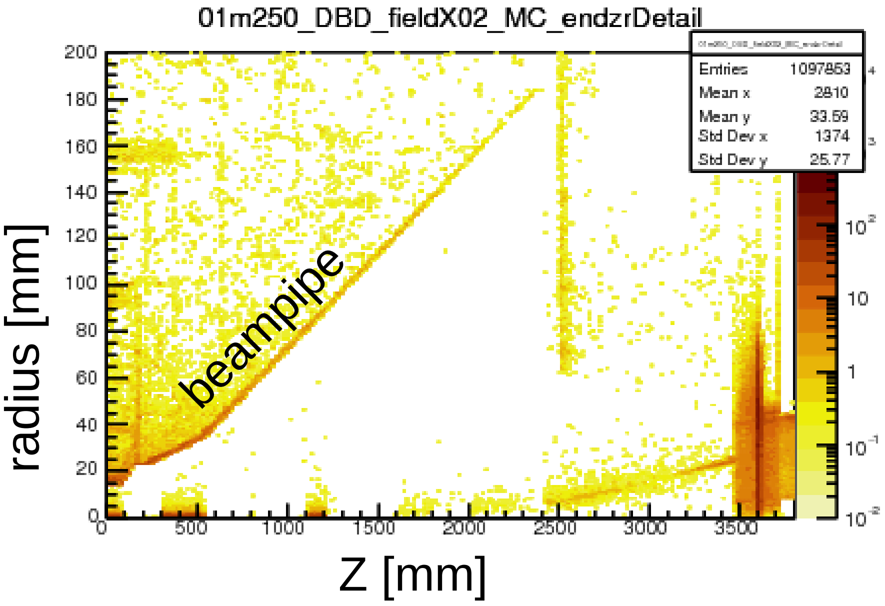
Anti-DID: impact on Backgrounds

Daniel Jeans, KEK
ILD integration meeting, 12 Feb 2019

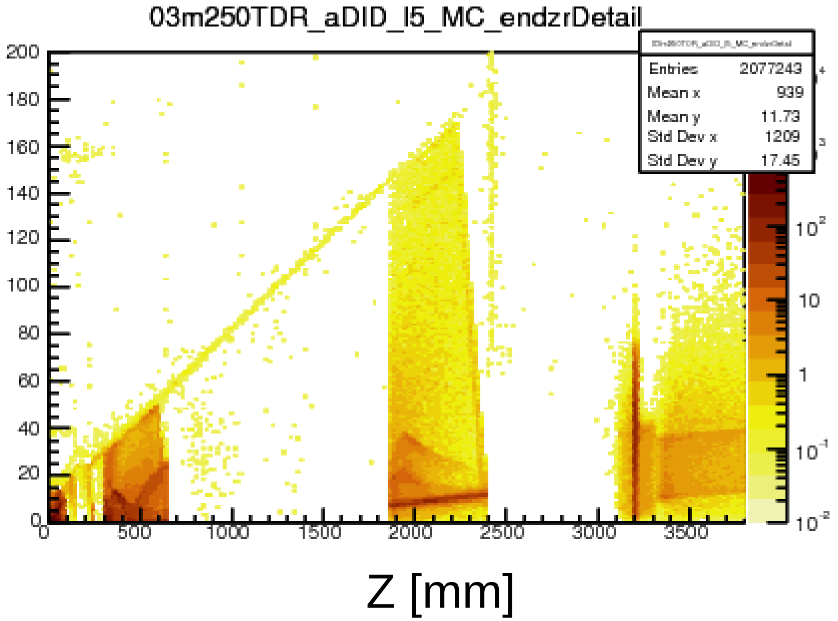
Pair background simulations

MC particle endpoints: z vs. r

DBD250
Mokka simulation



DD4hep simulation
(standard parameters)



In both cases, many low momentum particles stop inside beampipe
Geant4 “feature” in the extrapolation of particles in magnetic field

Adjust Geant4 step sizes inside the beampipe volume to minimise these problems
[reduce maximum step length from 10m to 10mm]

250 – new params

500 GeV

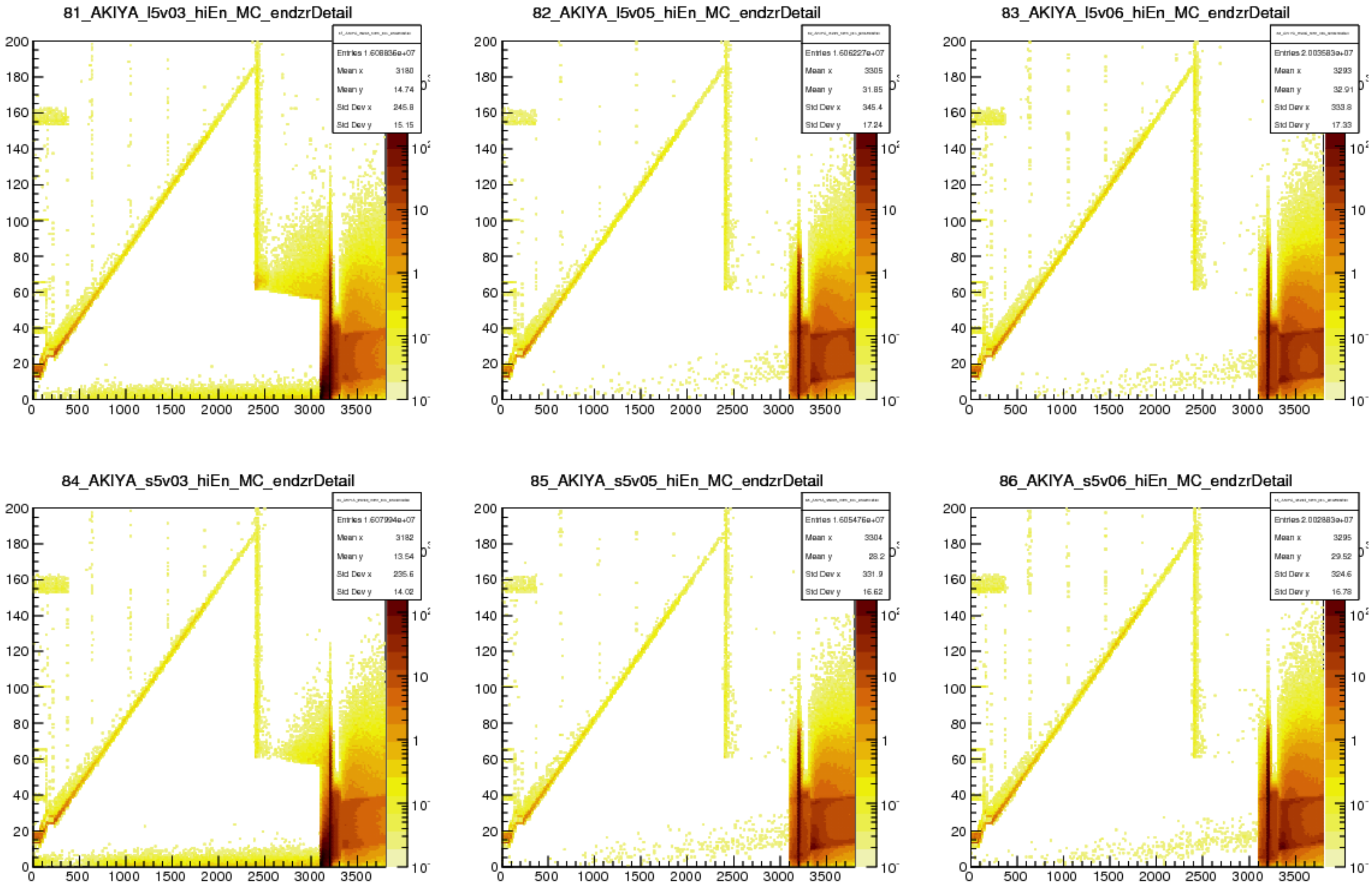
No a-DID

a-DID

DD4hep simulation

Large

Small



Now looks much more reasonable

100 bunch crossings simulated with these simulation parameters
[credit: A Miyamoto]

GuineaPig simulation, 250 GeV (new beam parameters),
500 GeV (TDR parameters)

[to improve efficiency of simulation, initial particles with E<2 MeV are cut:
these give only a per-mille level contribution to the number of detector hits,
while taking ~half the simulation time]

