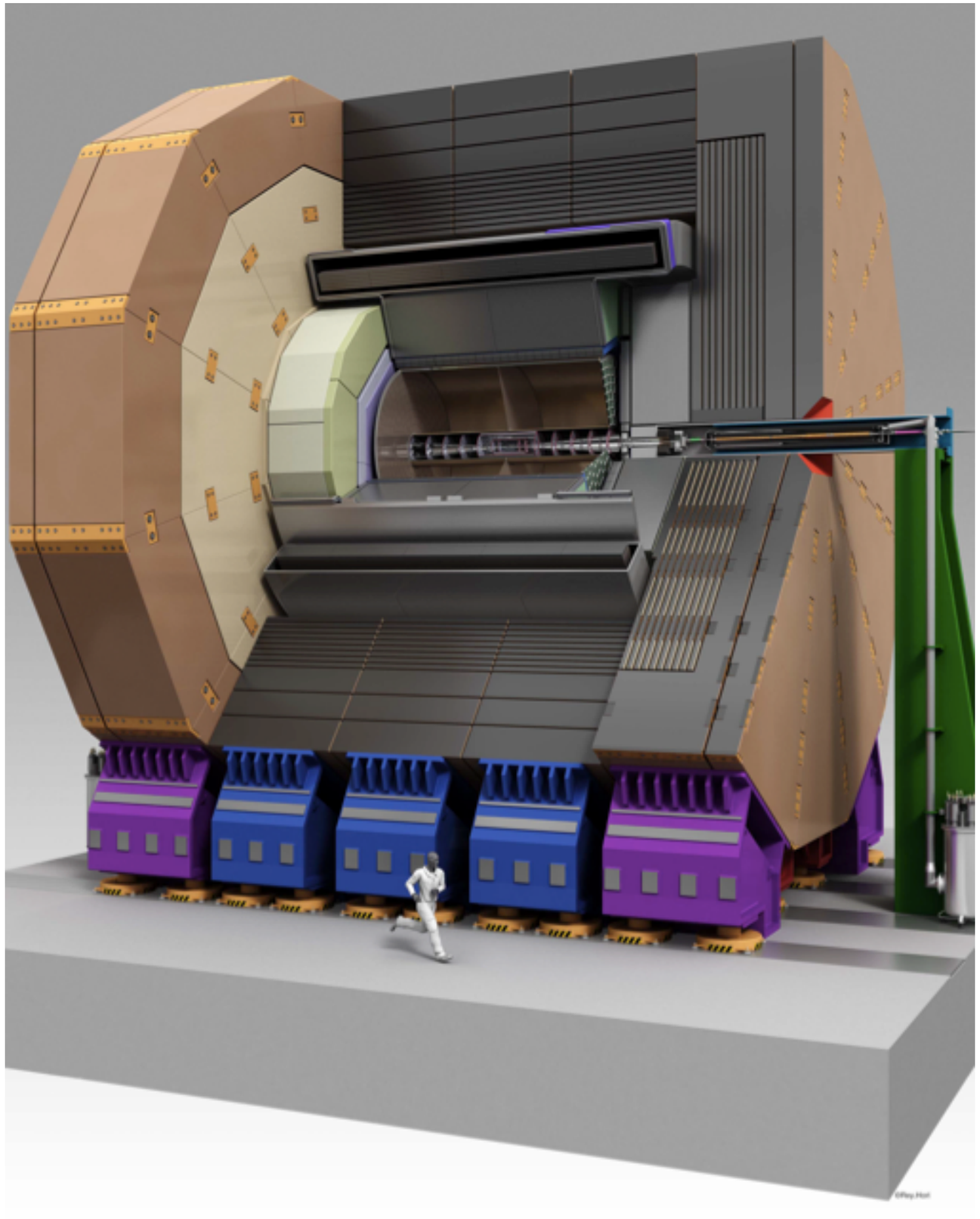
Physics Impact of the AntiDID

J. List (DESY)

ILD Technical Task Forces Meeting
LAL Orsay
November 7, 2016



The key advantages of e+e- colliders [M.Peskin, TDR Vol 2]

- **Cleanliness**
- Democracy
- Calculability
- Detail

The **antiDID** was adopted to maintain **cleanliness** when non-zero crossing angle was introduced

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=> would removal of antiDID endanger one of our key advantages?

Overview of (potential) effects on Physics

- beam polarisation
- pair background
  - forward calorimeters
    - hermeticity
- tracking performance
  - “random hits” => pattern recognition, eff./pur. of track finding
  - real tracks => additional source of background

Beam Polarisation and Crossing Angle & antiDID

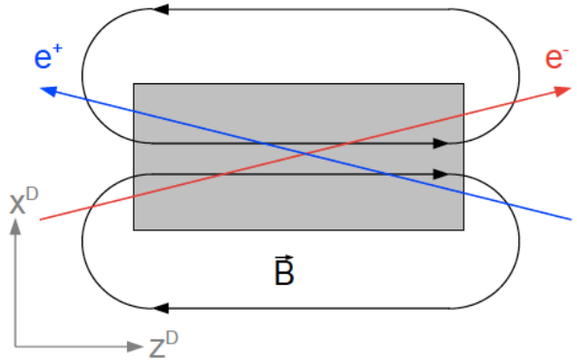
incoming beams not parallel to solenoid field:

- spin precession - longitudinal polarisation changes:
  only solenoid: 0.05%
  with antiDID: 0.6%

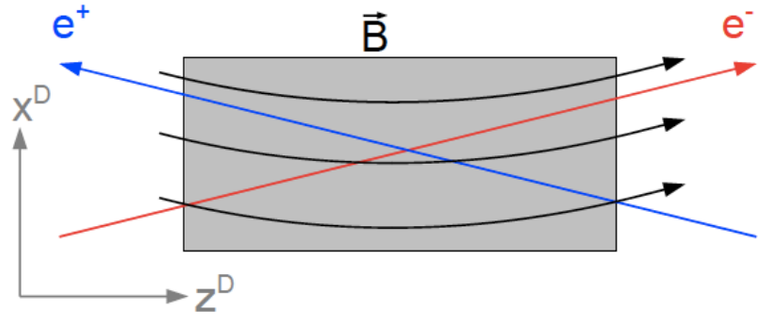
- *vertical* “kick” on beam
  => σ(y) at IP increases by factor 3-4
  (only solenoid, 50 with antiDID)
  => “anti-solenoids” required

Anti-solenoids will eliminate spin precession at the same time!

(Alternative: skew quadrupoles - would be bad for polarisation!)

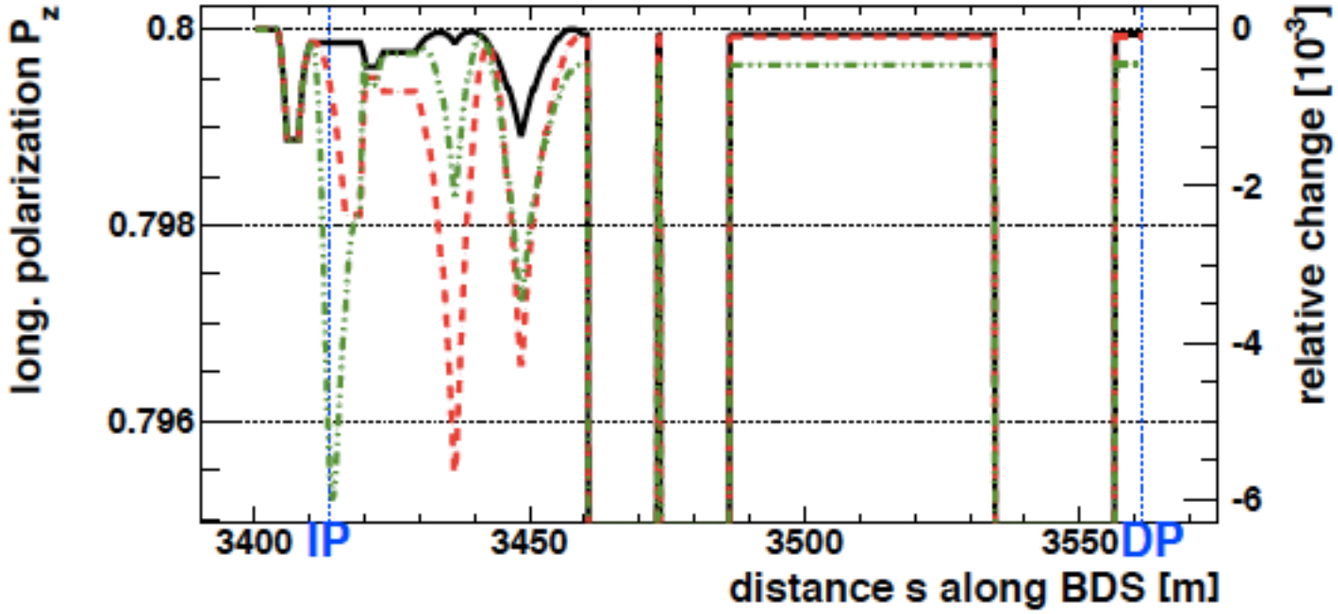


only solenoid



with antiDID

[PhD Thesis M.Beckmann, Hamburg 2013]



