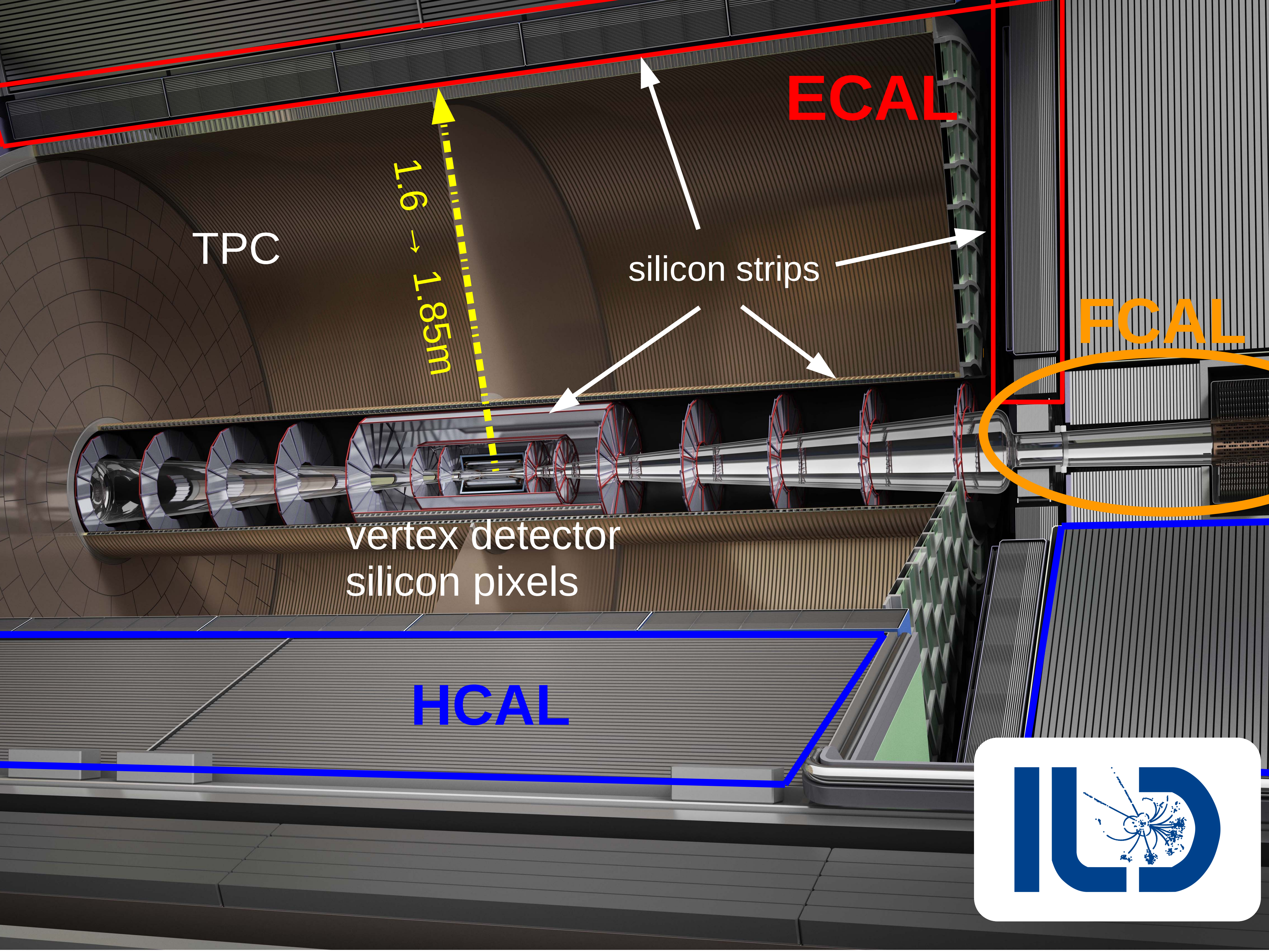
ILD Background Studies at ILC

Daniel Jeans, KEK

IAS/High Energy Physics/Jan 2020


ECAL
TPC
1.6 → 1.85m
silicon strips
FCAL
vertex detector
silicon pixels
HCAL

today focus on 2 subjects:

beamstrahlung

beamline muons

beamstrahlung

beamline muons

beamstrahlung

beam particles interact with those other bunch at collision point

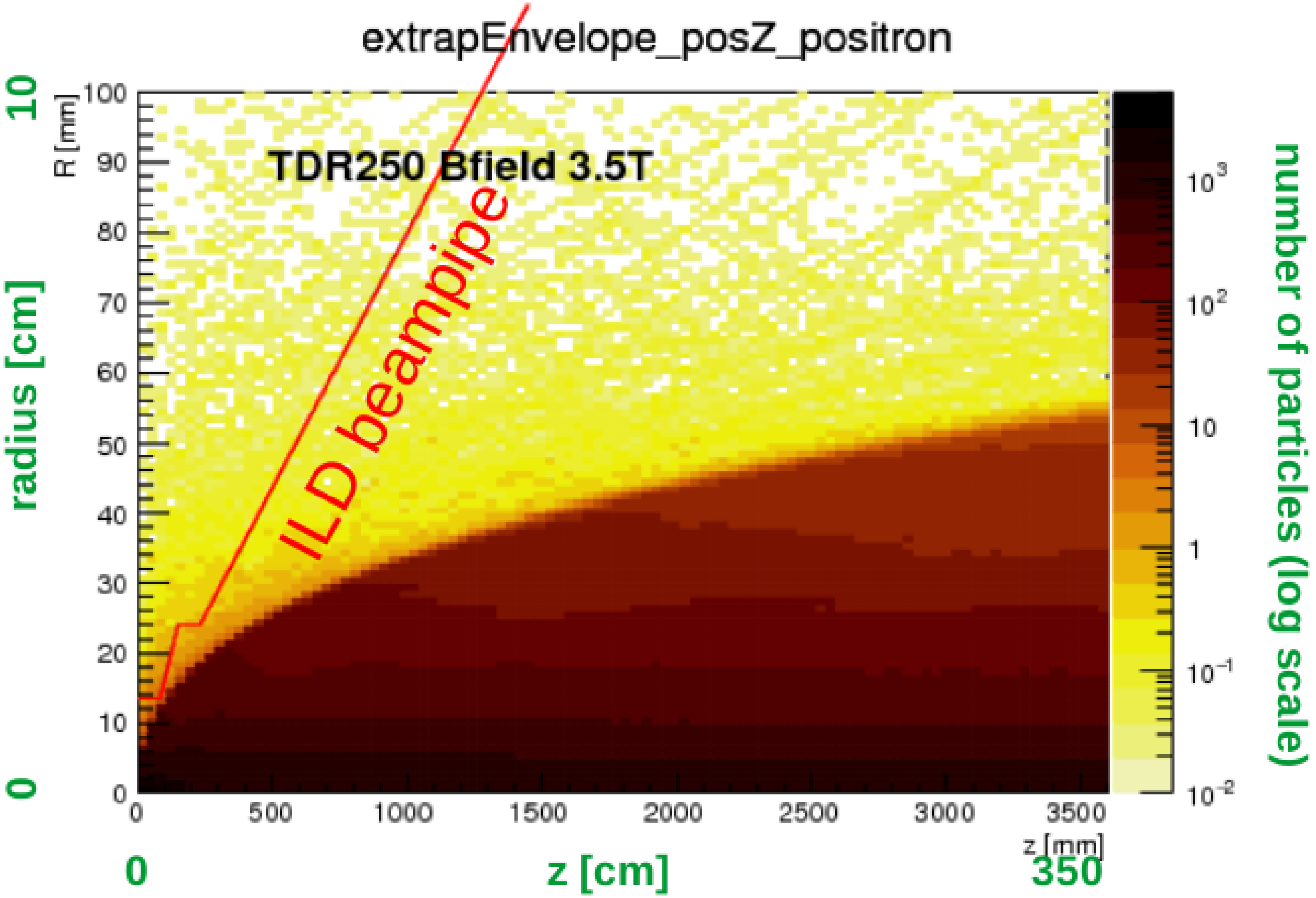
radiate photons → convert into e+ e-

typically very low p_T e+ e-

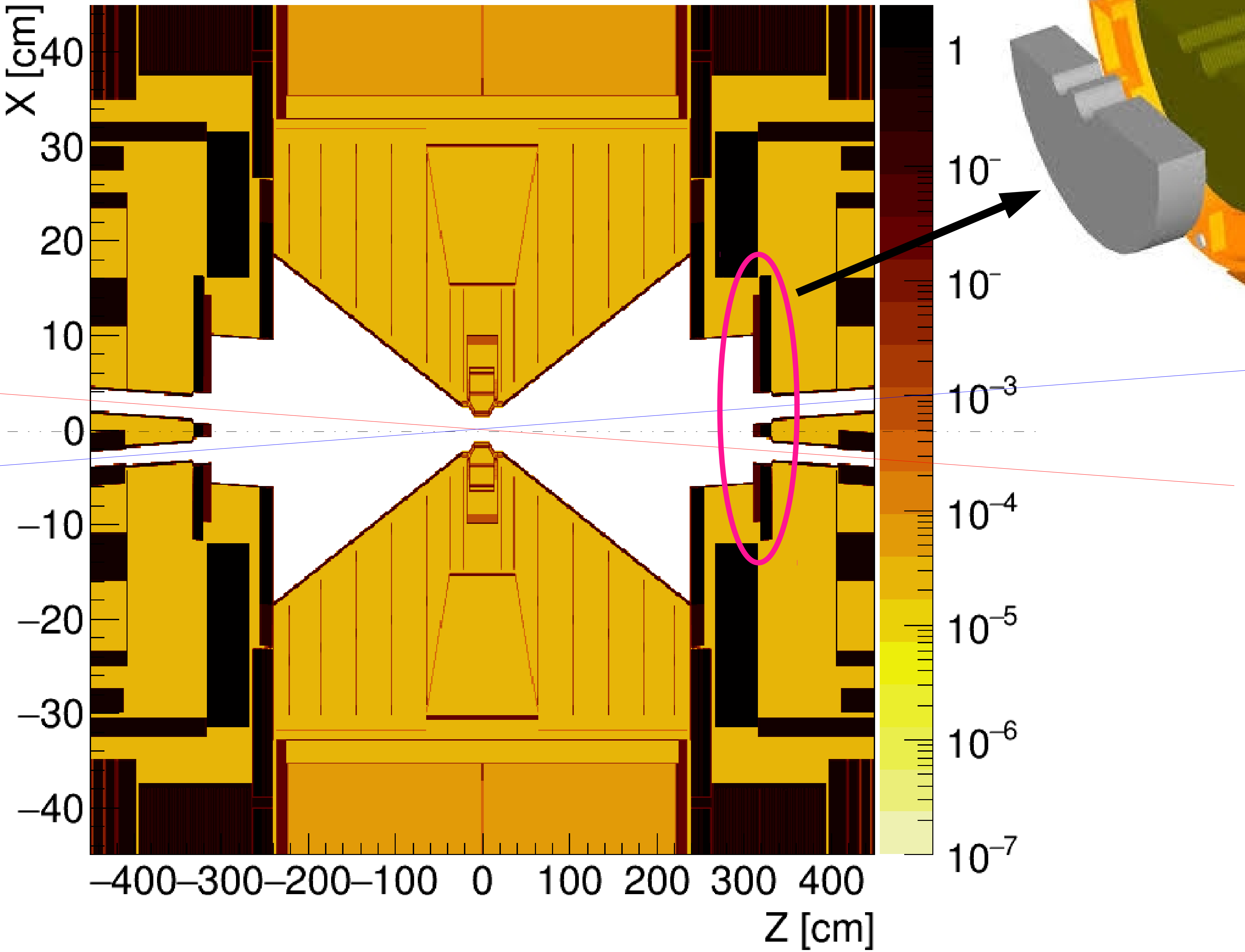
- high p_T tail can directly reach the inner detectors
- vast majority have low p_T , and “follow” the B-field lines

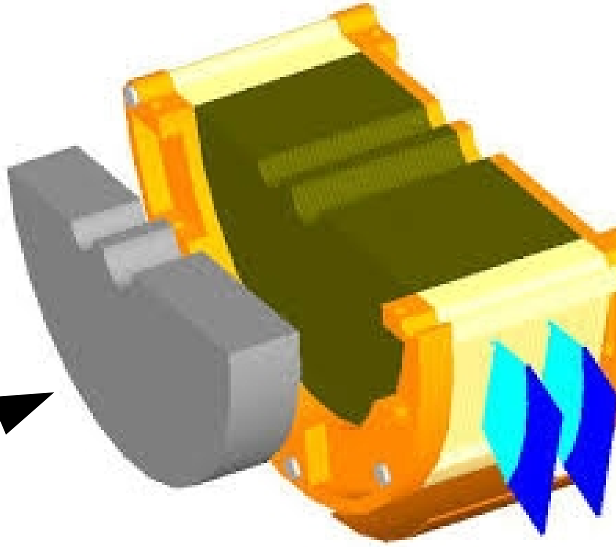
Distribution of incoherent pairs around beampipe

simple extrapolation in uniform 3.5T field, no beam crossing,
no material interactions, no backscatter from e.g. FCAL



beamcal, crossing angle





because of crossing angle,
magnetic field lines (from detector solenoid)
from IP do not pass into outgoing beam-pipe

→ bulk of beamstrahlung pairs hit forward calorimeters
→ (back-) scatter, interact
→ detector backgrounds

additional anti-DID field (field in x-direction)
applied to steer field lines into outgoing beampipe

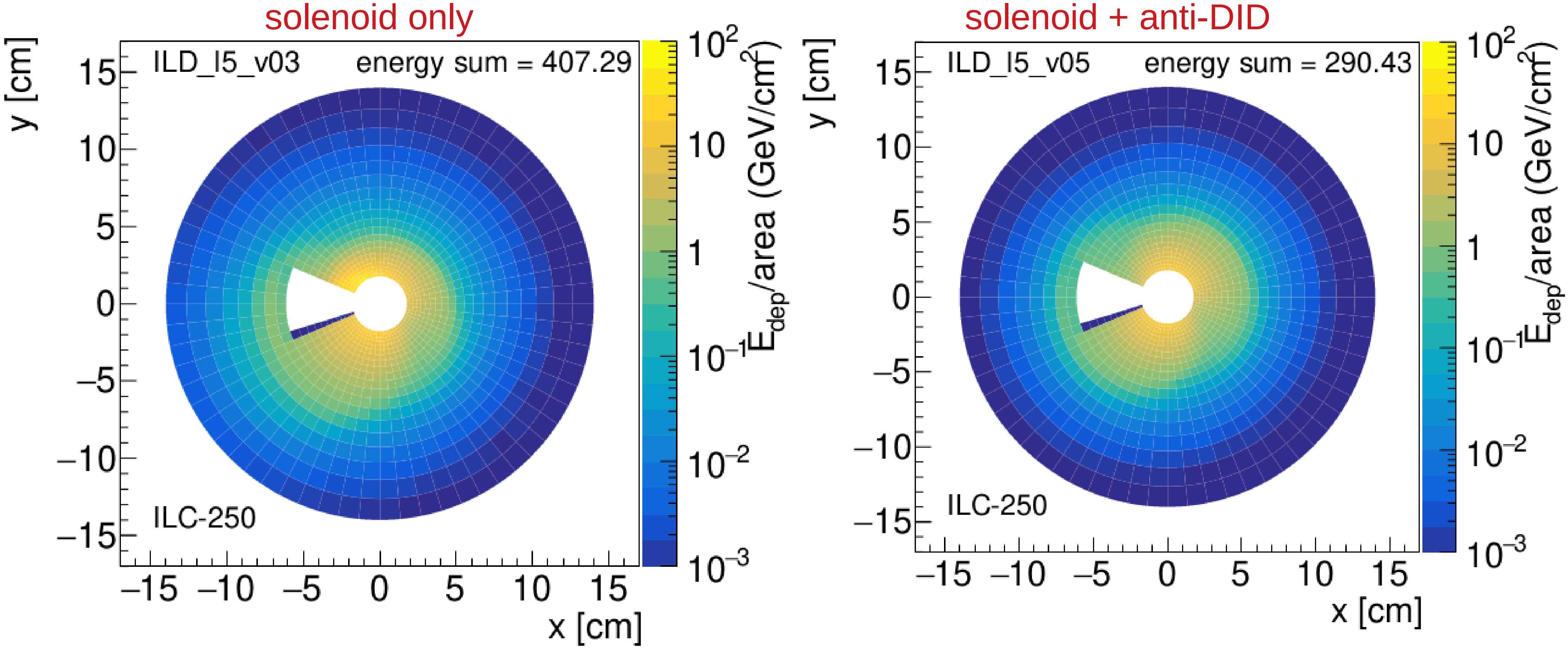
rather complex system
is it needed ?
how big is its effect on detector backgrounds ?

