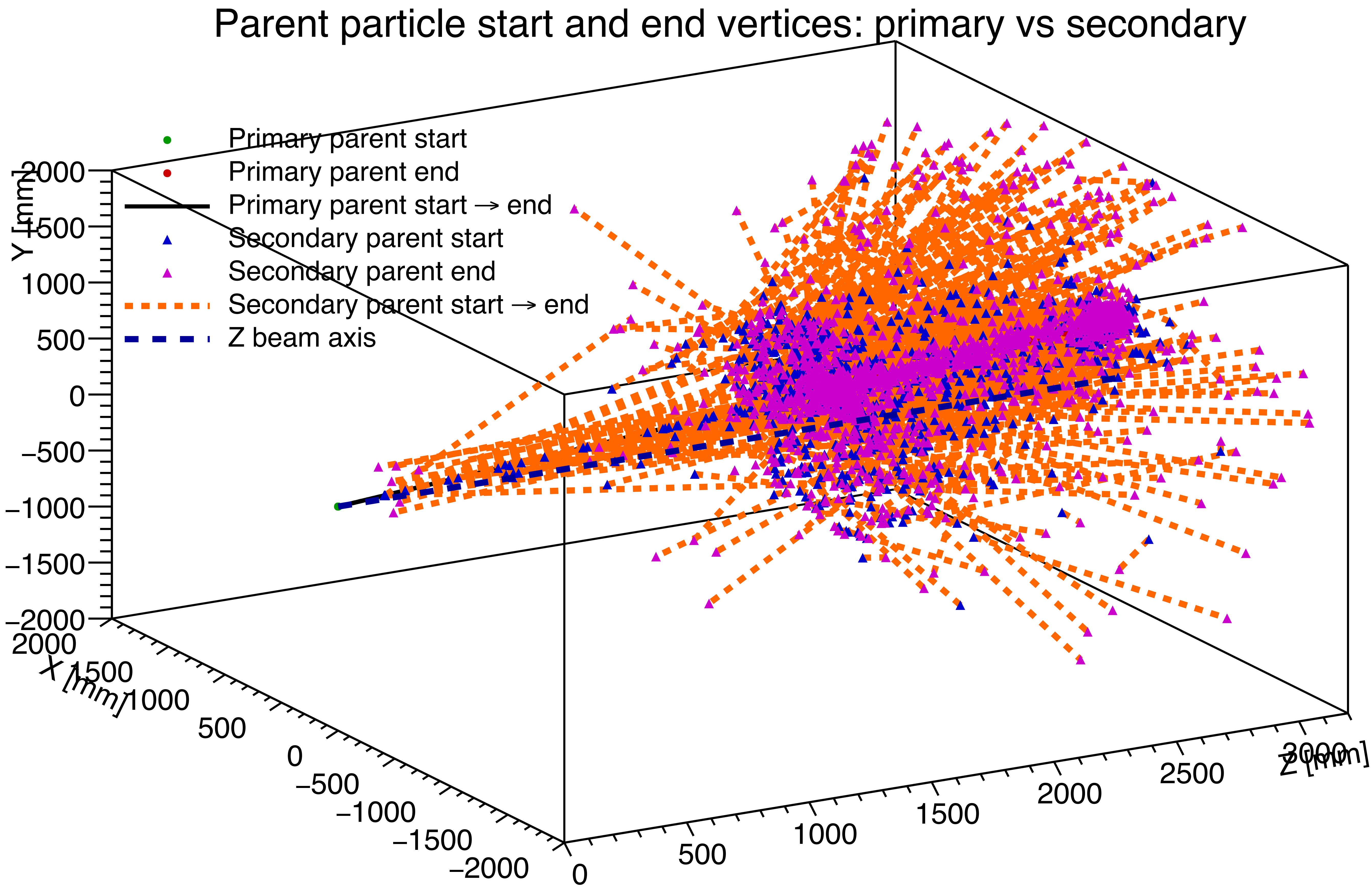
Full detector vs front-region and beam-pipe removal



