Seeding in the Tracker Subsystem: Updates on the Seeding Algorithm

LUXE Simulation and Analysis Meeting

Arka Santra, January 5, 2020
Weizmann Institute of Science,
Rehovot, Israel

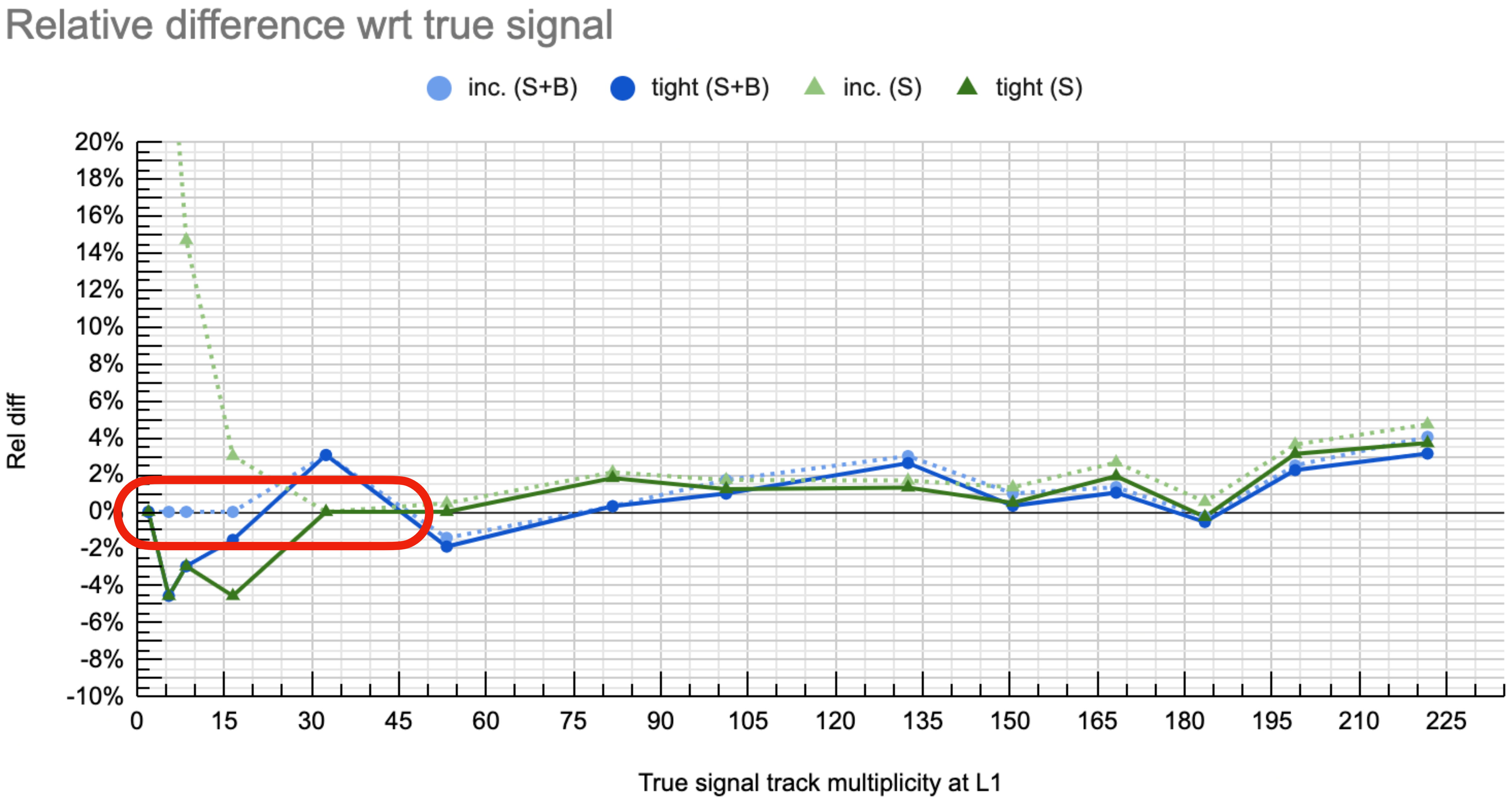
Update on the Seeding Cuts

- Discussed the basic cuts in the previous talk.
  - Not good at very low energy end (< 2 GeV)
  - Relative difference not good for low multiplicity case
- New today:
  - Put an energy cut of > 2 GeV.
  - Loosened the cut in the low track multiplicity region.
    - For low energy (< 4 GeV), road width is now 220 um instead of 130 um
    - The track fit cut and track y-momentum cuts were also changed depending on the track energy and the tight or loose tracks.
    - Full list of cuts in the backup