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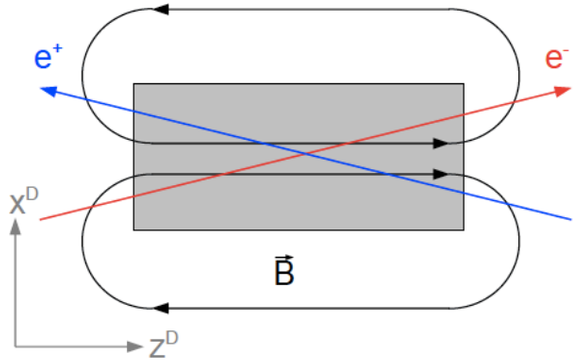

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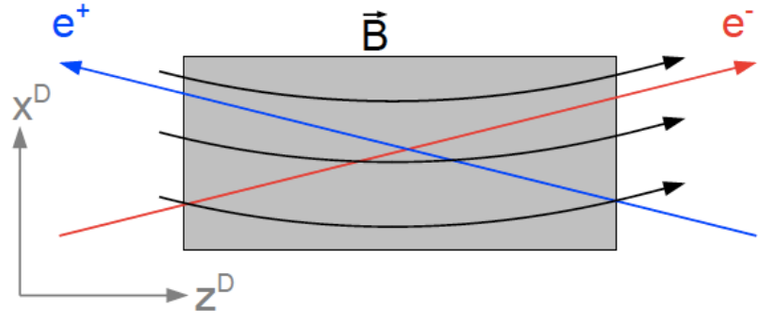

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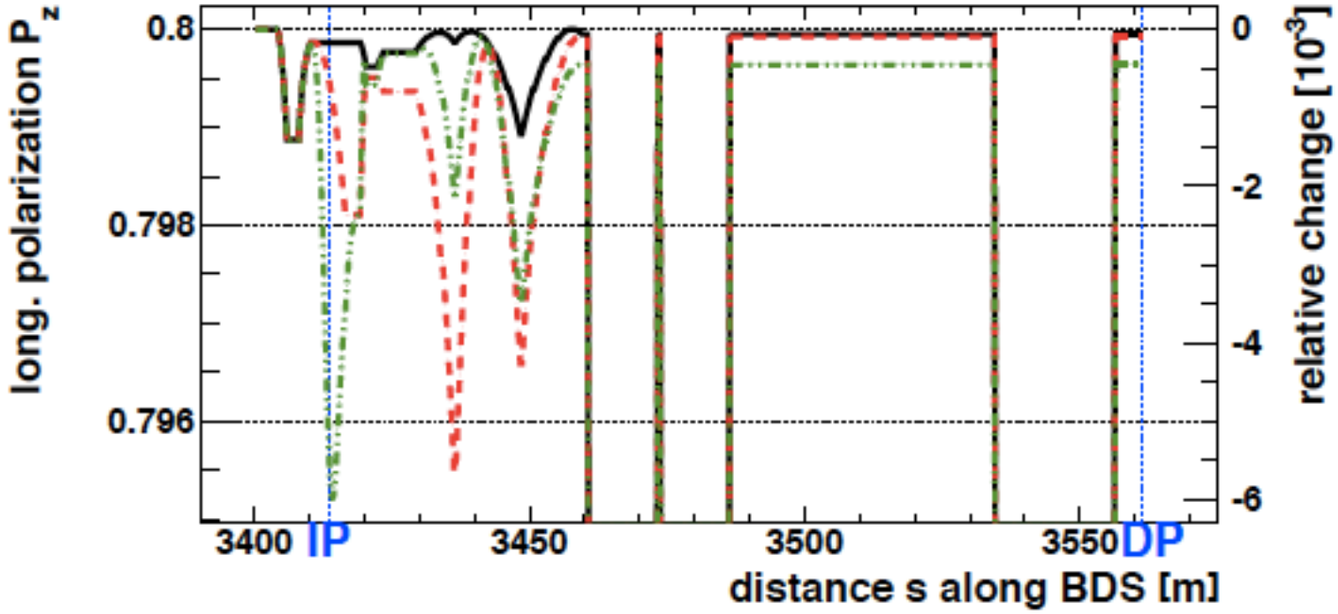


If luminosity is maintained via anti-solenoids, then polarisation is fine as well!

Pair Background and AntiDID

Effect of magnetic field:

- high-energetic particles slightly curve around B field, but keep polar angle given by their momentum
- low-energetic particles curl up tighly and “follow” the B field lines

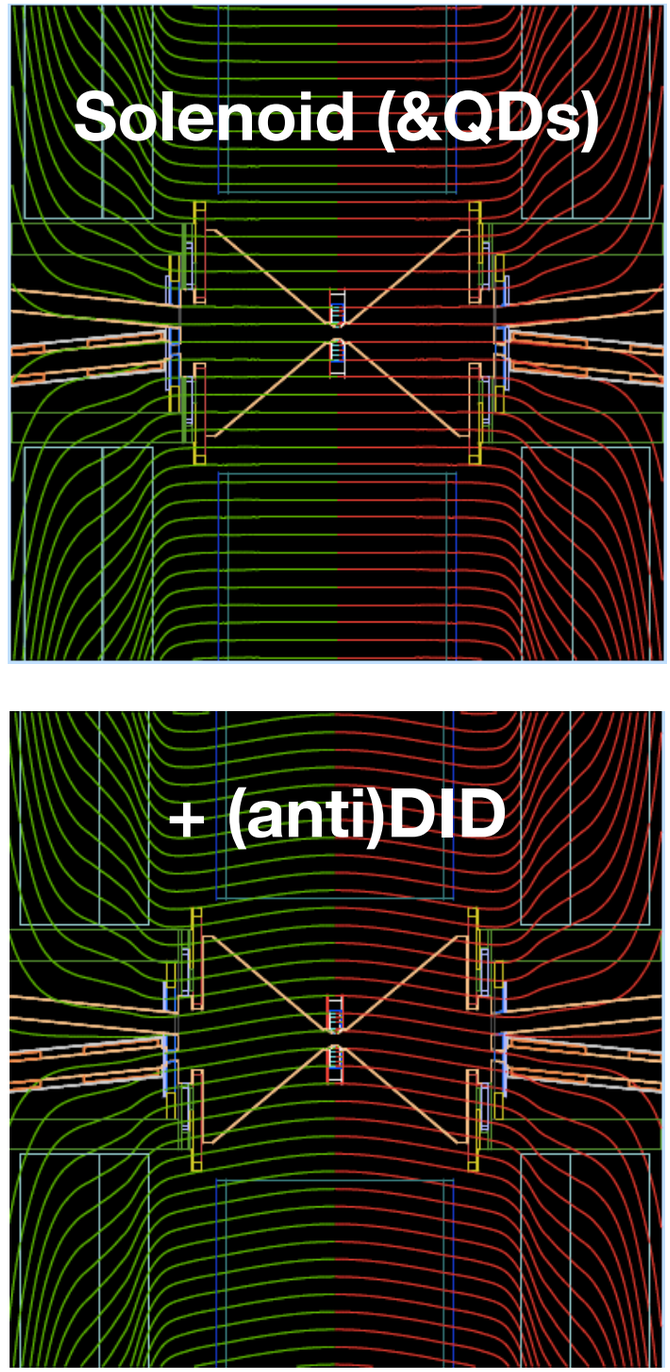
Pair background:

- huge amount of low-energetic particles
- very few with higher energy

Impact of antiDID:

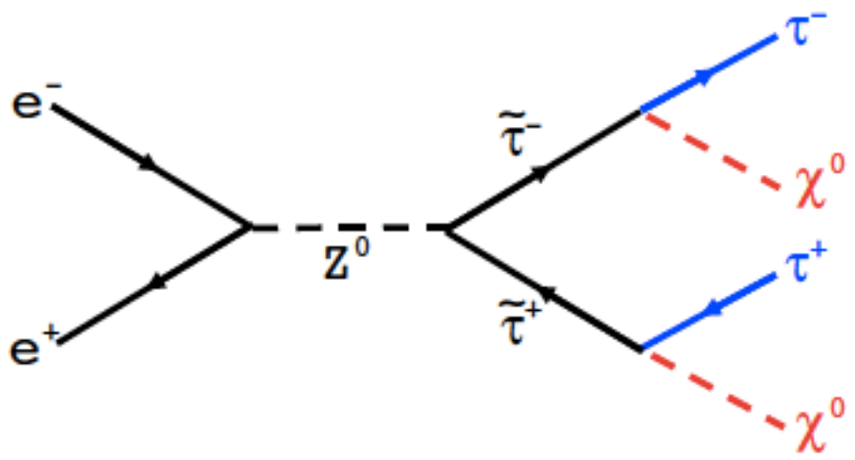
- guide majority of pairs into outgoing beampipe
- guide backscatter to back IP inside the beampipe - instead of straight into VTX!

conceptual pictures!