P2 region: Full detector vs without TOF / without TOF+MPGD

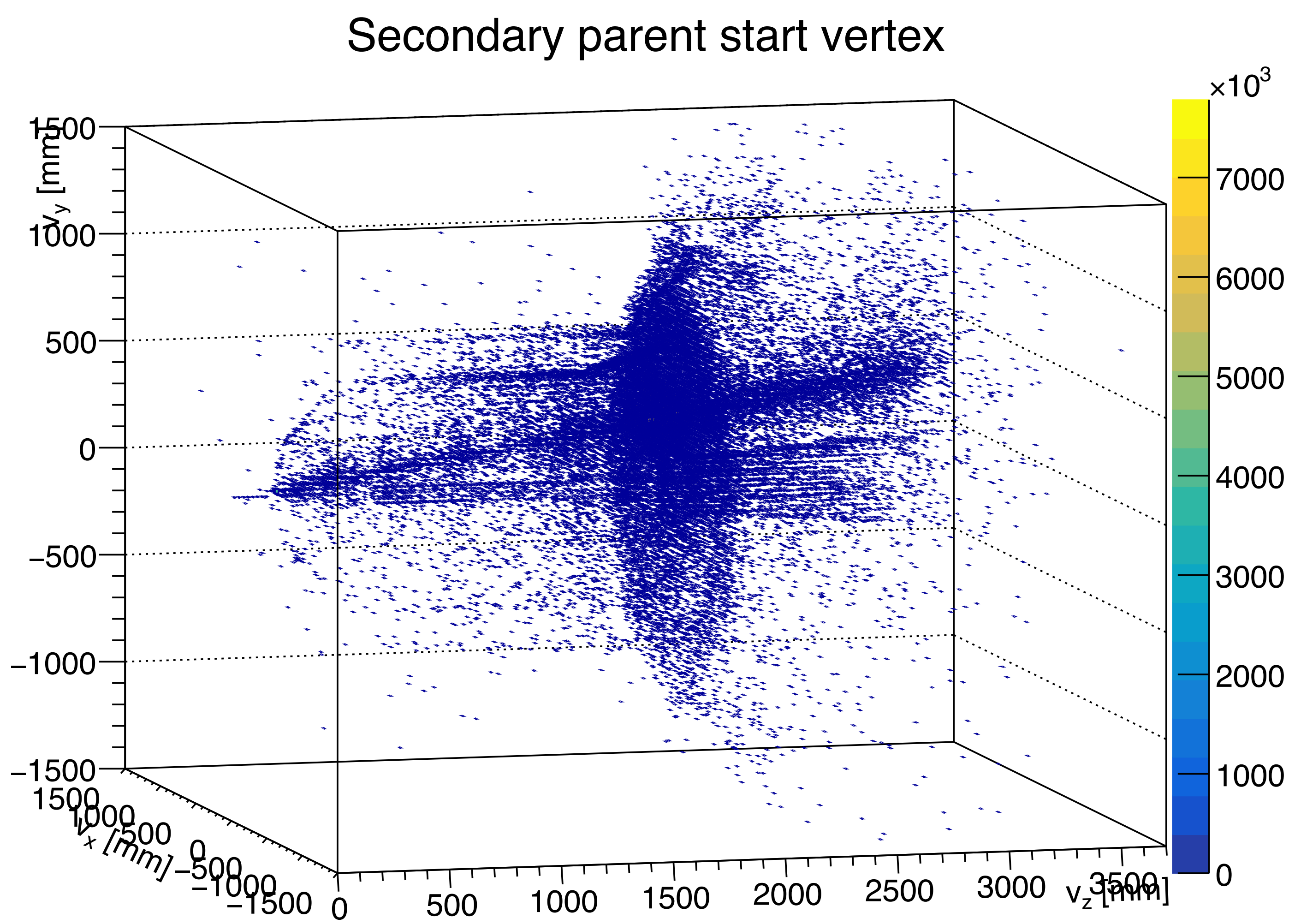


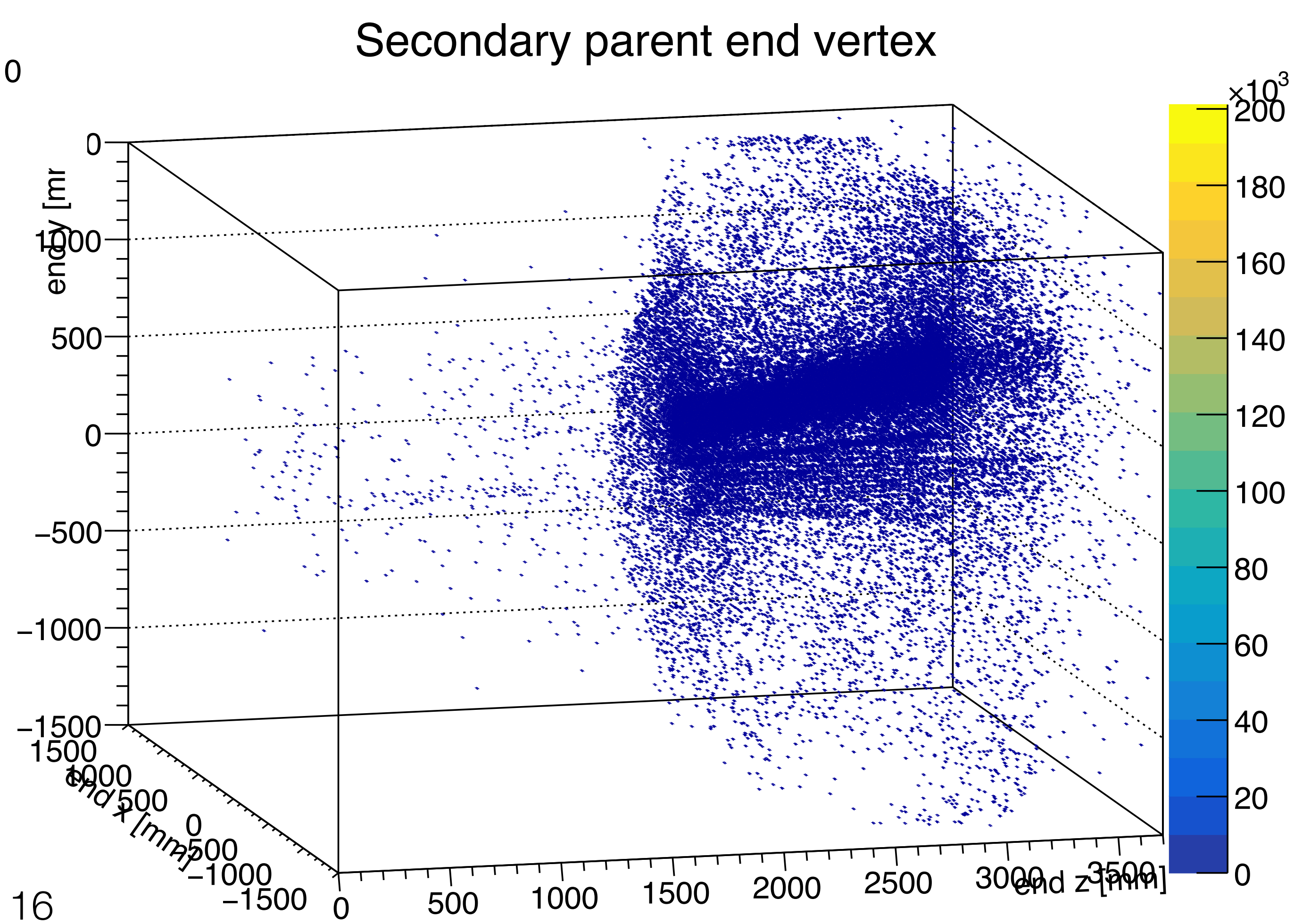
Observation: The strongest structures appear around the downstream region close to the TOF/dRICH transition, while smaller structures appear at earlier z.



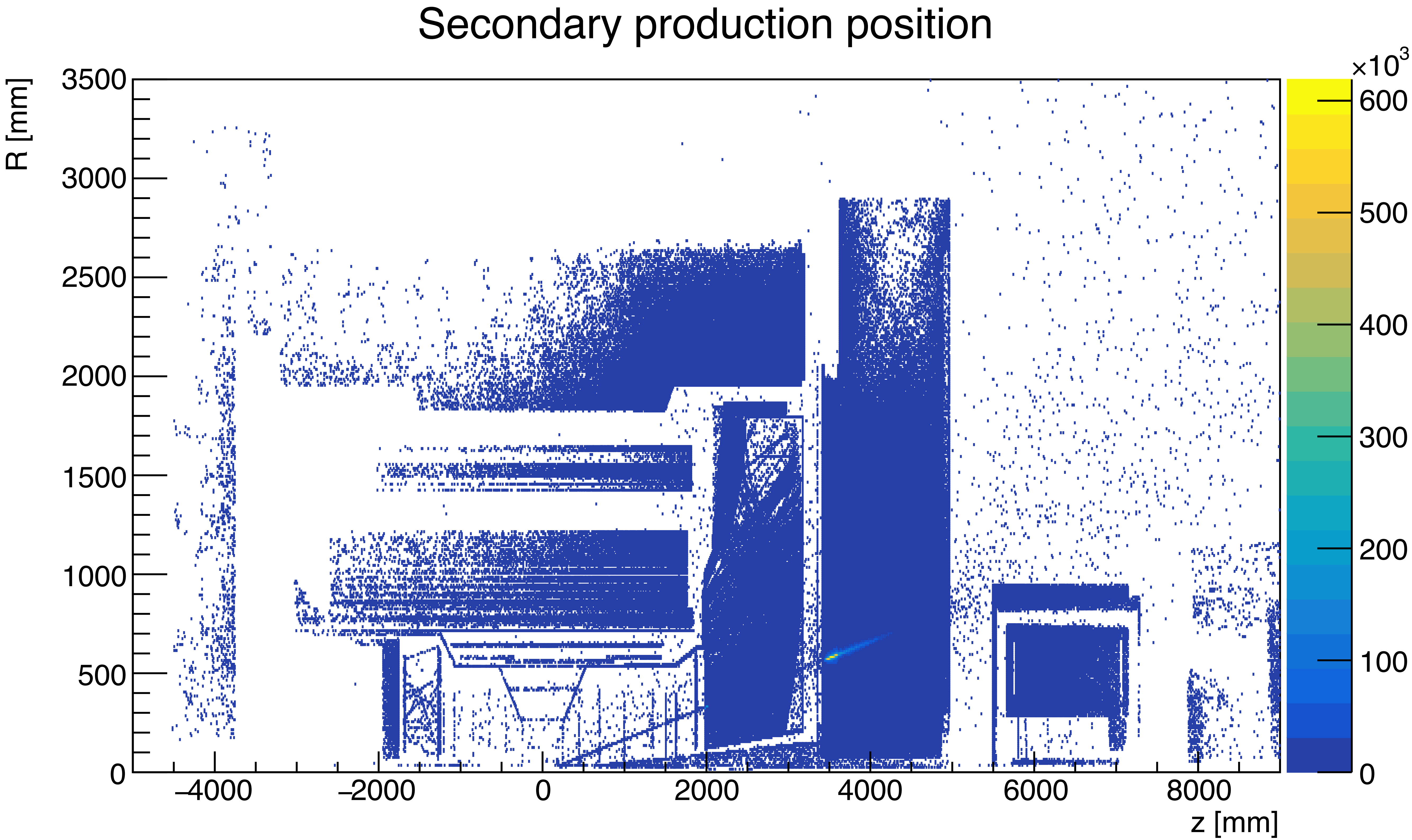
Parent particle start and end vertices: primary vs secondary
Primary parent start
Primary parent end
Primary parent start → end
Secondary parent start
Secondary parent end
Secondary parent start → end
Z beam axis
Y [mm]
X [mm]
Z [mm]
2000
1500
1000
500
0
−500
−1000
−1500
−2000
2500
3000

