Beamstrahlung backgrounds in ILD @ FCCee

(update)

contents to be shown at FCC physics meeting in Jan.

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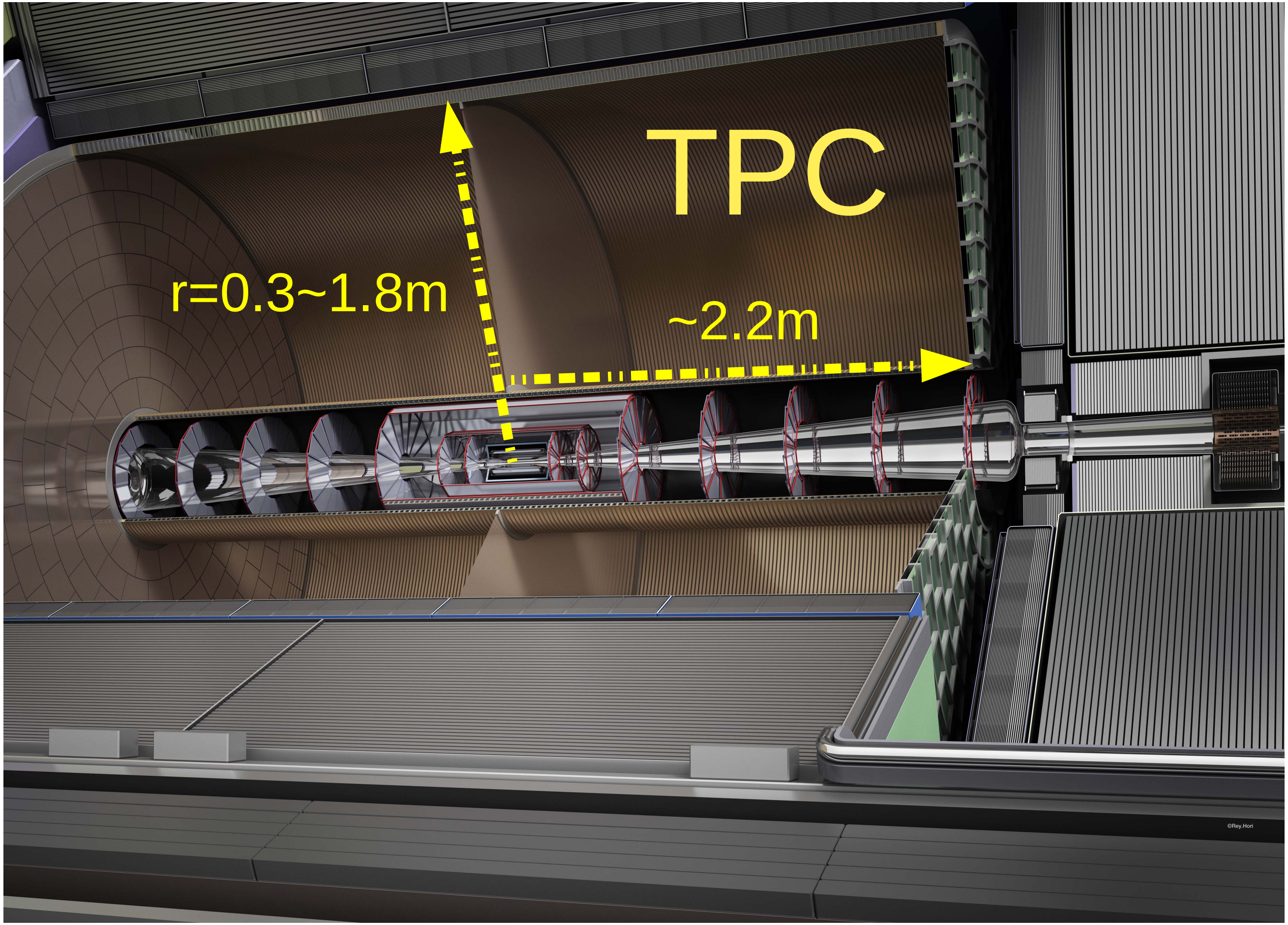
ILD sw/ana

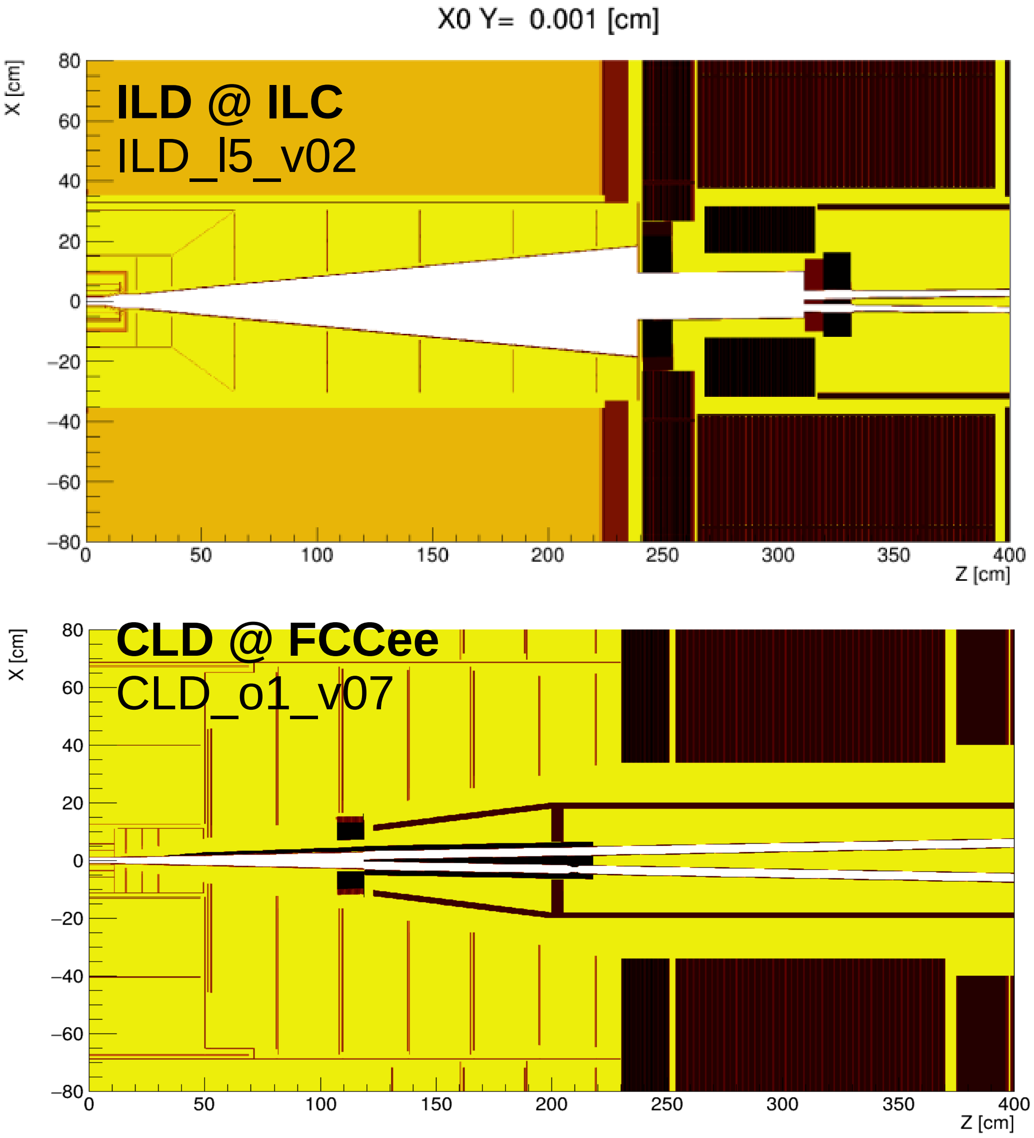
18th December 2024


TPC
r=0.3~1.8m
~2.2m

Machine-Detector Interface

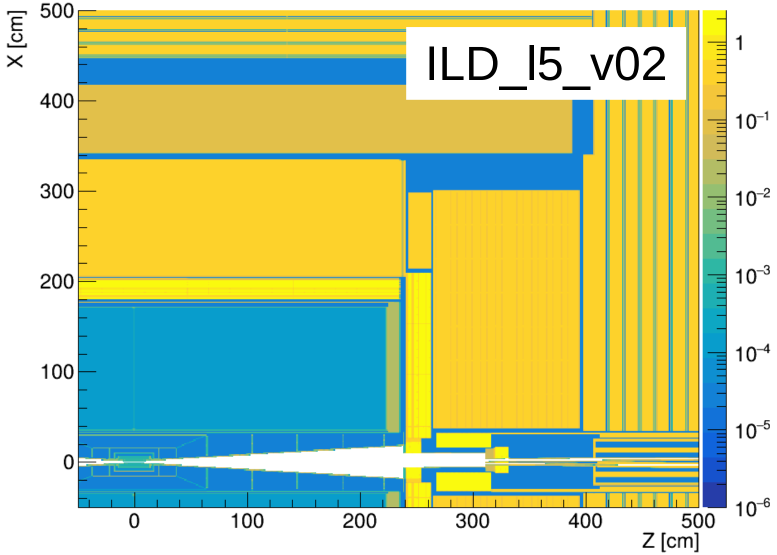
is significantly different @ ILC and FCCee