Seed exit window	25<|xExit|<330/2									
	|yExit|<5									
Seed Energy [GeV]	0.2<E<18									
Seed energy region [GeV]	E > 4 GeV					E < 4 GeV				
Road width [µm]	130					220				
Pre-fit seed mult.	Large	Moderate		Small		Large	Moderate		Small	
# of seeds thresh.	N>320	50<N<320		N<50		N>320	50<N<320		N<50	
# of true signal trks	N>100	15<N<100		N<15		N>100	15<N<100		N<15	
Track Energy [GeV]	2<E<15									
Track energy region [GeV]	E > 4 GeV					E < 4 GeV				
Category	All	Tight	Loose	Tight	Loose	All	Tight	Loose	Tight	Loose
2nd SVD par.	0.05	0.06	0.06	0.1	0.065	0.08	0.06	0.06	0.1	0.2
3rd SVD par.	0.01	0.06	0.06	0.1	0.065	0.02	0.05	0.05	0.1	0.05
Track y-momentum [GeV]	0.005	0.005	0.005	0.035	0.031	0.005	0.005	0.005	0.01	0.0095
x4:xExit outliers dist. [m]	0.003	0.004	0.003	0.004	0.005	0.005	0.006	0.005	0.006	0.005

Improvement in the relative difference

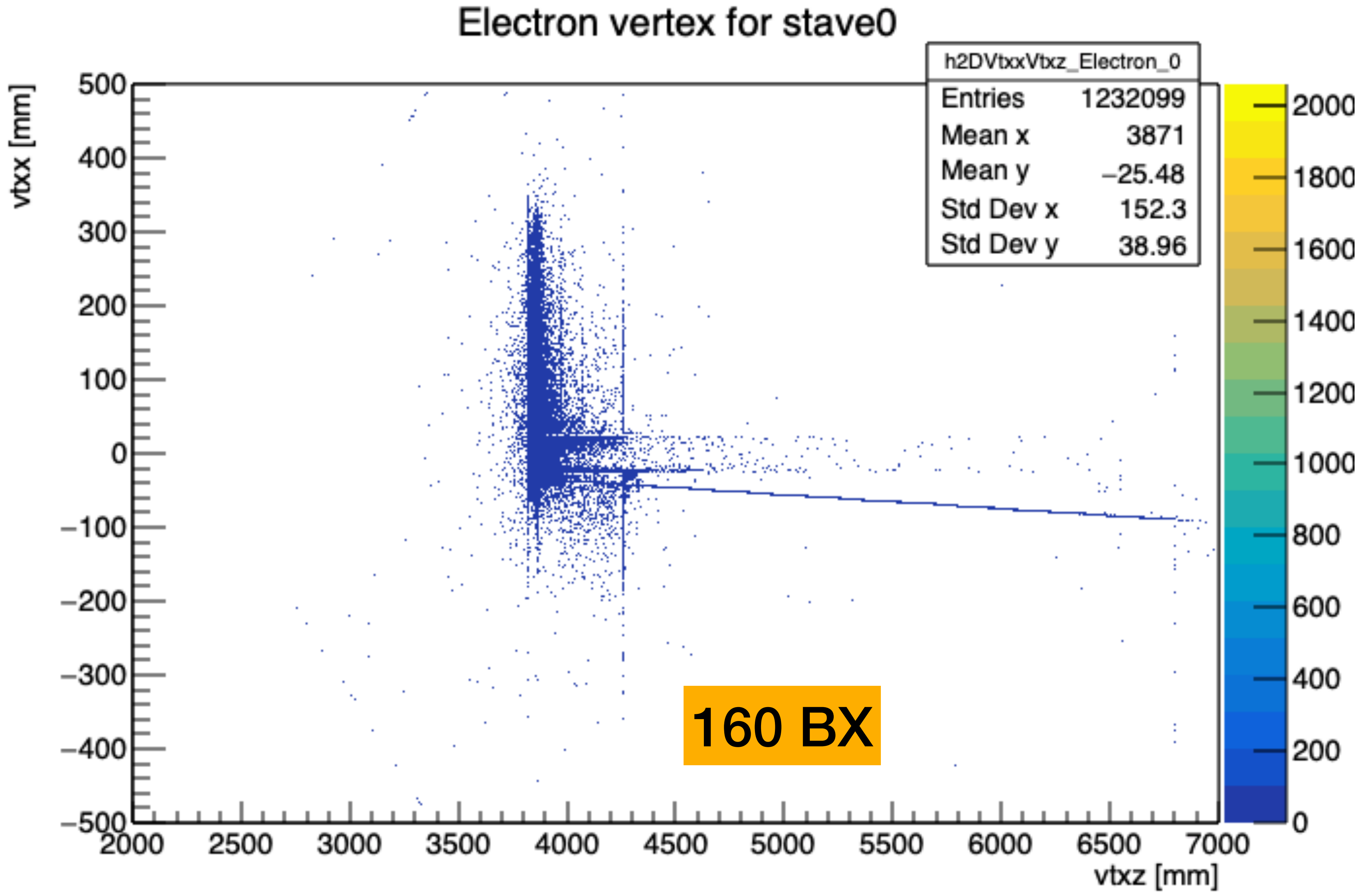
Approximate multiplicity of true signal tracks	S+B					S-only				