simulate beamstrahlung pairs at ILC-250

ILD Geant4-based simulation

detailed field maps of solenoid/yoke, with and without anti-DID field

energy deposit in BeamCal sensors



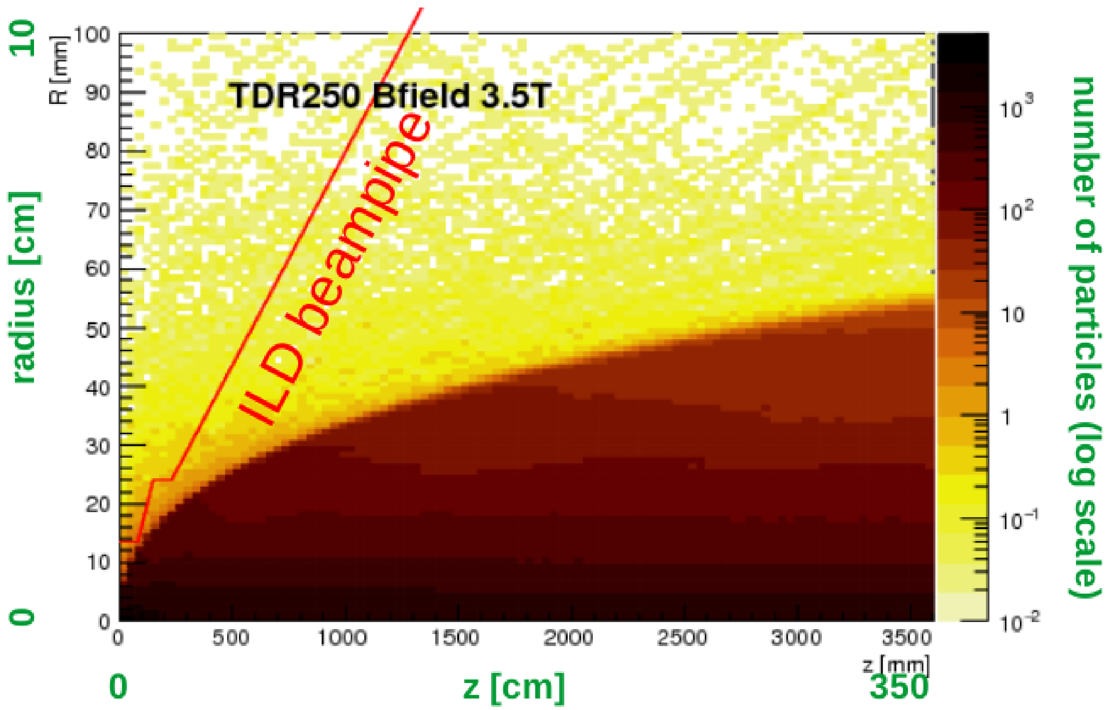
use of anti-DID better centres distribution on outgoing beampipe, reduces total energy deposit

beamstrahlung: hits in vertex detector

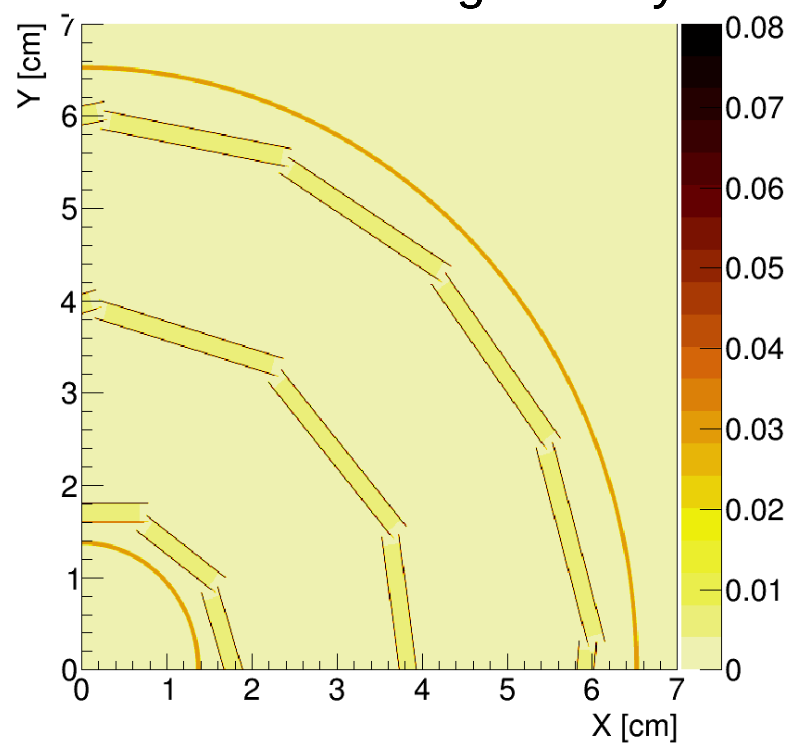
"direct" hits → particles directly coming from IP

"back-scattered" hits → secondaries produced
when e+ e- interact with forward calorimeters

in simulation, distinguish based on hit time:
"direct" = early / "back-scattered" = late