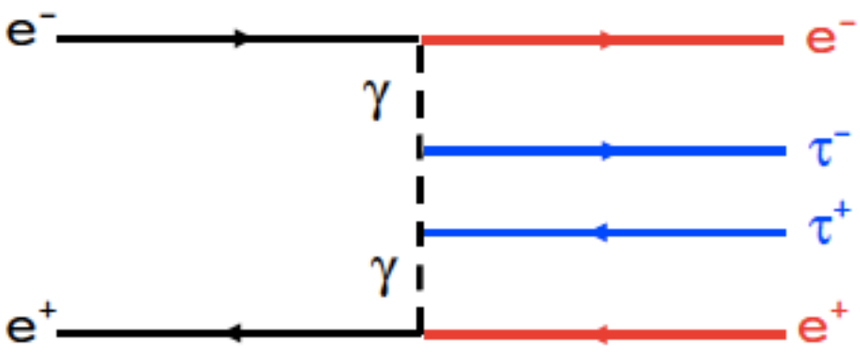


Physics with missing four-momentum

low delta-M SUSY: e.g. stau's



The Physics:
stau pair production
Signature:
$\tau^+ \tau^-$ + missing energy



The Background:
two-photon events
Signature:
$\tau^+ \tau^-$ + missing energy
(if electrons are not tagged)

i.e. mimic SUSY event

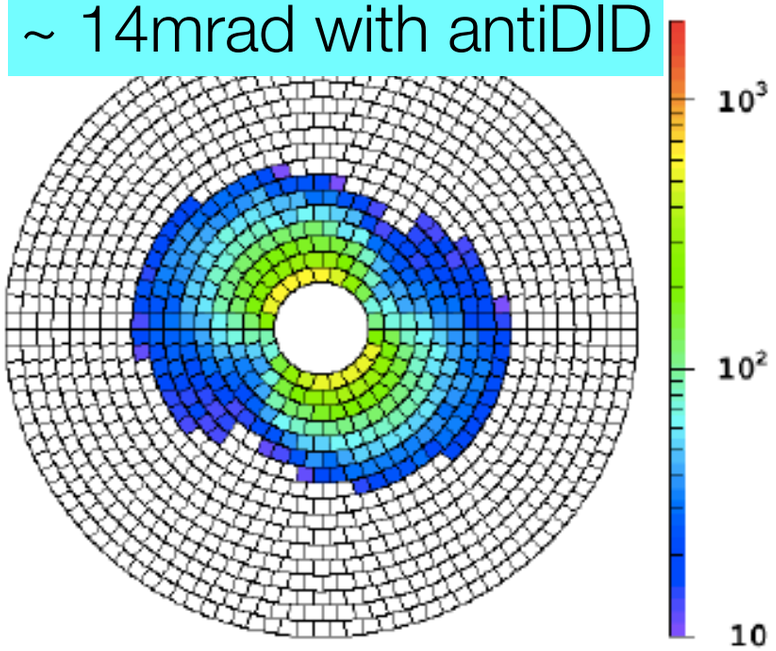
strategy:
- e^+e^- in BP: cut on $\tau\tau$ acoplanarity
- e hits BeamCal: electron veto is vital

[V. Drugakov, ECFA LC2005]

Pair background & BeamCal (2005, RDR nominal)