	# of seeds w/o fit	# of seeds w/ fit	Rel diff inc. (S+B)	# of seeds w/ fit	Rel diff tight (S+B)	# of seeds w/o fit	# of seeds w/ fit	Rel diff inc. (S)	# of seeds w/ fit	Rel diff tight (S)
0 (bkg only)	--	--	--	--	--	--	--	--	--	--
1	32.5	2.0	0%	2.0	0.0%	2.0	3.8	88%	2.0	0.0%
5	36.8	5.5	0%	5.3	-4.5%	5.5	7.0	27%	5.3	-4.5%
10	39.3	8.5	0%	8.3	-2.9%	8.3	9.8	15%	8.3	-2.9%
20	56.0	16.5	0%	16.3	-1.5%	17.5	17.0	3%	15.8	-4.5%
30	92.3	33.5	3%	33.5	3.1%	41.0	32.5	0%	32.5	0.0%
50	132.0	52.5	-1%	52.3	-1.9%	67.3	53.5	0%	53.3	0.0%
80	232.8	82.0	0%	82.0	0.3%	134.8	83.5	2%	83.3	1.8%
100	333.0	103.0	2%	102.3	1.0%	209.3	103.0	2%	102.5	1.2%
130	491.0	136.5	3%	136.0	2.6%	318.8	134.8	2%	134.3	1.3%
150	570.8	152.0	1%	151.0	0.3%	377.8	152.5	1%	151.3	0.5%
170	774.3	170.5	1%	170.0	1.0%	544.0	172.8	3%	171.5	1.9%
185	854.0	183.0	0%	182.5	-0.5%	578.8	184.5	1%	183.0	-0.3%
200	1091.0	204.0	3%	203.5	2.3%	782.5	206.3	4%	205.3	3.1%
220	1413.0	230.8	4%	228.8	3.2%	1040.0	232.3	5%	230.0	3.7%