	ILC	FCCee
crossing angle	14 mrad	30 mrad
L* [distance from IP to last accel focusing quadupole magnet]	4.1 m	2.0 m
detector solenoid	3.5 T	2.0 T
additional B-fields	anti-DID (?)	- compensating - screening



new models of
ILD for FCCee

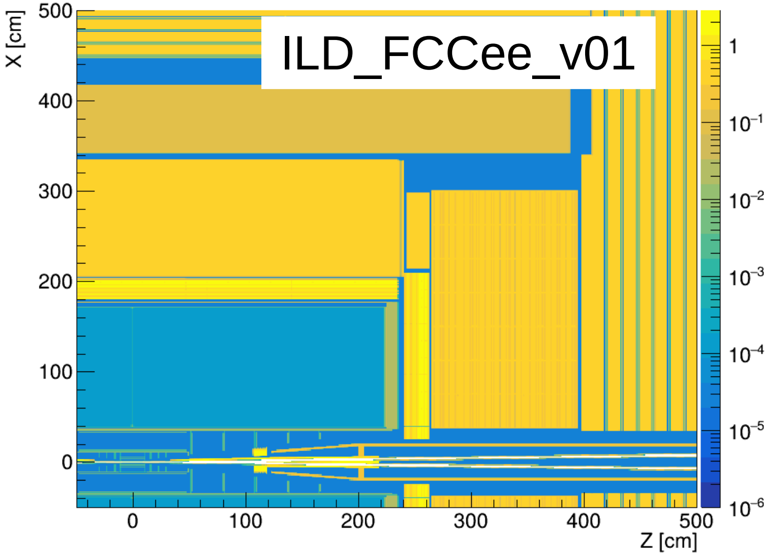
with V. Schwan



common MDI: MDI_o1_v00

vertex, inner tracker
adapted from CLD_o1_v07

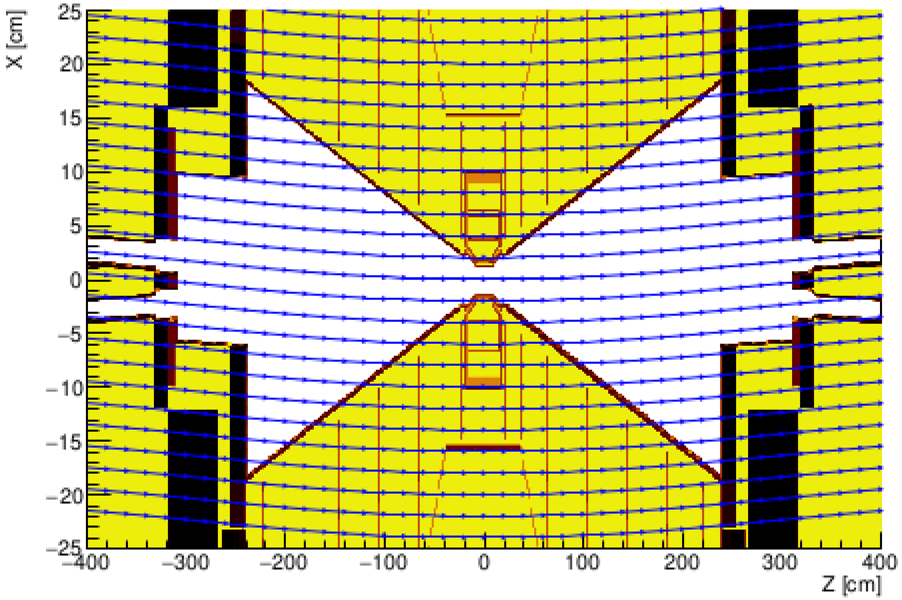
remainder from ILD



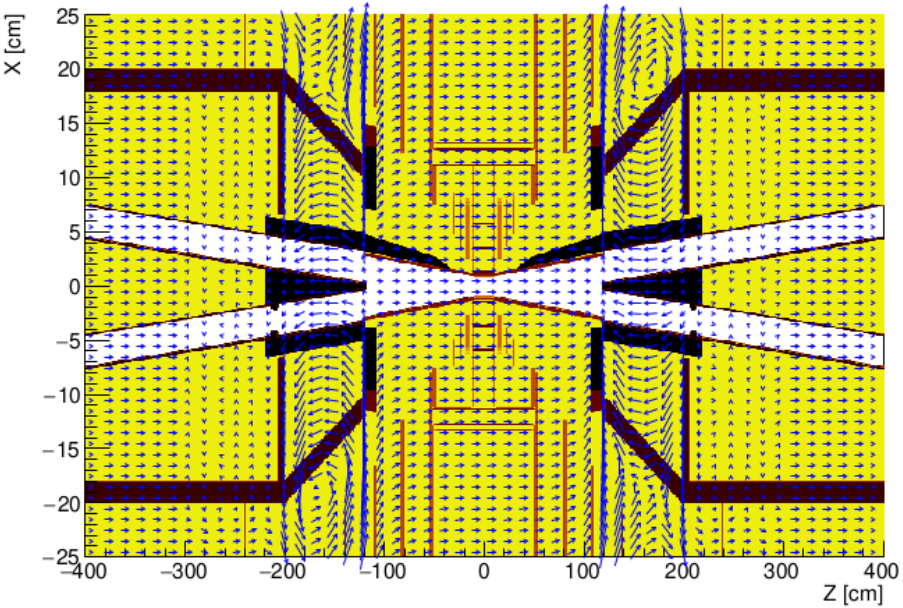
magnetic field maps

field lines

field magnitude & orientation



ILC with anti-DID



FCCee: screening and compensating coils

beamstrahlung: many very low p_T e+e- created in bunch collisions

very different bunch structure, materials and fields in the forward region
→ major effect on beamstrahlung backgrounds ?

reminder:

number of primary ions produced in the TPC per bunch crossing

model	B-field [T]	MDI	FCCee-91	FCCee-240	ILC-250
			thousand ions / bunch crossing mean $\pm$ RMS		
ILD_l5_v02	3.5 (uniform)	ILC	6.5 ± 19.9	14 ± 14	960 ± 150
ILD_l5_v02_2T	2.0 (uniform)	ILC	6.9 ± 11.1	15 ± 11	4700 ± 300
ILD_l5_v03	3.5 (map)	ILC	5.7 ± 7.9	14 ± 11	1100 ± 200
ILD_l5_v05	3.5 (map, anti-DID)	ILC	0.6 ± 1.5	3.7 ± 9.7	450 ± 110
new FCCee models					
ILD_FCCee_v01	2.0 (uniform)	FCC-ee	351 ± 115	987 ± 155	111000 ± 2100
ILD_FCCee_v01	2.0 (map)	FCC-ee	261 ± 86	823 ± 180	100000 ± 2100

“realistic” situations : a few 100k → 1M primary ions / BX

ILC and FCCee are similar

TPC integrates over many collisions; maximum ion drift time ~ 0.44 s

roughly estimate number of primary ions in the TPC volume (~42 m^3) at any time,
taking account of different collision rates

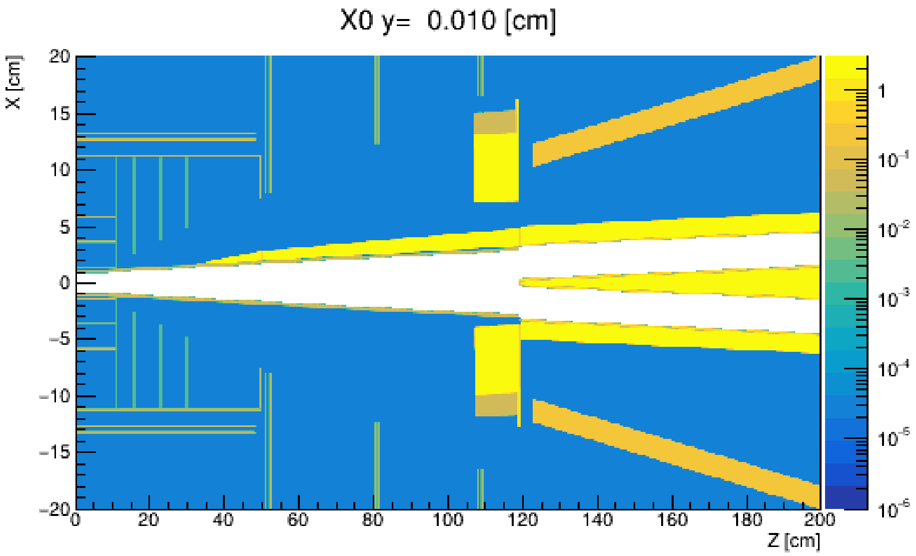
number of ions ~ primary ions/BX * BX freq * max drift time * 50% [some ions already reached cathode]

Collider	FCC-91	FCC-240	ILC-250
Detector model	ILD_FCCee_v01	ILD_FCCee_v01	ILD_l5_v05
average BX frequency	30 MHz	800 kHz	6.6 kHz
primary ions / BX	260 k	820 k	450 k
primary ions in TPC at any time	1.7×10^{12}	1.4×10^{11}	6.5×10^{8}
average primary ion charge density nC/m^3	6.4	0.54	0.0025

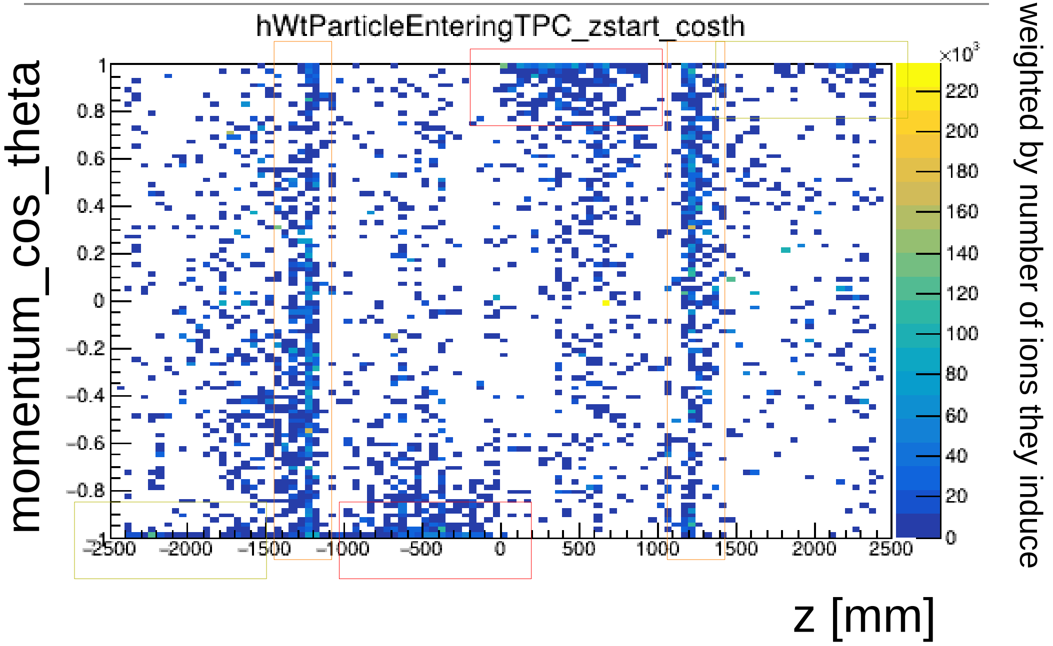
primary ion density in TPC: 2500 times higher at FCCee-91 than ILC-250
200 times higher at FCCee-240 than ILC-250