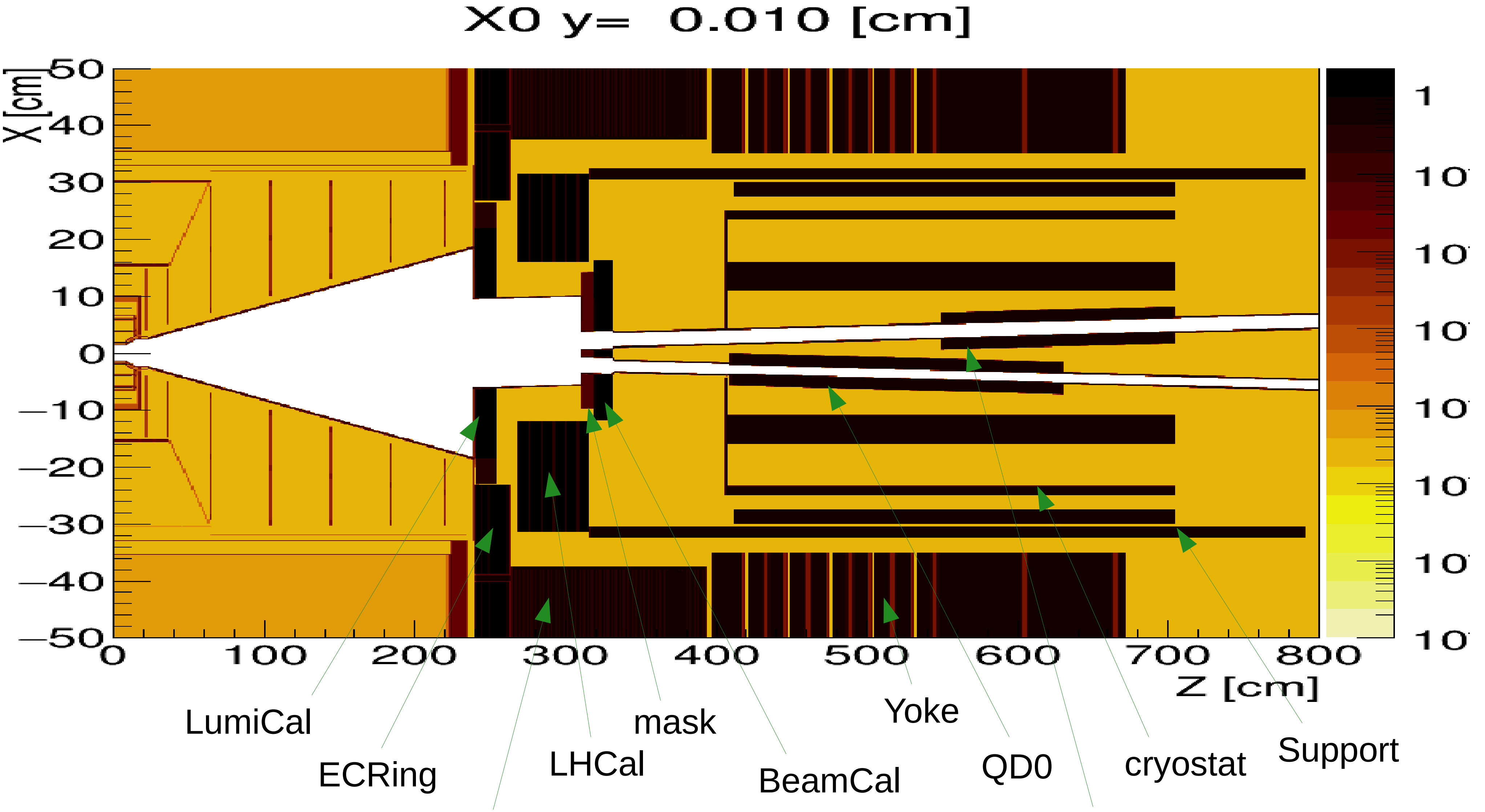
large & small models
relatively detailed description of forward region

using detailed B-field maps

with and without anti-DID field

Look at simulated hits in the various detectors

Material in the simulation



LumiCal

ECRing

HCAL endcap

LHCal

mask

BeamCal

Yoke

QD0

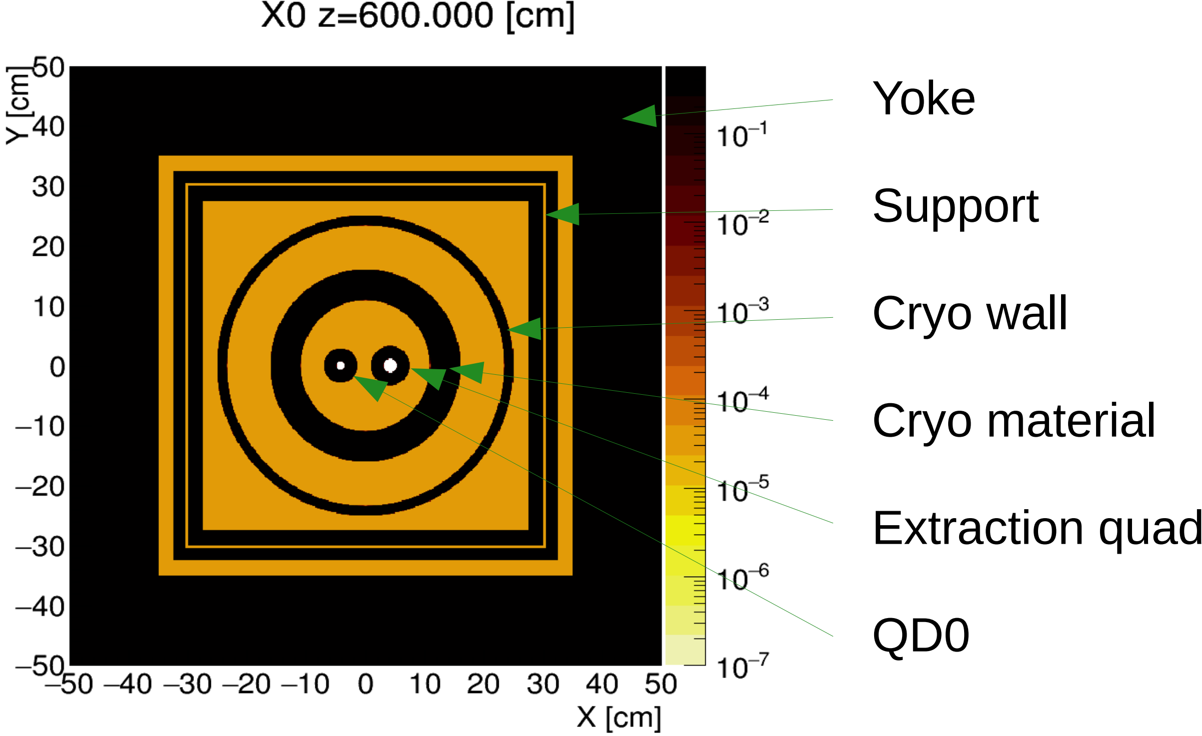
Extraction quad

cryostat

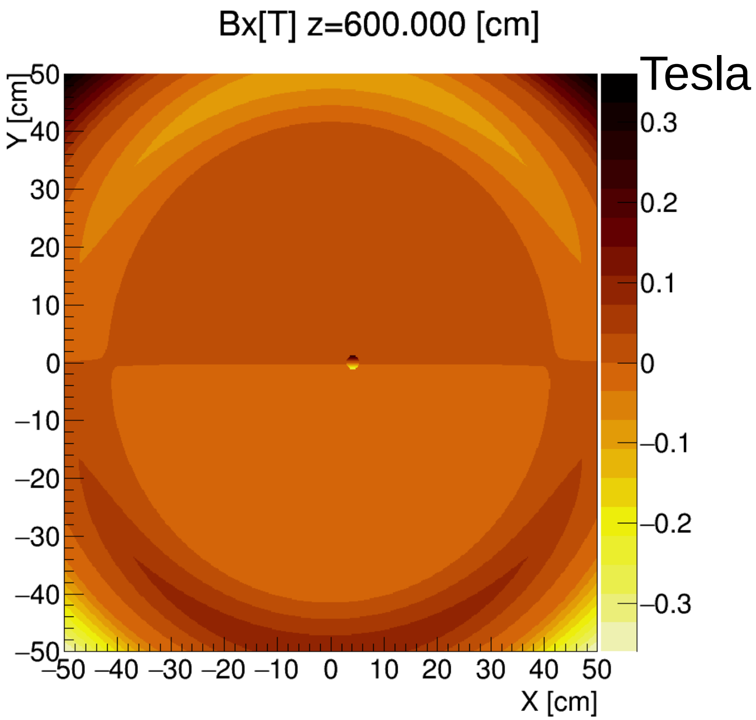
Support

Slice at z = +6 m

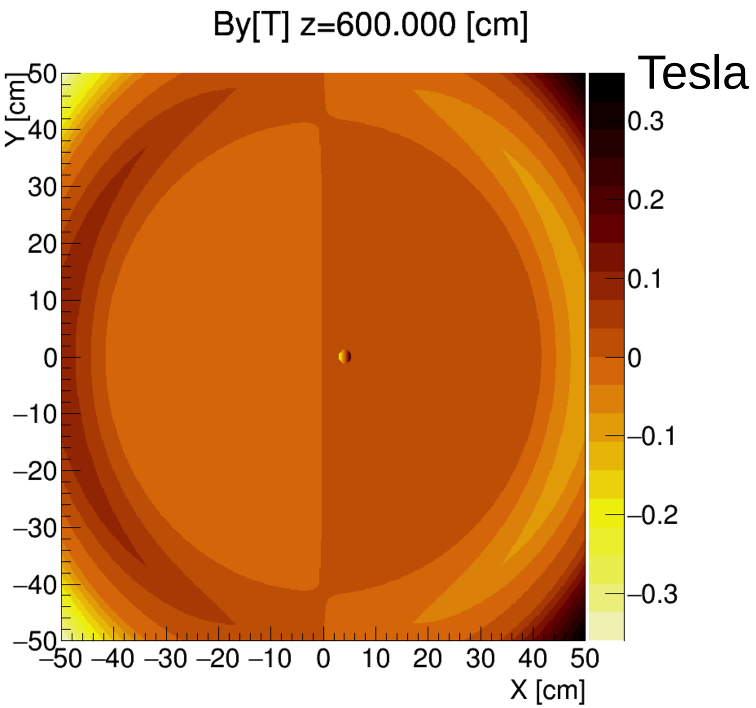
material



B-field (x-comp)