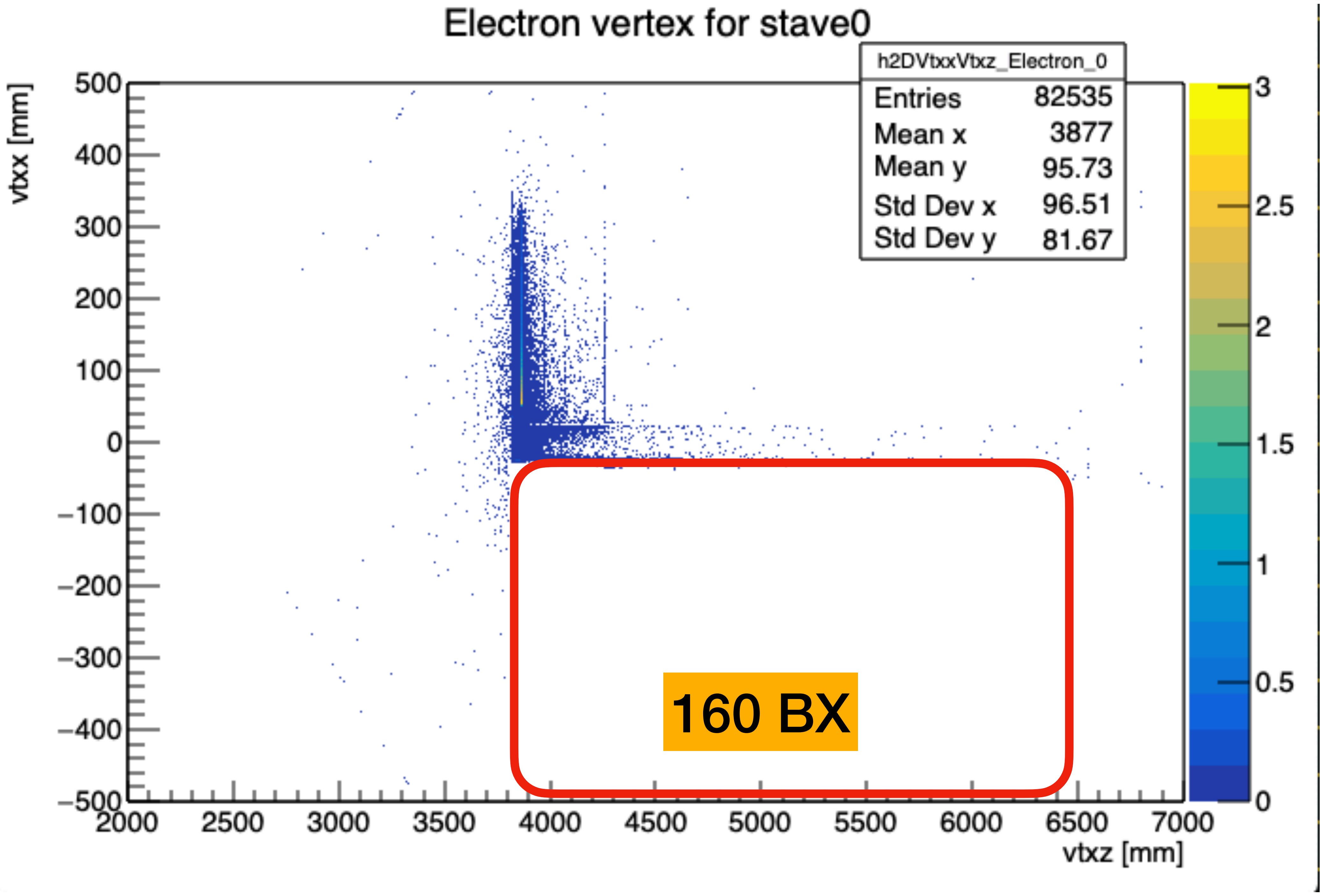


✦Low track multiplicity region now improved for S+B case
✦The relative difference is within 5% for high multiplicity case for S+B inclusive case, and close to 0% for low multiplicity case.

New electron beam only background sample

- Sasha produced 160 BX electron beam only files over the break.
- Processed them and tried to see the seeds coming from the background hits.





✦Many background electrons to tracker are coming from the beam

✦Removed all the background charged particles coming from the x < -25 mm and 380 cm < z < 650 cm

  ✦Reduces 2 orders of magnitude of tracks in the tracker

  ✦This reduces a lot of seed tracks from the background

  ✦In practice, this can be achieved by using a shielding wall so that the leakage from negative x does not happen to the tracker.