ILD_FCCee_v01 model (with field map)

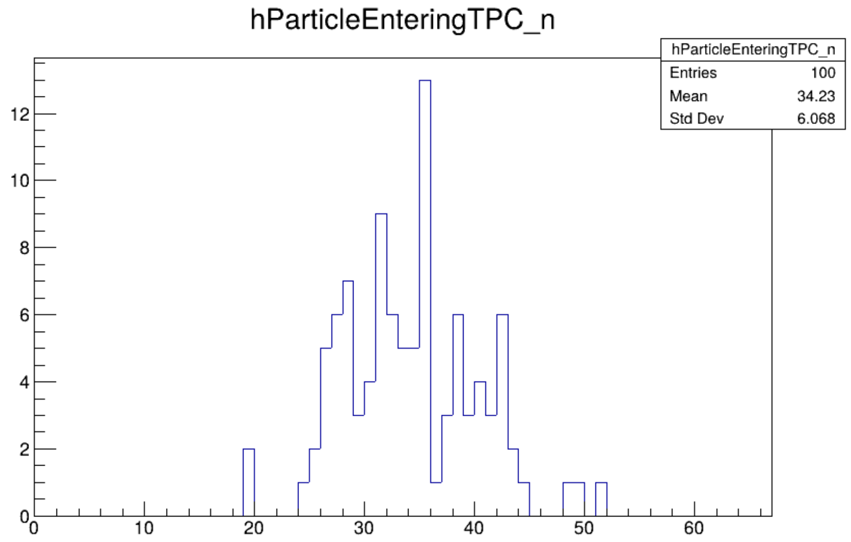
MDI exactly from MDI_o1_v00



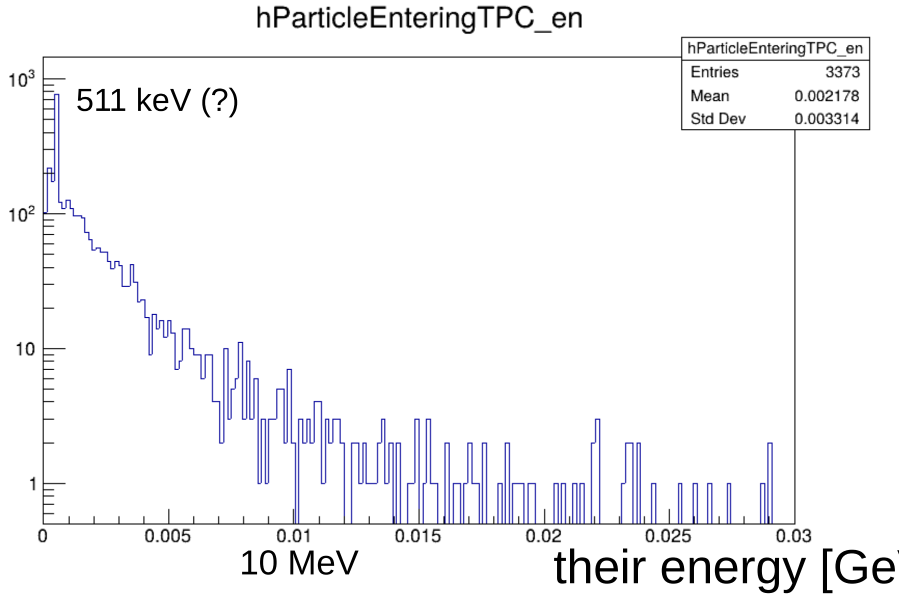
production point of
particles entering the TPC



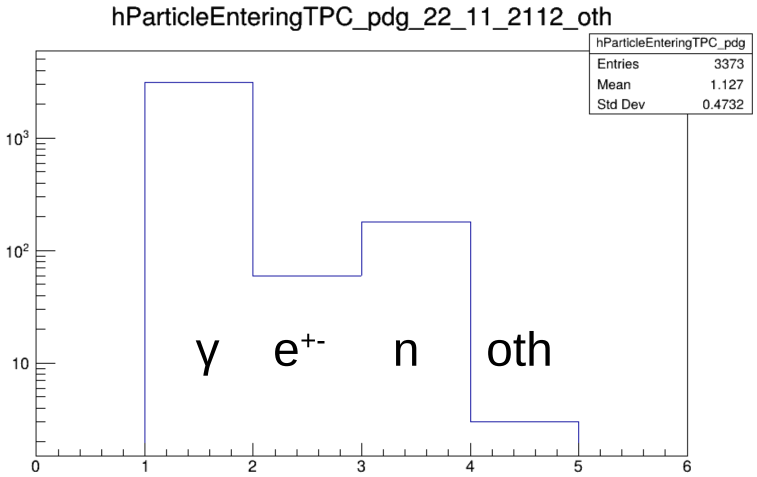
particles which induce TPC hits



number of particles entering TPC / BX

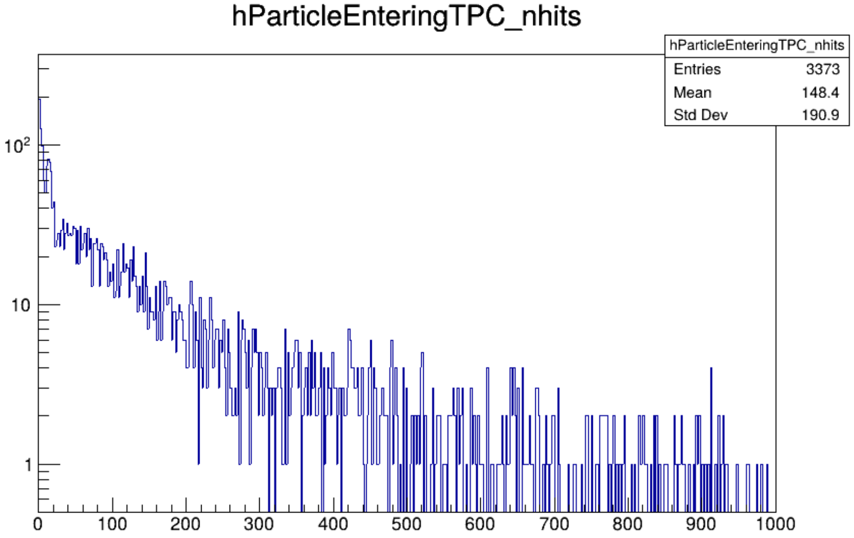


their energy [GeV]

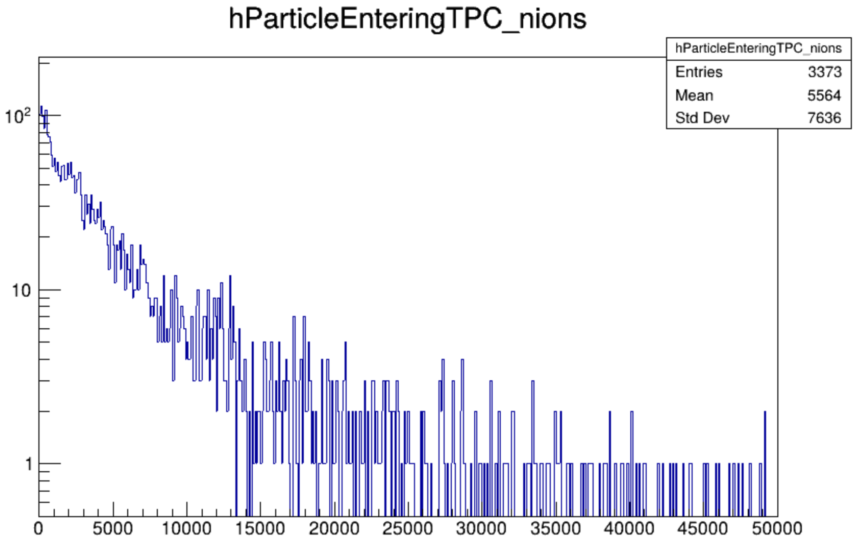


their type

ILD_FCCee_v01 model (with field map)