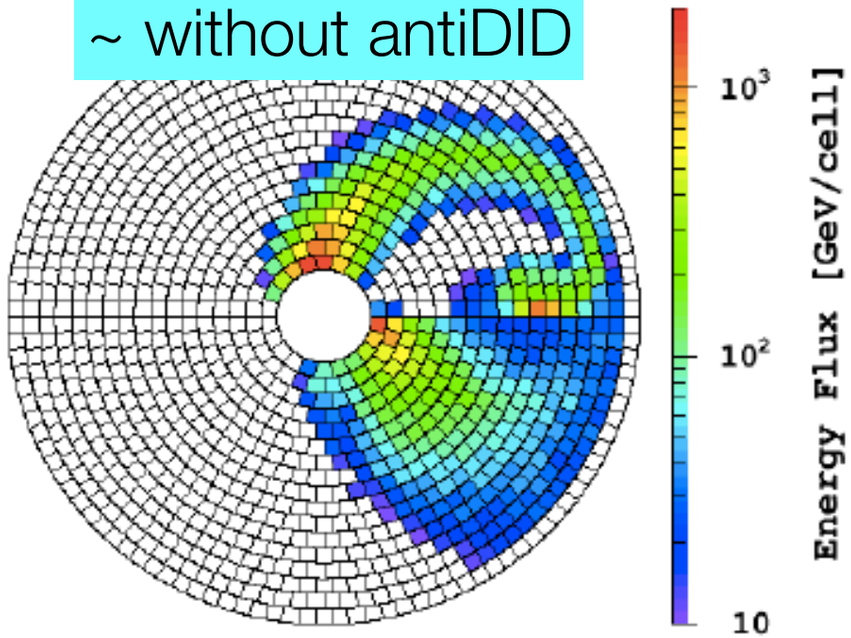
head-on

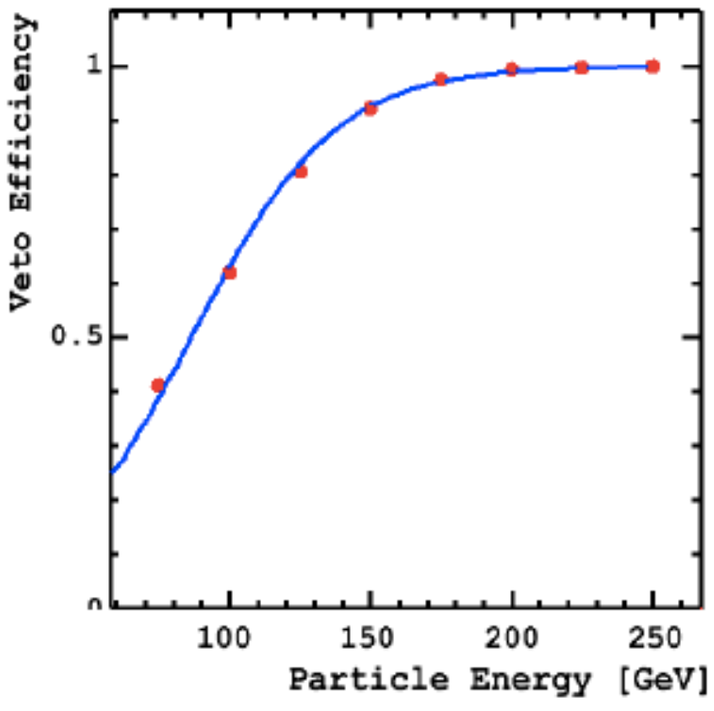
~ 14mrad with antiDID

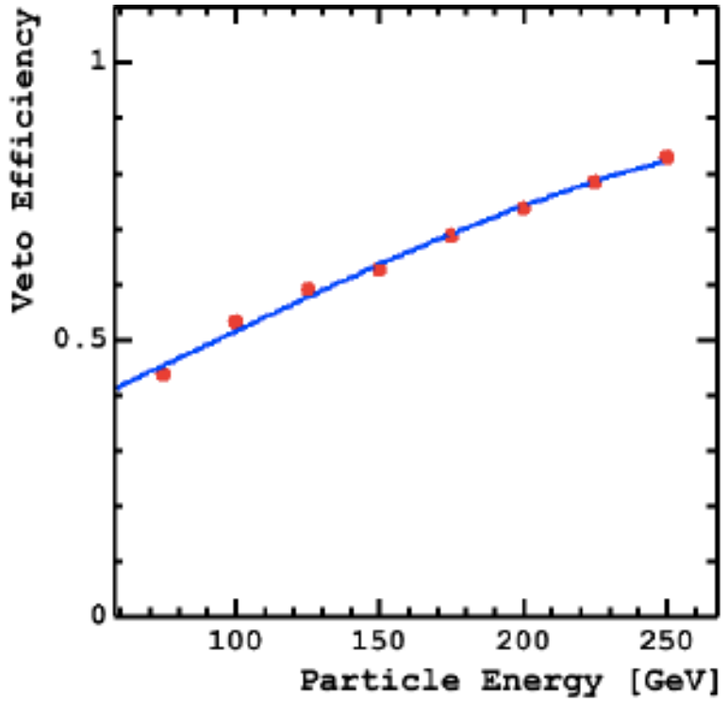


X-angle

~ without antiDID







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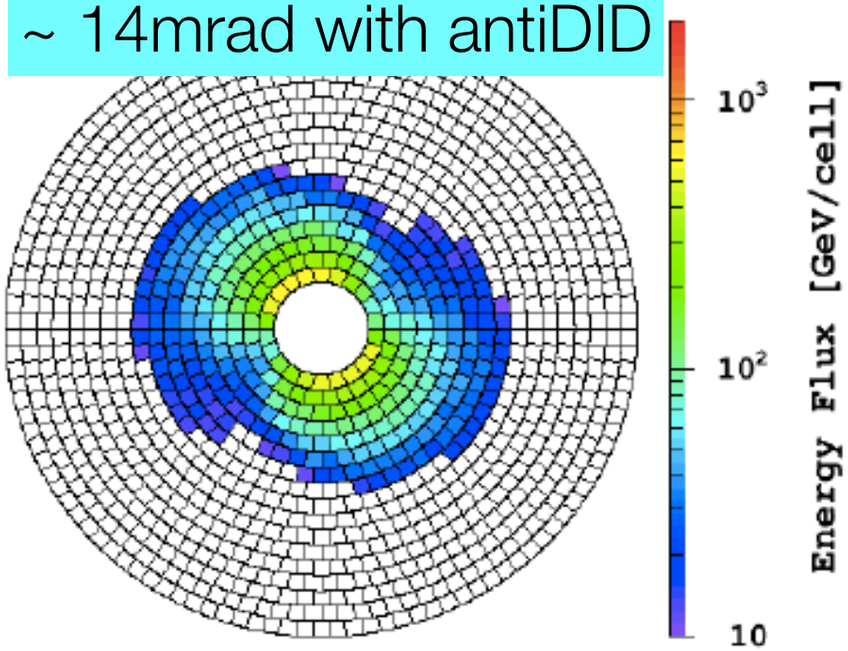

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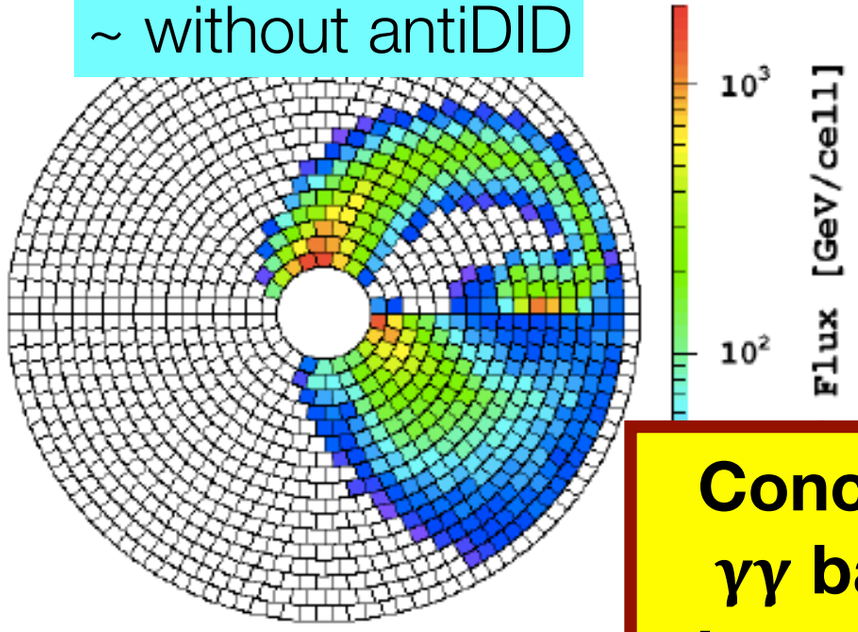
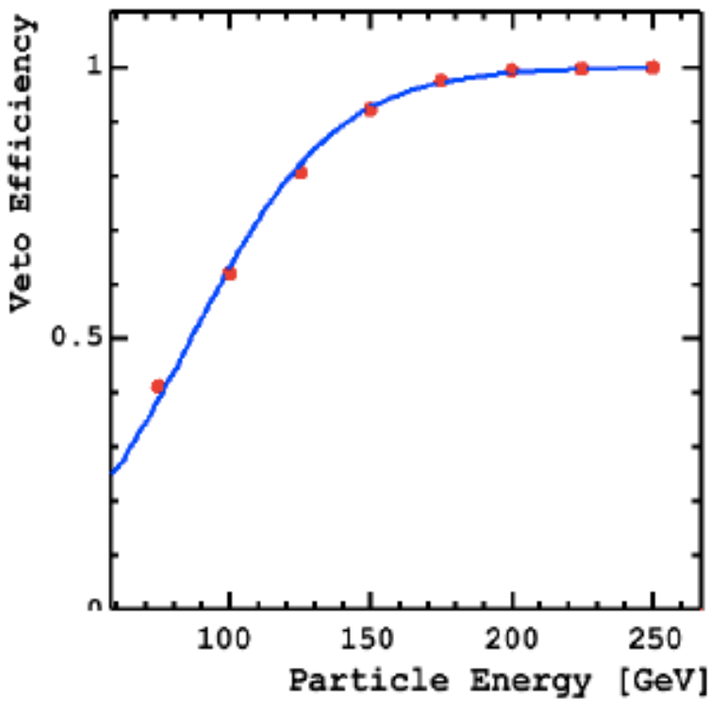
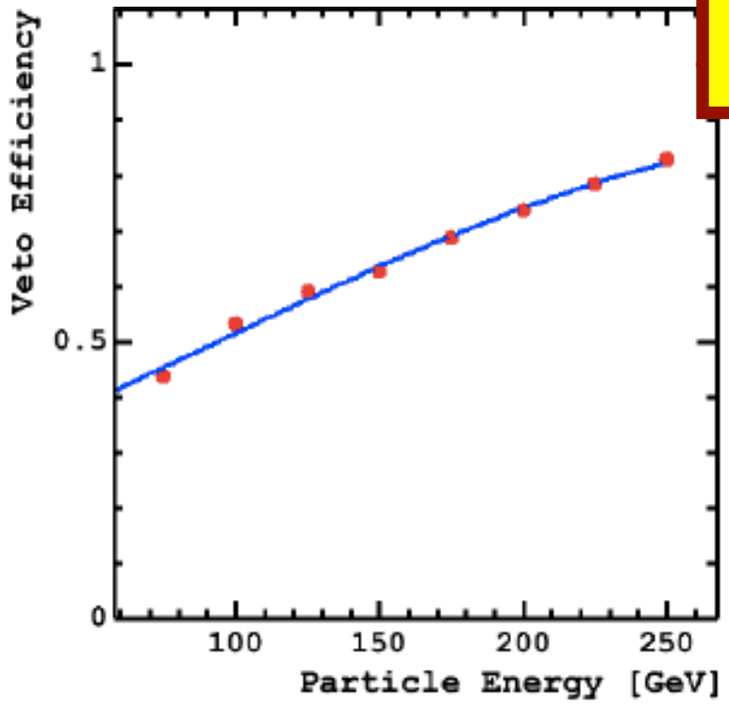