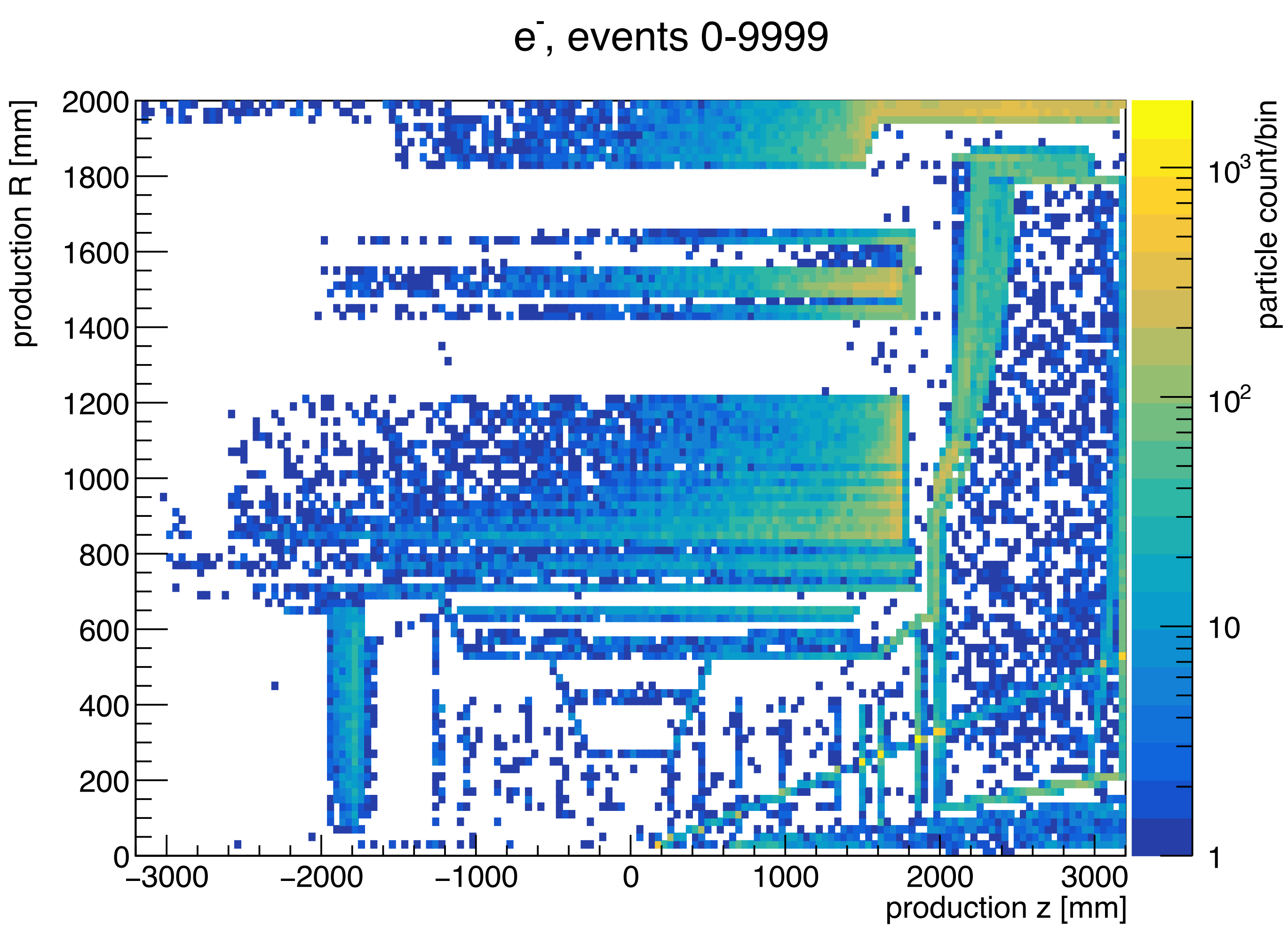
Start and End Vertices

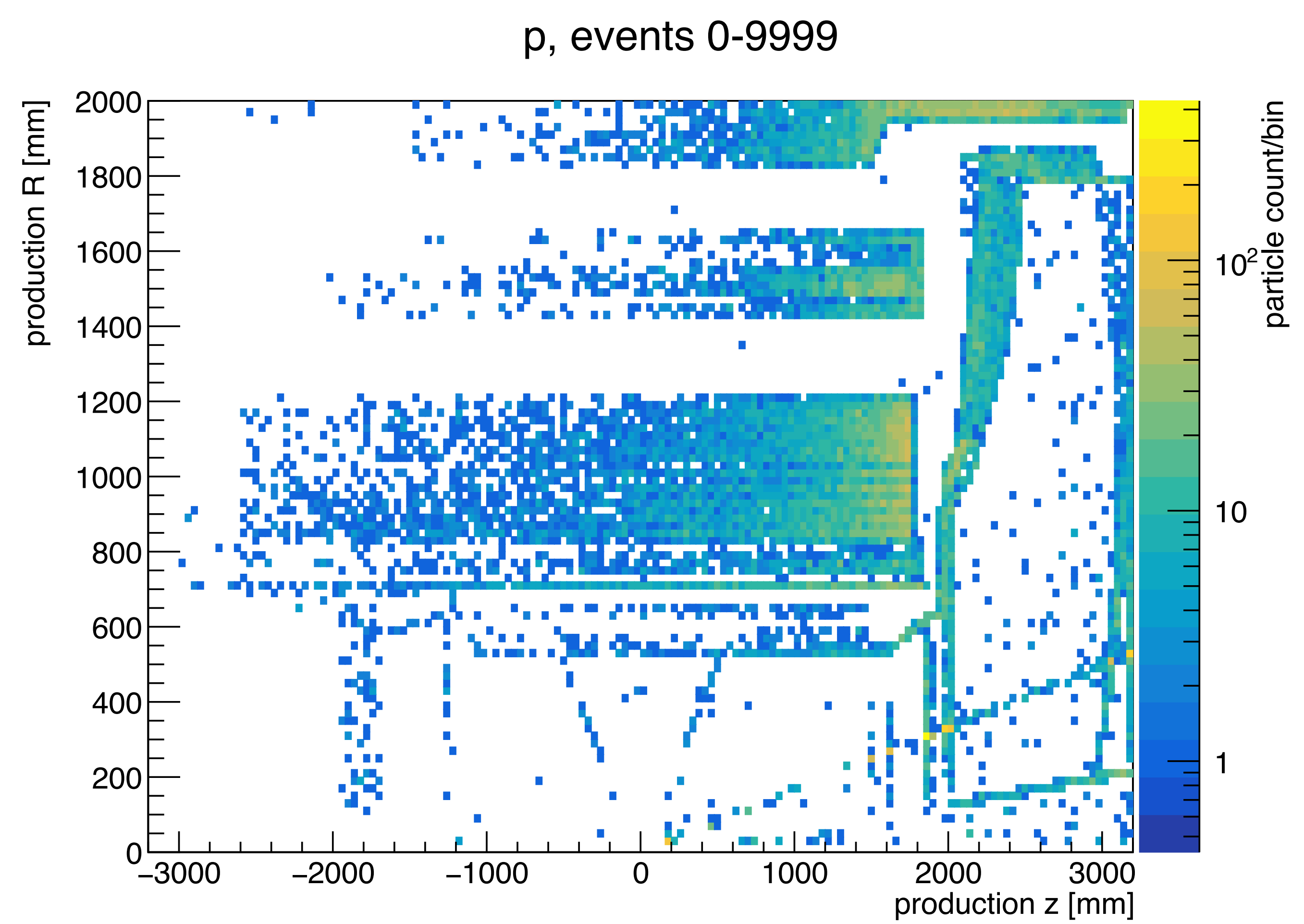


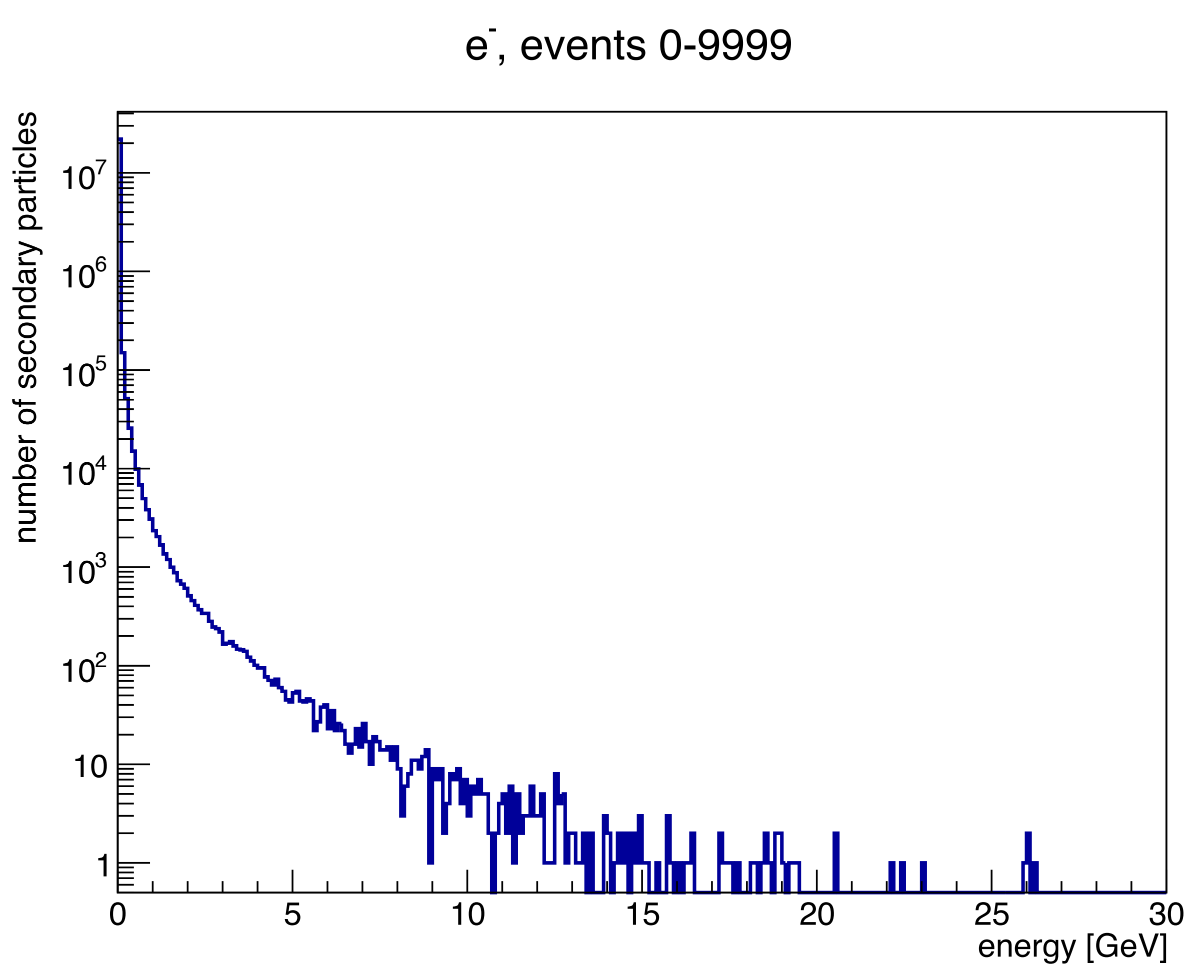