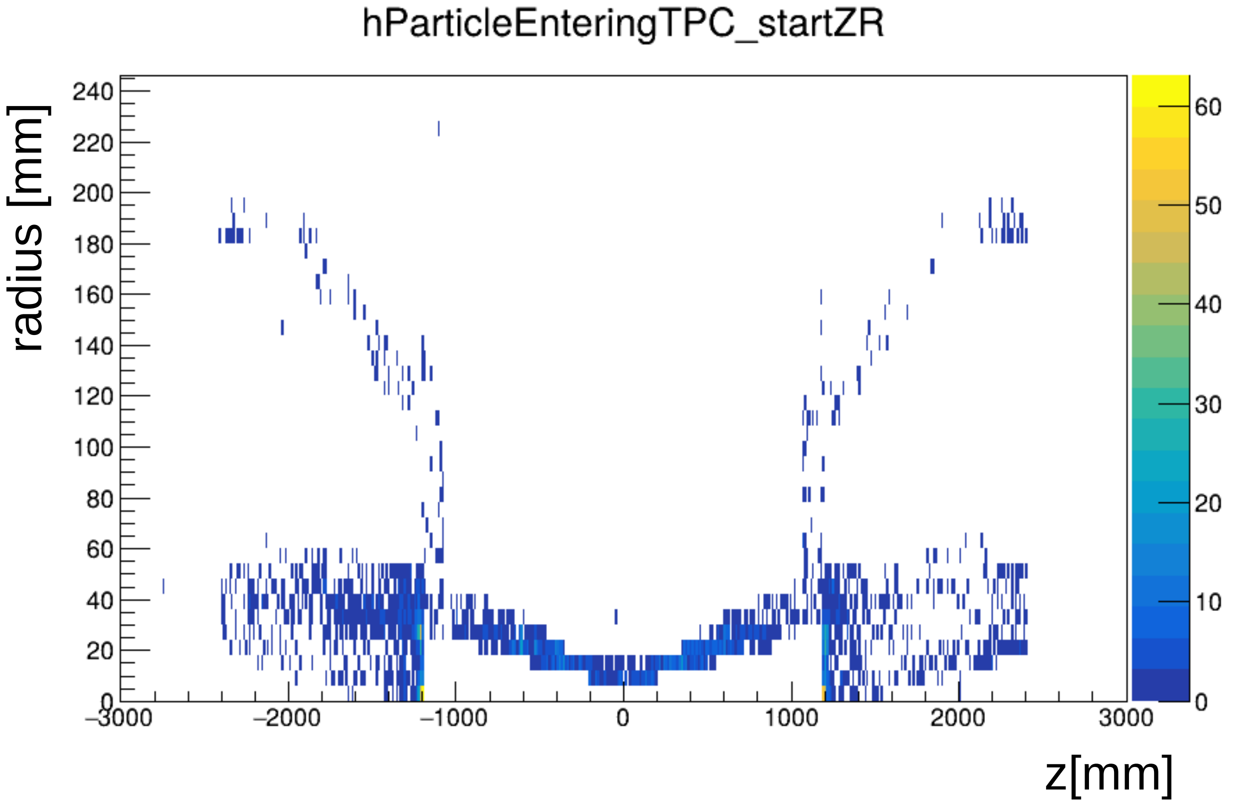
TPC hits induced per particle

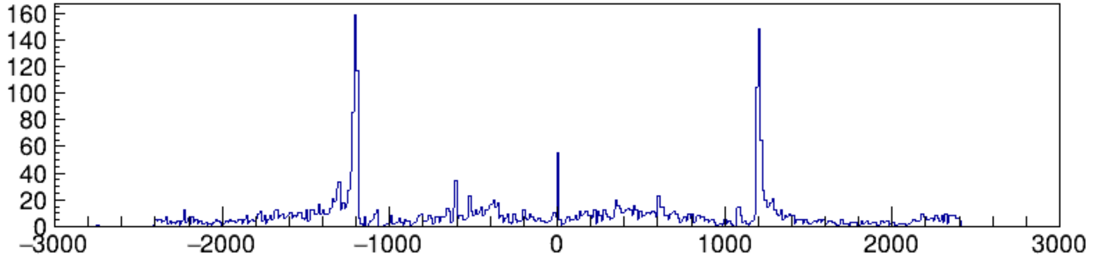


primary ions in TPC induced per particle

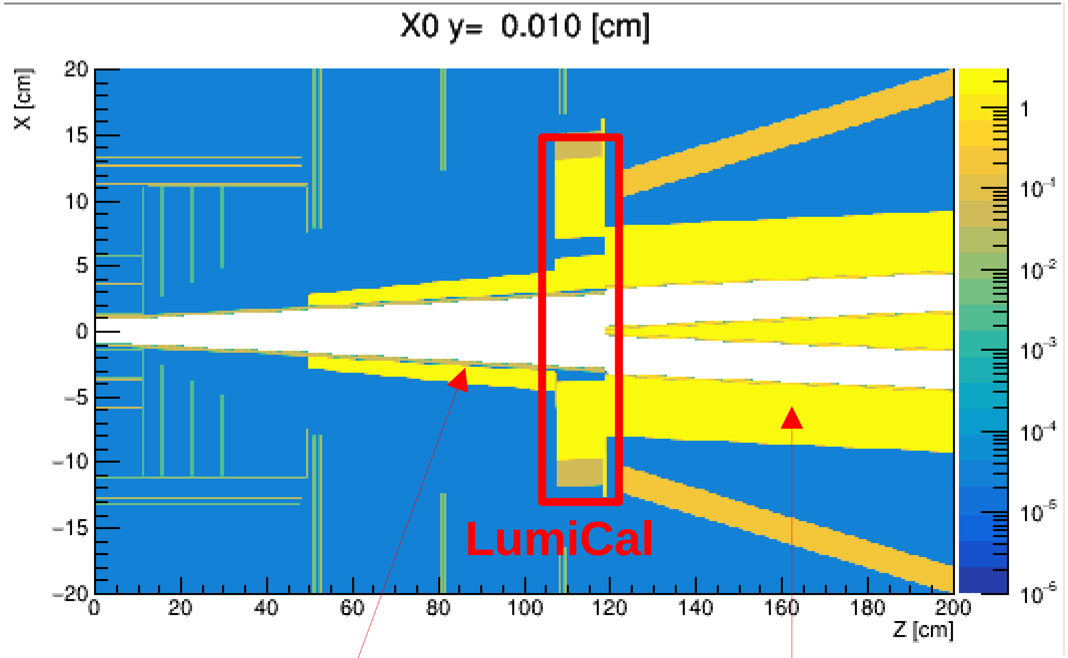
ILD_FCCee_v01 model (with field map)

birthplace of particle
which later enters TPC



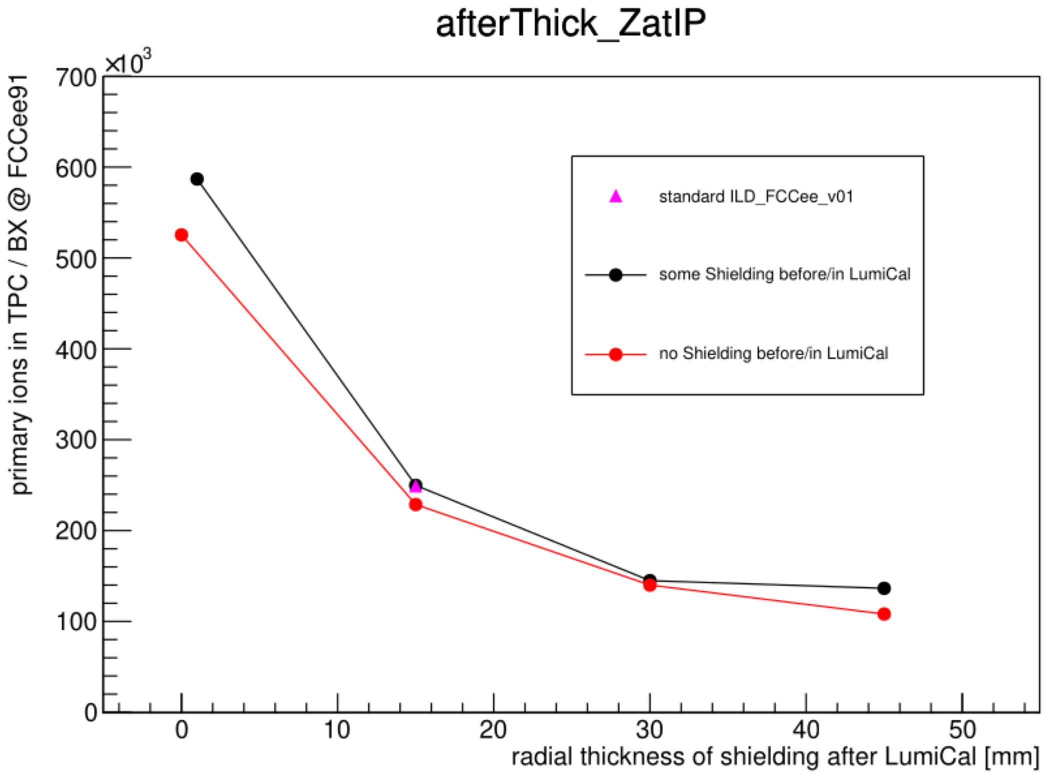


test different shielding configurations



up-stream
of LumiCal

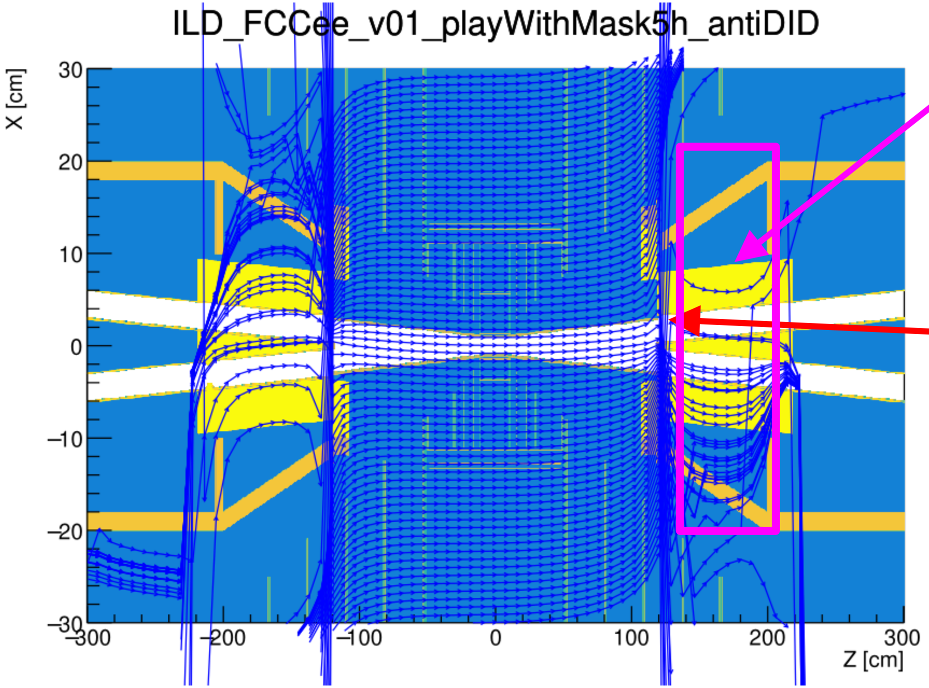
down-stream



“down-stream”

up-stream shielding *before or inside* LumiCal doesn’t reduce pair bg in TPC

thicker down-stream shielding *after* LumiCal does help: e.g. increase from 15 → 30 or 45 mm



compensating solenoid (–5T) ensures that integrated B_z seen by beam is 0

limited space available
→ strong compensating magnet,
limited detector solenoid

transition between
+ 2T detector solenoid and
– 5T compensating solenoid
is essentially a magnetic wall for low p_T e^{+-}
→ steered into the shielding just behind LumiCal

new proposal for alternative compensation scheme moves this strong compensating solenoid outside the detector

doi:10.18429/JACoW-IPAC2024-TUPC68

→ more space available for compensation → relaxed limit on detector solenoid strength

would there be any effect on beamstrahlung backgrounds?