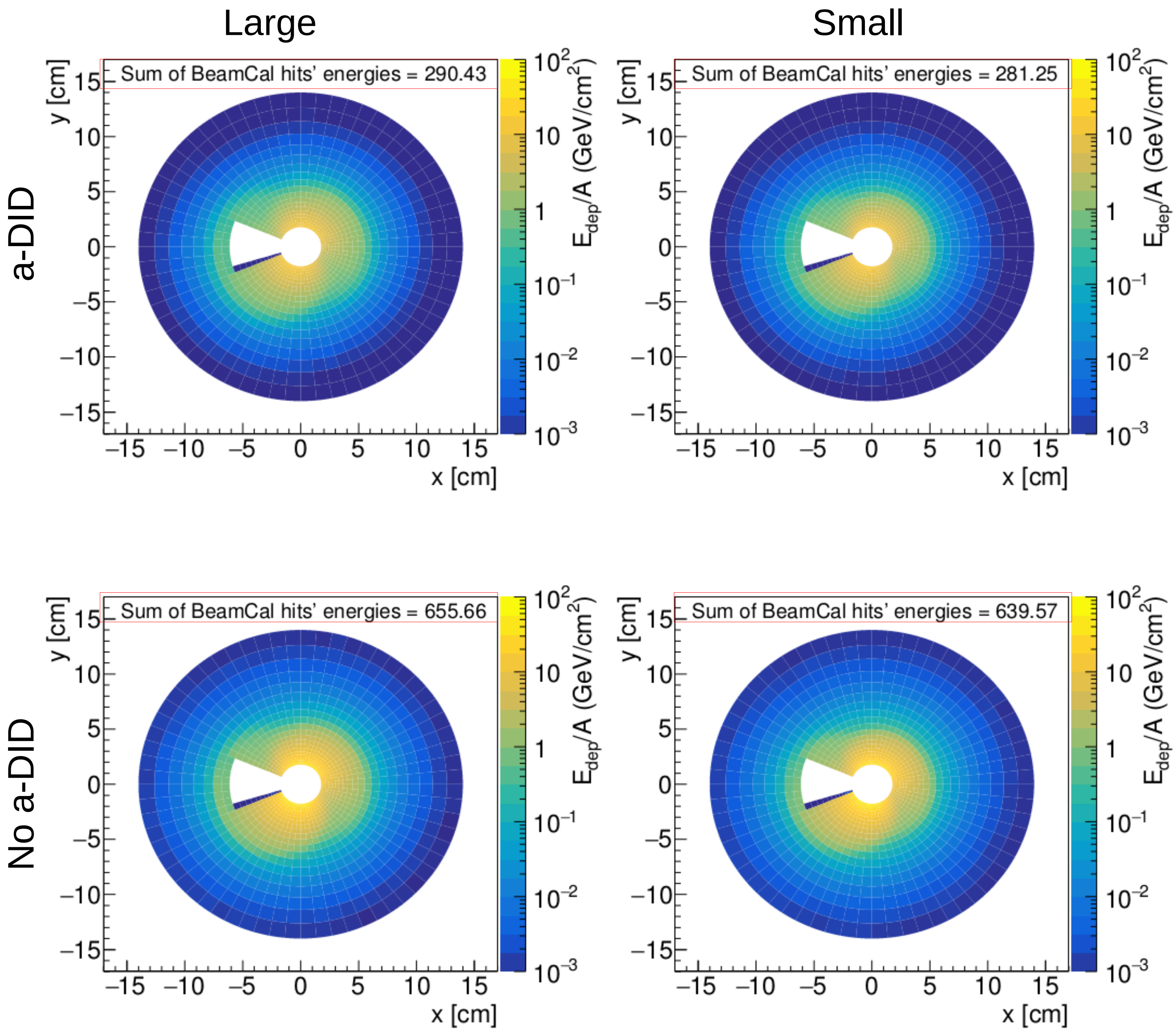
(y-comp)



First, look at BeamCal energy deposit

Anti-DID designed to steer BS pairs into outgoing beampipe

Energy distribution in the BeamCal : effect of anti-DID field



- by eye, a-DID better centres the energy deposit around BeamCal center (outgoing beampipe)
- anti-DID reduces total BeamCal energy by factor >2

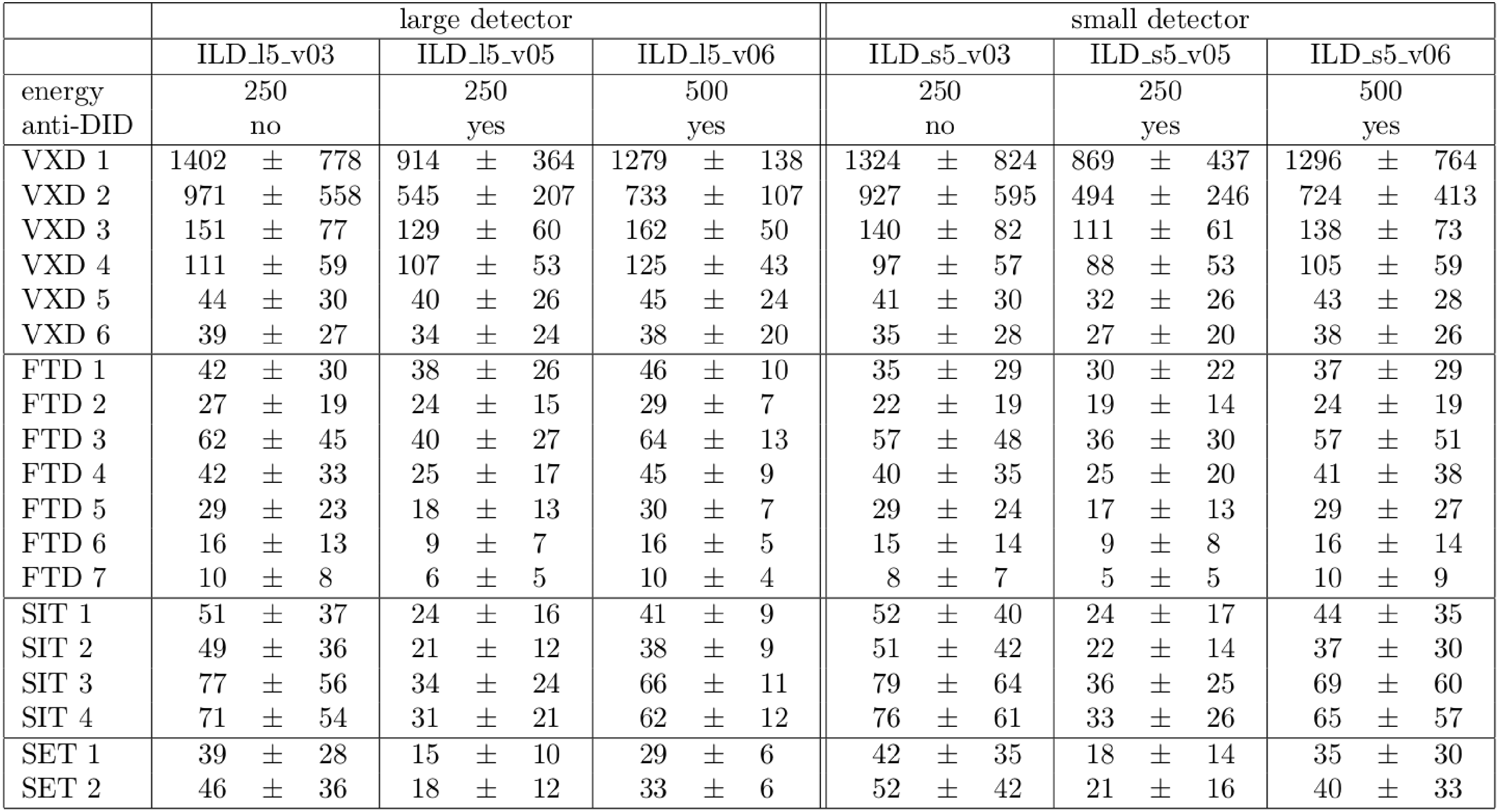
Simulation seems reasonable,

implemented anti-DID seems to do something reasonable,

→ let’s look at hits in the tracking detectors

Use these samples to extract expected hits / BX in different tracking detector layers

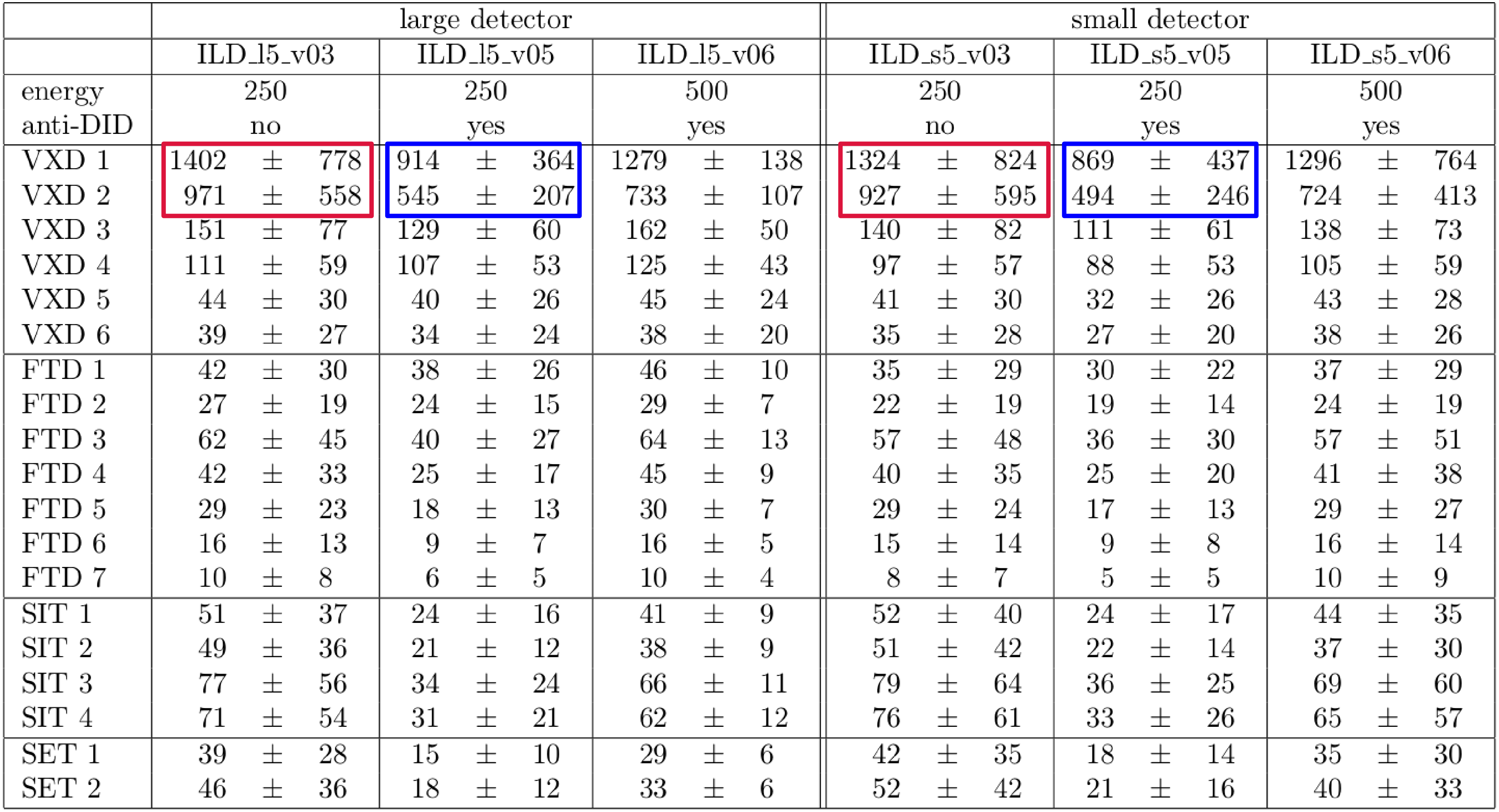
(mean # hits per bunch) ± (bunch-to-bunch variation [RMS])