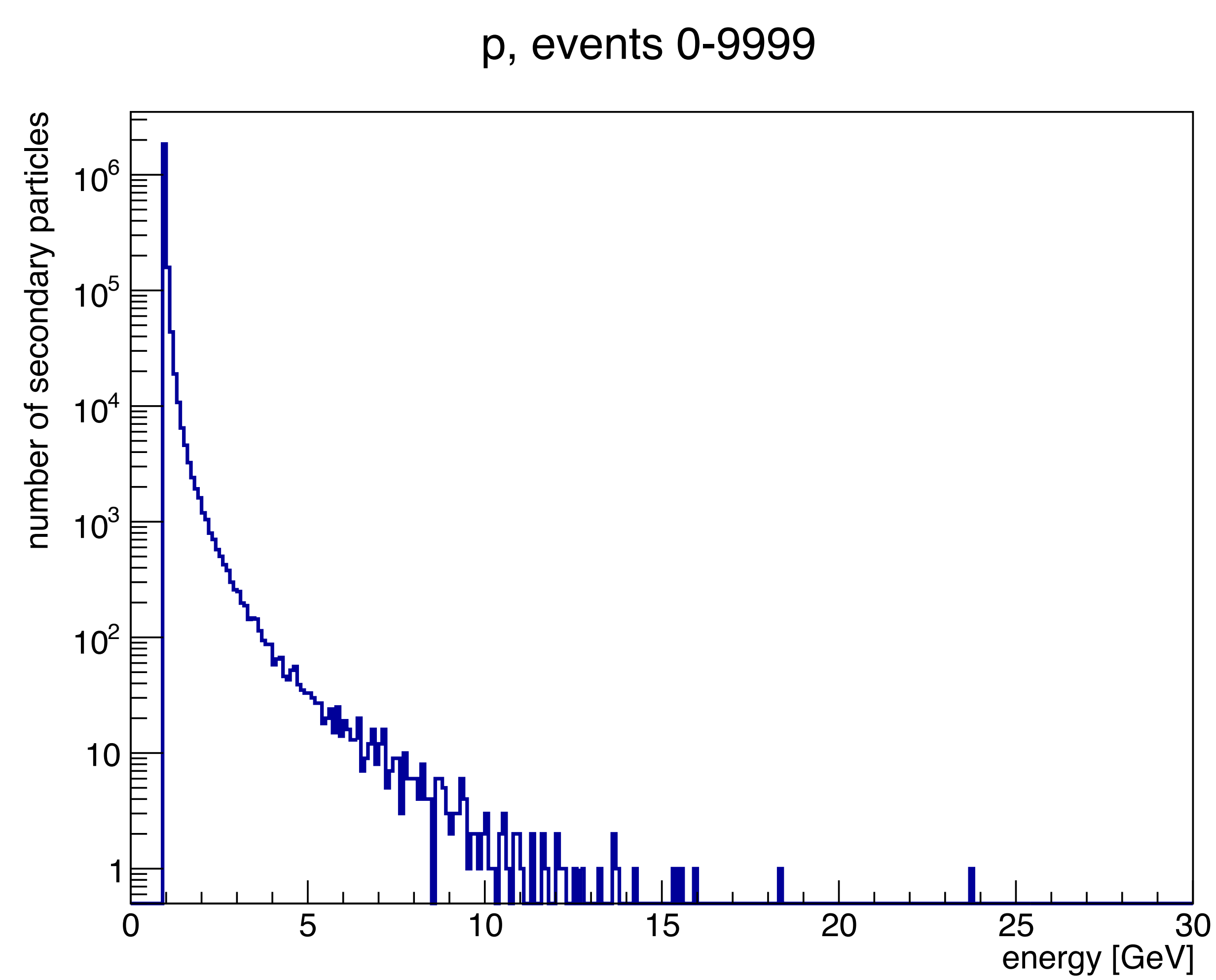
Start vertex: production point of the secondary parent
End vertex: endpoint/termination point of the secondary parent