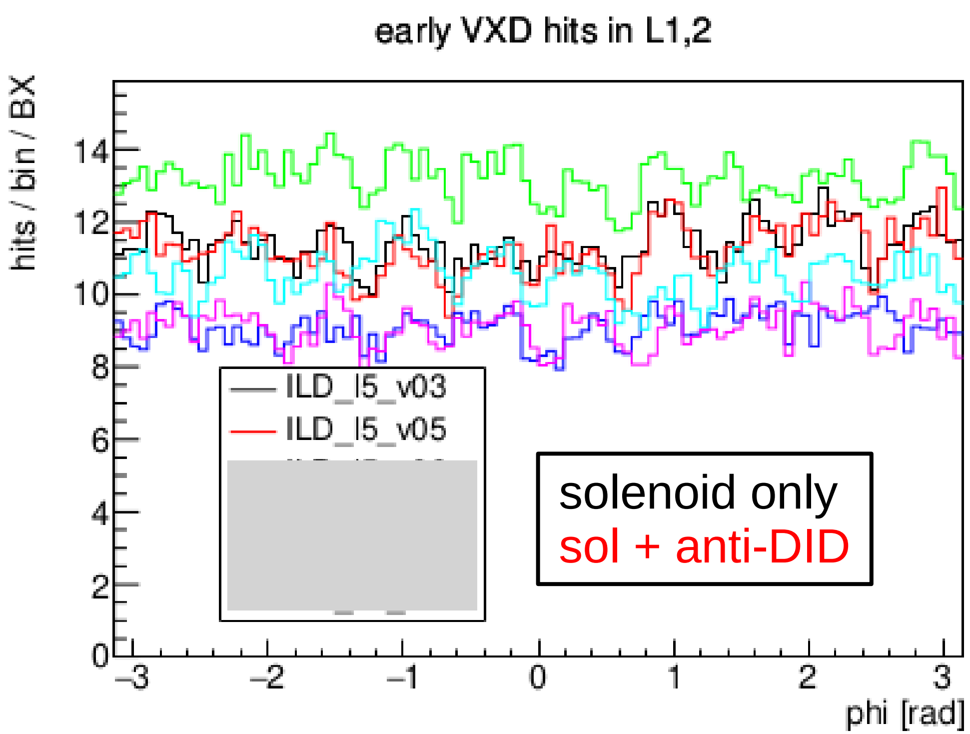


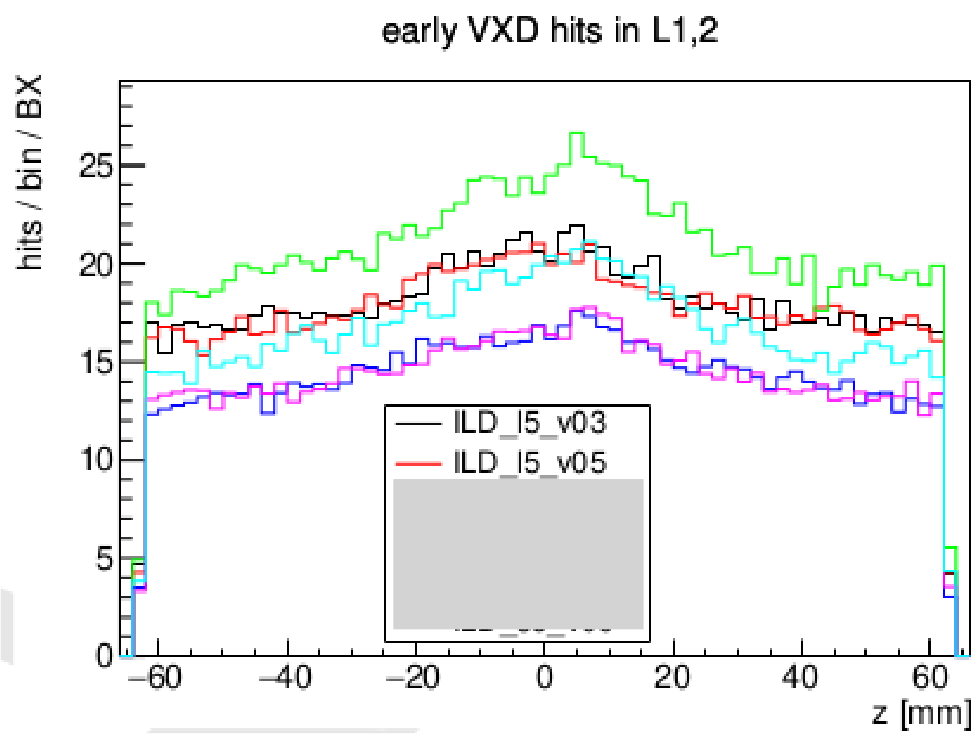
vertex detector geometry



early hits, produced by particles coming directly from the IP

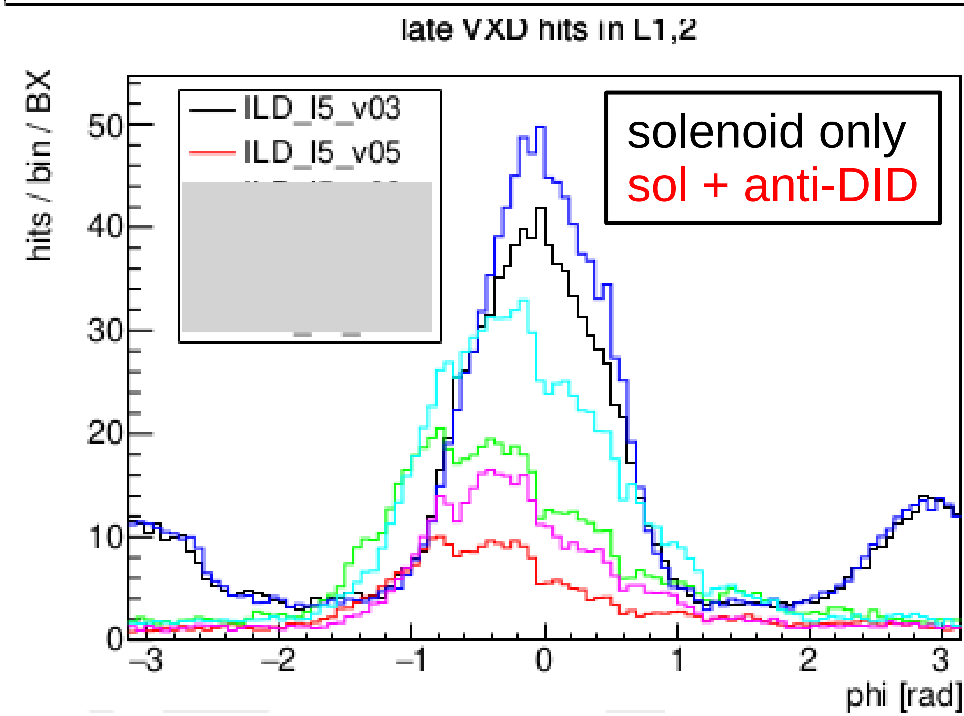
	ECOM	aDID	nom. field	VXD hits per BX					
				Layers 1, 2		Layer 3, 4		Layer 5, 6	
ILD model	[GeV]		[T]	Early	Late	Early	Late	Early	Late
ILD_l5_v03	250	no	3.5	1139		213		64	
ILD_l5_v05	250	yes	3.5	1125		222		69	

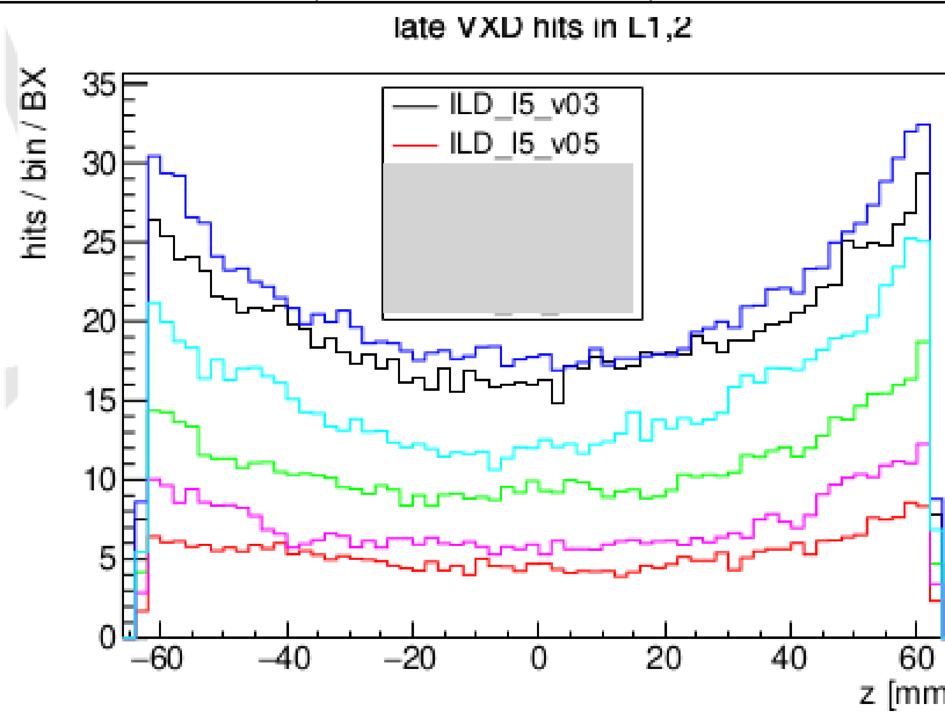




late hits, back-scattered from forward region

				VXD hits per BX					
	ECOM	aDID	nom. field	Layers 1, 2		Layer 3, 4		Layer 5, 6	
ILD model	[GeV]		[T]	Early	Late	Early	Late	Early	Late
ILD_l5_v03	250	no	3.5	1139	1234	213	48	64	19
ILD_l5_v05	250	yes	3.5	1125	334	222	14	69	6





Solenoid field strength

using a stronger detector solenoid better focuses the beamstrahlung pairs

“large” ILD → 3.5 T nominal field [standard ILD model]

“small” ILD → 4.0 T

[motivation: reduce cost.

Higher field preserves track momentum resolution for smaller tracker]

				VXD hits per BX					
	ECOM	aDID	nom. field	Layers 1, 2		Layer 3, 4		Layer 5, 6	
ILD model	[GeV]		[T]	Early	Late	Early	Late	Early	Late
ILD_l5_v03	250	no	3.5	1139	1234	[illegible]	[illegible]	[illegible]	[illegible]
ILD_l5_v05	250	yes	3.5	1125	334	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ILD_s5_v03	250	no	4.0	909	1343	[illegible]	[illegible]	[illegible]	[illegible]
ILD_s5_v05	250	yes	4.0	910	453	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