	large detector			small detector		
	ILD_l5_v03	ILD_l5_v05	ILD_l5_v06	ILD_s5_v03	ILD_s5_v05	ILD_s5_v06
energy	250	250	500	250	250	500
anti-DID	no	yes	yes	no	yes	yes
VXD 1	1402 ± 778	914 ± 364	1279 ± 138	1324 ± 824	869 ± 437	1296 ± 764
VXD 2	971 ± 558	545 ± 207	733 ± 107	927 ± 595	494 ± 246	724 ± 413
VXD 3	151 ± 77	129 ± 60	162 ± 50	140 ± 82	111 ± 61	138 ± 73
VXD 4	111 ± 59	107 ± 53	125 ± 43	97 ± 57	88 ± 53	105 ± 59
VXD 5	44 ± 30	40 ± 26	45 ± 24	41 ± 30	32 ± 26	43 ± 28
VXD 6	39 ± 27	34 ± 24	38 ± 20	35 ± 28	27 ± 20	38 ± 26
FTD 1	42 ± 30	38 ± 26	46 ± 10	35 ± 29	30 ± 22	37 ± 29
FTD 2	27 ± 19	24 ± 15	29 ± 7	22 ± 19	19 ± 14	24 ± 19
FTD 3	62 ± 45	40 ± 27	64 ± 13	57 ± 48	36 ± 30	57 ± 51
FTD 4	42 ± 33	25 ± 17	45 ± 9	40 ± 35	25 ± 20	41 ± 38
FTD 5	29 ± 23	18 ± 13	30 ± 7	29 ± 24	17 ± 13	29 ± 27
FTD 6	16 ± 13	9 ± 7	16 ± 5	15 ± 14	9 ± 8	16 ± 14
FTD 7	10 ± 8	6 ± 5	10 ± 4	8 ± 7	5 ± 5	10 ± 9
SIT 1	51 ± 37	24 ± 16	41 ± 9	52 ± 40	24 ± 17	44 ± 35
SIT 2	49 ± 36	21 ± 12	38 ± 9	51 ± 42	22 ± 14	37 ± 30
SIT 3	77 ± 56	34 ± 24	66 ± 11	79 ± 64	36 ± 25	69 ± 60
SIT 4	71 ± 54	31 ± 21	62 ± 12	76 ± 61	33 ± 26	65 ± 57
SET 1	39 ± 28	15 ± 10	29 ± 6	42 ± 35	18 ± 14	35 ± 30
SET 2	46 ± 36	18 ± 12	33 ± 6	52 ± 42	21 ± 16	40 ± 33

Use these samples to extract expected hits / BX in different tracking detector layers

(mean # hits per bunch) ± (bunch-to-bunch variation [RMS])



	large detector			small detector		
	ILD_l5_v03	ILD_l5_v05	ILD_l5_v06	ILD_s5_v03	ILD_s5_v05	ILD_s5_v06
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anti-DID	no	yes	yes	no	yes	yes
VXD 1	1402 ± 778	914 ± 364	1279 ± 138	1324 ± 824	869 ± 437	1296 ± 764
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SET 1	39 ± 28	15 ± 10	29 ± 6	42 ± 35	18 ± 14	35 ± 30
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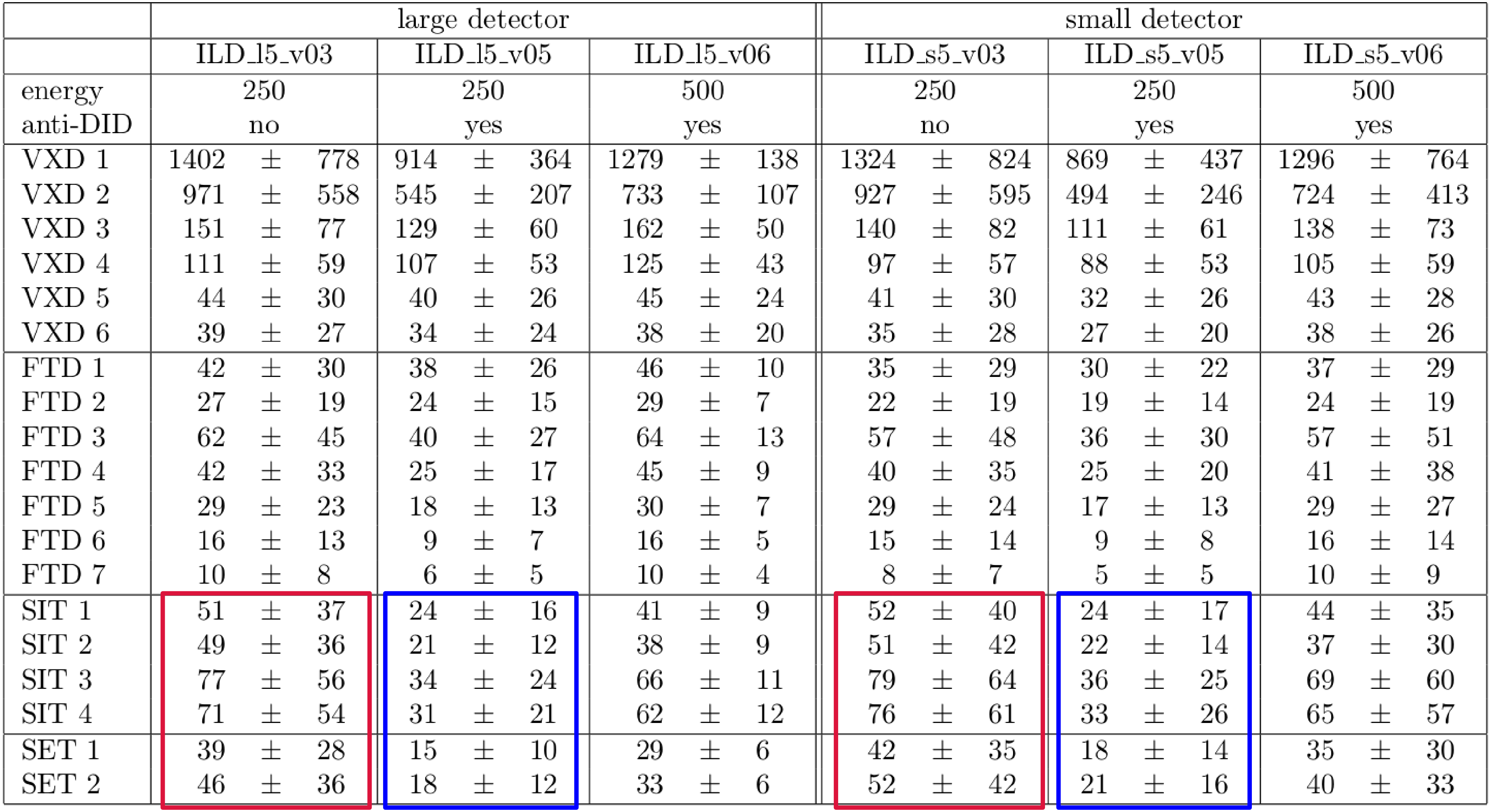
Most hits are in the inner vertex detector layers
Adding an a-DID field reduces the total number of hits in these layers by ~35%

Use these samples to extract expected hits / BX in different tracking detector layers

(mean # hits per bunch) ± (bunch-to-bunch variation [RMS])