Secondary production position
R [mm]
3500
3000
2500
2000
1500
1000
500
0
−4000
−2000
0
2000
4000
6000
8000
z [mm]
×10^3
600
500
400
300
200
100
0

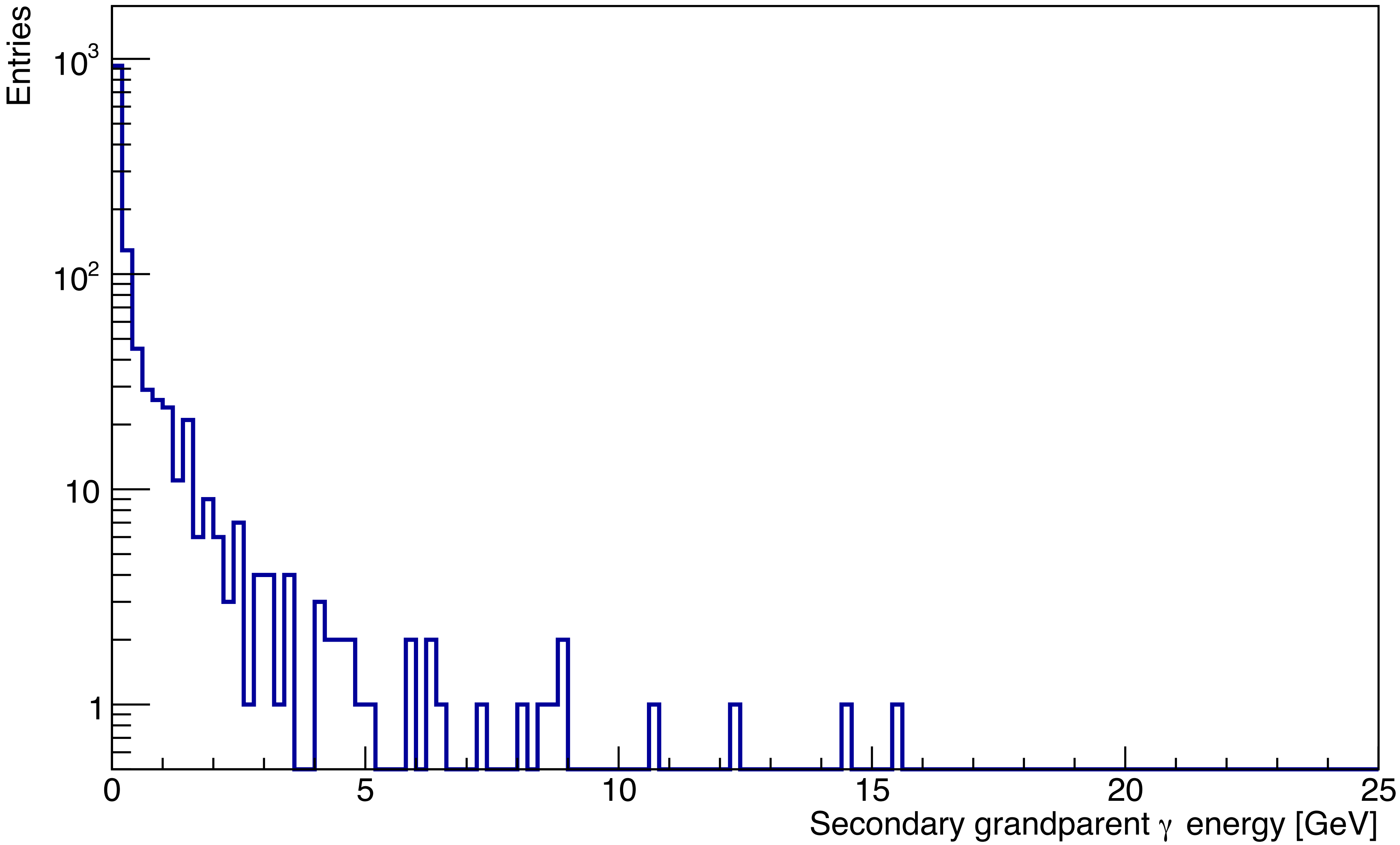

e-, events 0-9999
production R [mm]
production z [mm]
particle count/bin


p, events 0-9999
production R [mm]
production z [mm]
particle count/bin


e-, events 0-9999
number of secondary particles
energy [GeV]


p, events 0-9999
number of secondary particles
energy [GeV]

Secondary Grand-parent Photon Energy distribution:



Dependence on primary particle species, charge, and momentum

π^+, π^-, K^+, K^-, p, $\bar{p}$
Momentum: 5, 10, 20, 30, 40, 50, 60, 70 GeV
Events: 1000 per sample

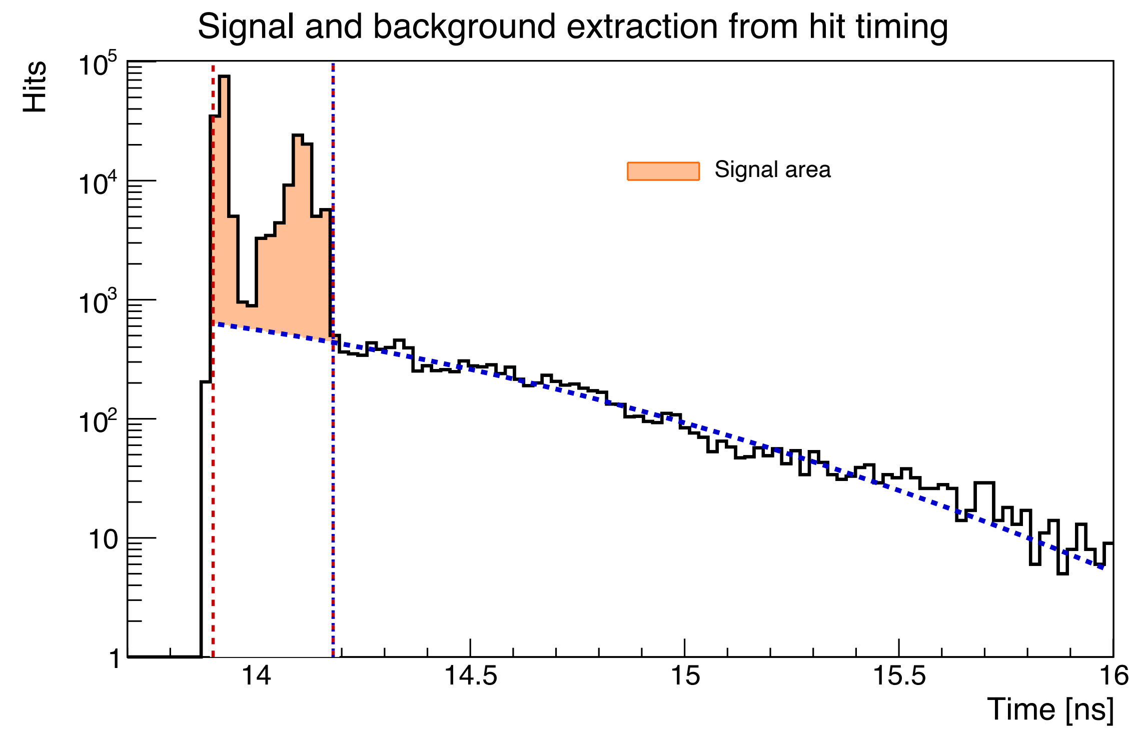
Brief Summary at 30 GeV (tail defined as t<14.2 ns)