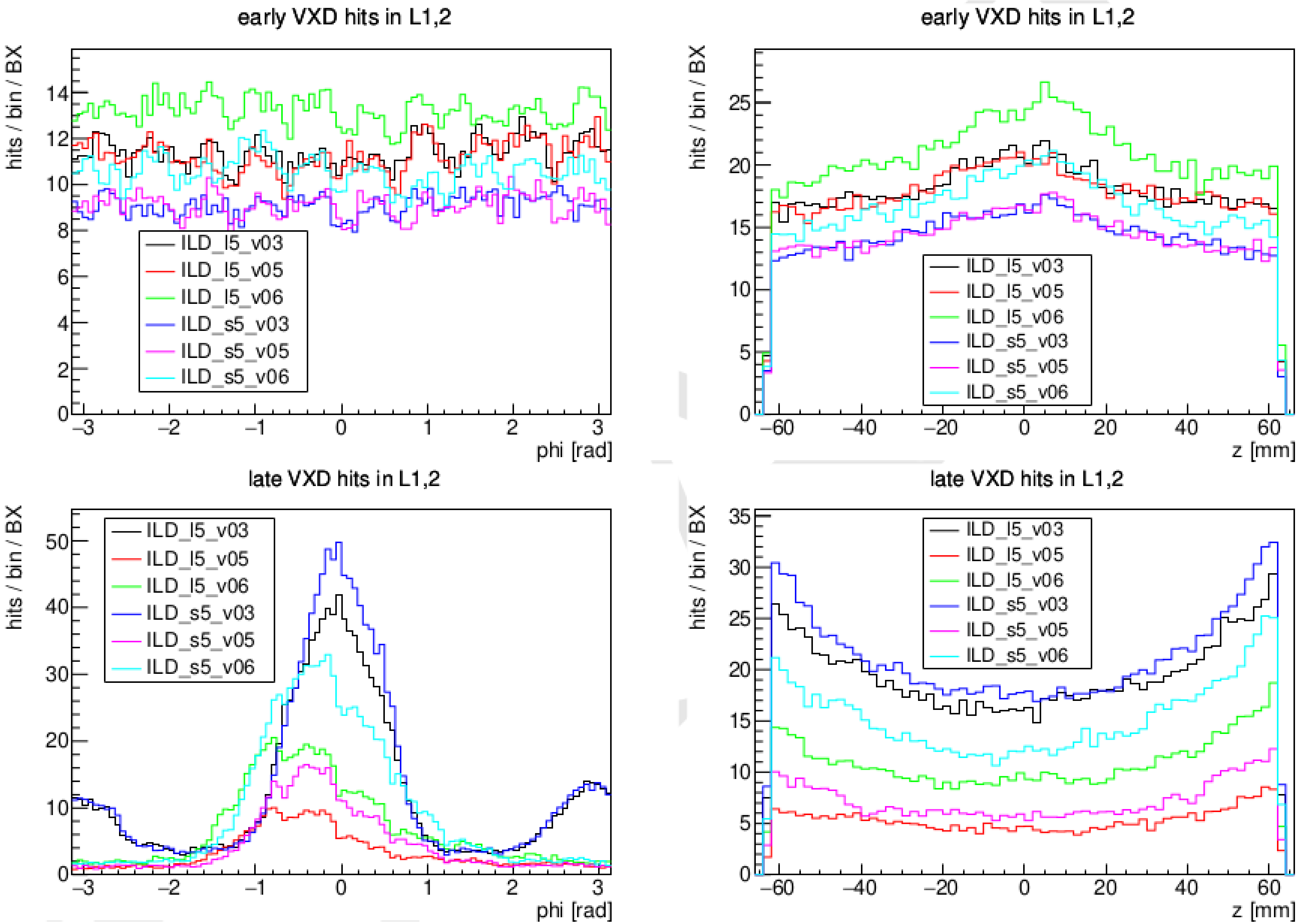
using stronger solenoid reduces the “early” hits by 10-20%,

perhaps a slight increase in the “late” hits

[strength of anti-DID may need more careful tuning]

situation at ILC-500

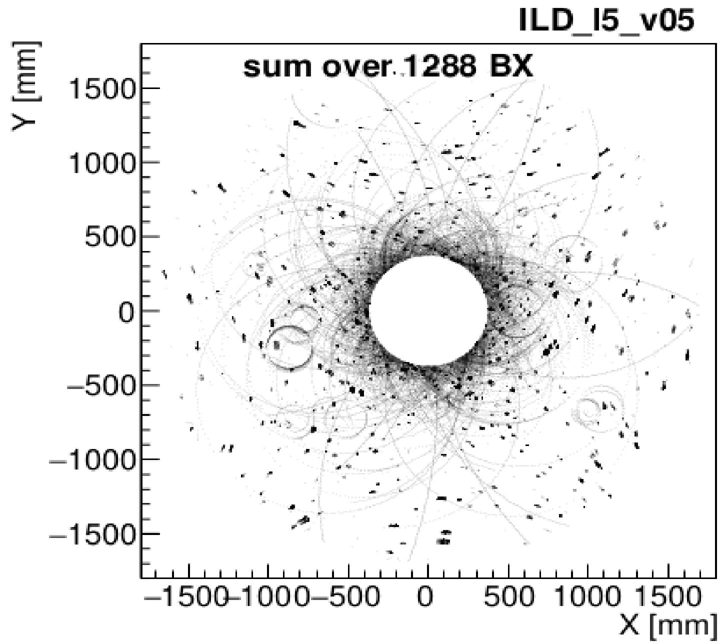
	ECOM	aDID	nom. field	VXD hits per BX					
				Layers 1, 2		Layer 3, 4		Layer 5, 6	
ILD model	[GeV]		[T]	Early	Late	Early	Late	Early	Late
ILD_l5_v03	250	no	3.5	1139	1234	213	48	64	19
ILD_l5_v05	250	yes	3.5	1125	334	222	14	69	6
ILD_l5_v06	500	yes	3.5	1321	691	258	29	70	13
ILD_s5_v03	250	no	4.0	909	1343	176	60	54	21
ILD_s5_v05	250	yes	4.0	910	453	177	22	52	7
ILD_s5_v06	500	yes	4.0	1057	963	206	38	63	18

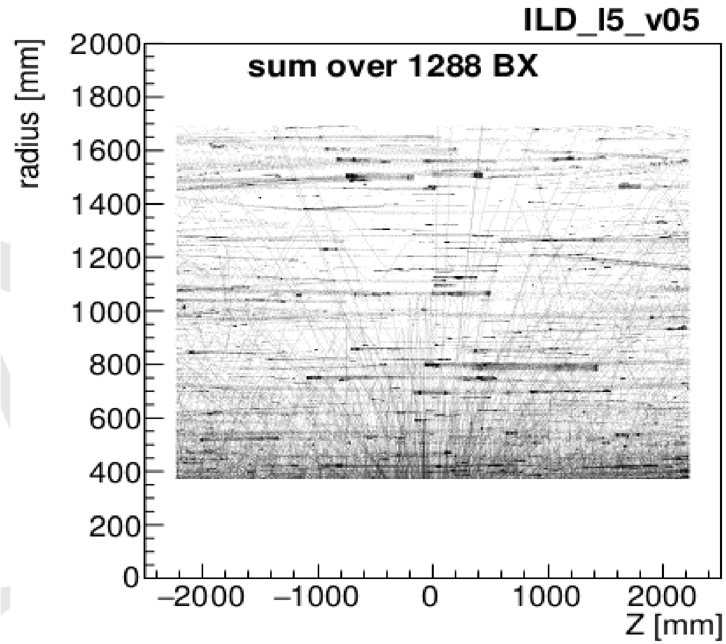


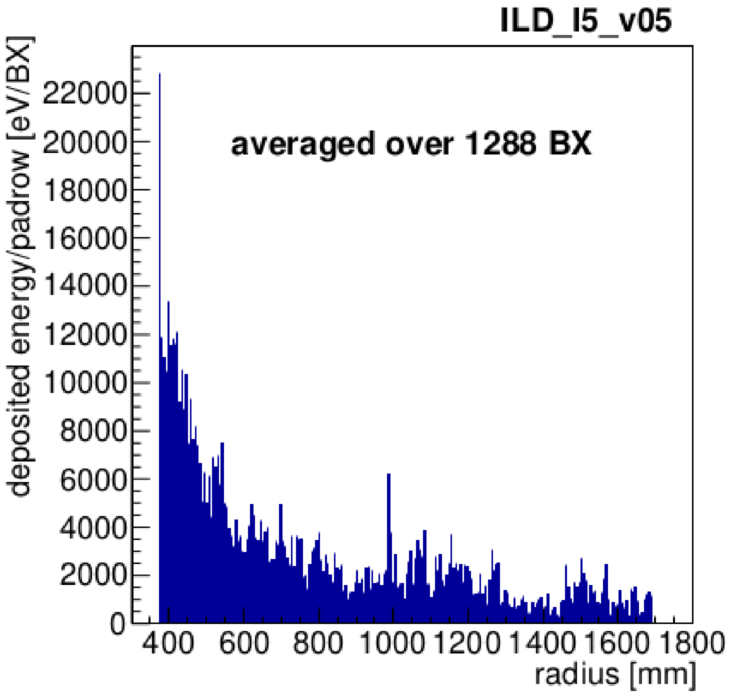
250 GeV	3.0 T	solenoid only
250 GeV	3.0 T	solenoid + anti-DID
500 GeV	3.0 T	solenoid + anti-DID
250 GeV	3.5 T	solenoid only
250 GeV	3.5 T	solenoid + anti-DID
500 GeV	3.0 T	solenoid only

beamstrahlung: hits in TPC central tracker

~1 bunch train







according to TPC experts, this looks manageable

anti-DID : summary

First vertex detector layers

with no anti-DID,
direct/early hits ~ # back-scattered/late hits

early hits in vertex detector unaffected by anti-DID [as expected]

if anti-DID field is used,
- late hits are reduced by a factor around three to four
- total number of hits reduced by ~40%

we have not yet concluded if we need anti-DID,
but we have information with which to decide...