	large detector			small detector		
	ILD_l5_v03	ILD_l5_v05	ILD_l5_v06	ILD_s5_v03	ILD_s5_v05	ILD_s5_v06
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anti-DID	no	yes	yes	no	yes	yes
VXD 1	1402 ± 778	914 ± 364	1279 ± 138	1324 ± 824	869 ± 437	1296 ± 764
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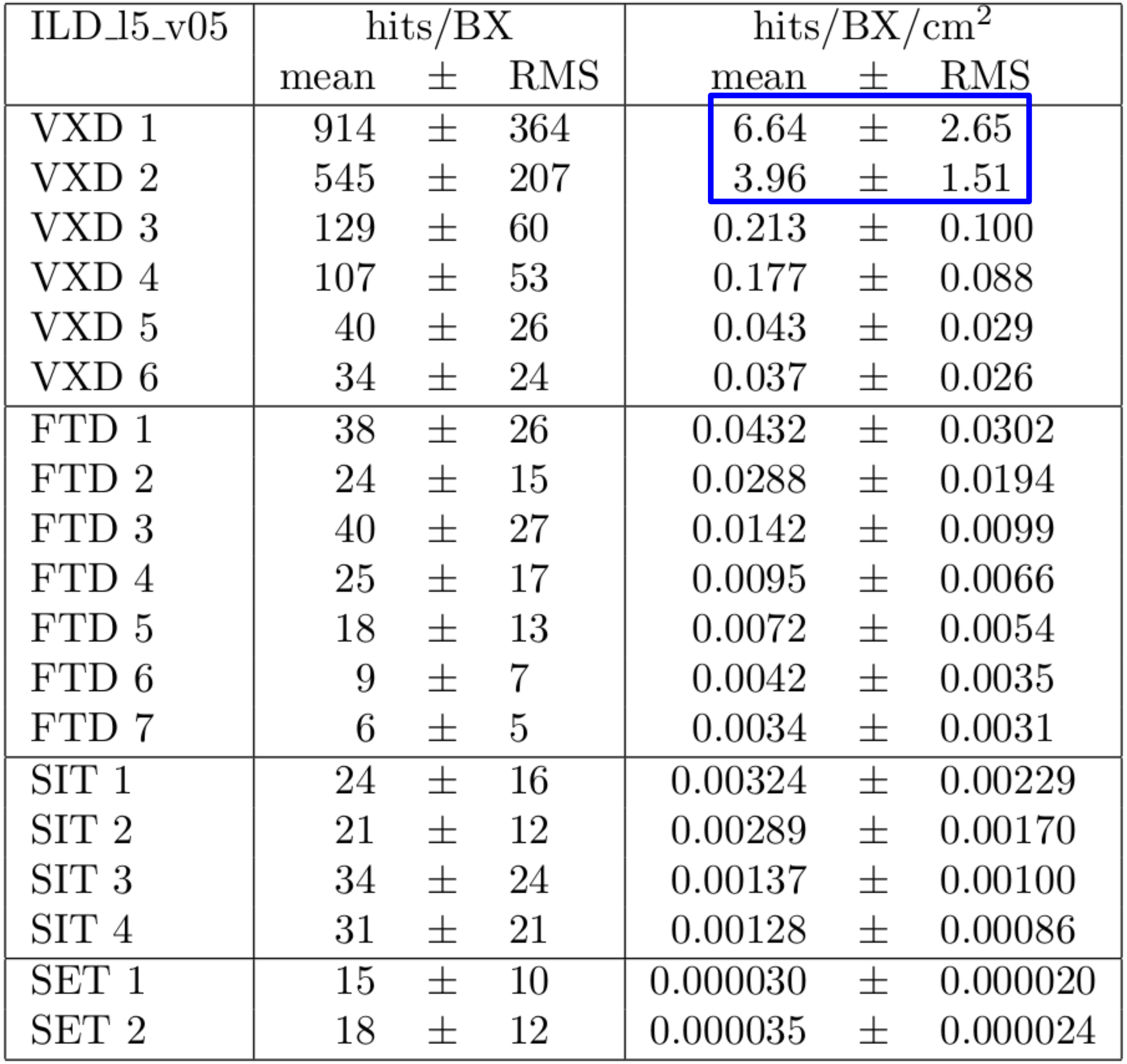
Relative effect a-DID on outer tracking detectors is larger (about a factor 2), but there are rather few hits due to pair backgrounds in these detectors

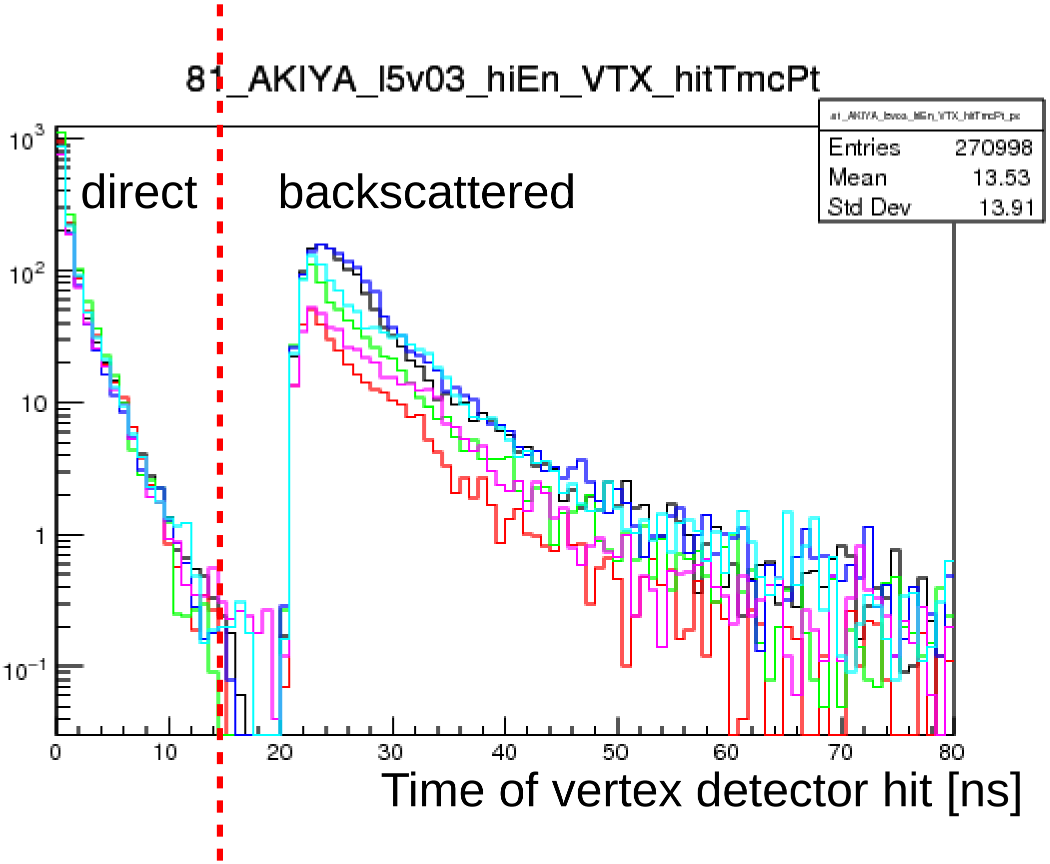
Convert to <u>average</u> hit densities in different layers

250 GeV, large detector, with a-DID field



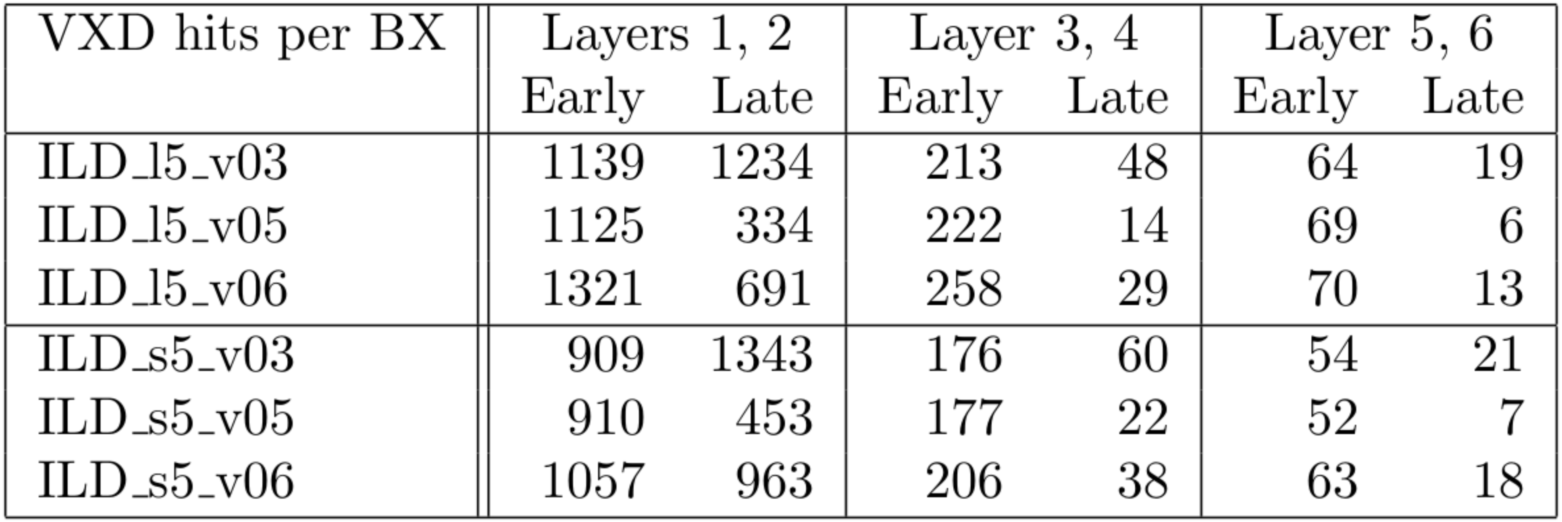
ILD_l5_v05	hits/BX			hits/BX/cm^2		
	mean	±	RMS	mean	±	RMS
VXD 1	914	±	364	6.64	±	2.65
VXD 2	545	±	207	3.96	±	1.51
VXD 3	129	±	60	0.213	±	0.100
VXD 4	107	±	53	0.177	±	0.088
VXD 5	40	±	26	0.043	±	0.029
VXD 6	34	±	24	0.037	±	0.026
FTD 1	38	±	26	0.0432	±	0.0302
FTD 2	24	±	15	0.0288	±	0.0194
FTD 3	40	±	27	0.0142	±	0.0099
FTD 4	25	±	17	0.0095	±	0.0066
FTD 5	18	±	13	0.0072	±	0.0054
FTD 6	9	±	7	0.0042	±	0.0035
FTD 7	6	±	5	0.0034	±	0.0031
SIT 1	24	±	16	0.00324	±	0.00229
SIT 2	21	±	12	0.00289	±	0.00170
SIT 3	34	±	24	0.00137	±	0.00100
SIT 4	31	±	21	0.00128	±	0.00086
SET 1	15	±	10	0.000030	±	0.000020
SET 2	18	±	12	0.000035	±	0.000024

large hit densities only in first 2 vertex detector layers


81_AKIYA_l5v03_hiEn_VTX_hitTmcPt
81_AKIYA_l5v03_hiEn_VTX_hitTmcPt_px
Entries 270998
Mean 13.53
Std Dev 13.91
direct
backscattered
10^3
10^2
10
1
10^{-1}
0
10
20
30
40
50
60
70
80
Time of vertex detector hit [ns]

