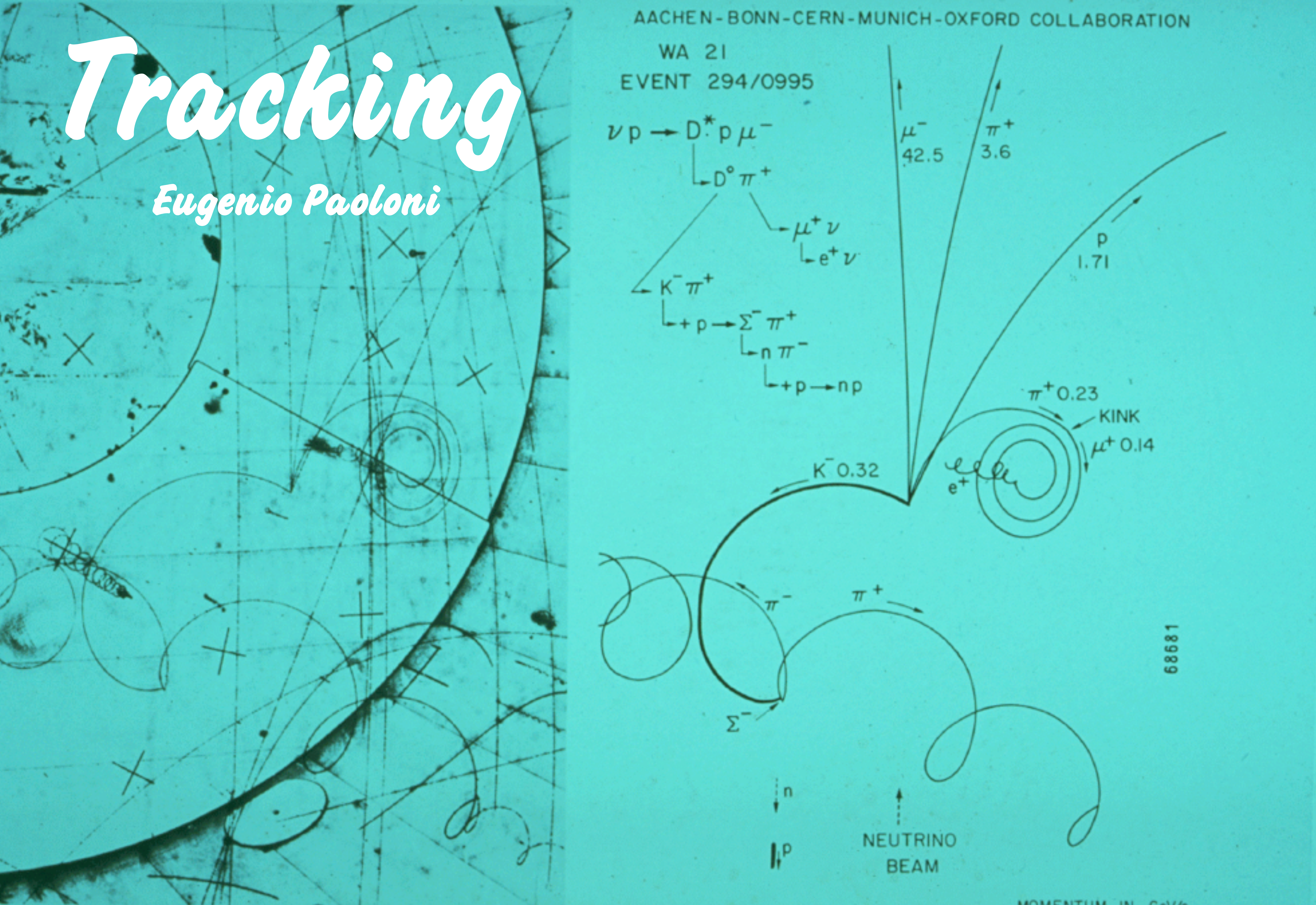
Tracking

Eugenio Paoloni



Hors D'Oeuvre: Résumé

- Status report on VXDTF2
- Status report on other activities
- Status report on open issues, pending activities

0) Pattern Recognition: Complexity of the Problem

- Given a set of **374** clusters (average Y4s event with background, present simulation) in how many way you can partition it in 12 non overlapping subsets?
  - 11 tracks +
  - background

StirlingS2 [374, 12] =
8579244752112013445320144183073086694228183791229192130021182058774964\
1436179559446247749968911846831518389612245740728531964526941049795459\
0694653776123576308210237582300645863076213963359103884113699331498842\
4984937253821782188530452612467489774779681511888099214869999009234797\
6489917458180327072450141088926514002010754791696457139830890200629213\
75001046883888823354468341866534155533175733 7

roughly

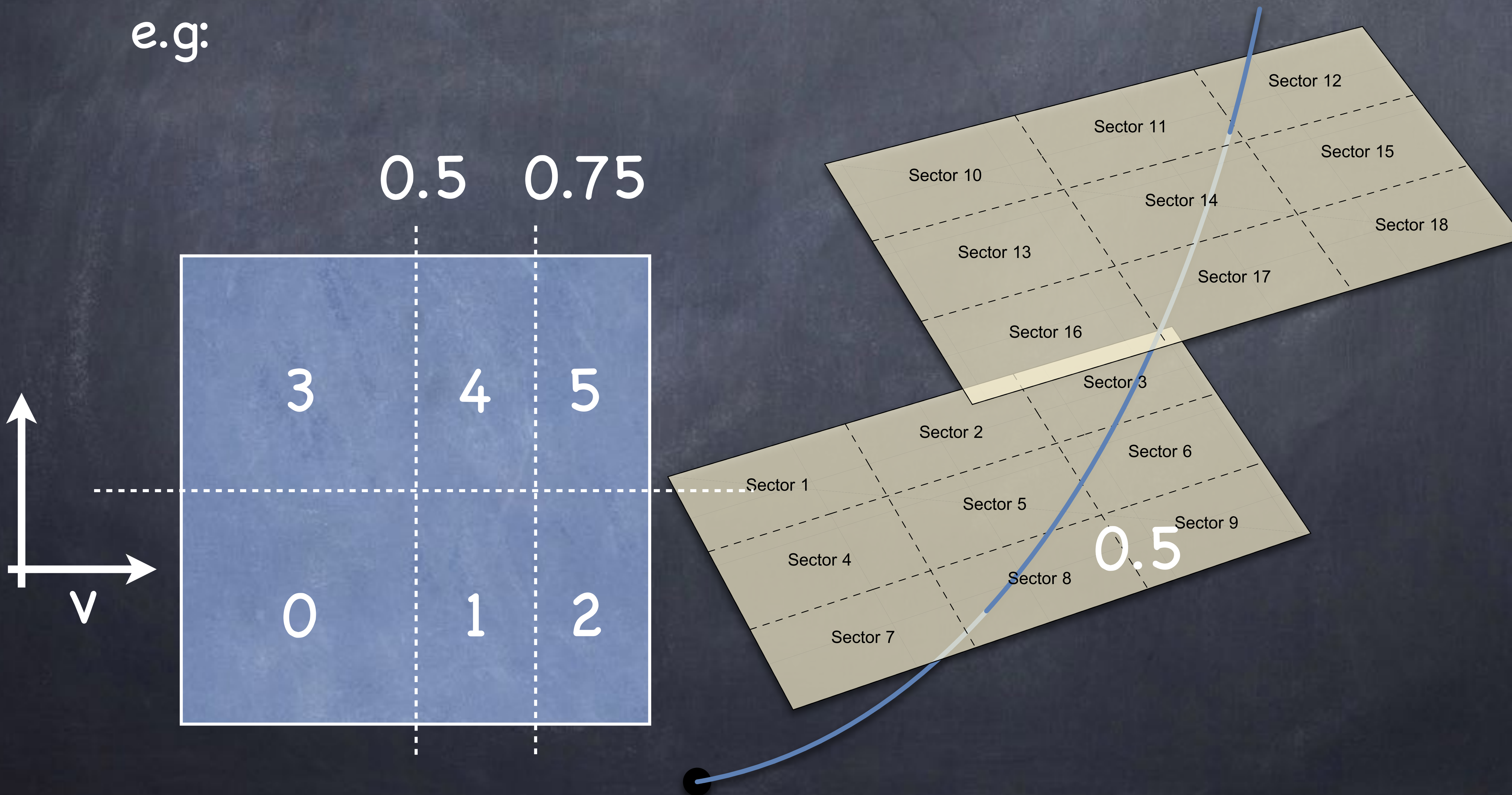
$$8.58\ 10^{394}$$

And just a single one of these partitions is the correct one. How to find it in milliseconds?