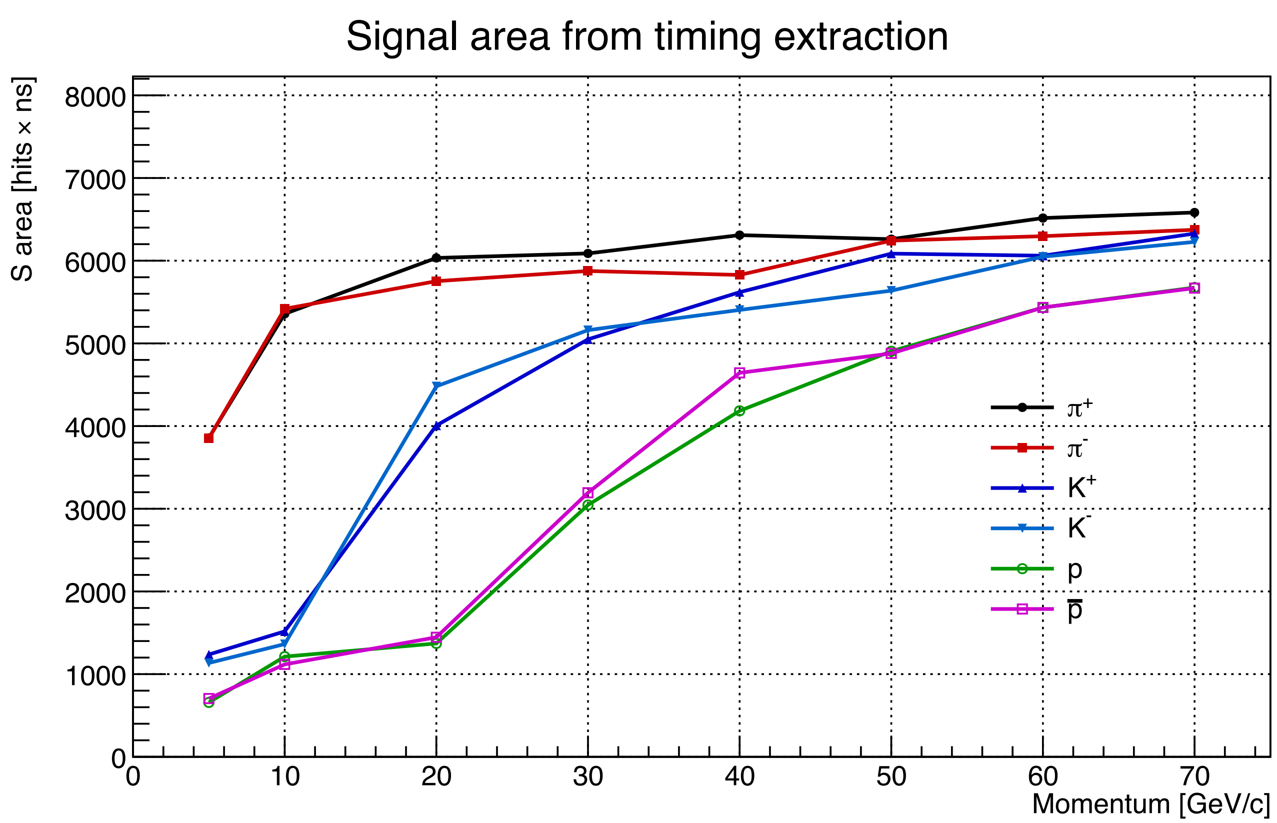
Primary	Events	Hits/event	Sec [%]	Tail [%]	Tail from secondary [%]
π^+	1000	327.0	15.8	3.7	78.4
π^-	1000	317.3	17.0	4.0	78.0
K^+	1000	274.0	15.6	3.9	74.9
K^-	1000	279.3	15.3	3.1	69.9
p	1000	185.9	25.0	5.9	76.3
$\bar{p}$	1000	211.6	32.4	6.9	83.2

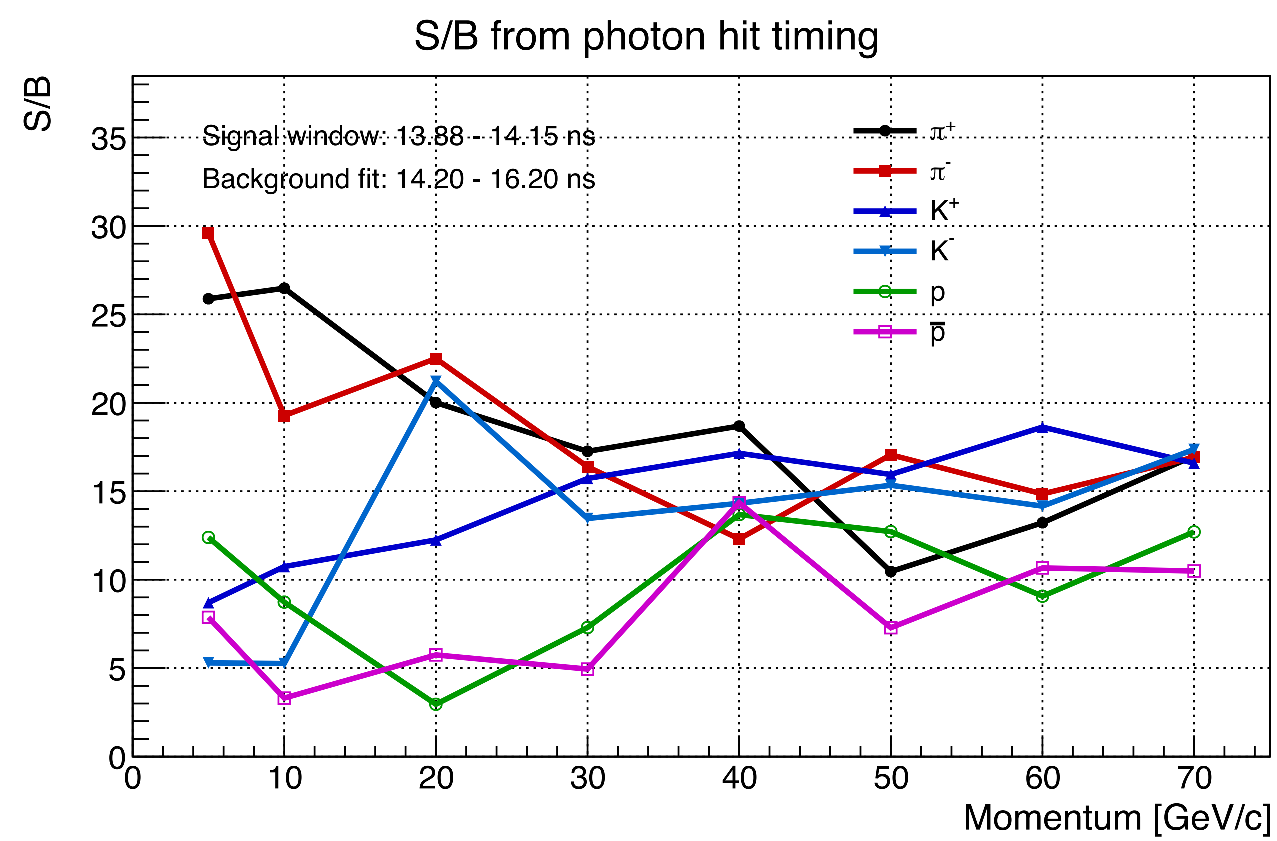
PS-Electron/Positron study is ongoing. Preliminary shows shorter tail than the counterparts described here.