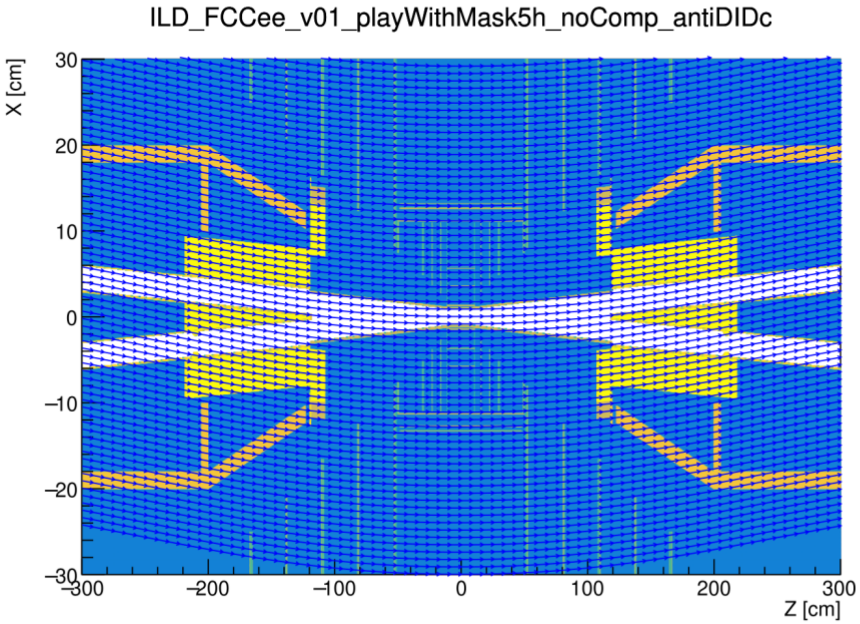
* test removing strong compensating solenoid field
    * also remove the “screening field” for technical reasons

* also try introducing an “anti-DID” field,
    a la ILD@ILC

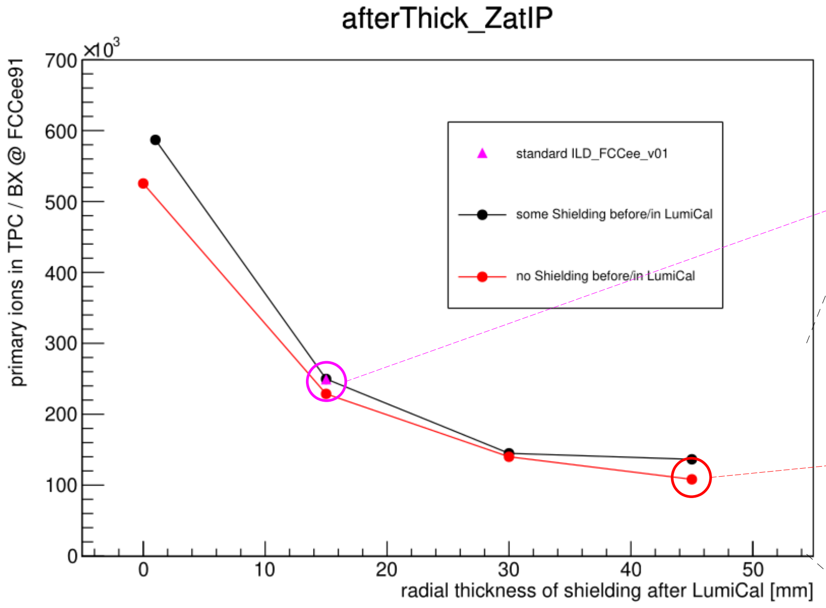
→ small B_x to bend field lines
    (and therefore low p_T particles)
        into outgoing beampipe

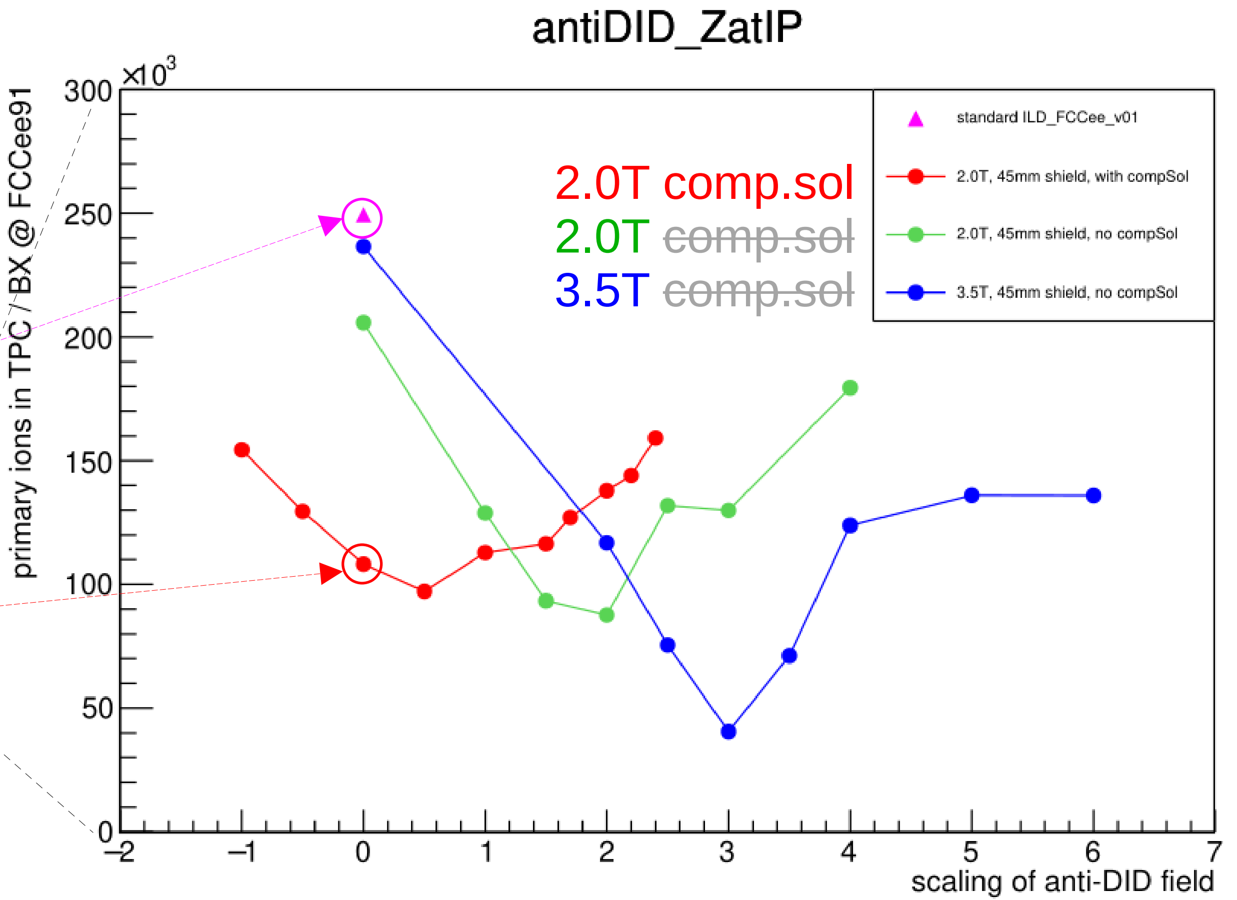
optimal anti-DID strength should depend on
    main solenoid field
    crossing angle
    …

use ILD@ILC field map for anti-DID field
    simple scaling of its strength



uniform solenoid + anti-DID





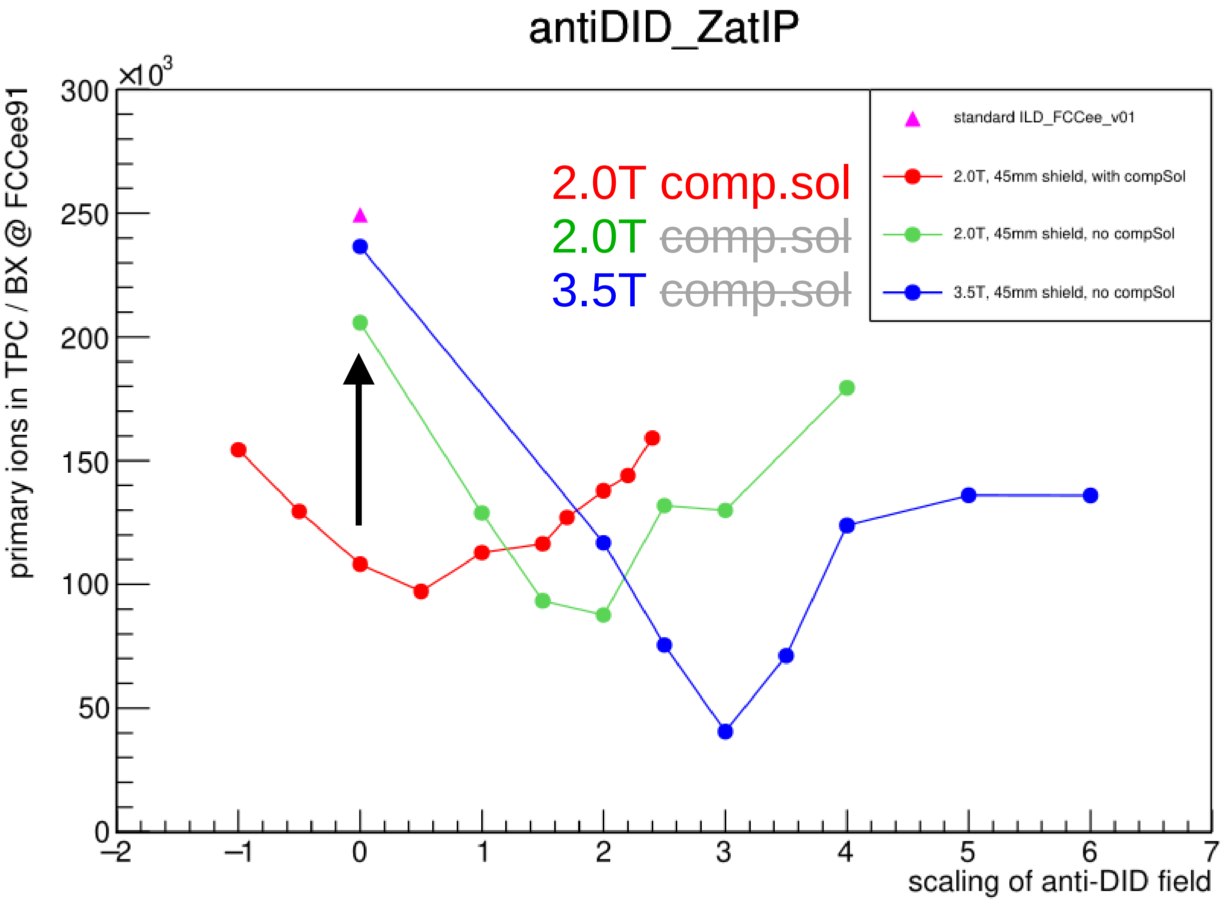
effect of anti-DID:

with the compensating solenoid, it doesn't help much → "magnetic wall"