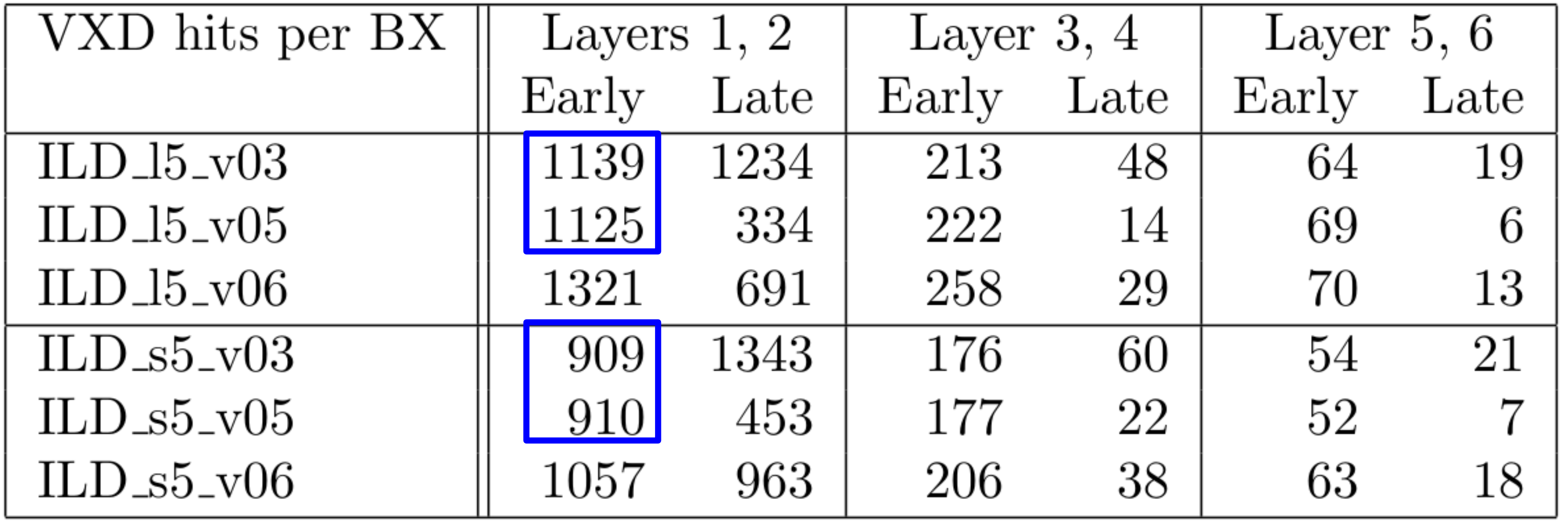
Cut at 15 ns

Compare early (<15 ns) and late (>15 ns) vertex detector hits



		VXD hits per BX	Layers 1, 2		Layer 3, 4		Layer 5, 6	
			Early	Late	Early	Late	Early	Late
Large	250, no aDID	ILD_l5_v03	1139	1234	213	48	64	19
	250, aDID	ILD_l5_v05	1125	334	222	14	69	6
	500, aDID	ILD_l5_v06	1321	691	258	29	70	13
Small	250, no aDID	ILD_s5_v03	909	1343	176	60	54	21
	250, aDID	ILD_s5_v05	910	453	177	22	52	7
	500, aDID	ILD_s5_v06	1057	963	206	38	63	18

Compare early (<15 ns) and late (>15 ns) vertex detector hits



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	250, aDID	ILD_s5_v05	910	453	177	22	52	7
	500, aDID	ILD_s5_v06	1057	963	206	38	63	18

Less early hits in small model → larger B-field

Compare early (<15 ns) and late (>15 ns) vertex detector hits

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			Early	Late	Early	Late	Early	Late
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Small	250, no aDID	ILD_s5_v03	909	1343	176	60	54	21
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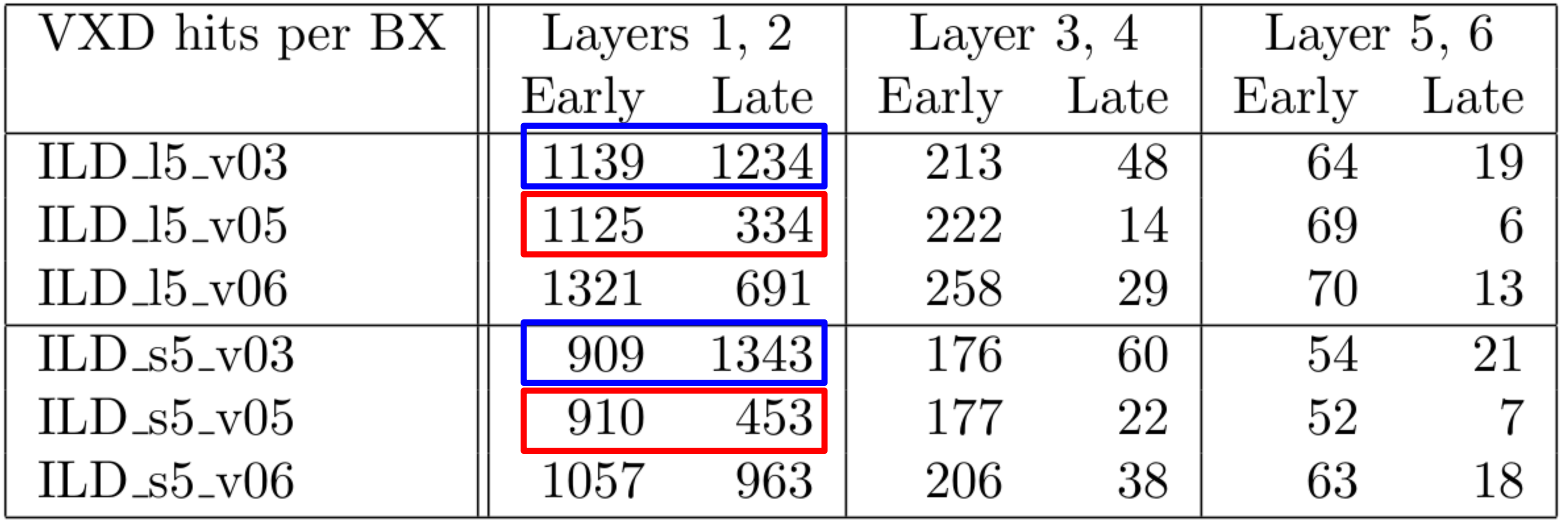
	500, aDID	ILD_s5_v06	1057	963	206	38	63	18

Applying a-DID reduced late hits in L1,2 by a factor 3 or 4
→ less back-scatter since more beam exits detector

Compare early (<15 ns) and late (>15 ns) vertex detector hits



		VXD hits per BX	Layers 1, 2		Layer 3, 4		Layer 5, 6	
			Early	Late	Early	Late	Early	Late
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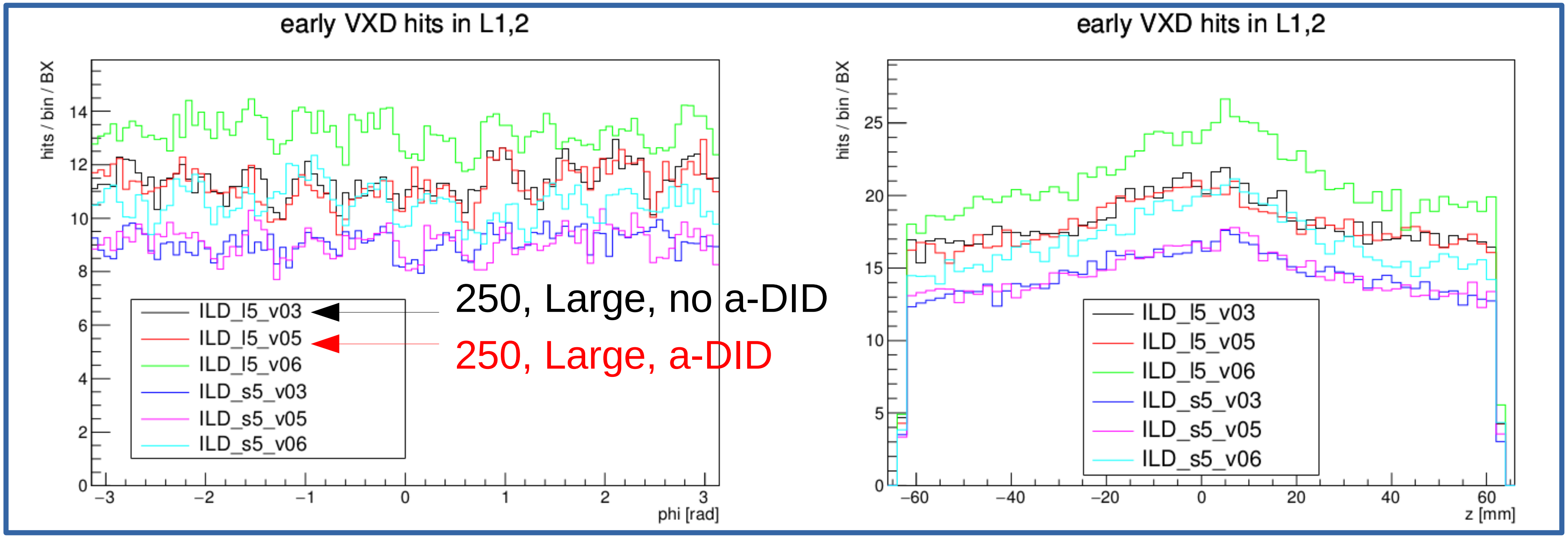
Small	250, no aDID	ILD_s5_v03	909	1343	176	60	54	21
	250, aDID	ILD_s5_v05	910	453	177	22	52	7
	500, aDID	ILD_s5_v06	1057	963	206	38	63	18

Applying a-DID reduced late hits in L1,2 by a factor 3 or 4
→ less back-scatter since more beam exits detector