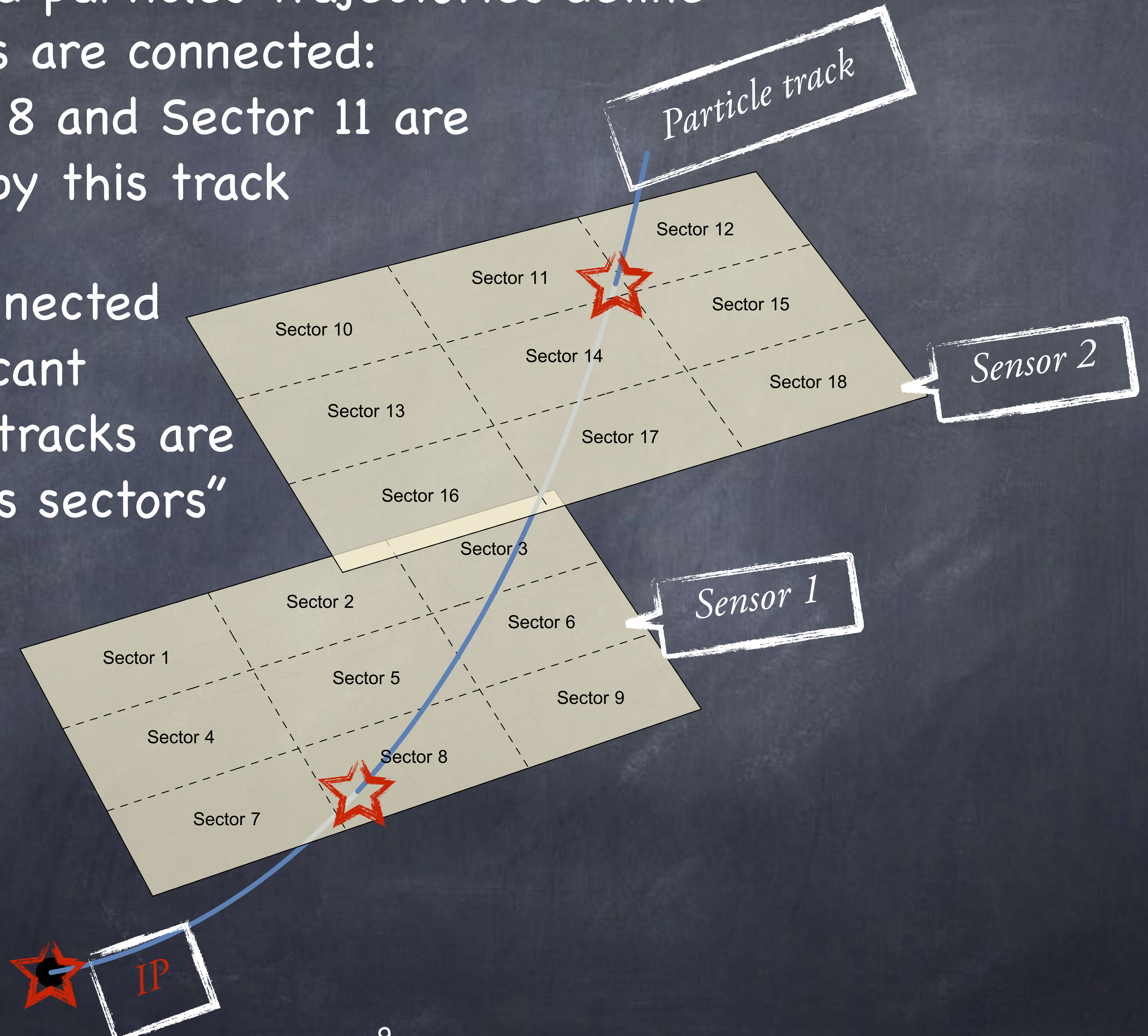
- Do not consider unlikely combinations
  - Subsets with more than 2 - 4 clusters per layer
  - Subsets whose clusters are scattered over erratically
- Just consider "reasonable combination" to reduce the haystack
  - Can we better define "reasonable combination"?

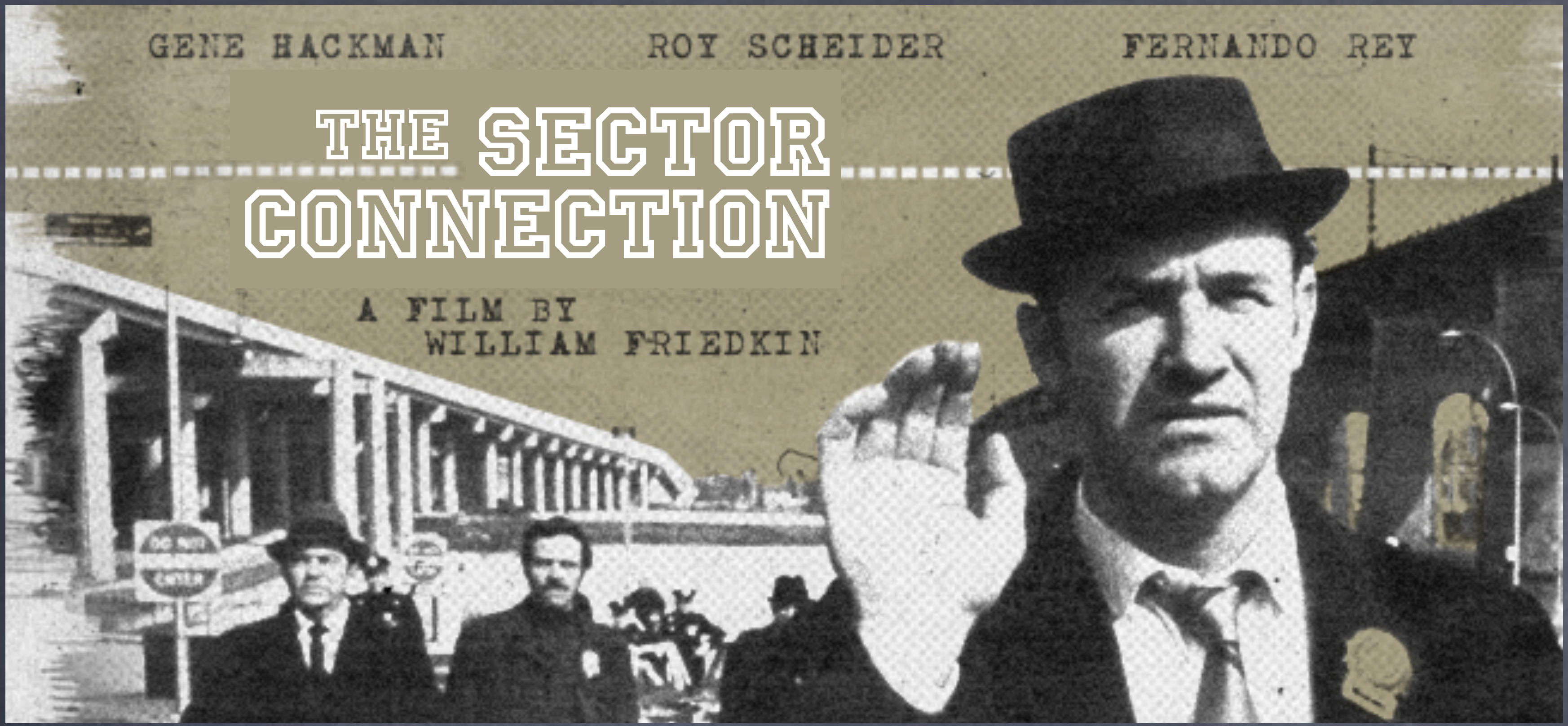
1) The Sector: Divide et Impera

- We divide the sensor active surface in sectors
  - The active surface is mapped to a square
  - The square is partitioned in rectangular areas, e.g:



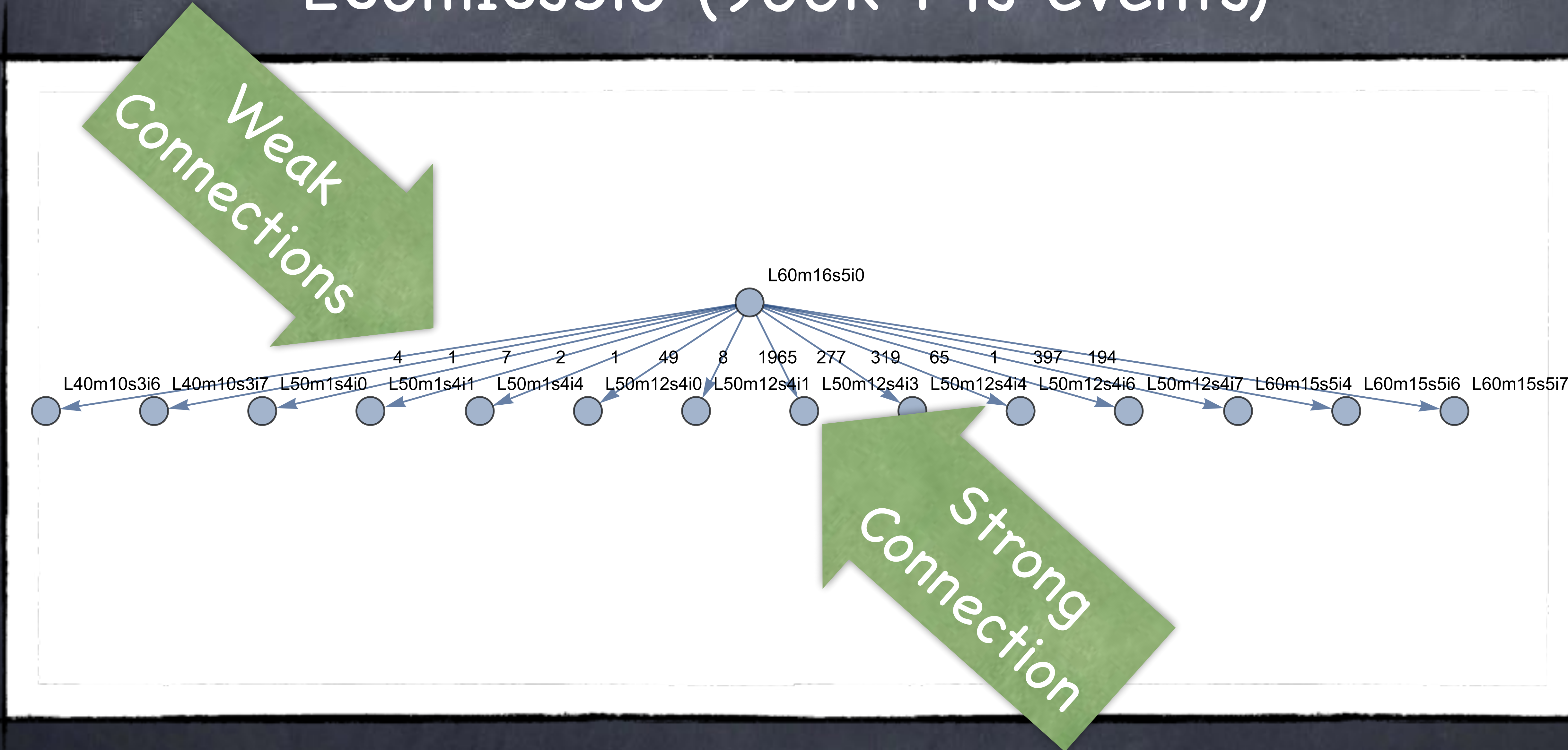
- The charged particles trajectories define how sectors are connected: E.g: Sector 8 and Sector 11 are connected by this track
- Sectors connected by a significant number of tracks are said “friends sectors”





The Sector Connection:
Il braccio violento della legge.
Al CINEMA!