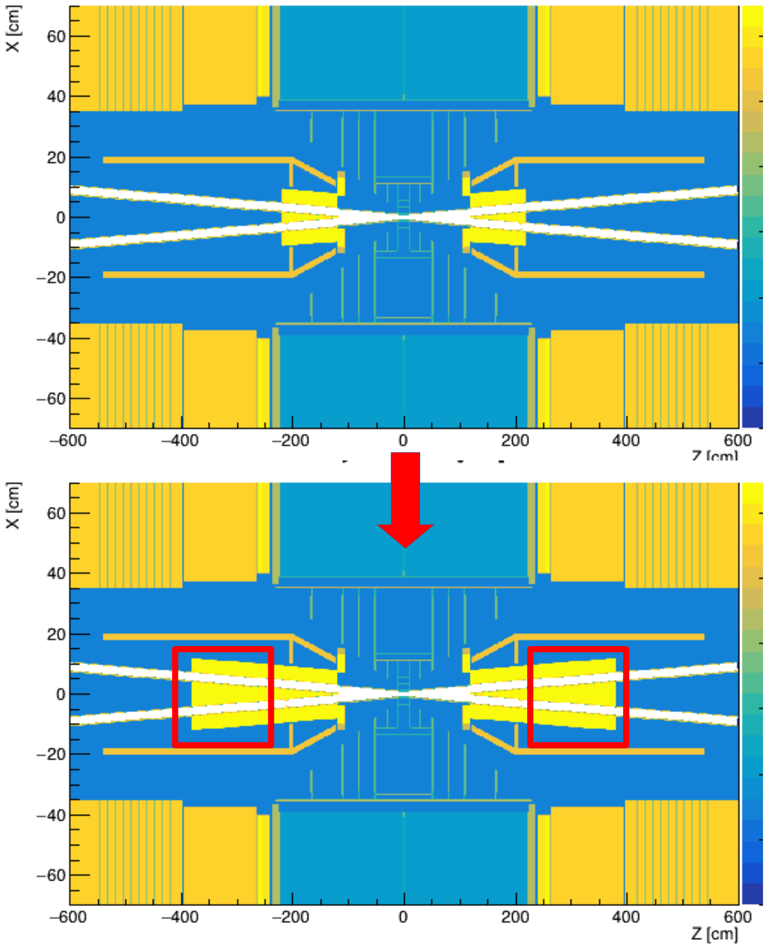
without compensating solenoid, it can reduce BG by factor ~2 @ 2T, ~6 @ 3.5T

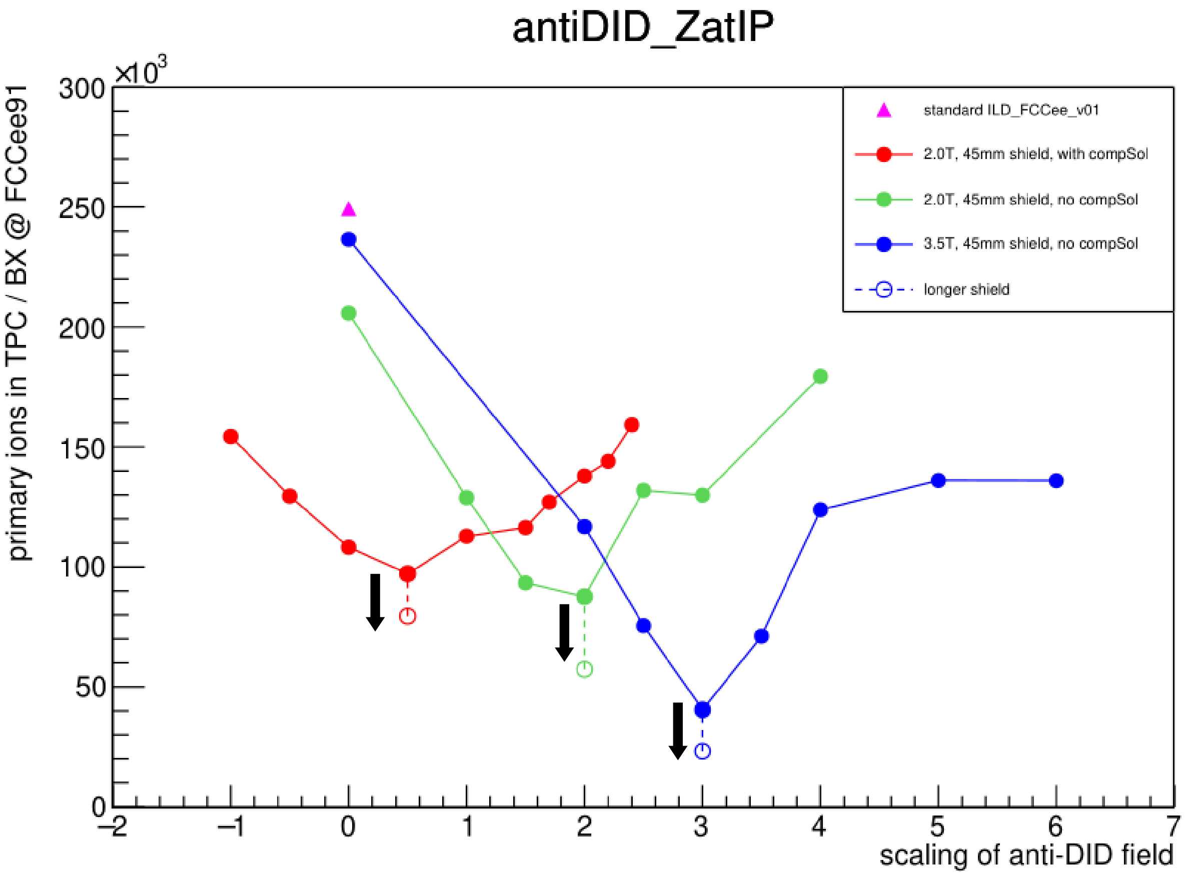
clear advantage of higher field (only if anti-DID available) the “magnetic wall” has some similar effects as anti-DID:

turning off the compensating solenoid significantly increases the bg



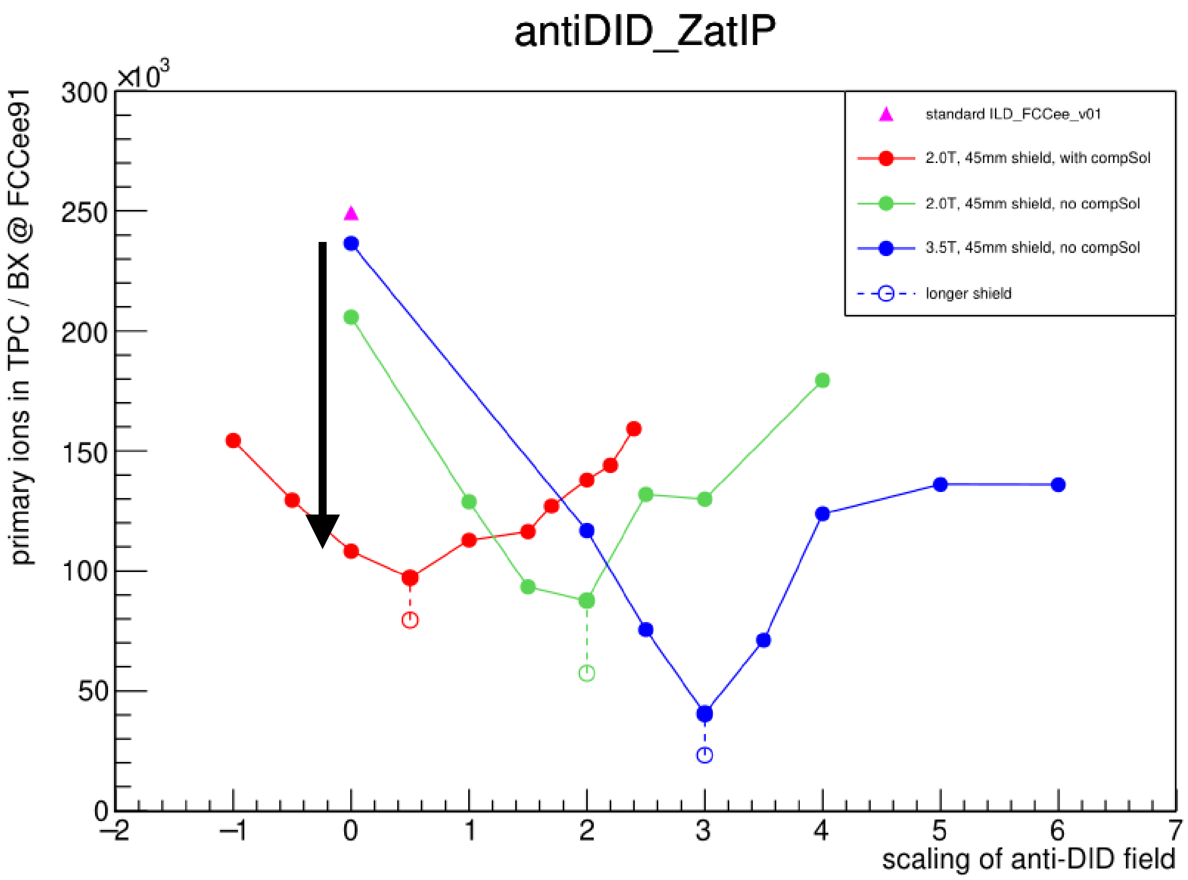
extend length of down-stream shielding



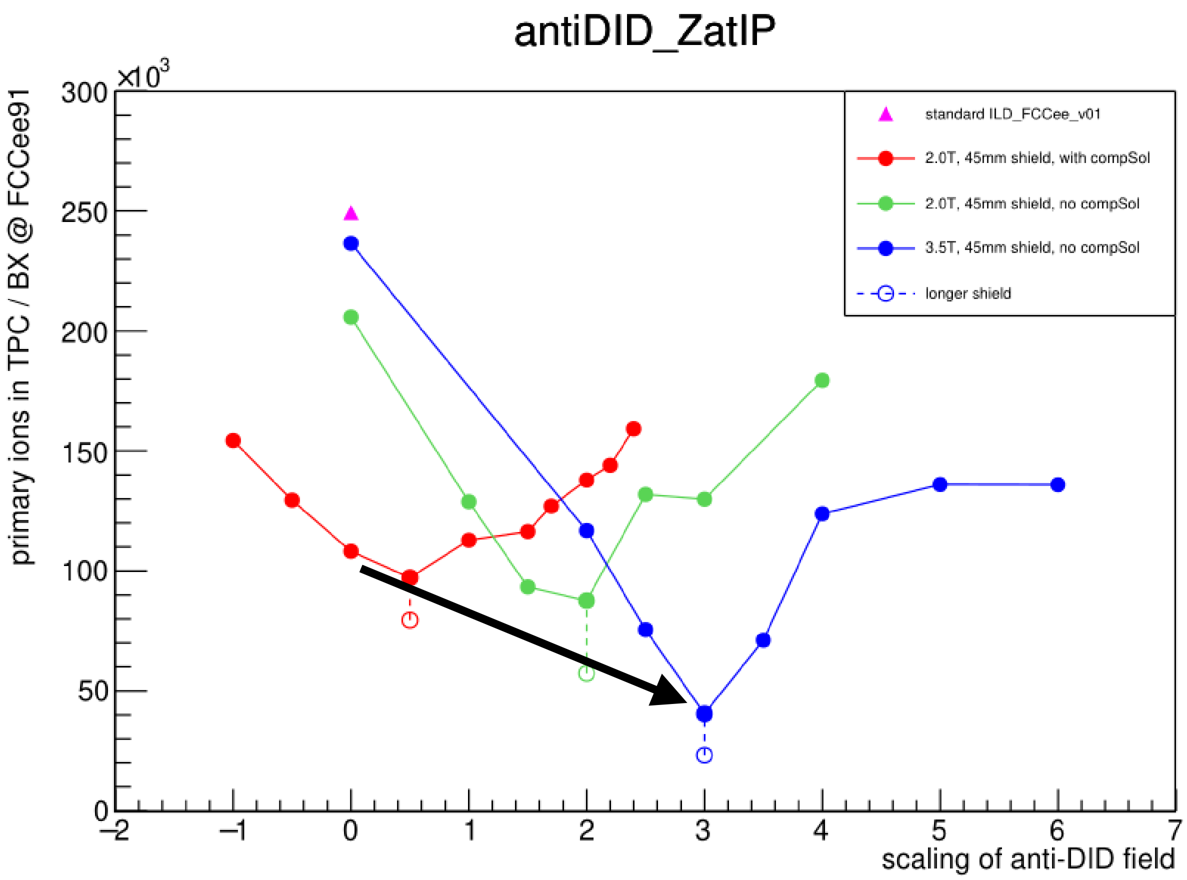


* just a toy model: eg QD0 needs space!