Conclusion in 2005: γγ background for stau search increases by factor ~ 8.5





… and from a stau study in 2004

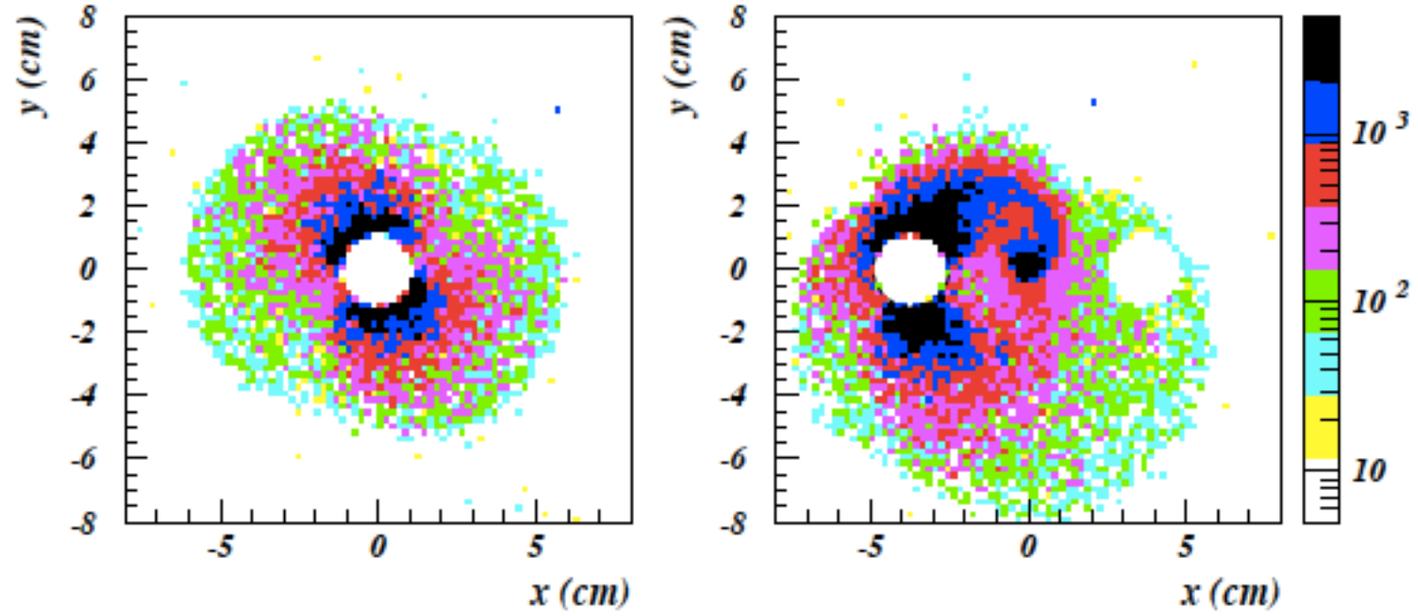
[Berggren et al hep-ph/0406010]

head-on

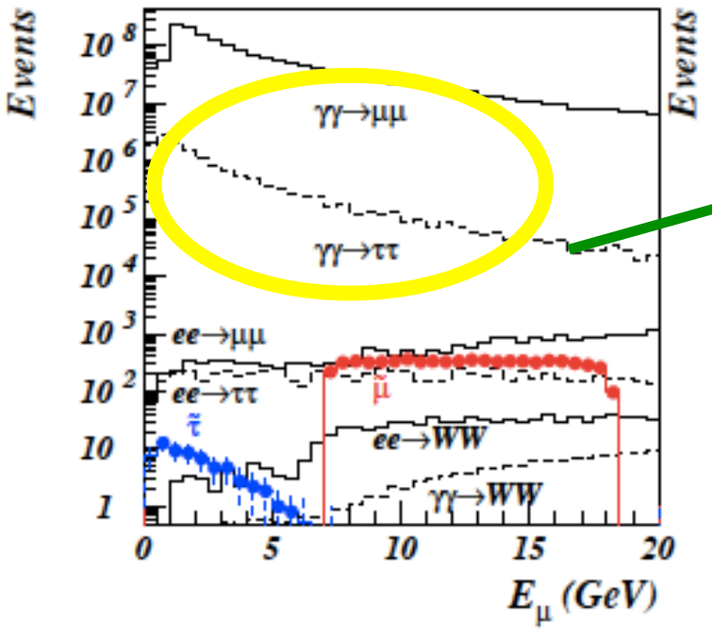
~ 14mrad with antiDID

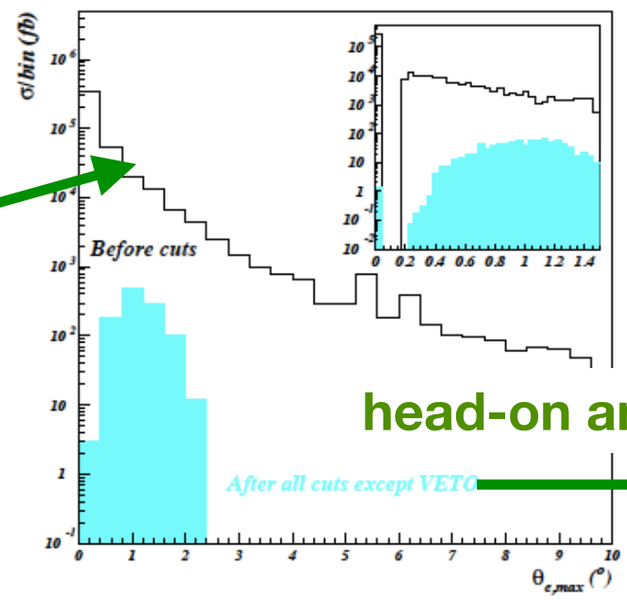
20mrad

~ without antiDID

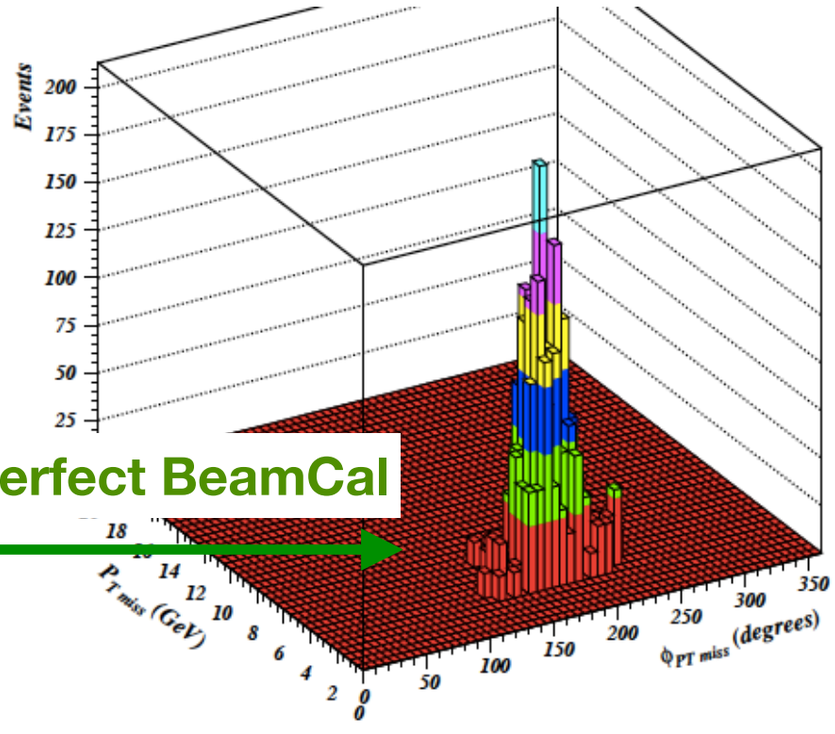


- crossing-angle without antiDID: larger blind area in BeamCal
- $\gamma\gamma$ background 7-8 orders of magnitude above signal
- part of phase space can only be identified by BeamCal veto