Let's have a look at the sectors connected to the sector 0 on the forward sensor on module 16 on layer 6: L60m16s5i0 (900k Y4s events)



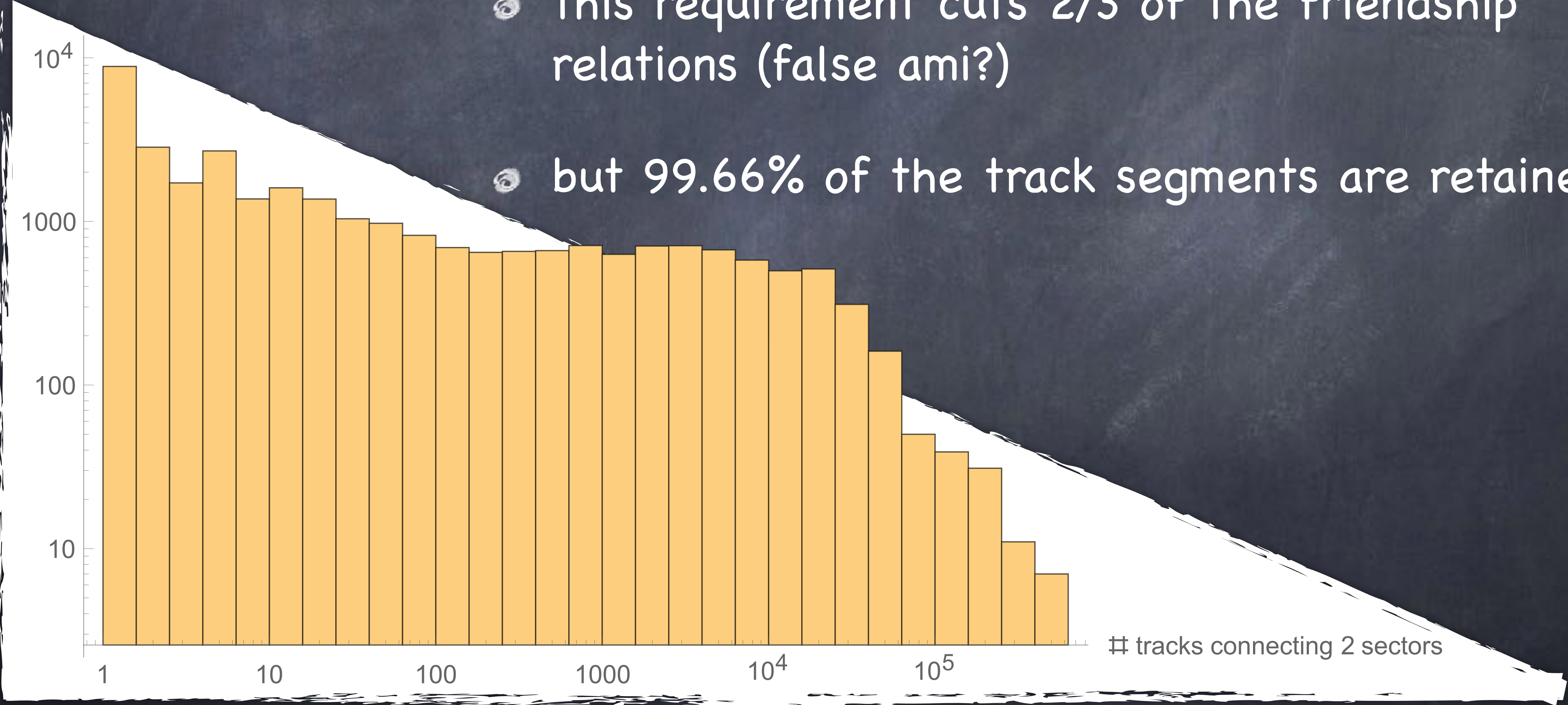
heuristic | hyo͞oˈristik |

adjective

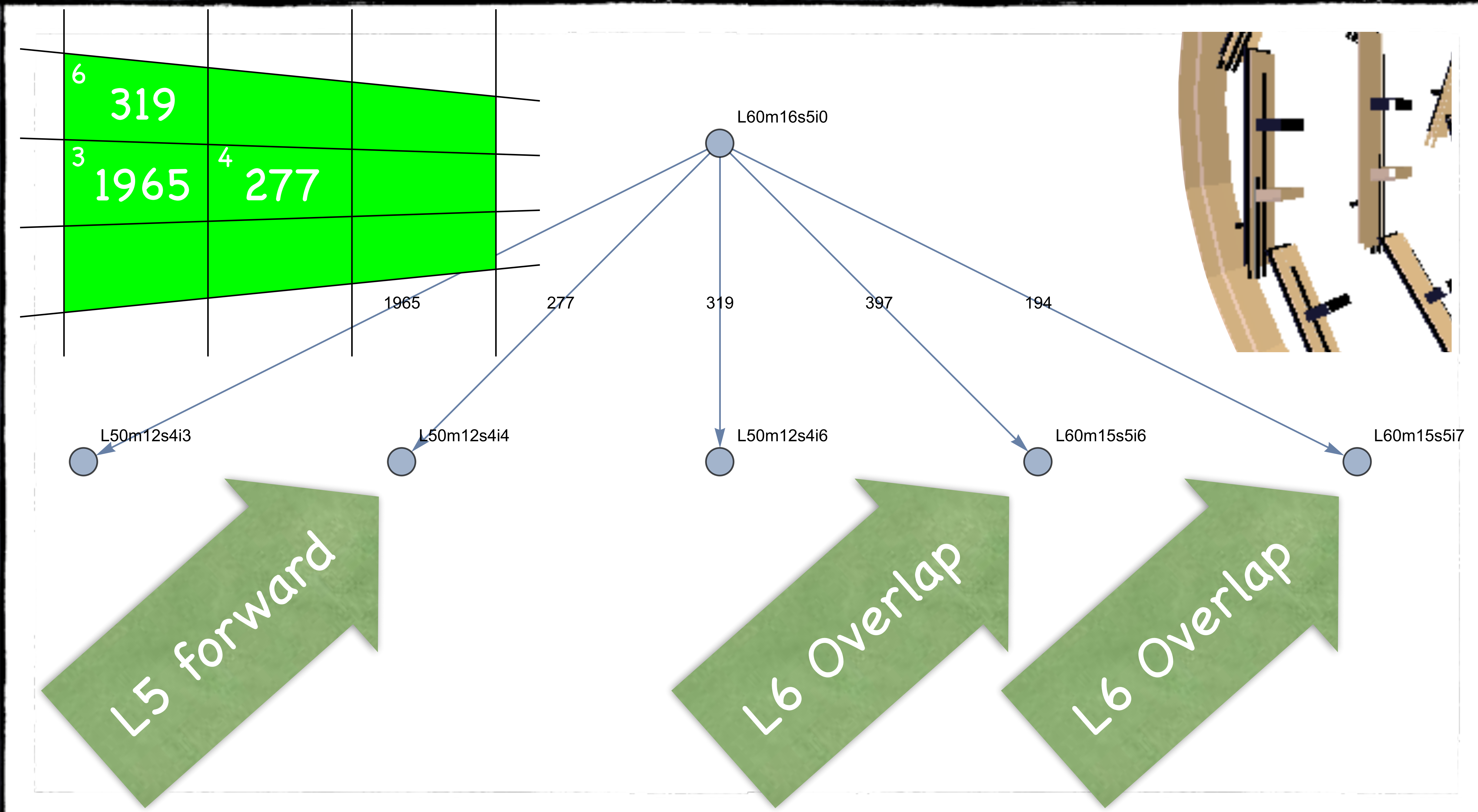
enabling a person to discover or learn something for themselves: *a "hands-on" or interactive heuristic approach to learning.*

- *Computing* proceeding to a solution by trial and error or by rules that are only loosely defined.