Reduction in <u>total</u> number of L1,2 hits is < factor 2

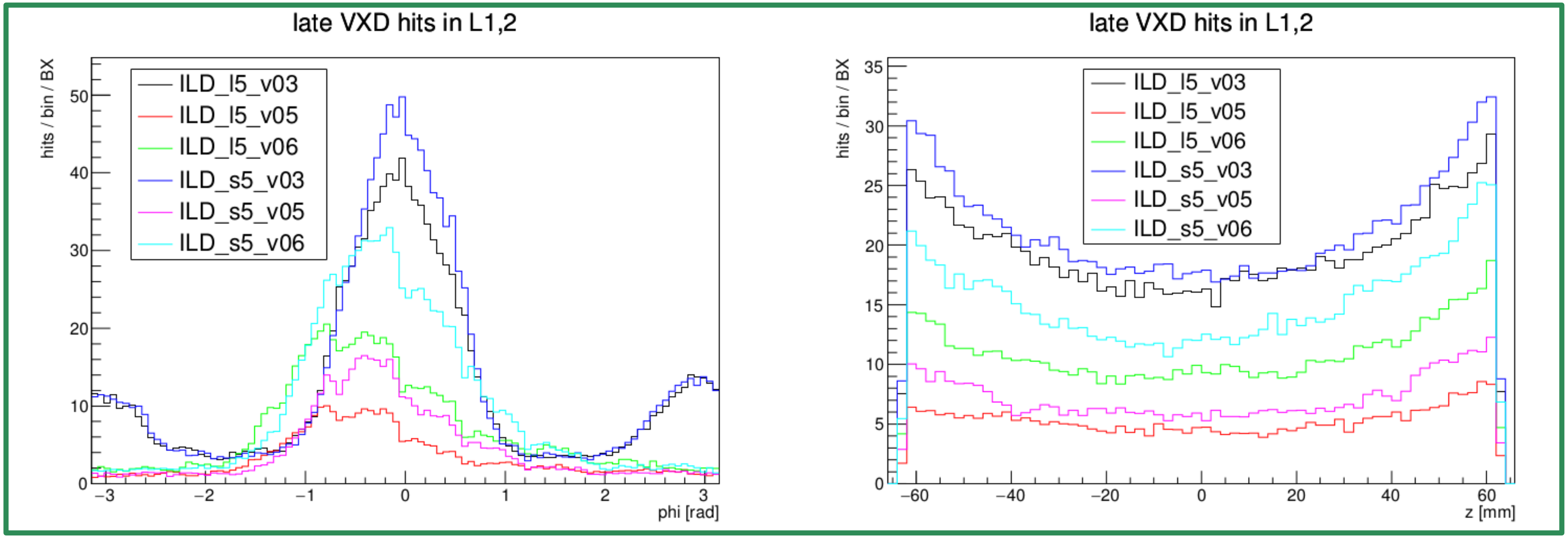
Distribution of hits in first 2 vertex layers



250, Large, no a-DID

250, Large, a-DID

Early



Late

azimuthal angle

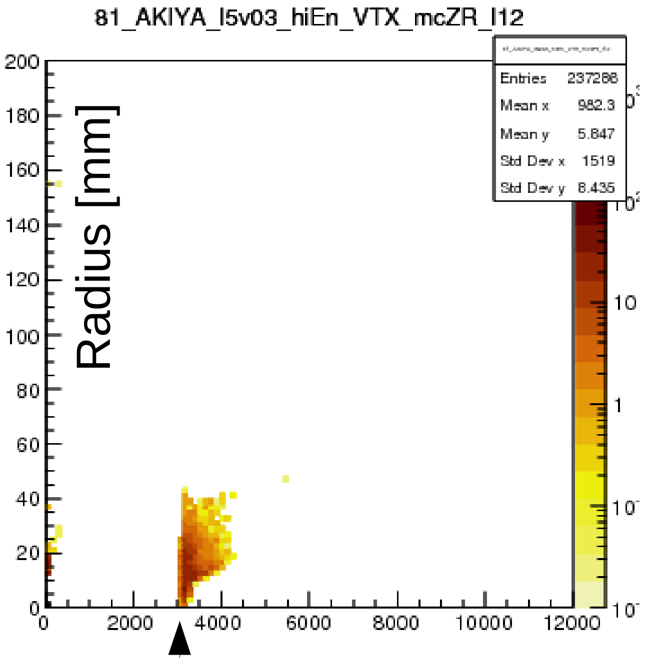
z position

n.b. local hit densities can be significantly larger than average

Production vertex of particles producing hits in VDX L1,2

z vs radius

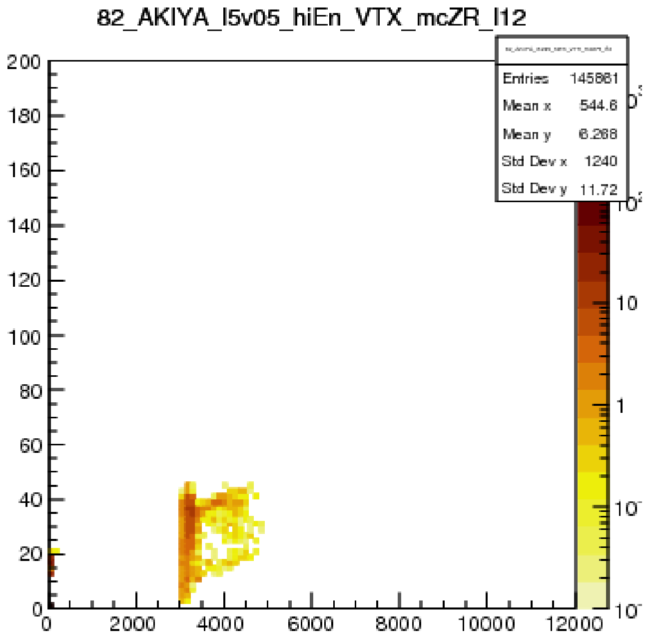
250, no aDID



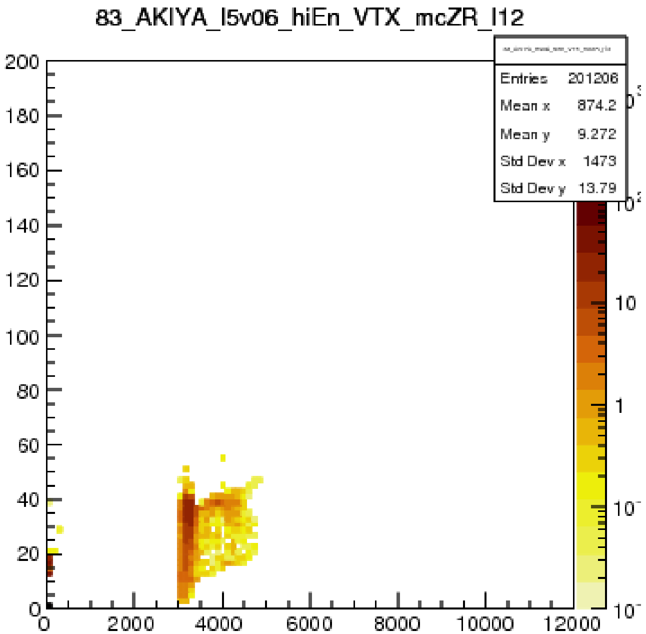
Z [mm]

beamcal

250 aDID



500 aDID

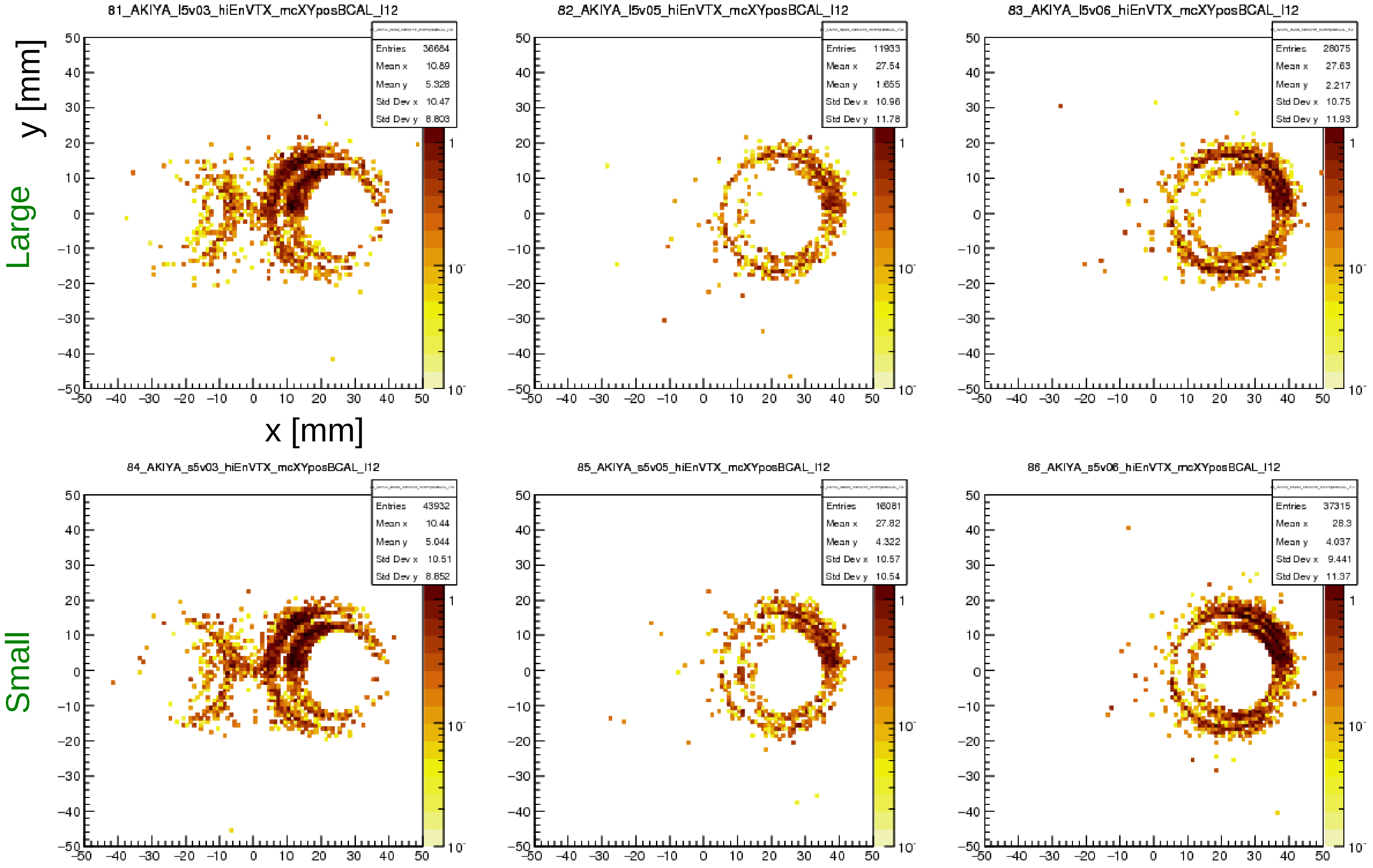


Production vertex [in the +z BeamCal region] of particles producing hits in VDX L1,2