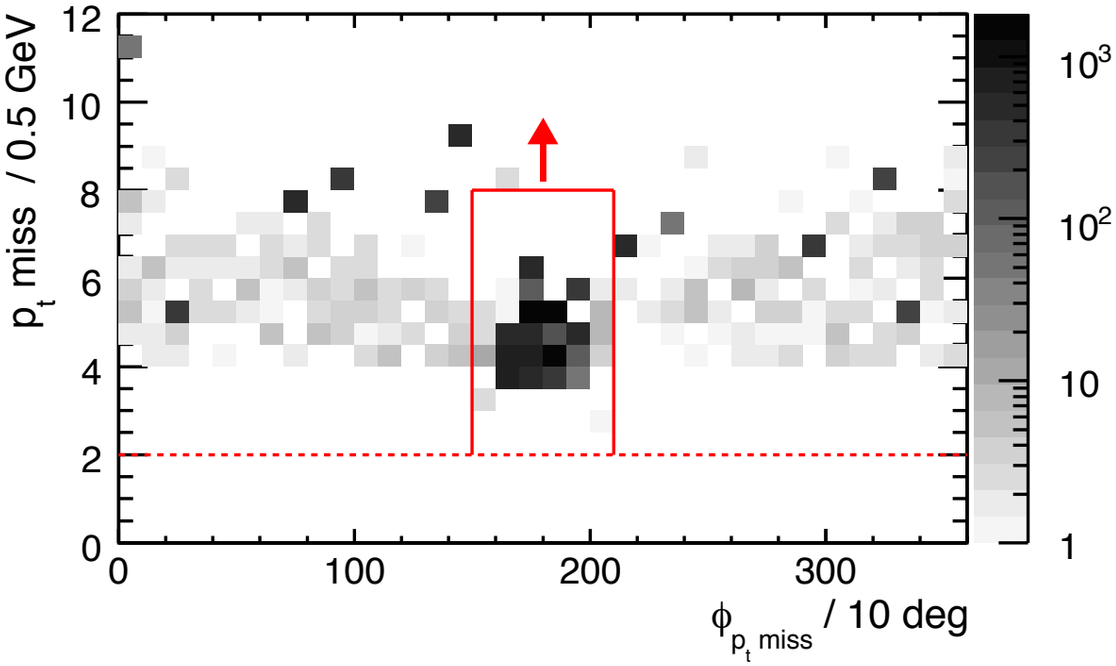


head-on and perfect BeamCal

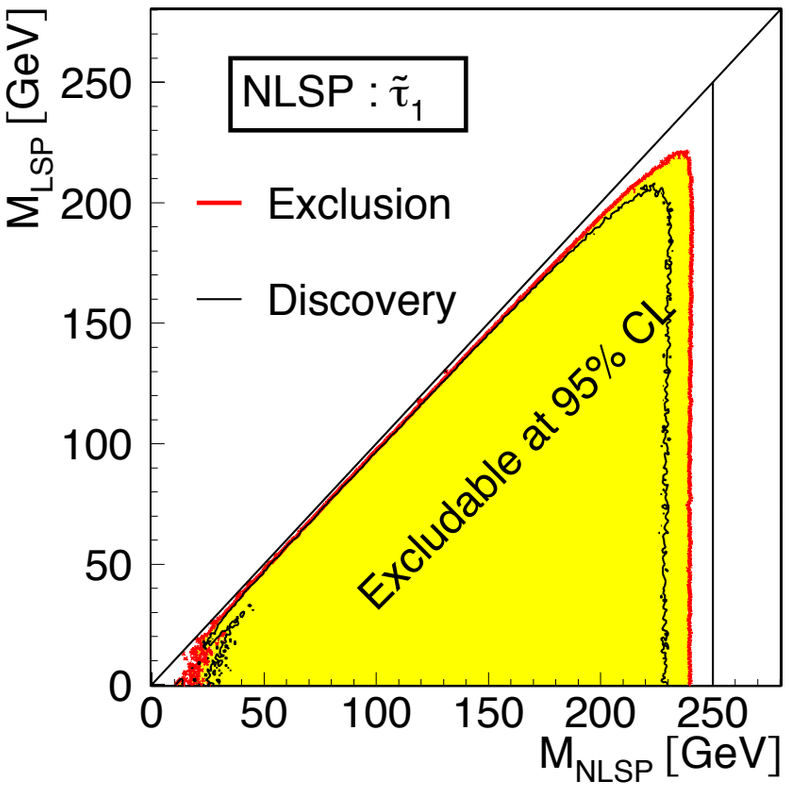


… and with ILD 2009

[Bechtle et al Phys.Rev. D82 (2010) 055016, Berggren 1308.1461]



- with parametrised BeamCal response from full sim with pair background (14mrad, antiDID)
- gamma-gamma bkg: fake missing pt if beam electron goes down the incoming beam pipe - **or not visible above pair background!**



- "grey band" similar to what SiD calls "plug region"
- more background => grey band turns black => can't use this kinematic region
- loose low-delta-M region (at diagonal) **=> loose complementarity with LHC**

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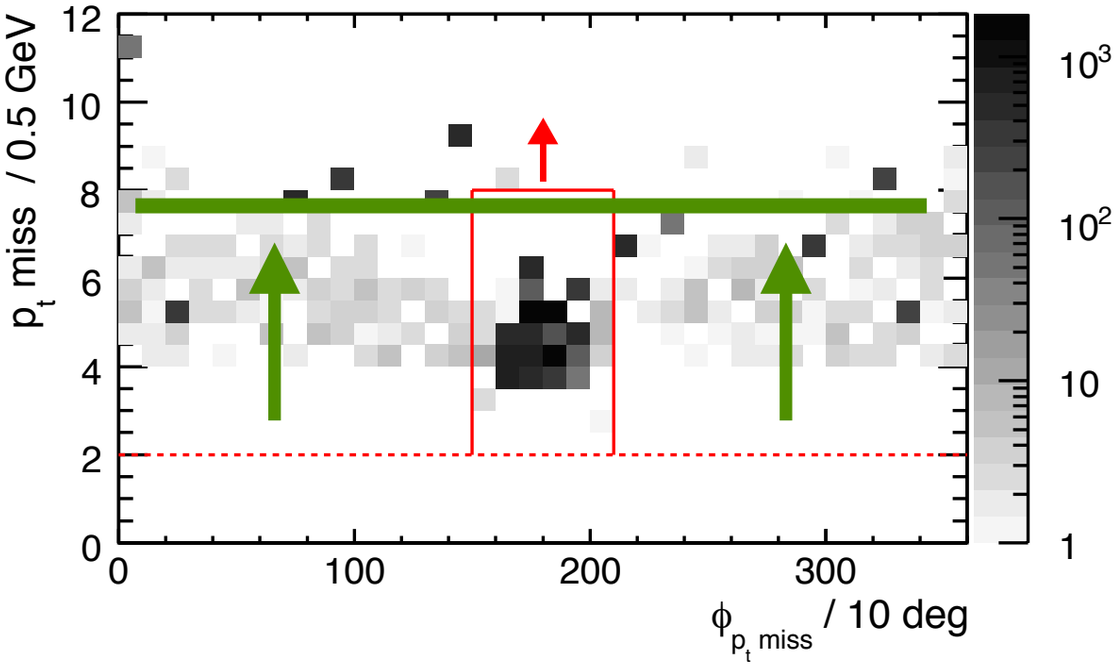

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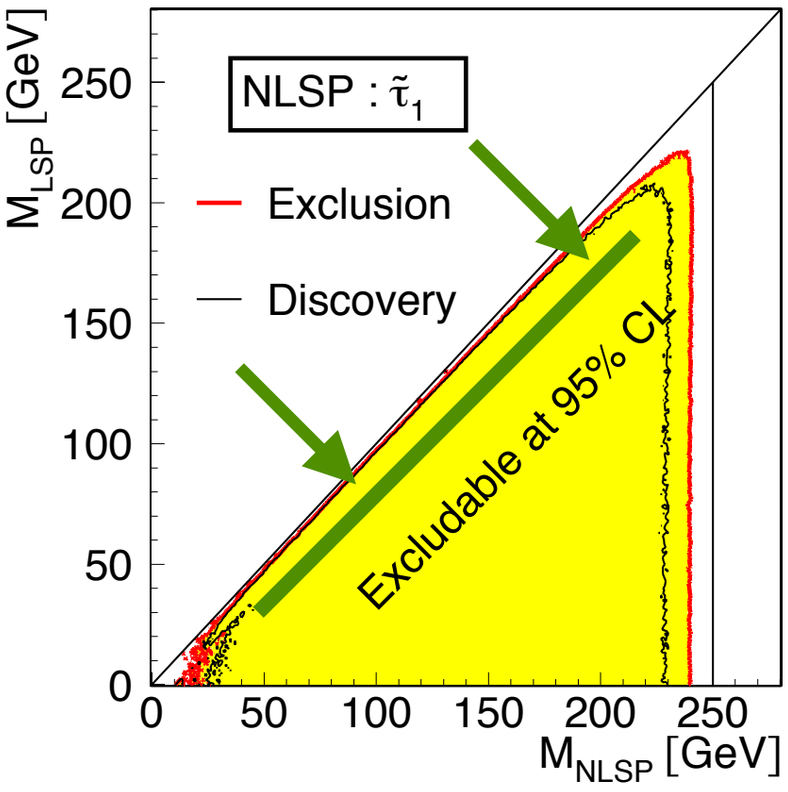