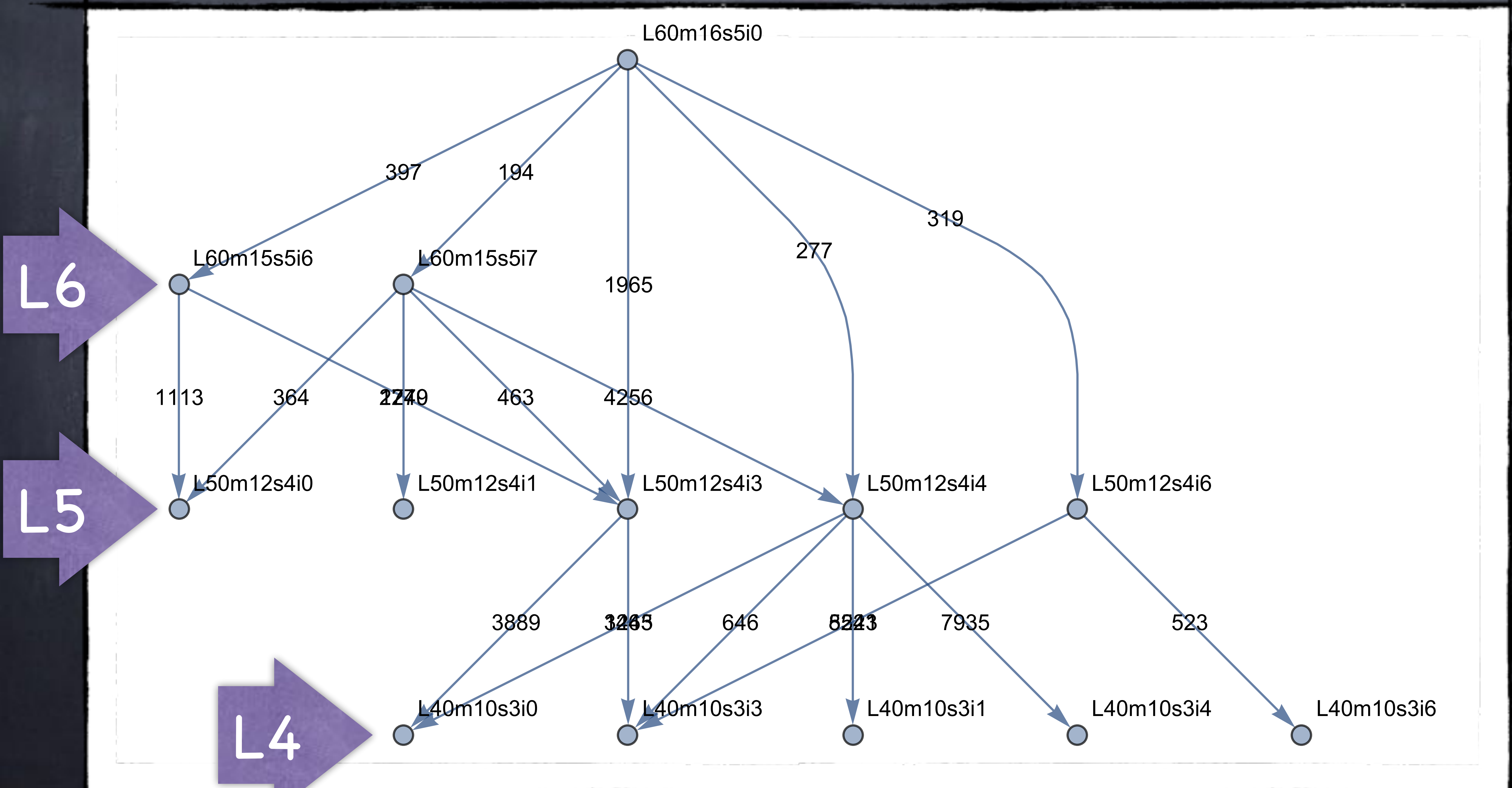
- Let's define "friends" two sectors connected by more than 100 tracks in 900k Y4S events
  - this requirement cuts 2/3 of the friendship relations (false ami?)
  - but 99.66% of the track segments are retained



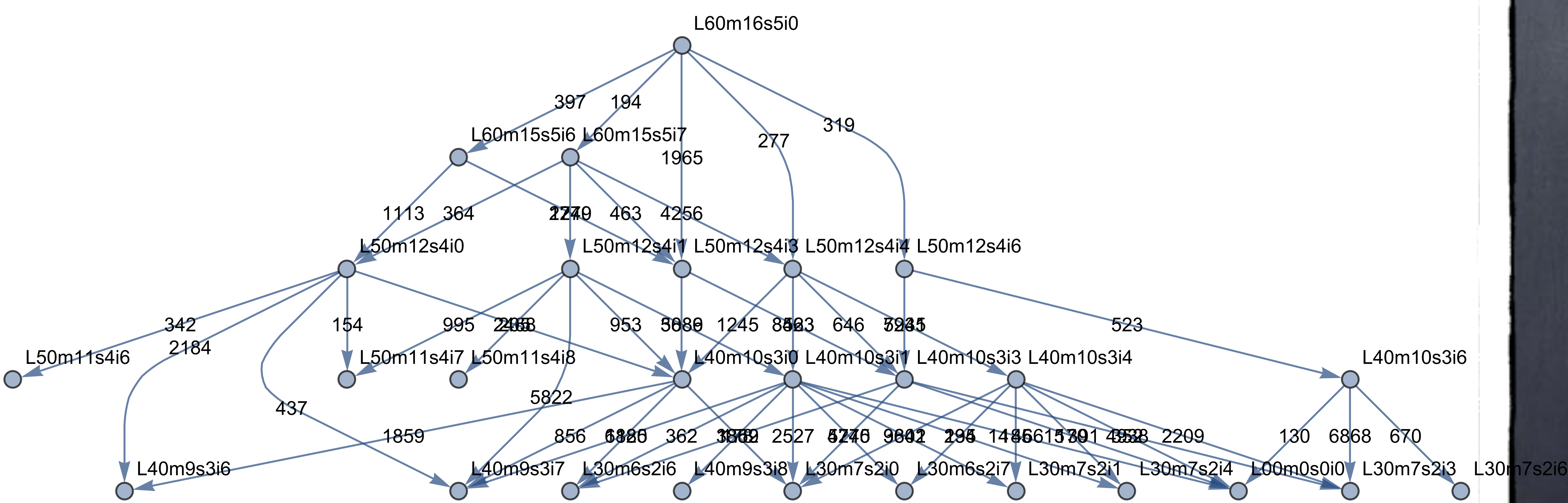
Let's have a look at the sectors connected to the sector 0 on the forward sensor on module 16 on layer 6: L60m16s5i0 (900k Y4s events)



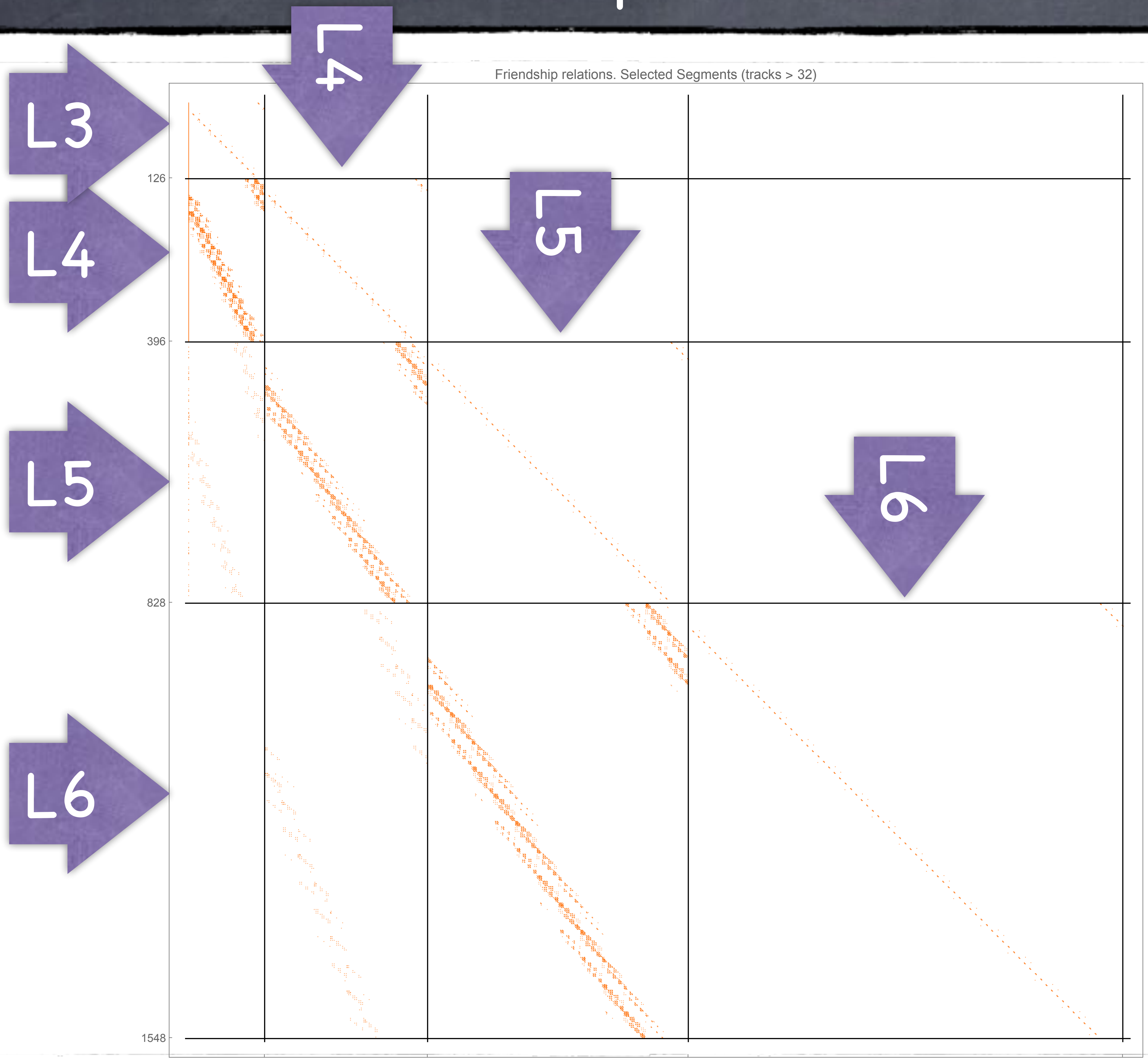
Let's have a look at the sectors connected to the sector 0 on the forward sensor on module 16 on layer 6: L60m16s5i0 (900k Y4s events)



Let's have a look at the sectors connected to the sector 0 on the forward sensor on module 16 on layer 6: L60m16s5i0 (900k Y4s events)



The Friendship relation matrix



Who takes care of the creation of the sectors?