250, no aDID

250 aDID

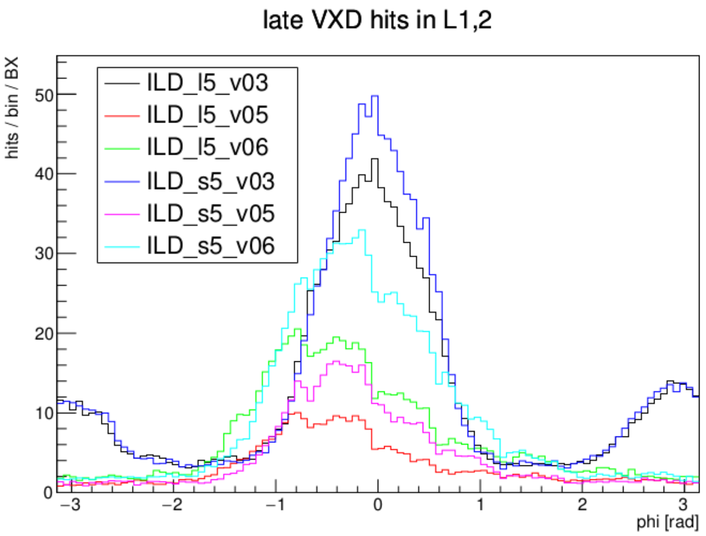
500 aDID



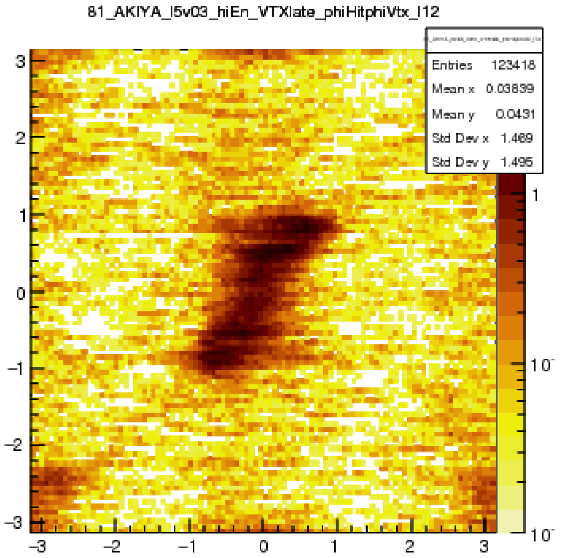
What causes strong phi-non-uniformity of late VXD hits

Late VXD hits L1,2

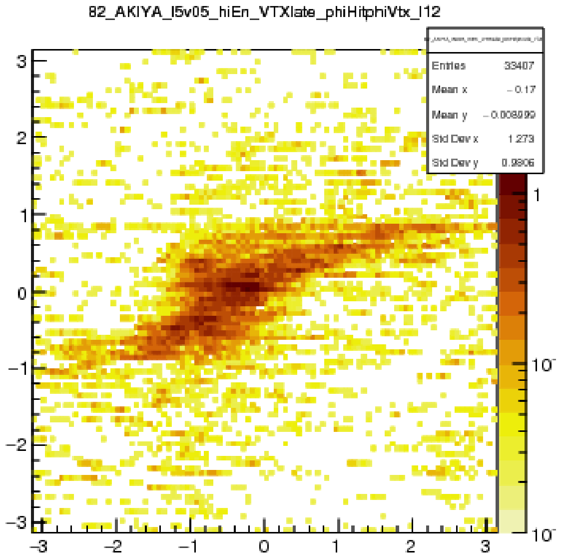
(Phi of hit) vs. (phi from which particle backscattered)



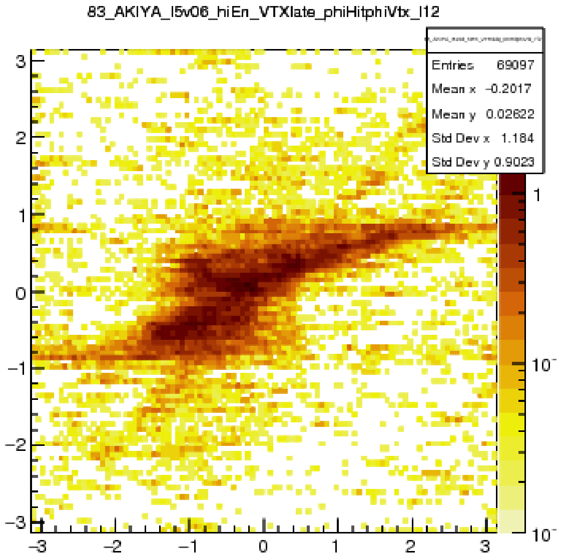
250, no aDID



250 aDID



500 aDID



Phi of scattering point

Phi of VXD hit

Summary

Simulation of beamstrahlung pair backgrounds is not trivial
now seems more solid than in the past…

Using an anti-DID field:

reduces total energy in BeamCal by factor ~2

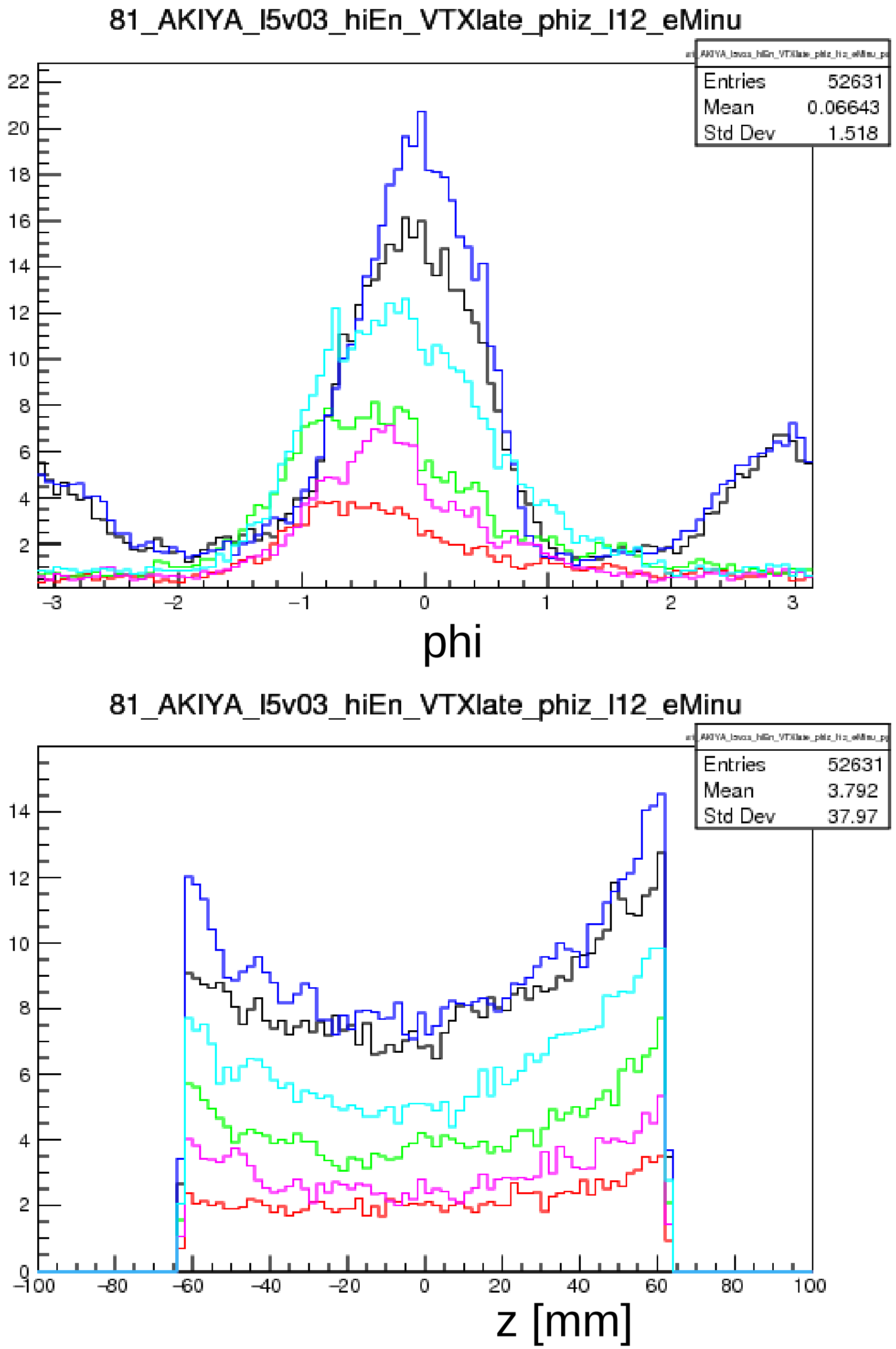
reduces vertex detector hits due to backscattered particles by factor 3-4

reduces total number of vertex detector by factor <2

VXD backgrounds strongly non-uniform,
→ significantly more significant effects in some regions

Position of late VXD L1,2 hits produced by

electrons



positrons