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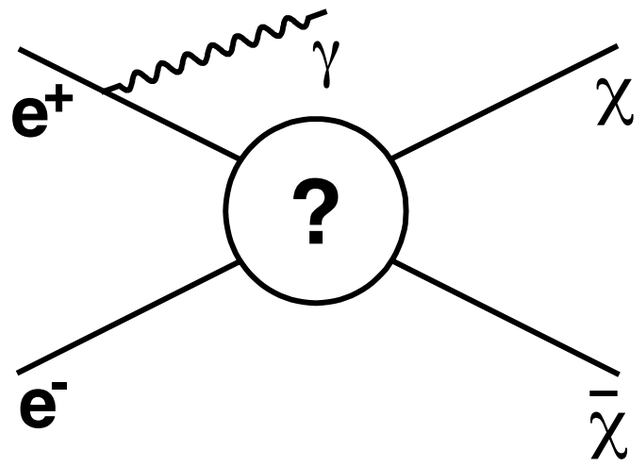
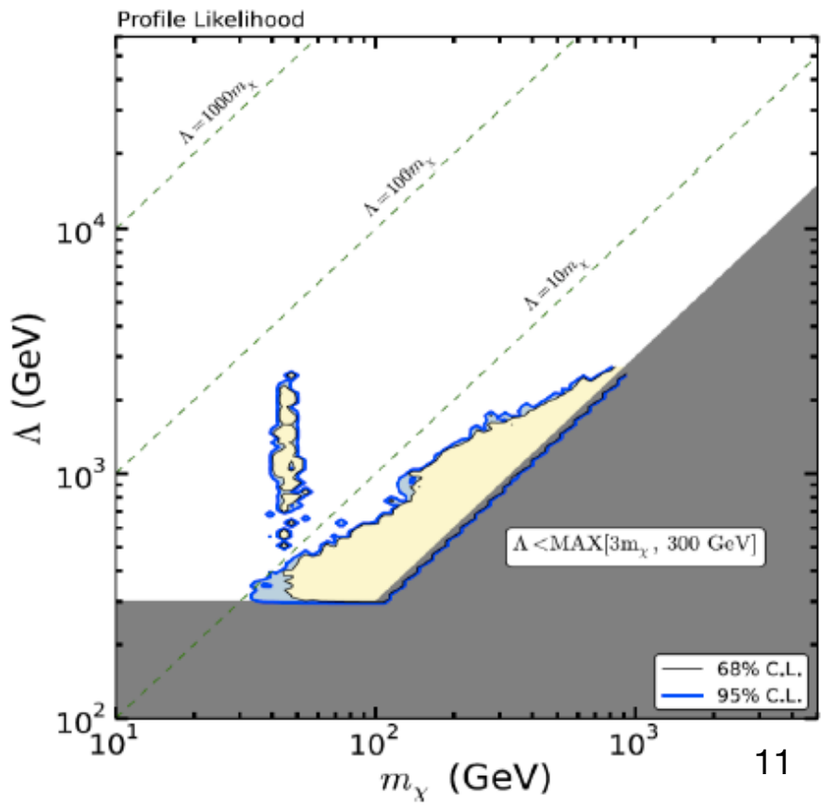
WIMP Dark Matter

- model-independent dark matter searches using mono-photon signature
- complementary to LHC, direct detection, indirect detection [arxiv:1604.02230]
- backgrounds:
  - $\nu\nu$ +(n)γ: reduced by 1/100 with P=(+80%,-30%)
  - rad. Bhabhas: crucially depends on hermeticity





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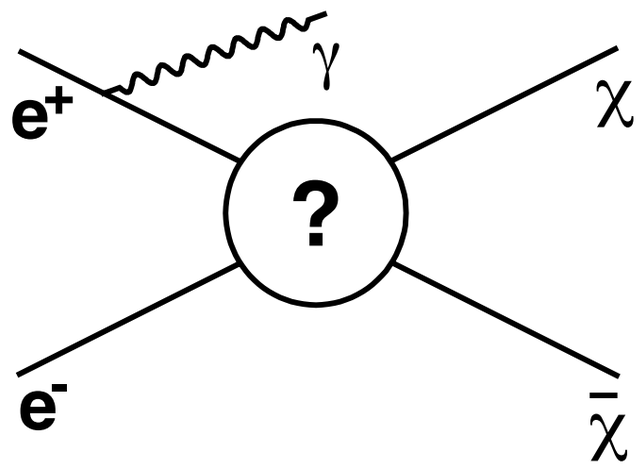