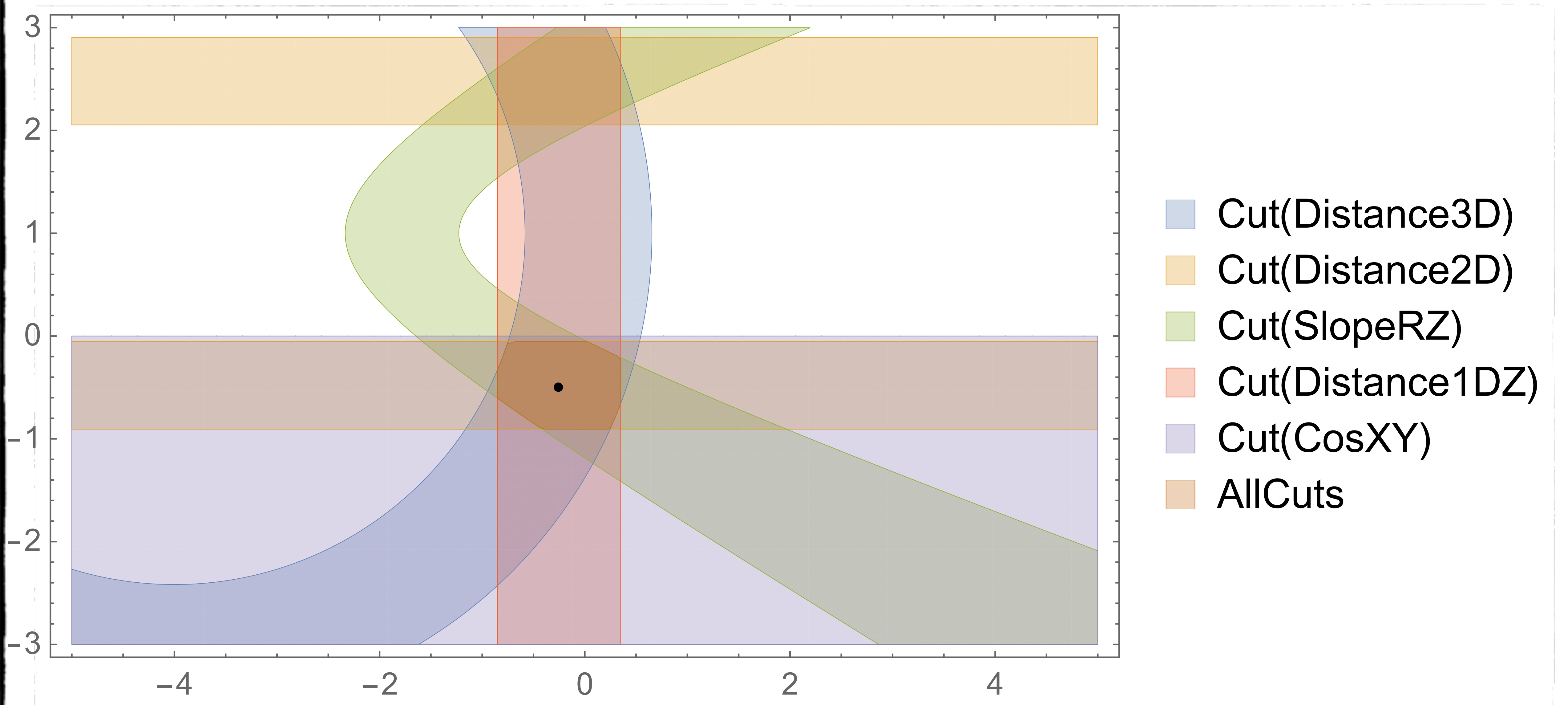
- The SectorMapBootstrapModule in module/vxdtfRedesign
- At present all the sectors are partitioned in the very same way (3x3 / sensor, that is 1548 sectors / SVD)
  - We need to investigate how close to the optimum this is (trade off memory foot print / speed)
  - We can tailor the sector to cope with sensor defects (broken APV, clusters of broken strips, etc.)

3) Filters

Filters for SpacePoints combination

- We define a filter for each pair of friend sectors in order to select reasonable SpacePoints pair combinations (aka Segments).

2 Space point Filters type



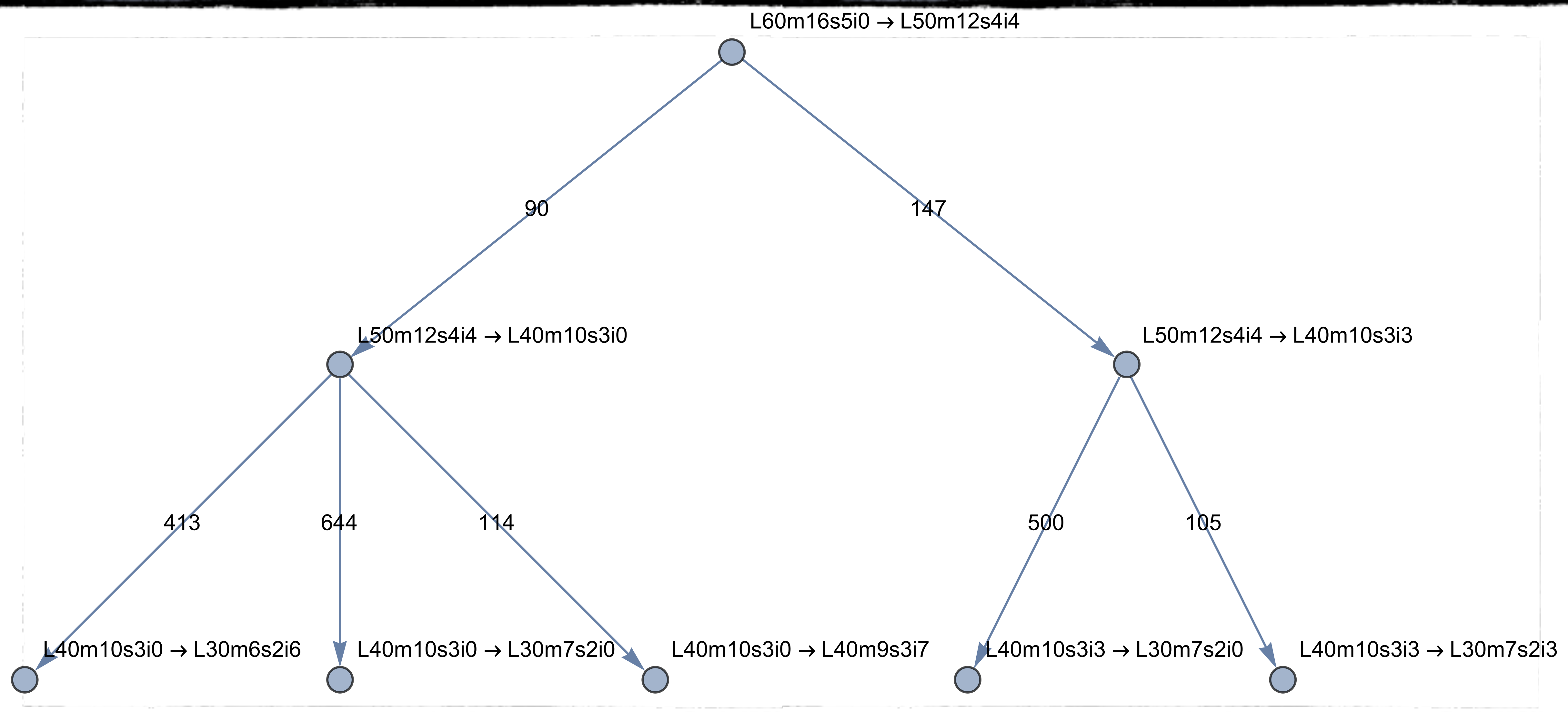
Training

- At present the implementation of the training is not yet very terse
  - One module collects the data from simulated events: VXDTFTrainingDataCollector
  - One module merges the data, it defines the friendship relations and it trains the filters: RawSecMapMerger