extra downstream length: gain a factor ~2 can reduce beamstrahlung bg in TPC



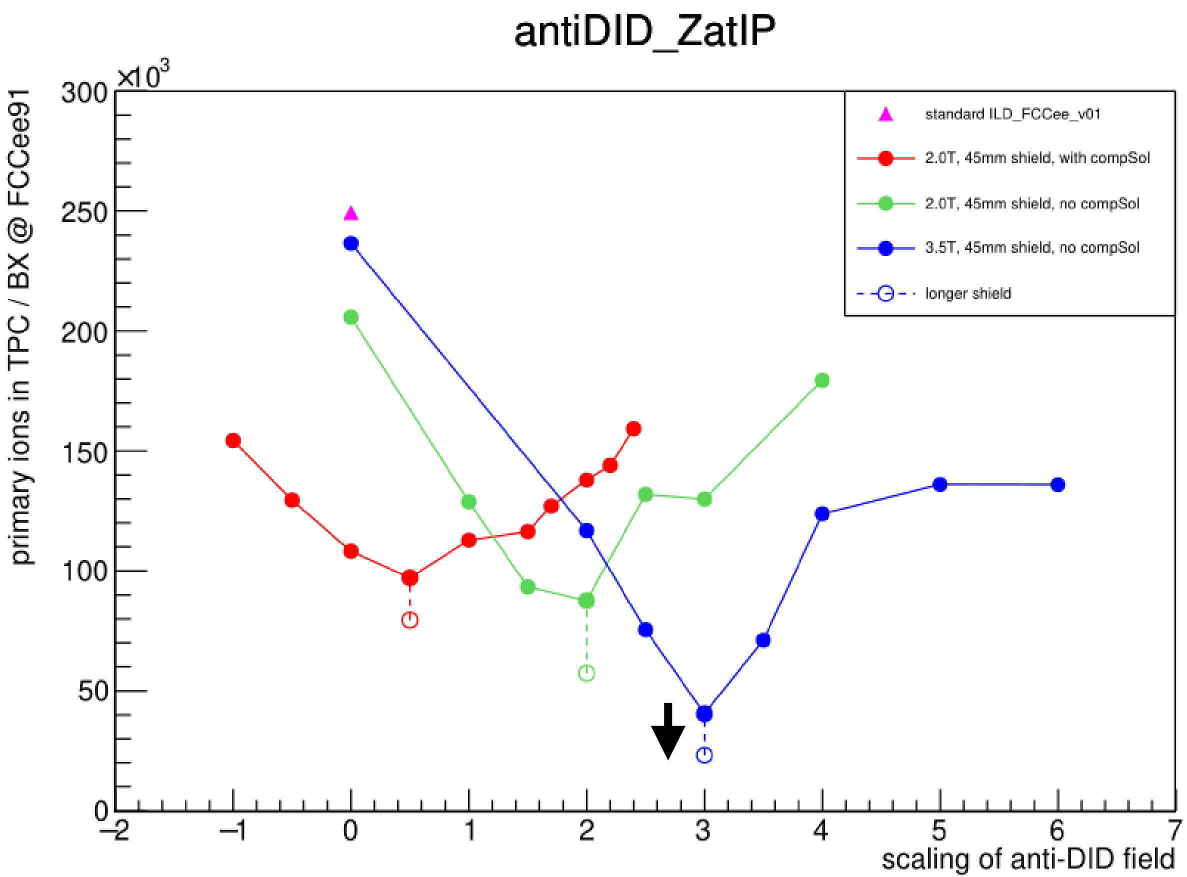
1. **thicker** shield after LumiCal



can reduce beamstrahlung bg in TPC

1. **thicker** shield after LumiCal

2. 2.0 → **3.5 T + anti-DID**

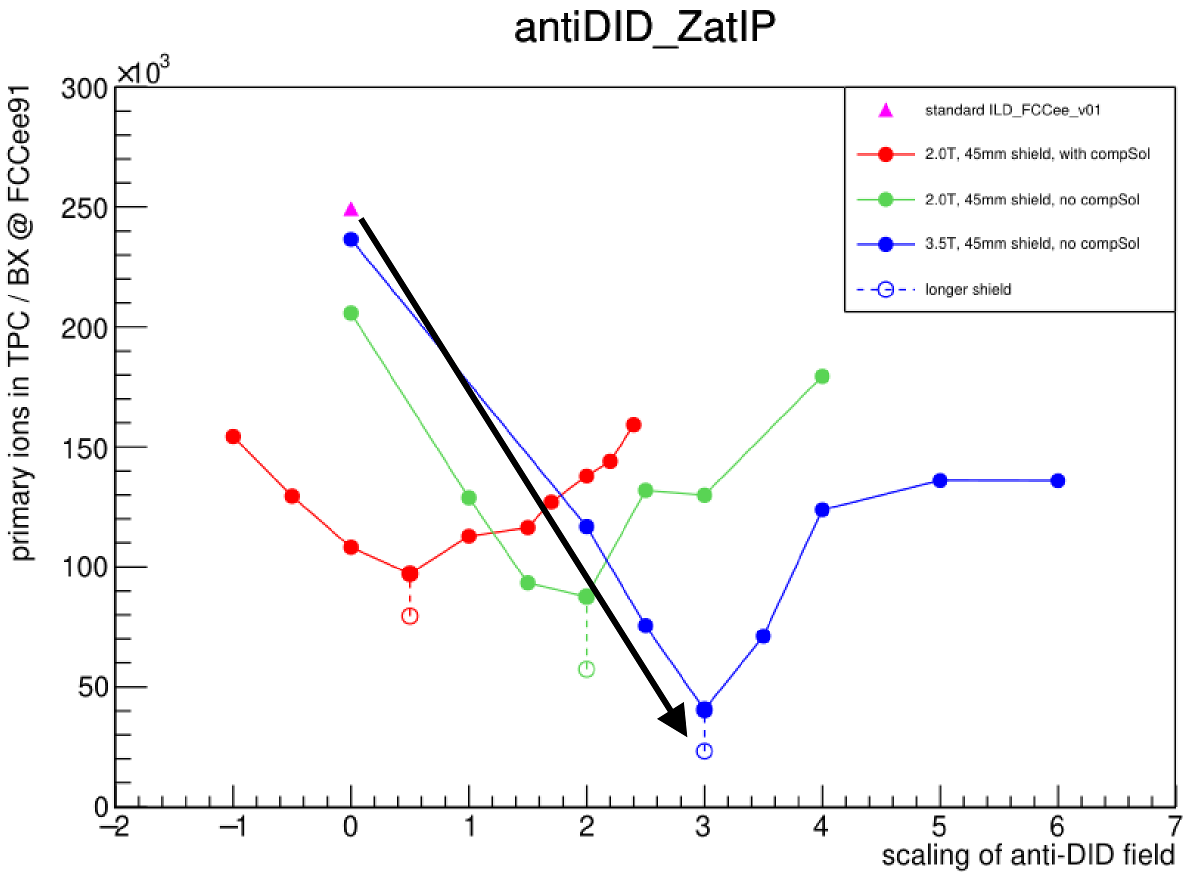


can reduce beamstrahlung bg in TPC

1. **thicker** shield after LumiCal

2. 2.0 → **3.5 T + anti-DID**

3. **longer** shield after LumiCal

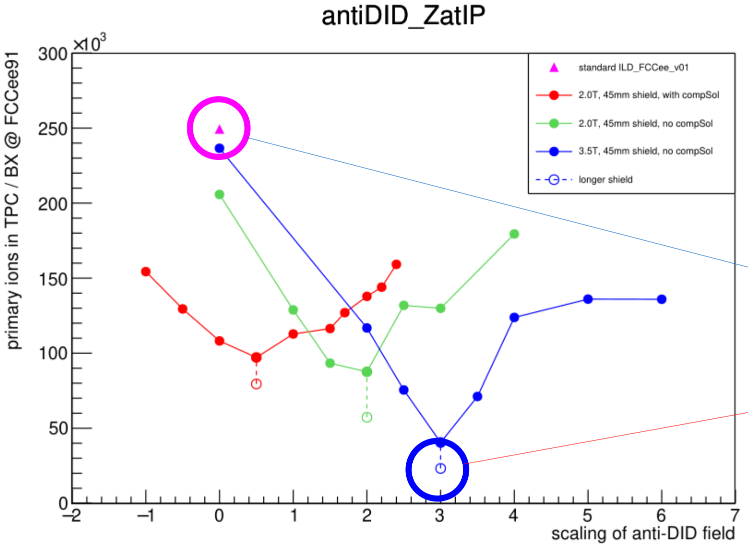


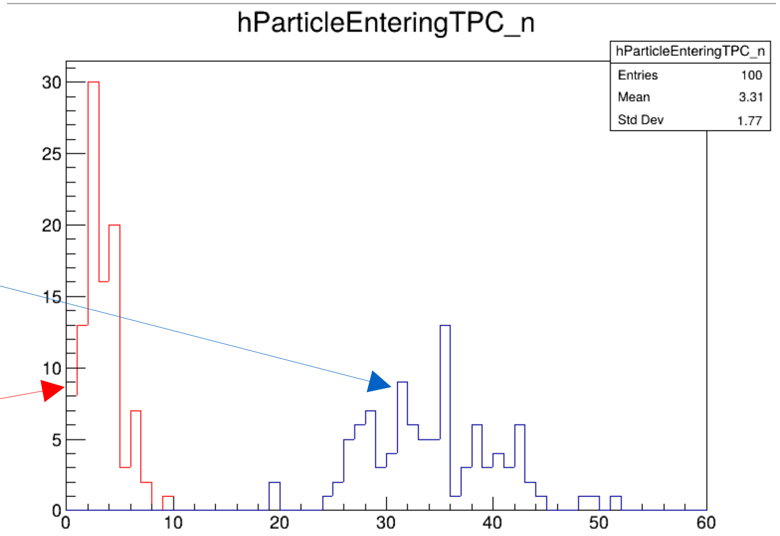
can reduce beamstrahlung bg in TPC

1. **thicker** shield after LumiCal x1/2.5
2. 2.0 → **3.5 T + anti-DID** x1/2
3. **longer** shield after LumiCal x1/2

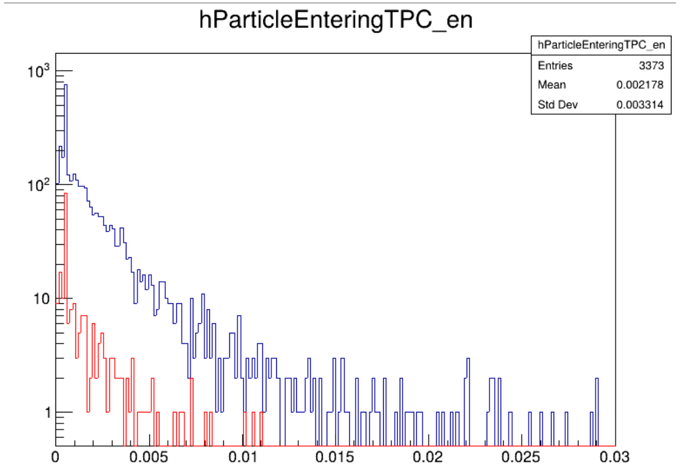
overall, ~10x reduction in TPC BG compared to MDI_o1_v00

properties of particles which induce TPC hits

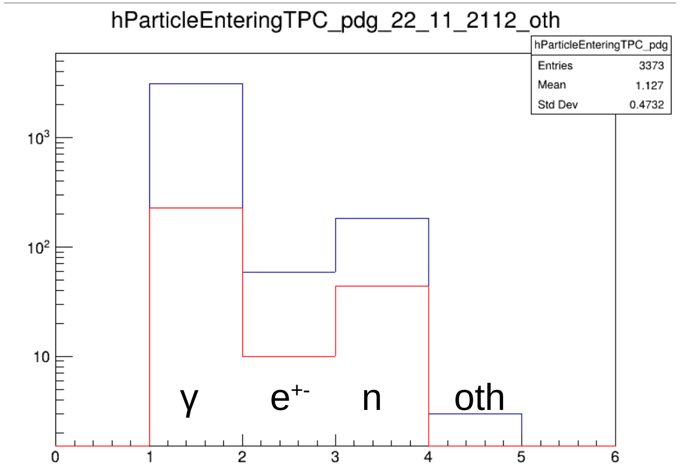




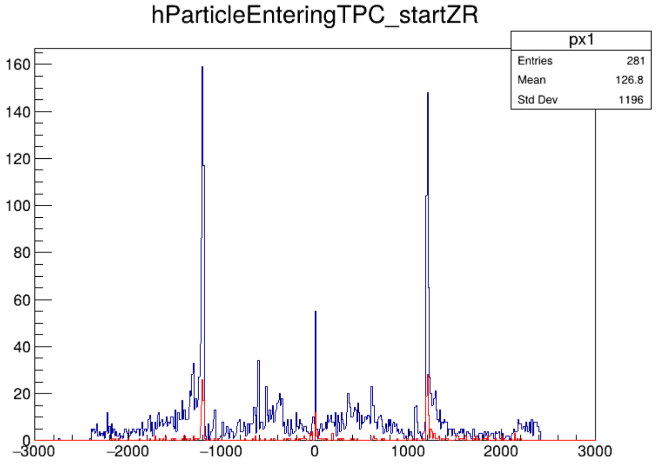
number of particles entering TPC/BX



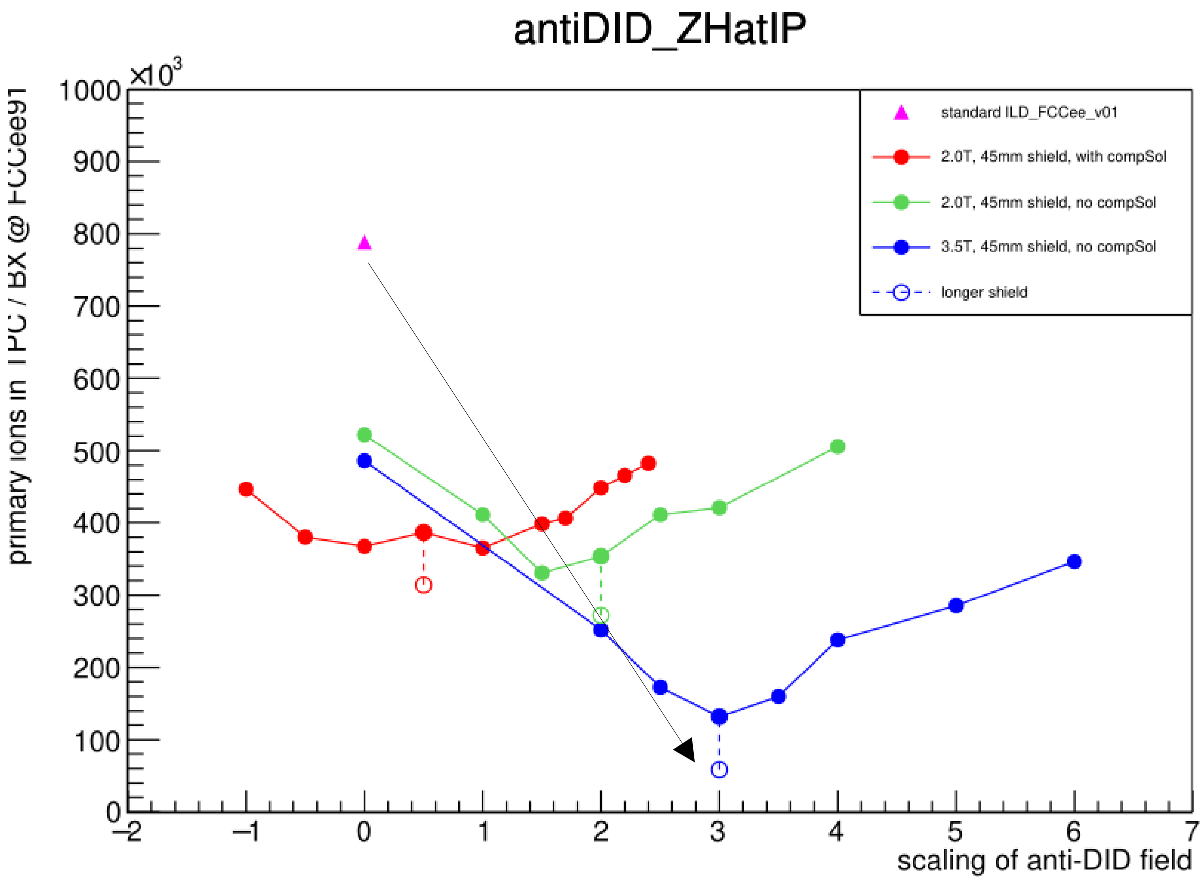
energy of particles entering TPC [GeV]



type of particles entering TPC [GeV]



production point (z) of particles entering TPC [mm] how about at 240 GeV ?



rather similar conclusions

reduction by factor >10 seems possible

conclusion

Collider	FCC-91	FCC-240	ILC-250
Detector model	ILD_FCCee_v01	ILD_FCCee_v01	ILD_l5_v05
average BX frequency	30 MHz	800 kHz	6.6 kHz
primary ions / BX	260 k	820 k	450 k
primary ions in TPC at any time	$1.7 \times 10^{\cancel{12}\ 11}$	$1.4 \times 10^{\cancel{11}\ 10}$	6.5×10^{8}
average primary ion charge density nC/m^3	~~6.4~~ 0.6	~~0.54~~ 0.05	0.0025

*rough estimates

primary ion density in TPC: ~~2500~~ 250 times higher at FCCee-91 than ILC-250
~~200~~ 20 times higher at FCCee-240 than ILC-250

better conditions for TPC, but maybe still not easy?

n.b. this comparison does not consider
the secondary ions created in gas amplification
→ almost certainly worse at circular collider due to “no” gating