Summary

- ✦Few minor updates to the seeding algorithm made
  - ✦Increased the road from 130 um to 200 um for low energy (< 4 GeV) tracks
  - ✦Changed the distance cuts and track pY cuts for medium multiplicity and low multiplicity region.
  - ✦The fit parameter cuts were also changed.
- ✦Now low track multiplicity region is improved.
- ✦**First processing of 160 BX of background samples**
  - ✦Need to use the vertex cut to remove unwanted background electrons from negative x side.
  - ✦The cut flow shows that on average per BX we get 1 loose track and 0 tight track

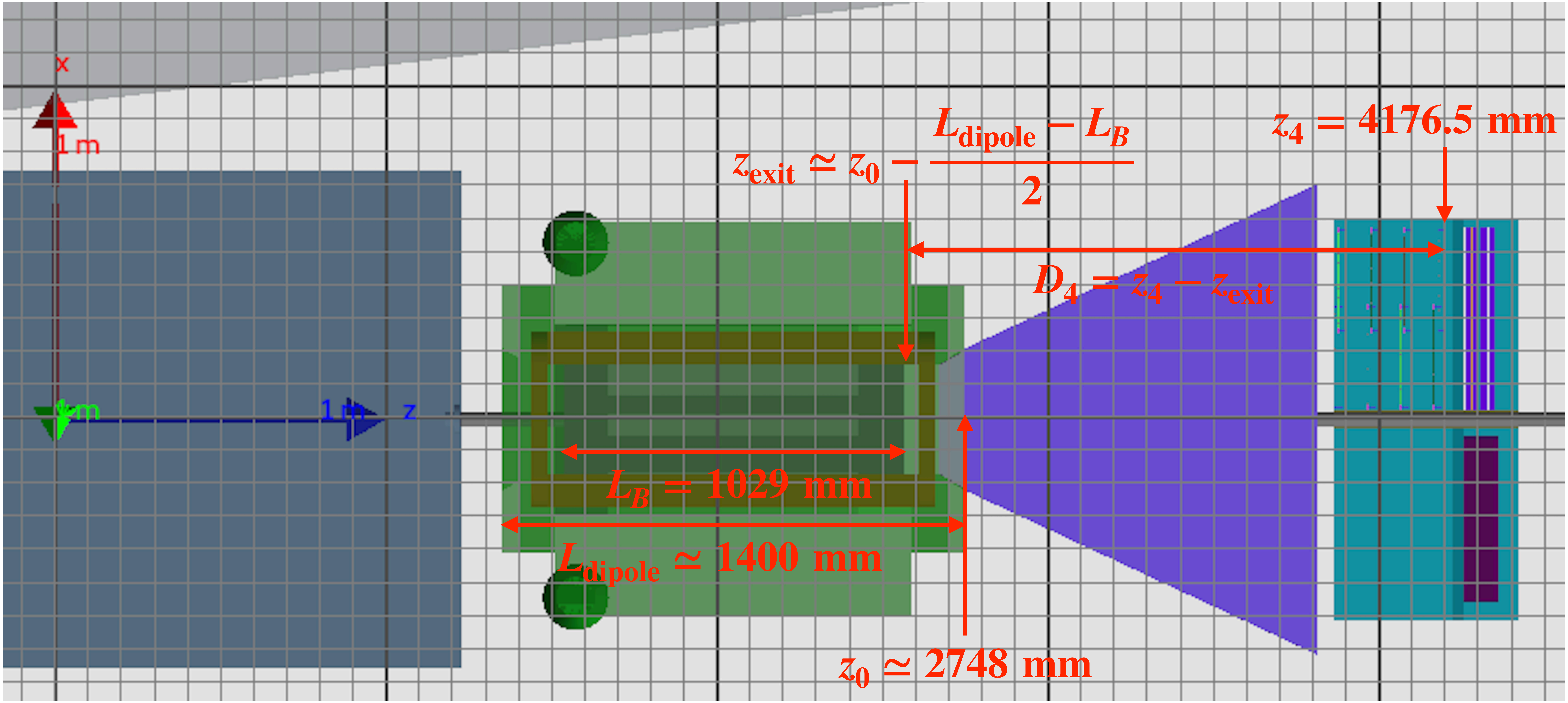
Cut flow from 160 BX of background, seeding done per BX:

('noCut', 17017806),
('x1Gtx4', 7870611),
('x1*x4Negative', 7870611),
('z1Eqz4', 7870611),
('yDipoleExitGt5p4', 1176112),
('xDipoleExitLt25', 1079387),
('xDipoleExitGt165', 464196),
('xDipoleExitLt0', 201238),
('seedEnergy', 146406),
('checkClusterTracksMiddleLayers', 4754),
('checkClusterFit', 1480),
('trackEnergy', 1202),
('checkClusterXDistance', 264),
('checkClusterTrackPy', 170),
('checkClusterTrackPyLoose', 170),
('checkClusterTrackPyTight', 0)

Backup

Numbers

z4: 4176.5 [mm], z0: 2748 [mm], zExit: 2562.5 [mm], D4: 1614 [mm]

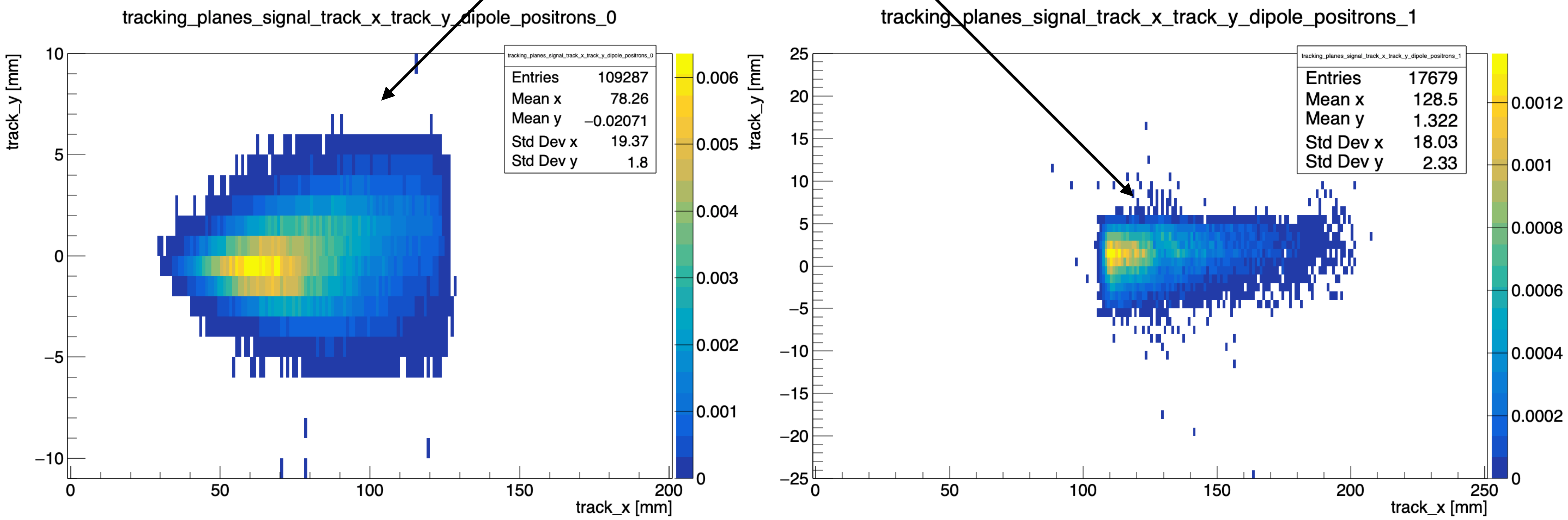


From Noam

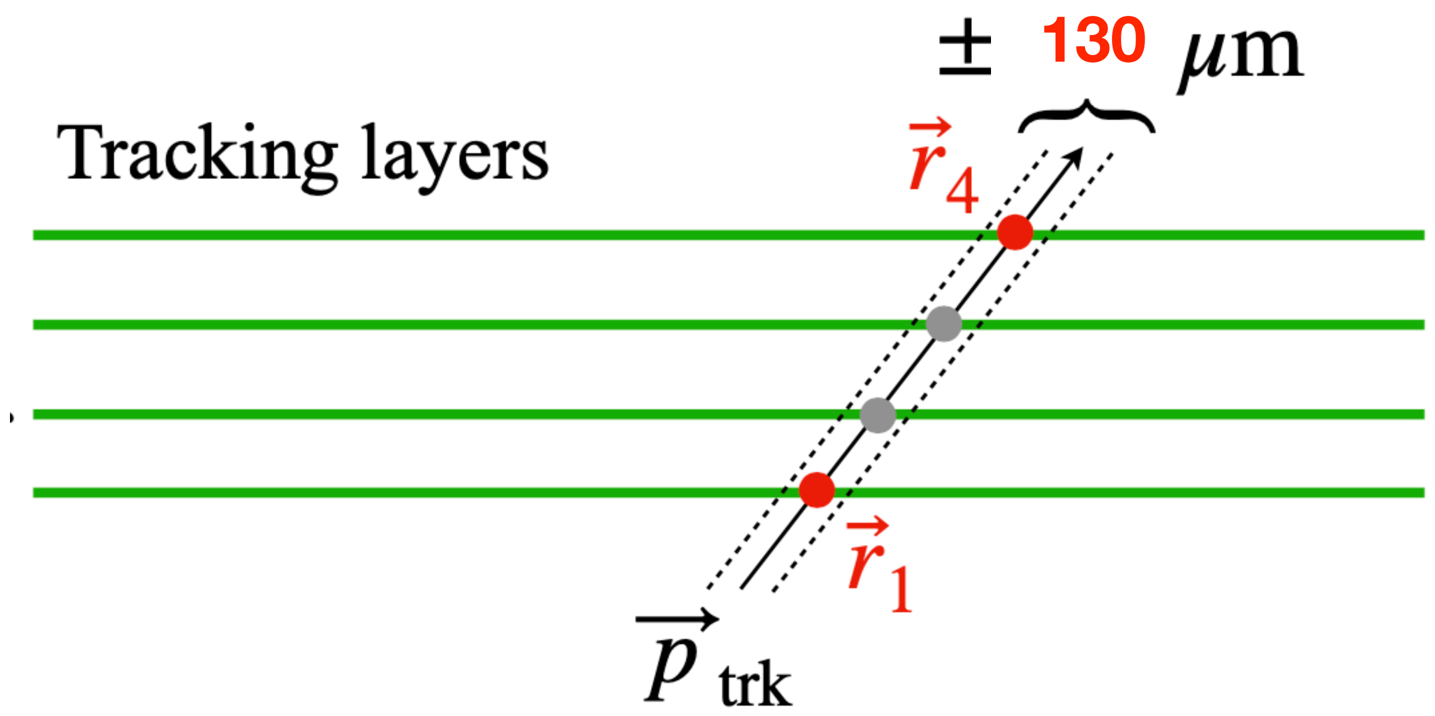
The seeding algorithm

- Keep unique set of tracks from first layer and last layer of tracker.
  - Overlap region is removed (by cutting on x value of the tracks from
    the outer stave of first layer (innermost) and from the inner stave of
    the last layer (outermost).
- Loop over all pairs in layers 4 and 1, now only positron side (x>0).
- Reject pair of clusters if
  - |x1| > |x4| or they have different sign
  - |z1| == |z4|
  - |y_exit| > 5.4 mm
  - |x_exit| < 20 mm and |x_exit| > 165 mm
  - If not one cluster in the road of 130 (220 um for < 4 GeV) um connecting vector r1 and r4 in both layer 2 and layer 3.
  - The seed energy is greater than 17.5 GeV or less than 0.5 GeV.
    - The seed energy is calculated from the track.
  - Apply the SVD fit parameter cut, distance cut and p_Y cut
    - After a good fit, the energy requirement of the track is [2,13] GeV

P side Signal at the Dipole exit (New signal)