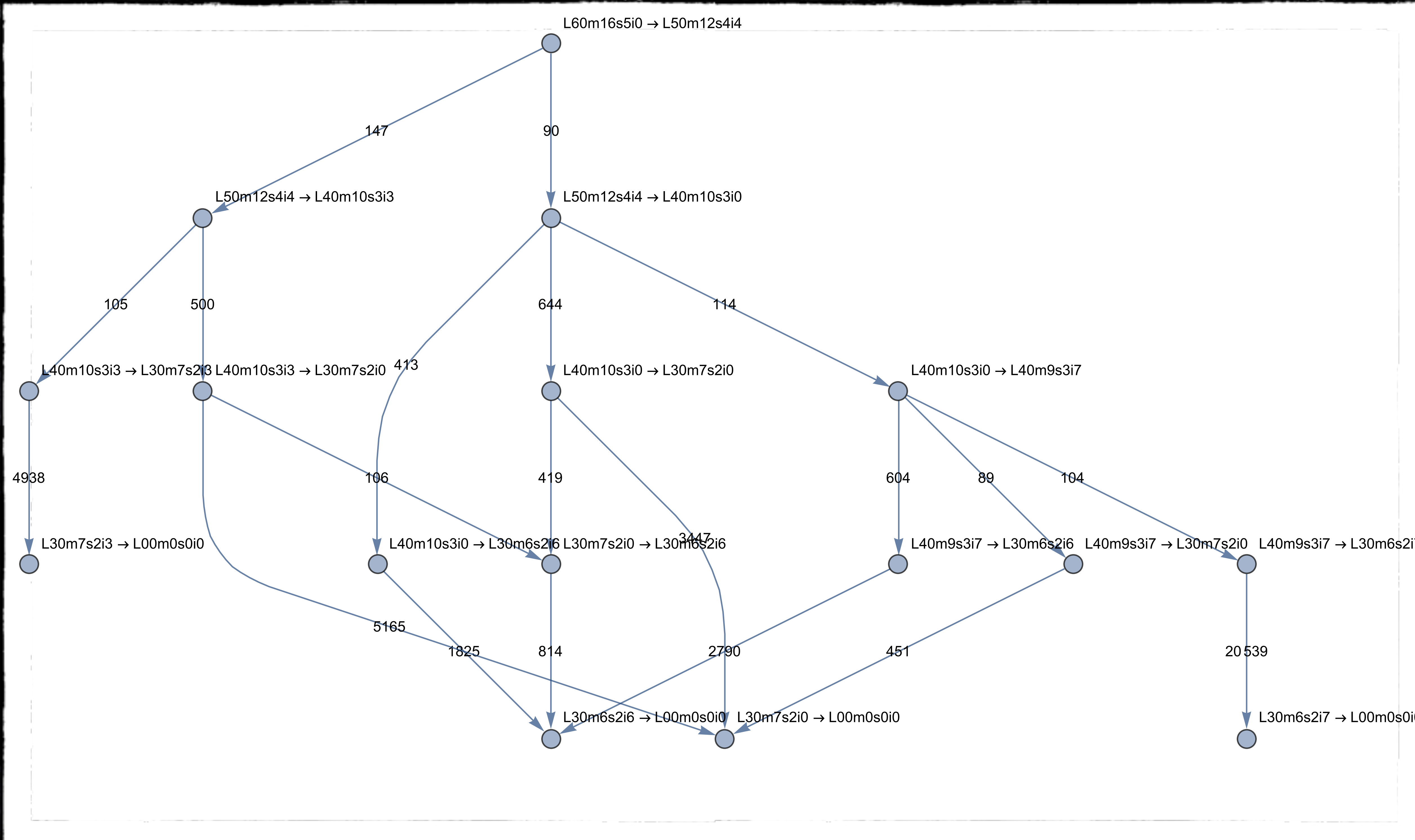
From Segments to Triplets

- Each friendship relation is treated as a node in a graph.
- By a MC sample we define the edges of the graph, i.e. the allowed combinations of segments sharing the mid VXD hit

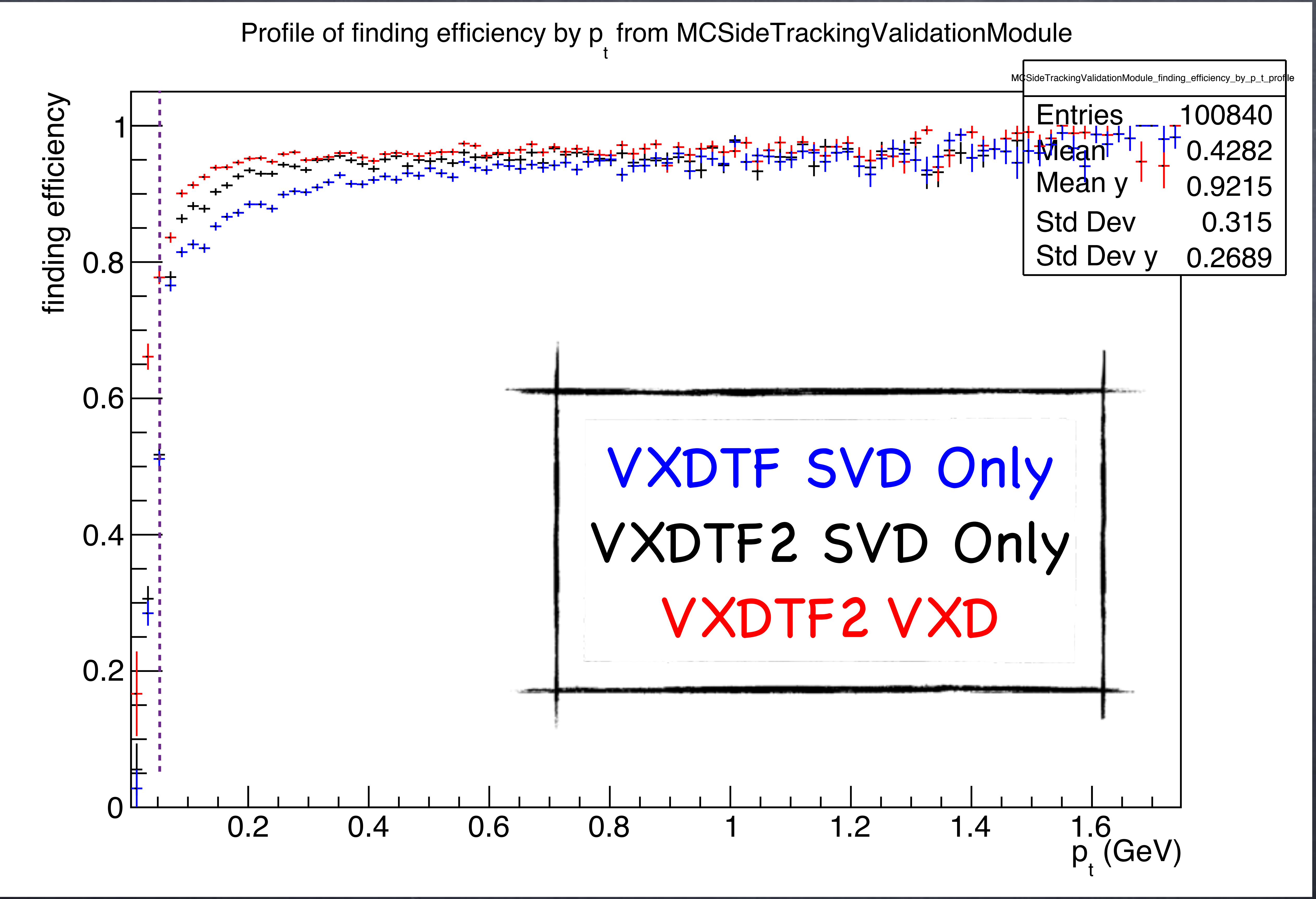
Let's have a look at the segment connection