https://indico.bnl.gov/event/33070/

Dependence on primary particle species, charge, and momentum

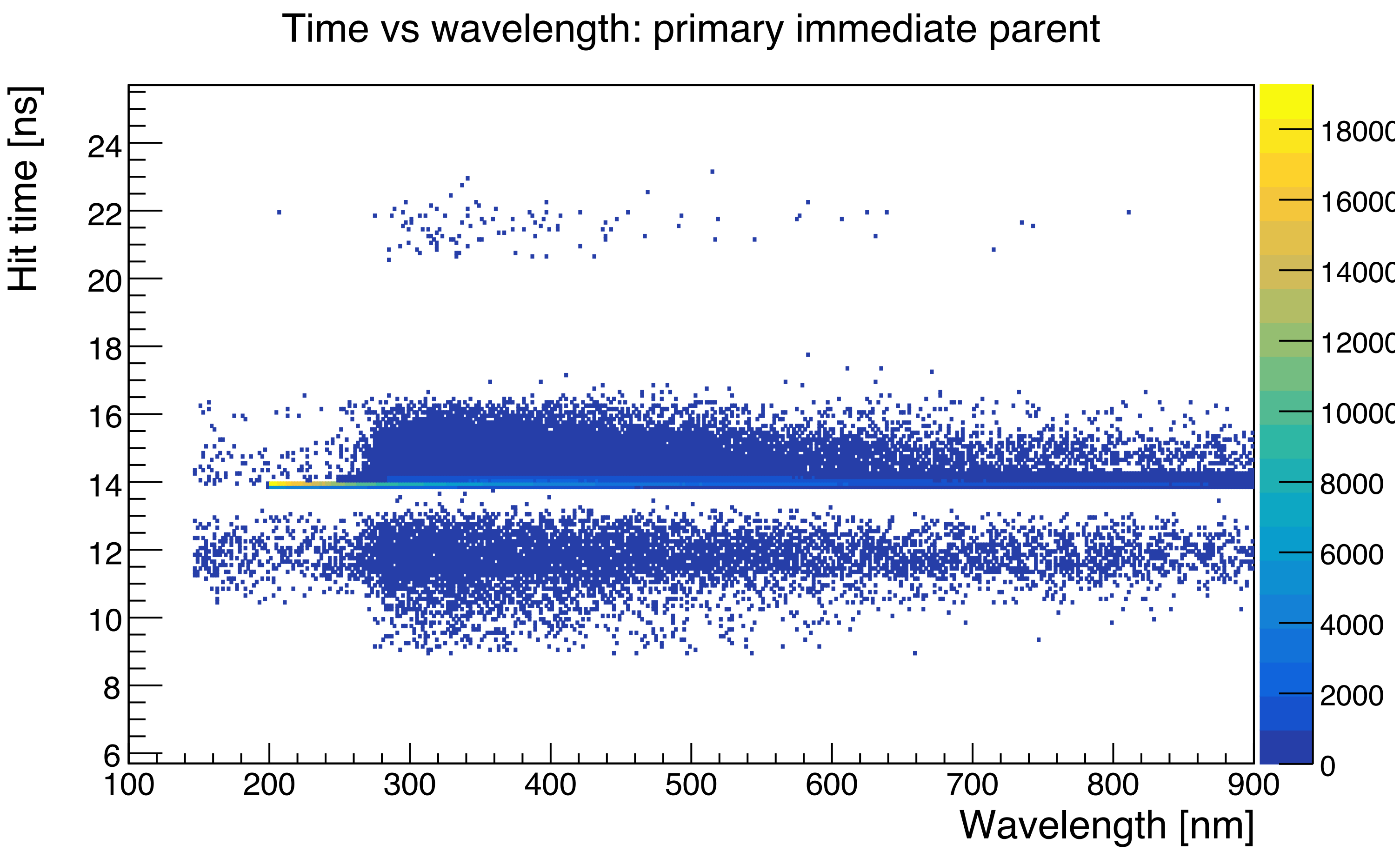




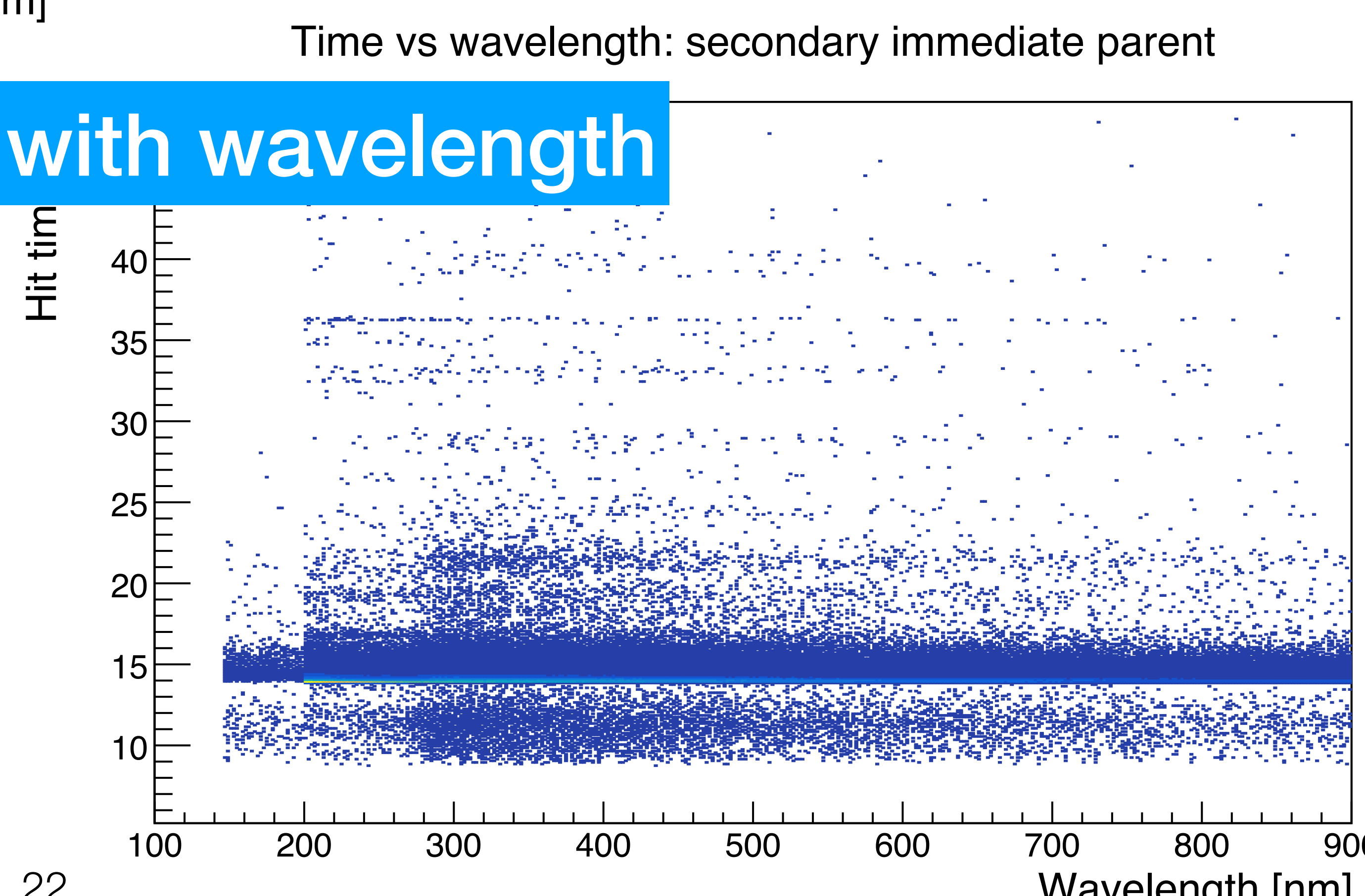


The signal yield generally increases with momentum, while S/B shows species-dependent behavior and is lower for baryons in some momentum regions.

Ongoing :



✤ Time vs λ: whose **Parent is Primary** particle.



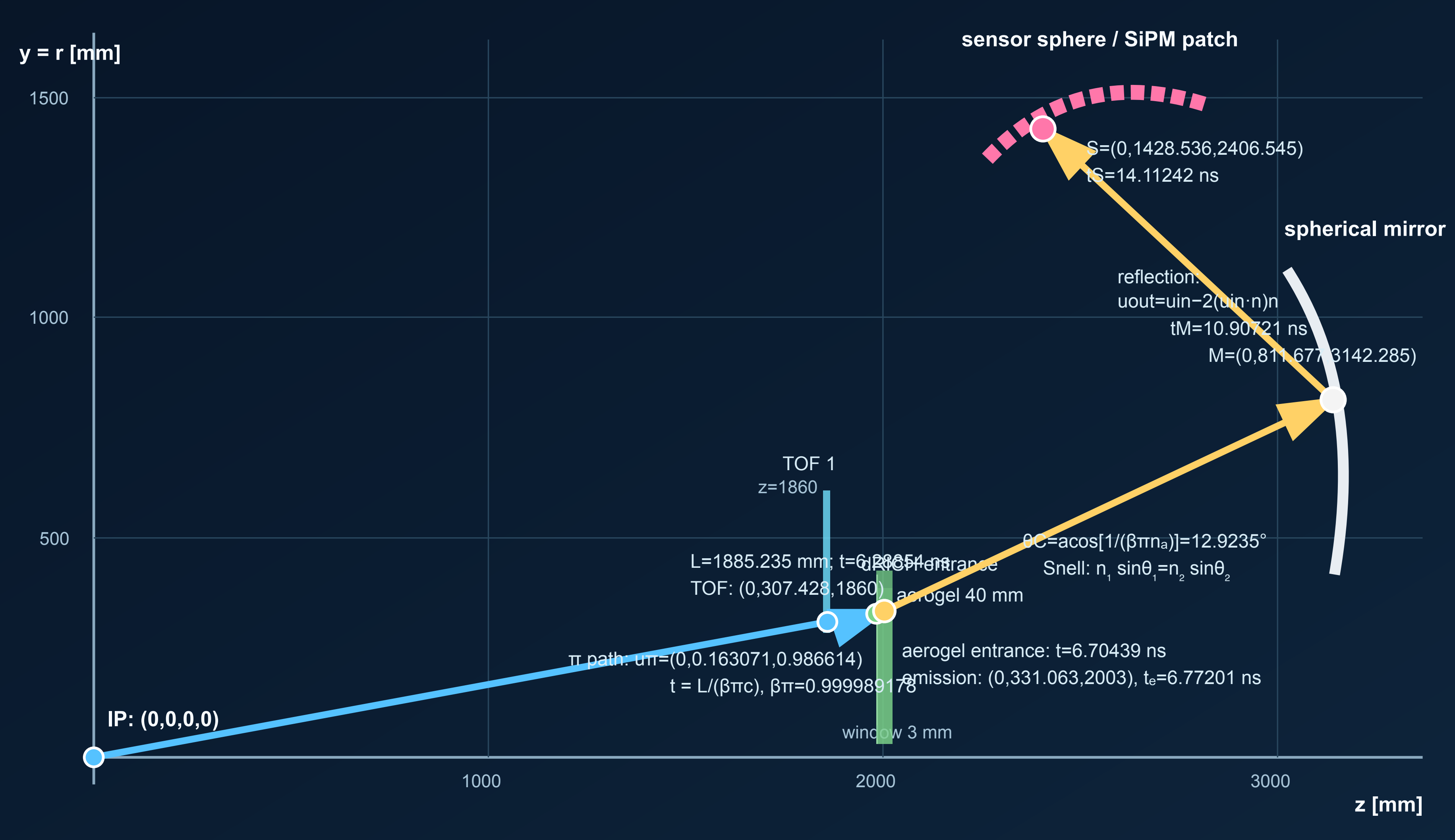
Incorporate QE with wavelength

✤ Time vs λ: whose **Parent is Secondary** particle.

Comparison with analytical calculation

30 GeV/c pion → aerogel Cherenkov photon → dRICH sensor

Meridional y–z sketch for η = 2.5, φ = 90°, midpoint emission, λ = 400 nm, cone azimuth α = 90°



How each number is obtained

1 θ_π = 2 atan(exp(−η)) = 9.38521°

$\beta_\pi = p/\sqrt{p^2+m_\pi^2}$ = 0.999989178

L(IP→TOF) = zTOF/cosθ_π

tTOF = L/(β_πc) = 6.28854 ns

2 zaero = 1950+30+3 = 1983 mm

Δt = (1983−1860)/(β_πc cosθ_π)

= 0.41585 ns

3 λ=400 nm → Eγ=1239.84/λ=3.0996 eV

na=1.02600; ngas≈1.000765