other detector subsystems less affected

beamstrahlung

beamline muons

particles in beam halo interact with collimators etc

→ can produce muons

very penetrating, can reach the experiment in a linear collider

simulation of muon production,

transport in Beam Delivery System of ILC

L. Keller, G. White @ SLAC,

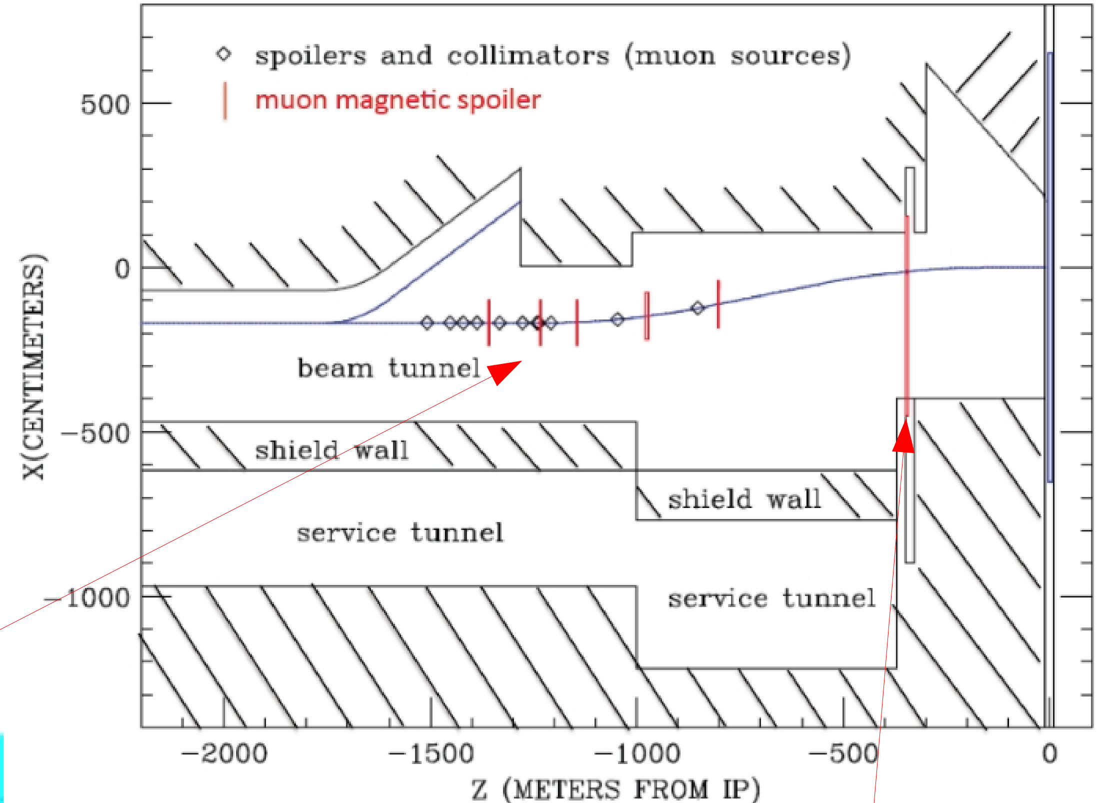
arXiv:1901.06449

with and without use of magnetised-iron muon spoilers

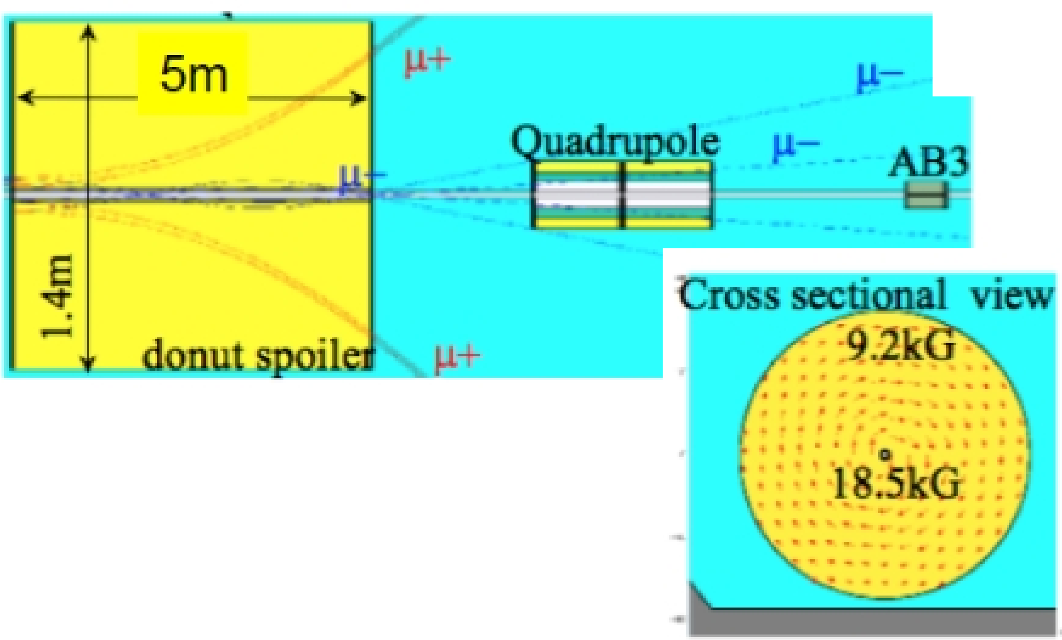
MUCARLO simulation code

beamline muon spoiling

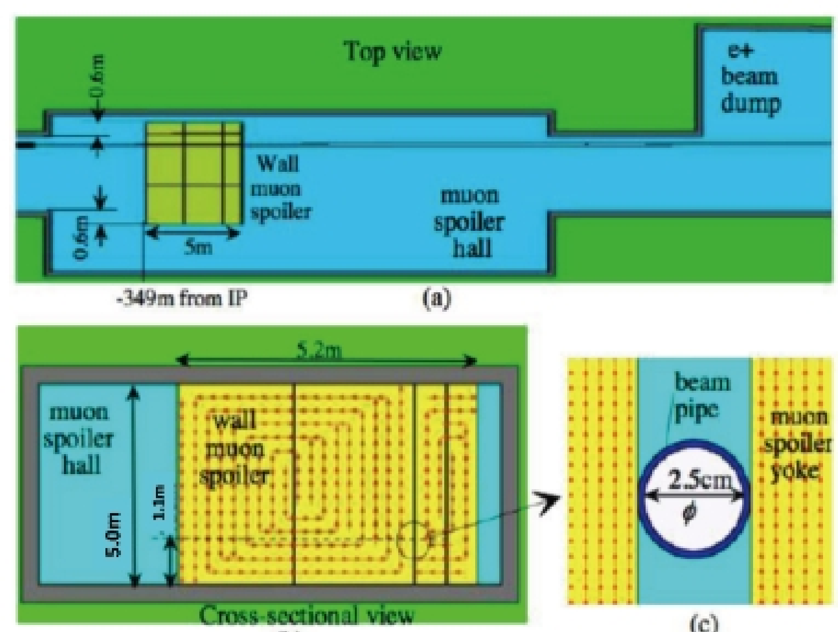
from Keller, White
arXiv:1901.06449



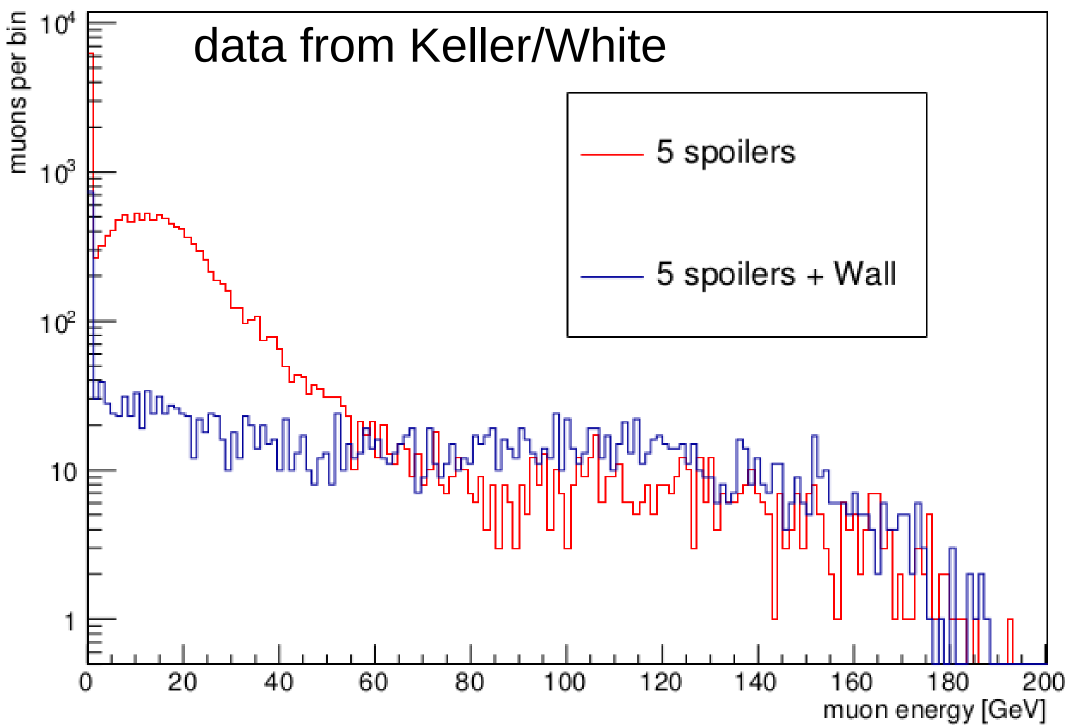
toroidal spoilers



muon wall



question: is the muon wall needed ?



2625 bunches of ILC-500,
assuming 0.1% of beam interacts in BDS
→ likely very pessimistic

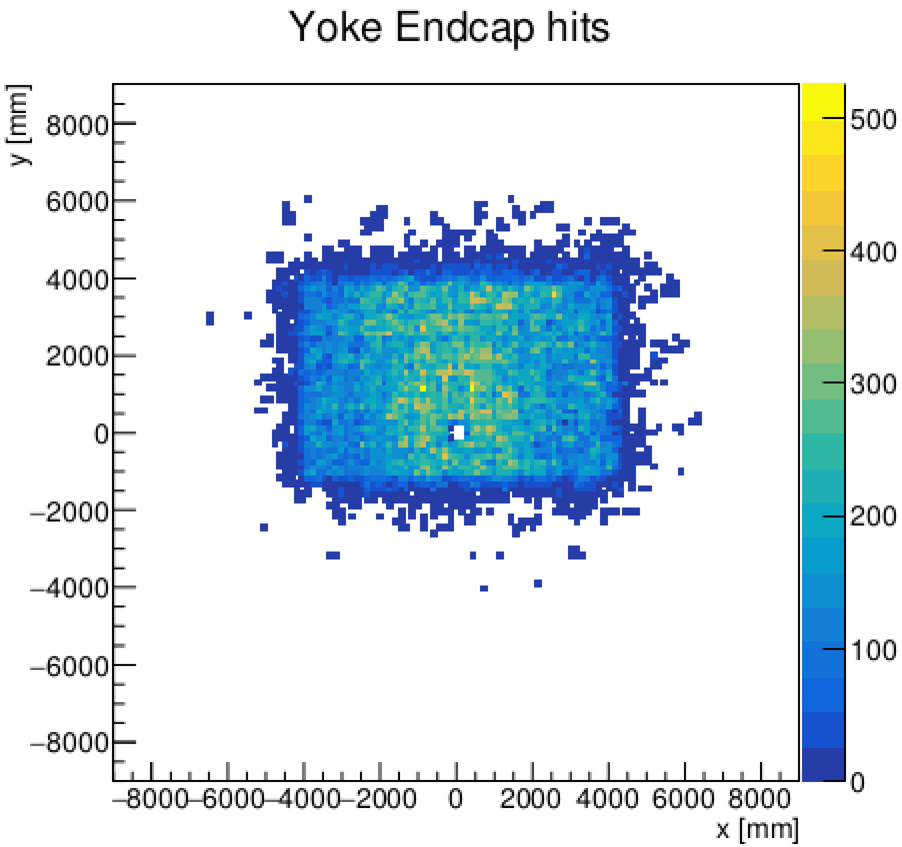
Keller/White

muons per bunch crossing
a 6.5m radius disk at IP ~ detector:

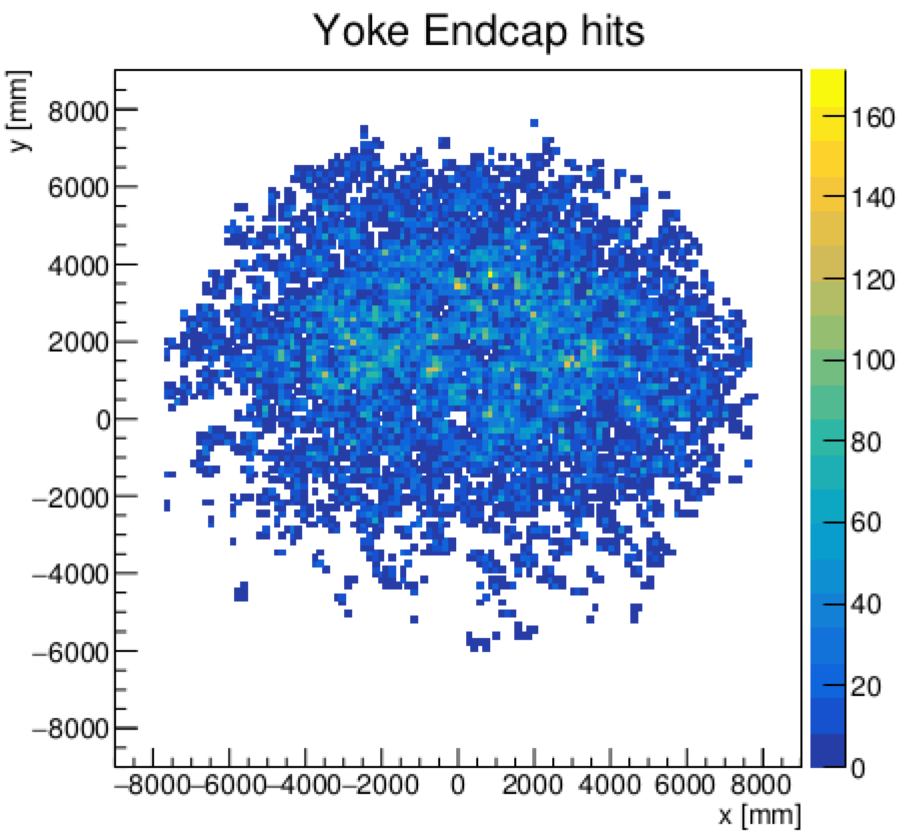
no spoilers	130
5 “donut” spoilers	4.3
+ muon wall	0.6

input these muon momenta into the ILD detector simulation

e.g. hits in the endcap muon detectors:



5 toroidal spoilers



5 toroidal spoilers + “wall”

thanks to their penetrating nature (ie ~ no showers),
and rather collimated "beam",
these muons should be easy to identify with the highly segmented readout of ILD subdetectors

→ we'll be able to subtract their contribution from physics events on a hit-by-hit basis

a few muons per bunch crossing seems manageable
→ prediction for 5 donut spoilers (no muon wall) ~ 4/BX

muon wall probably not needed,
from an event reconstruction standpoint
→ probably good idea to reserve space for it,
in case of future need (eg unexpectedly large backgrounds…)
→ should be taken into account for estimating detector data rates

summary

showed current status of studies into

beamstrahlung, and effect of anti-DID

→ anti-DID reduces hits in innner vertex detector by ~40%

beamline muons, and effect of muon “wall”