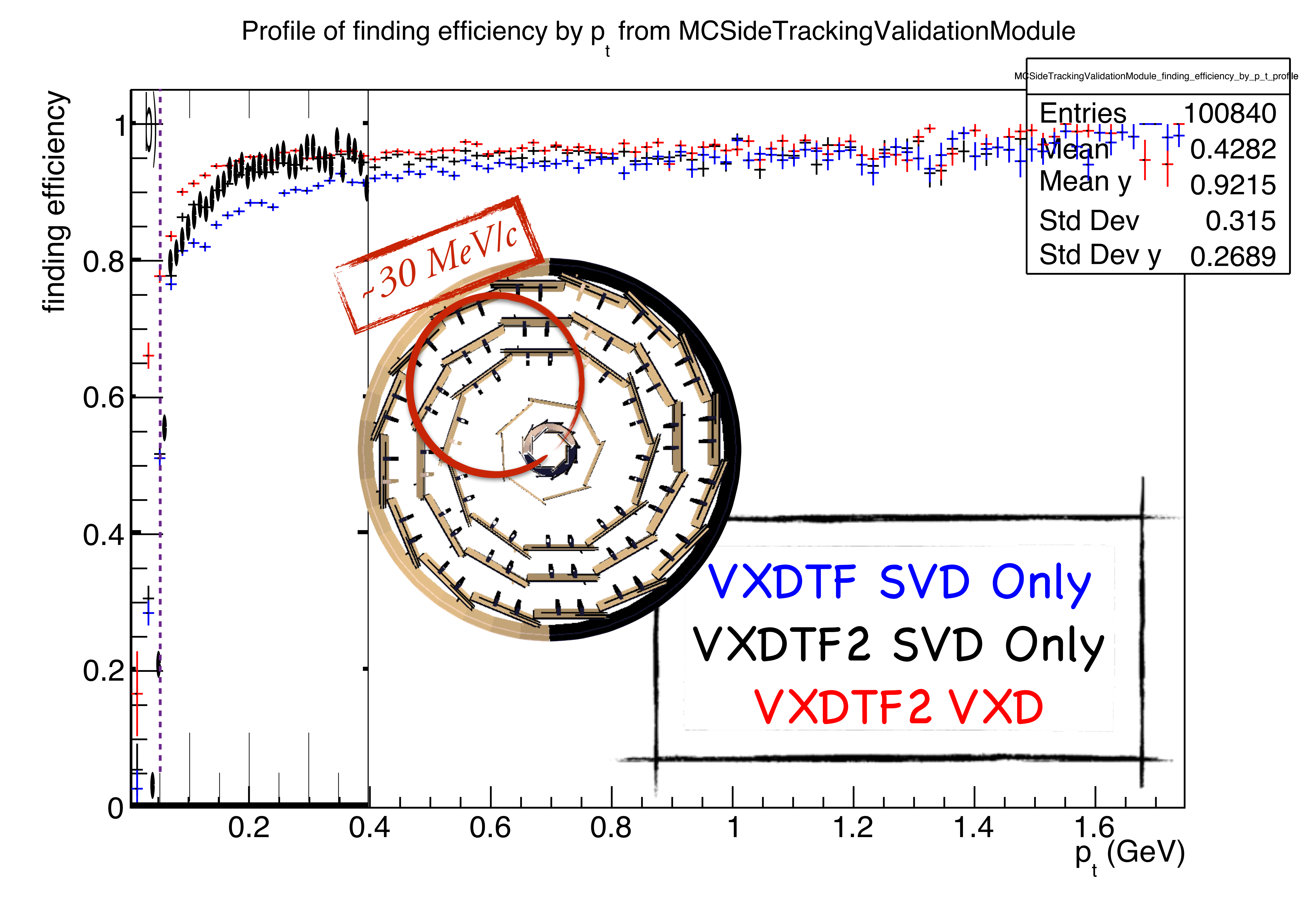


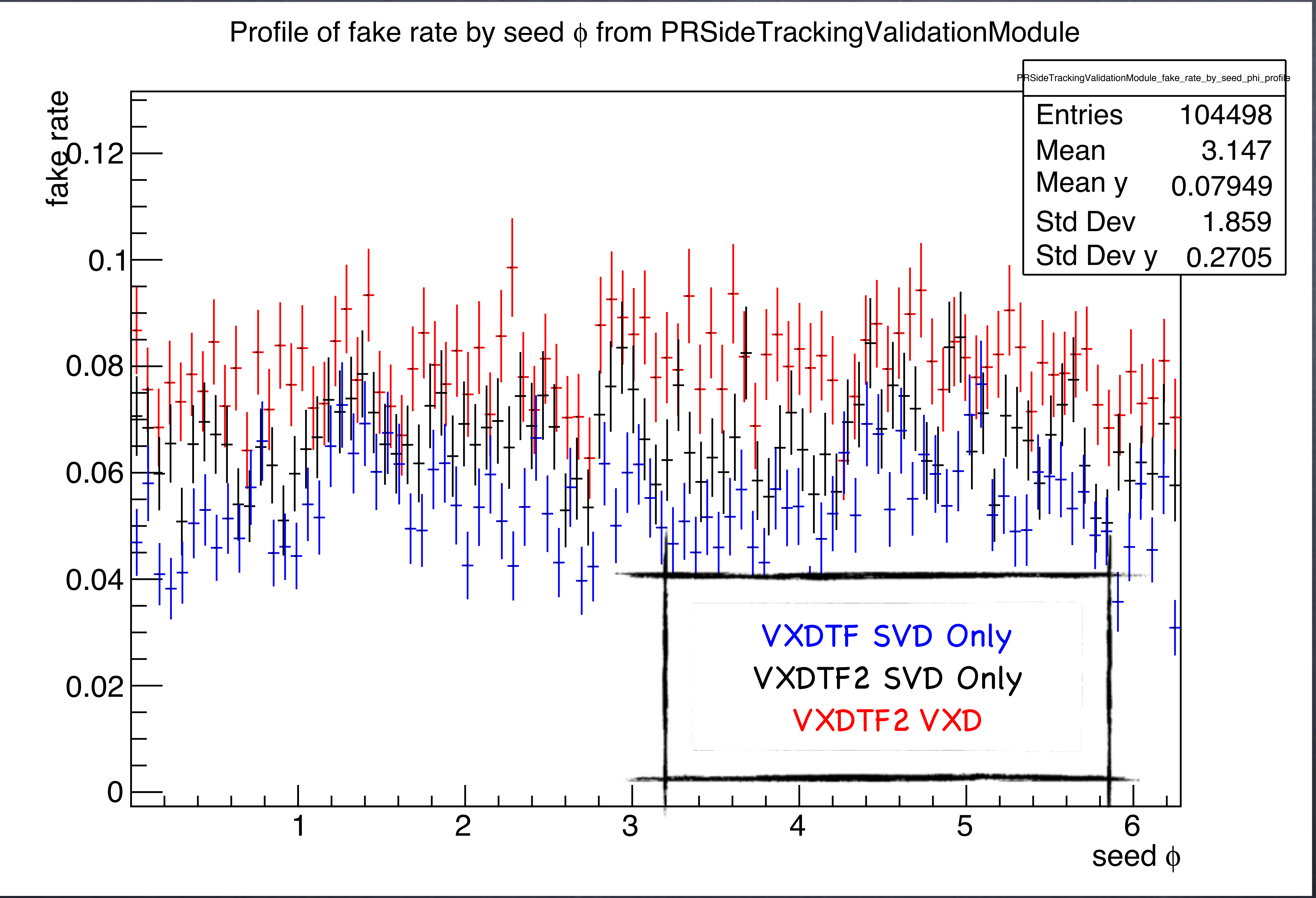
Let's have a look at the segment connection



Ok… what are the performances?


Profile of finding efficiency by p_t from MCSideTrackingValidationModule
MCSideTrackingValidationModule_finding_efficiency_by_p_t_profile
Entries 100840
Mean 0.4282
Mean y 0.9215
Std Dev 0.315
Std Dev y 0.2689
finding efficiency
p_t (GeV)
VXDTF SVD Only
VXDTF2 SVD Only
VXDTF2 VXD

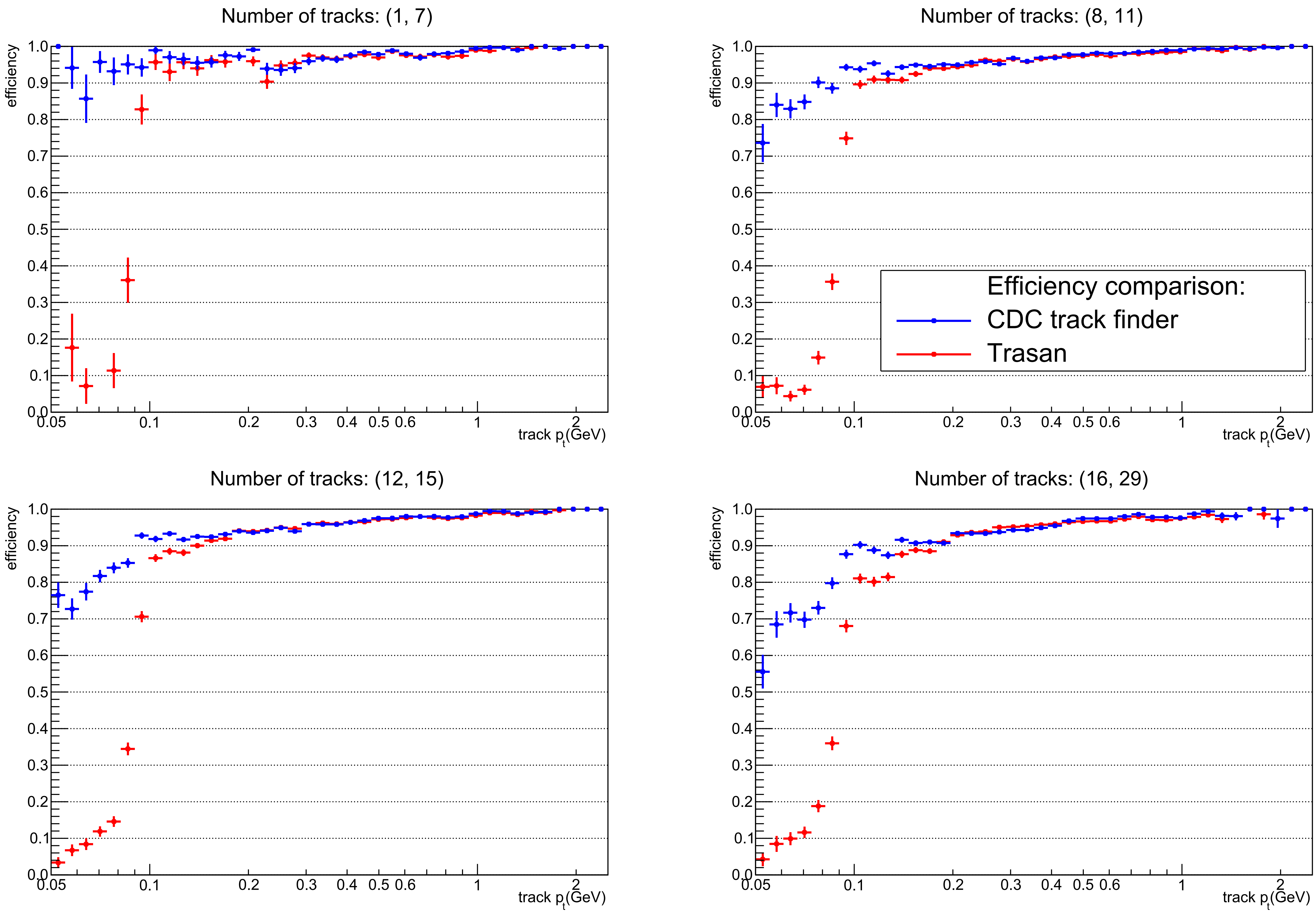

Profile of finding efficiency by p_t from MCSideTrackingValidationModule
MCSideTrackingValidationModule_finding_efficiency_by_p_t_profile
Entries 100840
Mean 0.4282
Mean y 0.9215
Std Dev 0.315
Std Dev y 0.2689
finding efficiency
p_t (GeV)
~30 MeV/c
VXDTF SVD Only
VXDTF2 SVD Only
VXDTF2 VXD


Profile of fake rate by seed ϕ from PRSideTrackingValidationModule
PRSideTrackingValidationModule_fake_rate_by_seed_phi_profile
Entries 104498
Mean 3.147
Mean y 0.07949
Std Dev 1.859
Std Dev y 0.2705
fake rate
0.12
0.1
0.08
0.06
0.04
0.02
0
1
2
3
4
5
6
seed ϕ
VXDTF SVD Only
VXDTF2 SVD Only
VXDTF2 VXD