θC=12.9235°; α=90°

ray/sphere: $|r_0+Lu-C_m|^2=R_m^2$

Lfilter→mirror=1211.806 mm

tm=te+Σ(ng,i Li/c)=10.90721 ns

4 Cm=(0,1142.802,936.463) mm

Rm=2230.537 mm

n=(M−Cm)/Rm

uref=(0,0.642482,−0.766301)

Cs=(0,1834,1384) mm; Rs=1100 mm

$|M+Lu_{ref}-C_s|^2=R_s^2$

Lmirror→sensor=960.119 mm

Δtms=ng,gas L/c=3.20522 ns

Total representative hit time

t(hit) = 14.11242 ns

Schematic is coordinate-based but not drawn with equal z/y scale. The result is one valid sensor-hitting ray, not the full photon-time distribution.

Courtesy : ChatGPT (but YES! The numbers are actual number used by me for simulation)

ID	*	hitTime	*	photonProdT	*	phFlightT	*	pProZ
203	*****	**14.997286**	*****	**6.8215518**	*****	**8.175735**	*****	**2017.6647**
210	*	14.550011	*	6.8073000	*	7.7427115	*	2013.4494
219	*****	**16.057050**	*****	**6.8116898**	*****	**9.2453608**	*****	**2014.7429**
232	*	14.729516	*	6.7586669	*	7.9708490	*	1999.0651
247	*	14.402454	*	6.7125868	*	7.6898675	*	1985.4358
249	*	14.245842	*	6.7065315	*	7.5393104	*	1983.6447