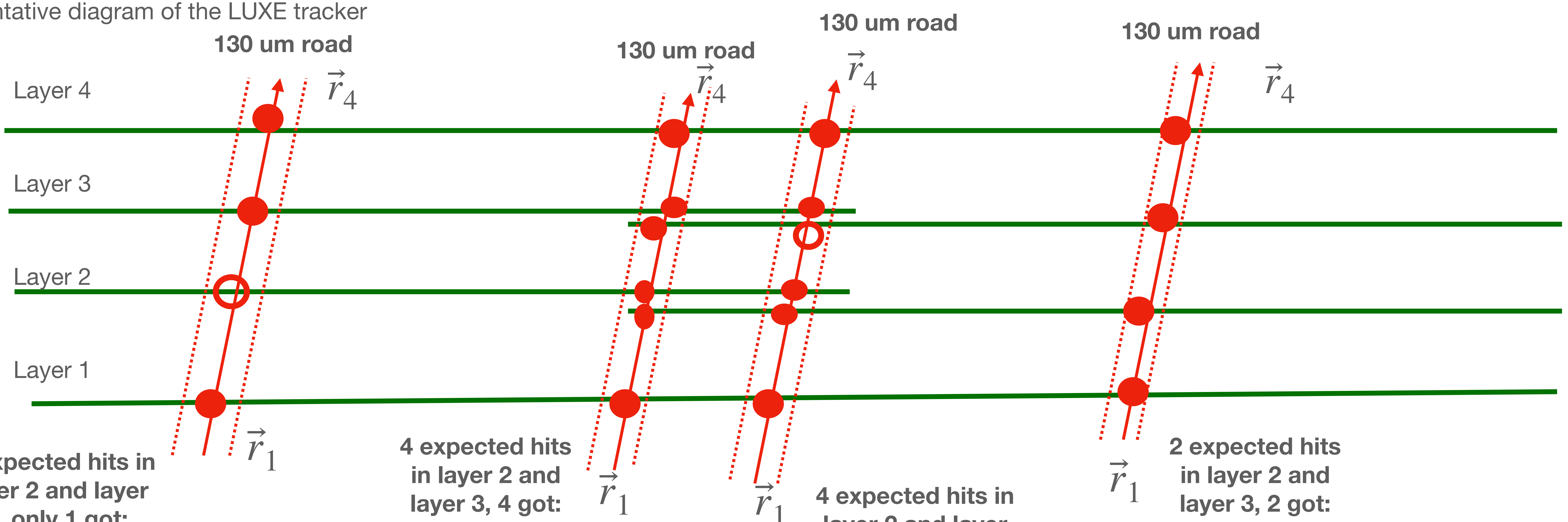
Stave 0 **Stave 1**



Tight Tracks and Loose Tracks Scenario Depending on the Hits in the Tracker Layers

- The seeding algorithm always starts from one hit in layer 4 (outer layer) and one hit in layer 1 (inner layer).

Representative diagram of the LUXE tracker



2 expected hits in layer 2 and layer 3, only 1 got: **Loose** case

4 expected hits in layer 2 and layer 3, 4 got: **Tight** case

4 expected hits in layer 2 and layer 3, only 3 got: **Loose** case

2 expected hits in layer 2 and layer 3, 2 got: **Tight** case

✦**Expected number (nExpected) of hits are obtained**
by the projection of line joining $\vec{r}_1$ and $\vec{r}_4$ and see how many hits expected in layer 2 and layer 3 given the direction.
if the projection road goes through the inactive material between two chips, then expected hit in that layer is 0.

✦**Tight case if expected hit equals to obtained hit (nObtained == nExpected)**

✦**Loose case if obtained hit is one less than expected hit (nObtained == nExpected - 1)**

✦**Any other scenarios are rejected from further processing.**

SVD track fitting

- A common application of the singular value decomposition (SVD) is in fitting solutions to linear equations.
- Suppose we collect (x_i, y_i) data, which can be fit to some linear homogeneous equation $ax_i + by_i - c = 0$. If we have our data in a matrix A, and the coefficients in some vector v, we can write this problem as $Av = 0$, where we'd like to figure out what v is given A
- We usually have more data than coefficients, in which case we can't solve this
- However, we can fit v to A in order to minimise the value of Av via SVD
- Suppose we take the singular value decomposition of $A \rightarrow A = U\Sigma V^{\mathrm{T}}$
- If one of the singular values is 0 then we have an exact solution
- If none of the singular values are zero, we have no exact solution
- However, it can be shown that the smallest singular value corresponds to the solution of the linear least squares fitting problem
- Namely, if we want to find the least squares fit to the data, we need to look at the smallest (usually the last) singular value and read the respective column of V to get the best fit coefficients (a, b, c)

From Noam