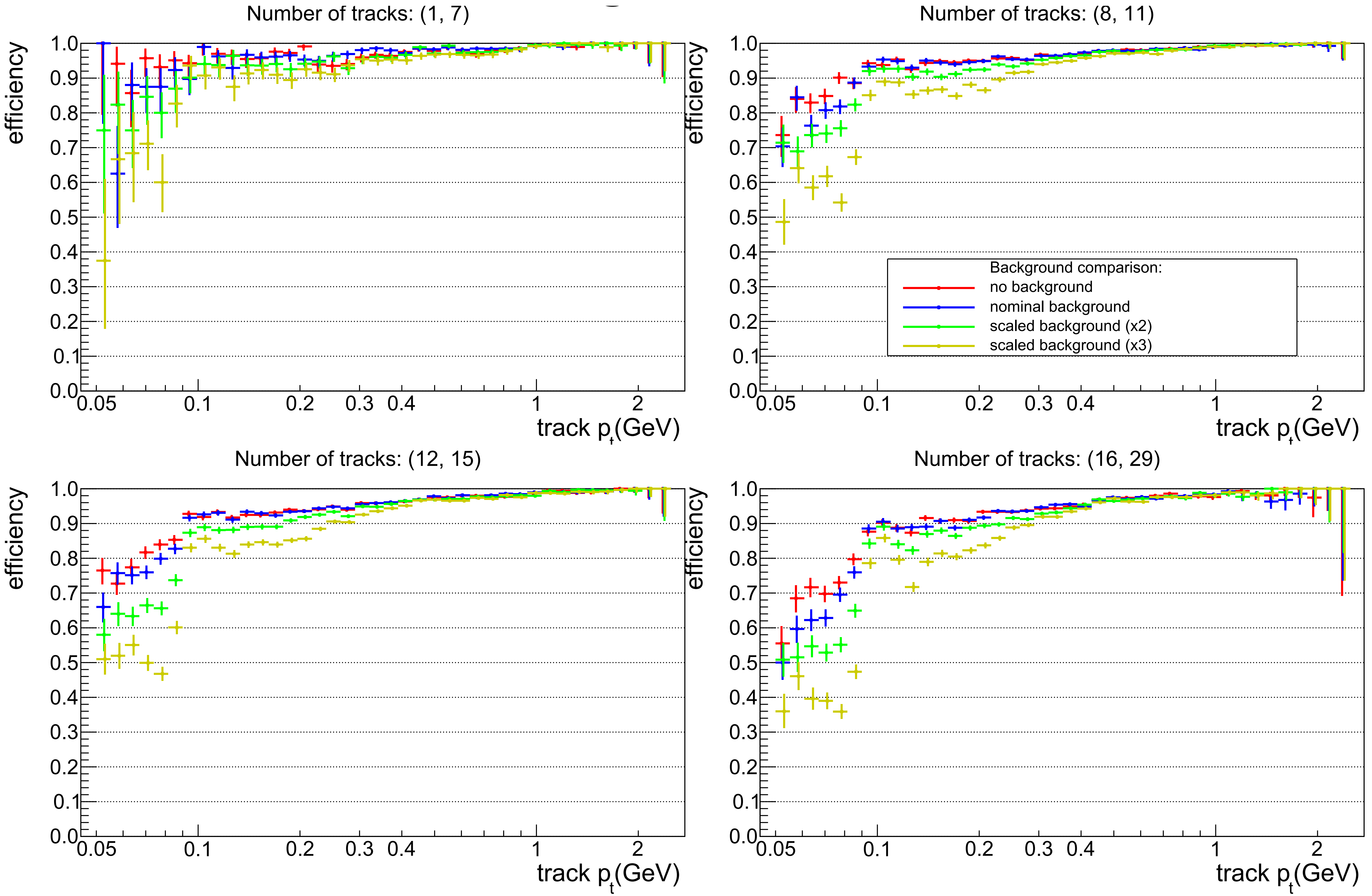
- We are almost there to say "Good farewell VXDTF"
- VXDTF2 will be optional in the next release and standard in the next to next one
- We have to:
  - use the condition database for storing the sector map
  - optimize the training procedure of the VXDTF2
  - test the VXDTF2 resilience against dead channels, dead APV, etc...
  - replicate in BelleII the efficiency studies done in BaBar

CDC track finding

CDC track finding efficiency vs p_t vs multiplicity



Track finding efficiency vs background rate



Open issues :' (

- Multiple mass hypothesis fit is not working as advertised.
- pion mass hypothesis always give the best results ??
- lack of expertise on Genfit2

Motivation

CKF

A Combinatorial Kalman Filter uses the principles of the Kalman Filter for track finding. Starting with a seed, it adds hits with some kind of Monte Carlo Tree Search algorithm.
First implementation: extrapolate from CDC to VXD (SVD).

- Reduction of fakes
- Reduction of `SpacePoint` combinations
- Increased finding efficiency

Primary

All MC tracks	10325							
MC track has VXD hits	Yes						No	
	10241						84	
VXD part was found	Yes			No			No	
	8340			1901			84	
MC track has CDC hits	Yes		No	Yes		No	Yes	
	7955		385	1622		279	84	
CDC part was found	Yes	No	No	Yes	No	No	Yes	No
	7023	932	385	1321	301	279	38	46
	Merging Efficiency	CKF	Criteria?	CKF	Very bad!	VXDTF Must help	Criteria?	CDCTF Must help

Conclusions

- Lot of work done
- The work done is paying the dividends
- Lot of exciting work to do
- Join the tracking group, work with us!

version 1 svd only

Name	Calls	VMemory(MB)	Time(s)	Time(ms)/Call
RootInput	10000	0	48.05	4.81 +- 18.69
EventInfoPrinter	10000	0	0.02	0.00 +- 0.00
Gearbox	10000	0	0.00	0.00 +- 0.00
Geometry	10000	0	0.00	0.00 +- 0.00
EventCounter	10000	0	0.50	0.05 +- 0.02
SetupGenfitExtrapolation	10000	0	0.01	0.00 +- 0.00
VXDTF	10000	0	45.59	4.56 +- 25.06
RecoTrackCreator	10000	0	3.52	0.35 +- 0.10
MCRecoTracksMatcher	10000	0	9.68	0.97 +- 0.32
CombinedTrackingValidationModule (3 modules):	10000	0	0.73	0.07 +- 0.06
EventwiseTrackingValidationModule	10000	0	29.71	2.97 +- 9.97
PRSideTrackingValidationModule	10000	0	130.26	13.03 +- 5.71
MCSideTrackingValidationModule	10000	0	71.11	7.11 +- 2.08
Total	10000	0	353.02	35.30 +- 35.63

VXDTF SVD: 4.56 ms/Events

Name	Calls	VMemory(MB)	Time(s)	Time(ms)/Call
RootInput	10000	0	58.09	5.81 +- 25.98
EventInfoPrinter	10000	0	0.02	0.00 +- 0.00
Gearbox	10000	0	0.00	0.00 +- 0.00
Geometry	10000	0	0.00	0.00 +- 0.00
EventCounter	10000	0	0.56	0.06 +- 0.02
SpacePointCreatorSVD	10000	0	6.24	0.62 +- 0.55
SectorMapBootstrap	10000	0	0.01	0.00 +- 0.00
SegmentNetworkProducer	10000	0	8.02	0.80 +- 2.47
TrackFinderVXDCellOMat	10000	0	6.06	0.61 +- 1.16
QualityEstimatorVXDCircleFit	10000	0	1.22	0.12 +- 0.27
SPTCvirtualIPRemover	10000	0	0.04	0.00 +- 0.01
SVDOverlapChecker	10000	0	39.46	3.95 +- 75.36
TrackSetEvaluatorHopfieldNNDEV	10000	0	43.56	4.36 +- 89.43
SPTCmomentumSeedRetriever	10000	0	8.30	0.83 +- 1.67
SPTC2RTConverter	10000	0	4.34	0.43 +- 0.15
MCRecoTracksMatcher	10000	0	10.77	1.08 +- 0.45
CombinedTrackingValidationModule (3 modules):	10000	0	0.81	0.08 +- 0.07
EventwiseTrackingValidationModule	10000	0	32.04	3.20 +- 9.87
PRSideTrackingValidationModule	10000	0	145.22	14.52 +- 6.01
MCSideTrackingValidationModule	10000	0	77.16	7.72 +- 2.40
Total	10000	0	462.52	46.25 +- 171.20

VXDTF SVD: 11.7 ms/Events

Y(4S) event with and without background

Case	$\Upsilon(4S)$-only	BG-only	$\Upsilon(4S)$ + BG	$\Upsilon(4S)$ + 2×BG
L3 strips u/v	49.2/36.7	260.0/121.7	308.1/158.0	562.2/278.8
L3 clusters u/v	11.8/11.8	39.0/37.9	50.3/49.3	87.0/86.1
L3 SPs	26.1	233.9	318.0	791.0
L4 strips u/v	39.4/29.1	120.3/61.2	159.1/90.1	277.8/150.6
L4 clusters u/v	12.7/12.6	29.9/26.7	42.5/39.2	71.8/65.3
L4 SPs	22.5	100.5	143.1	320.4
L5 strips u/v	37.3/28.5	122.7/67.2	160.1/95.8	282.7/162.9
L5 clusters u/v	12.3/12.1	35.0/30.5	47.3/42.7	82.0/72.9
L5 SPs	19.2	99.3	132.3	299.3
L6 strips u/v	38.3/28.6	134.6/76.8	172.9/105.4	307.1/182.0
L6 clusters u/v	12.4/12.2	42.1/36.3	54.4/48.5	96.2/84.5
L6 SPs	17.0	100.8	127.9	283.1
Average strips/layer u/v	164.3/122.8	159.4/81.7	200.1/112.3	1429.8/774.4
Total clusters u/v	49.2/48.7	146.0/131.3	194.4/179.6	337.1/308.9
Total SPs	84.8	534.6	721.3	1693.8

Signal Noise

- SP : Space Points. "u" is the local r φ direction. "v" is the local z direction.
- The combinatorial problem is dominated by background hits

StirlingS2 [85, 12] =
111394576340782713702378973006452804304336834481971947045728406152661518248995703170

more than

$1.11\ 10^{83}$