→ 5 toroidal spoilers alone seem to reduce
muon backgrounds to a manageable rate

more effort required to investigate these and
other background sources in more detail

backup

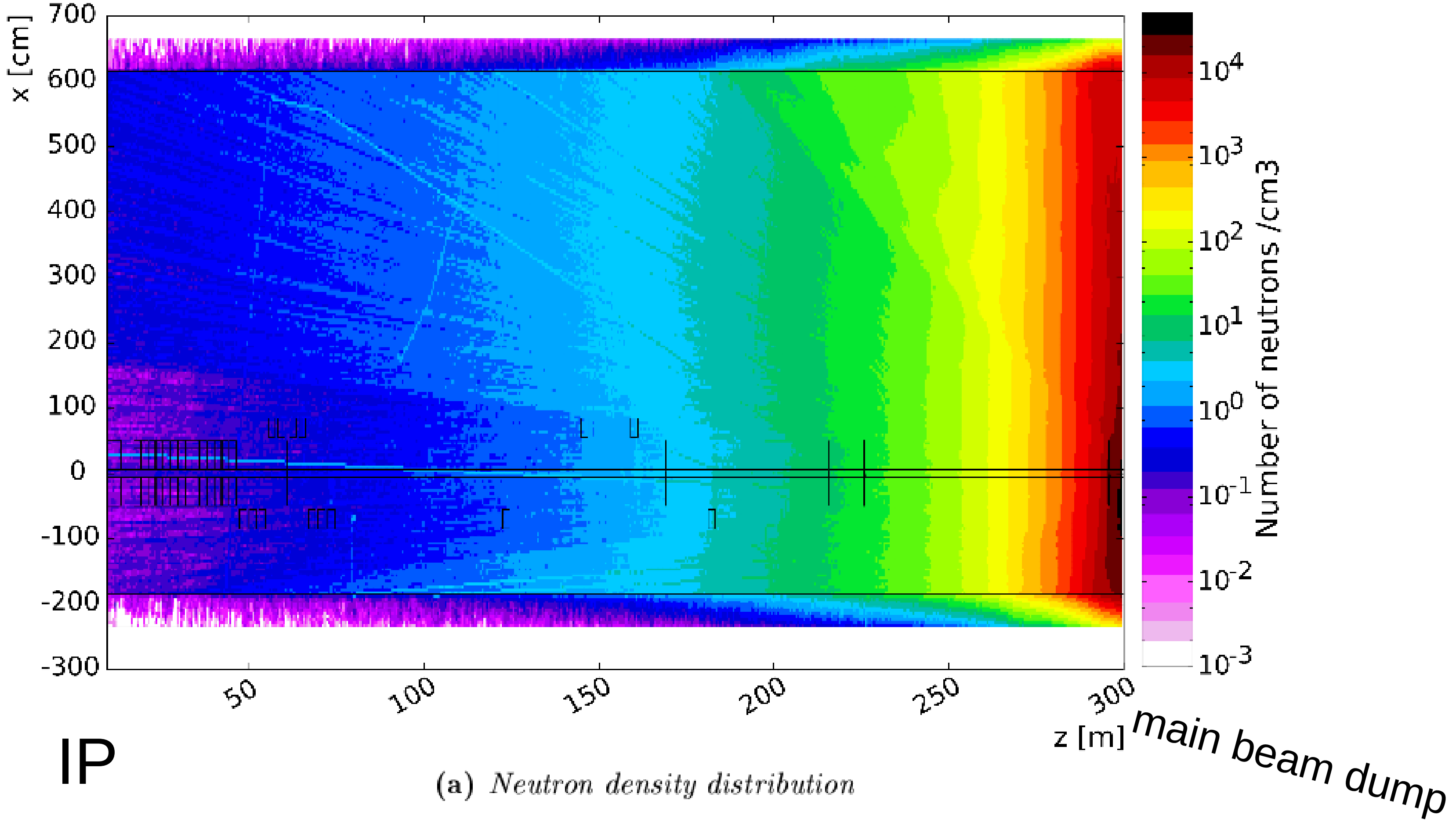
pair backgrounds: hit densities

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

after collision, ILC bunches are dumped
in a shielded water dump, ~300m downstream of the IP

A. Schuetz has simulated this situation using FLUKA code:
full details in DESY-THESIS-2018-017

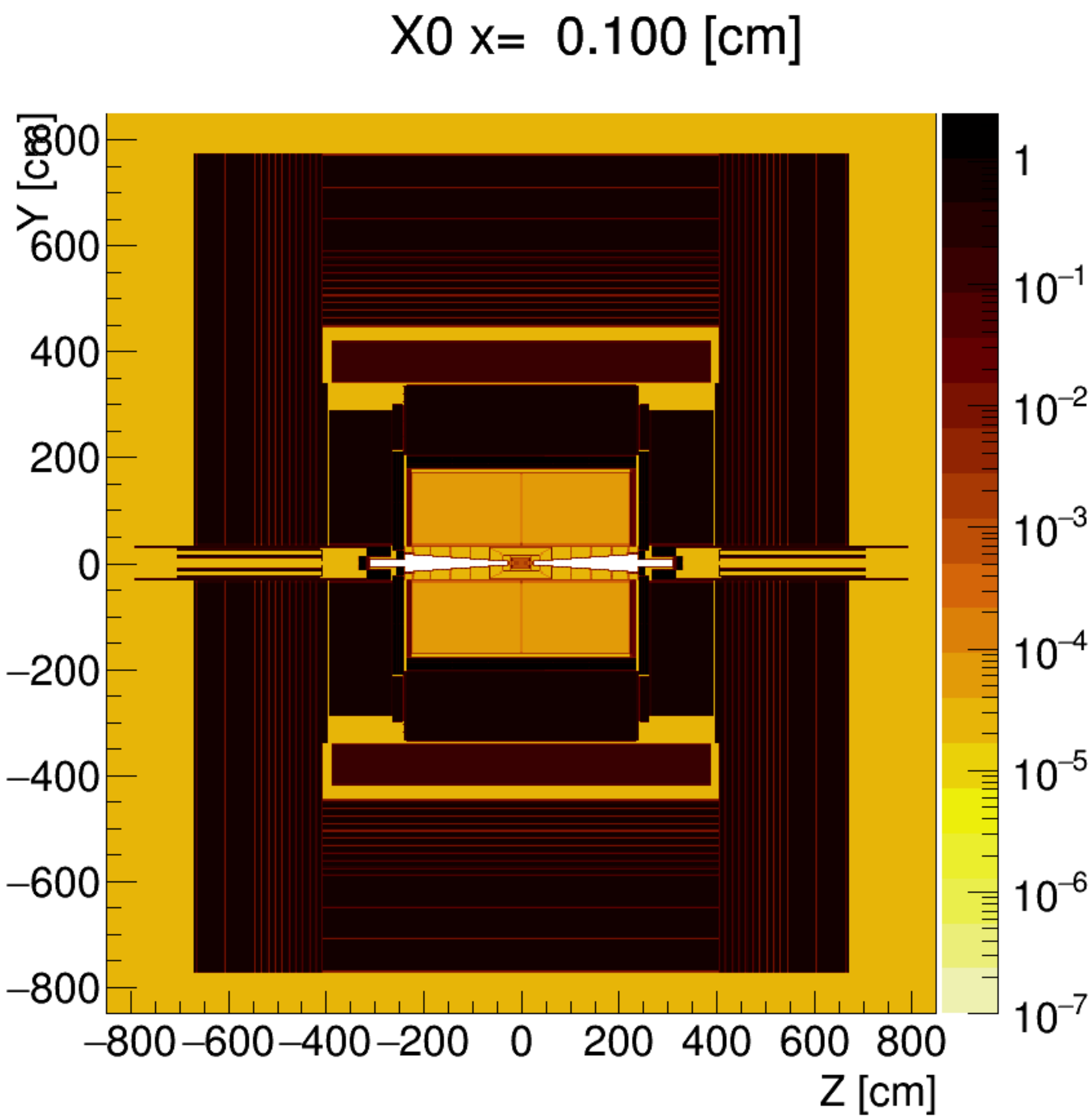
500 GeV electron bunch (ie ILC-1TeV) into water dump
transmission of neutrons back into detector hall



(a) *Neutron density distribution*

A. Scheutz has provided a set of momentum vectors
of neutrons entering the experimental hall

These were then input into the Geant-4 ILD simulation model



present simulation ILD model does not include so-called “pac-man” shielding between ILC tunnel and experimental hall

→ limits realism of simulation,
so likely to be an overestimate

→ more work needed...

endpoint of all stopped simulated particles