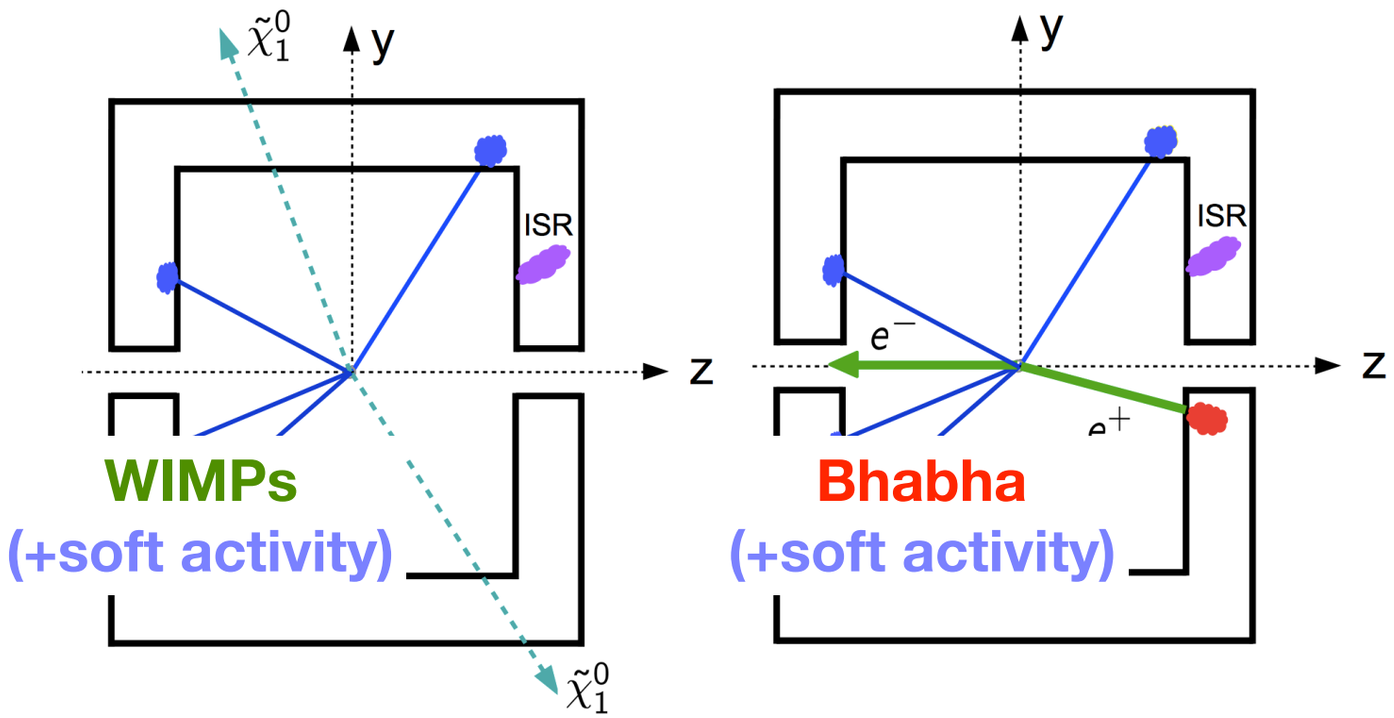

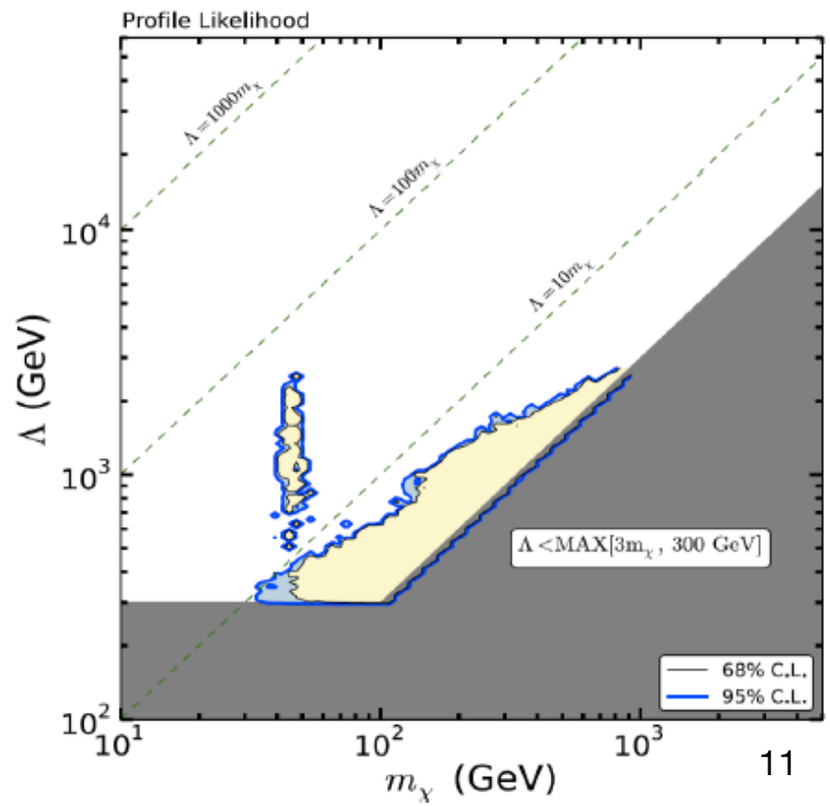

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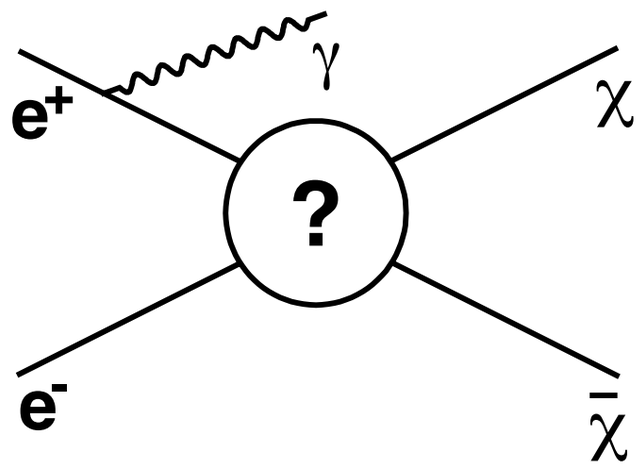
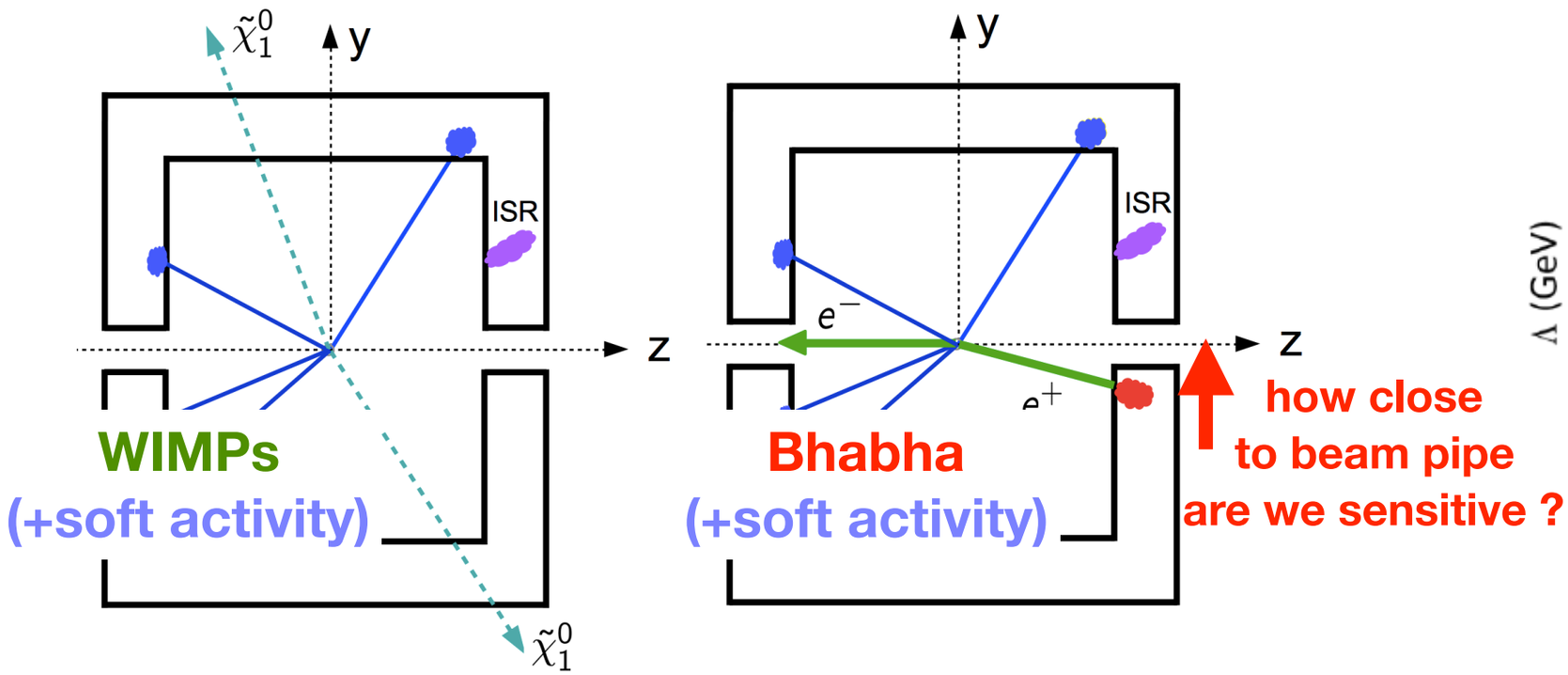
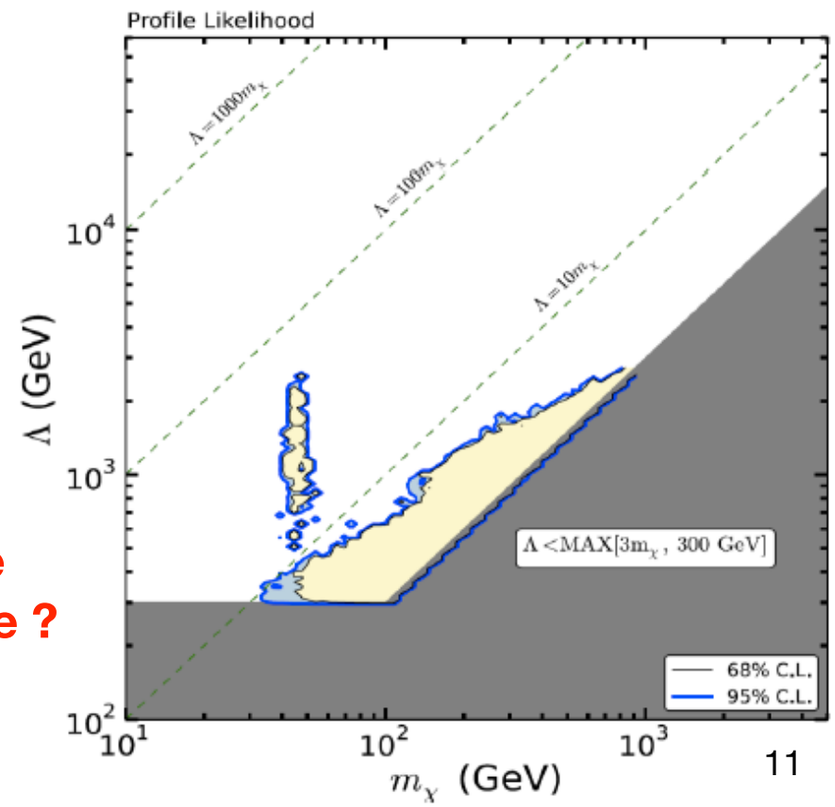
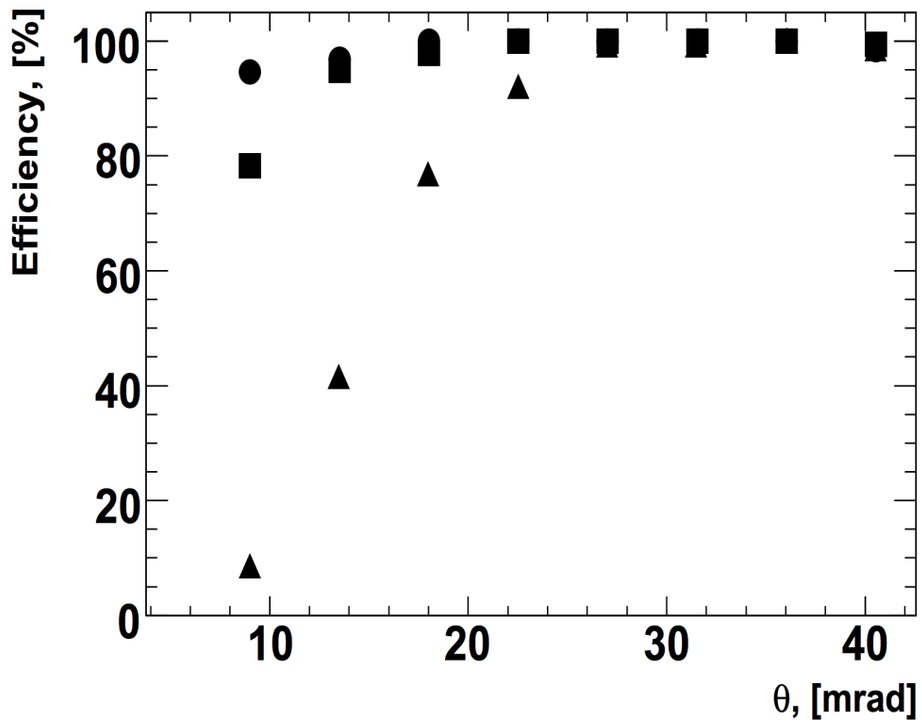


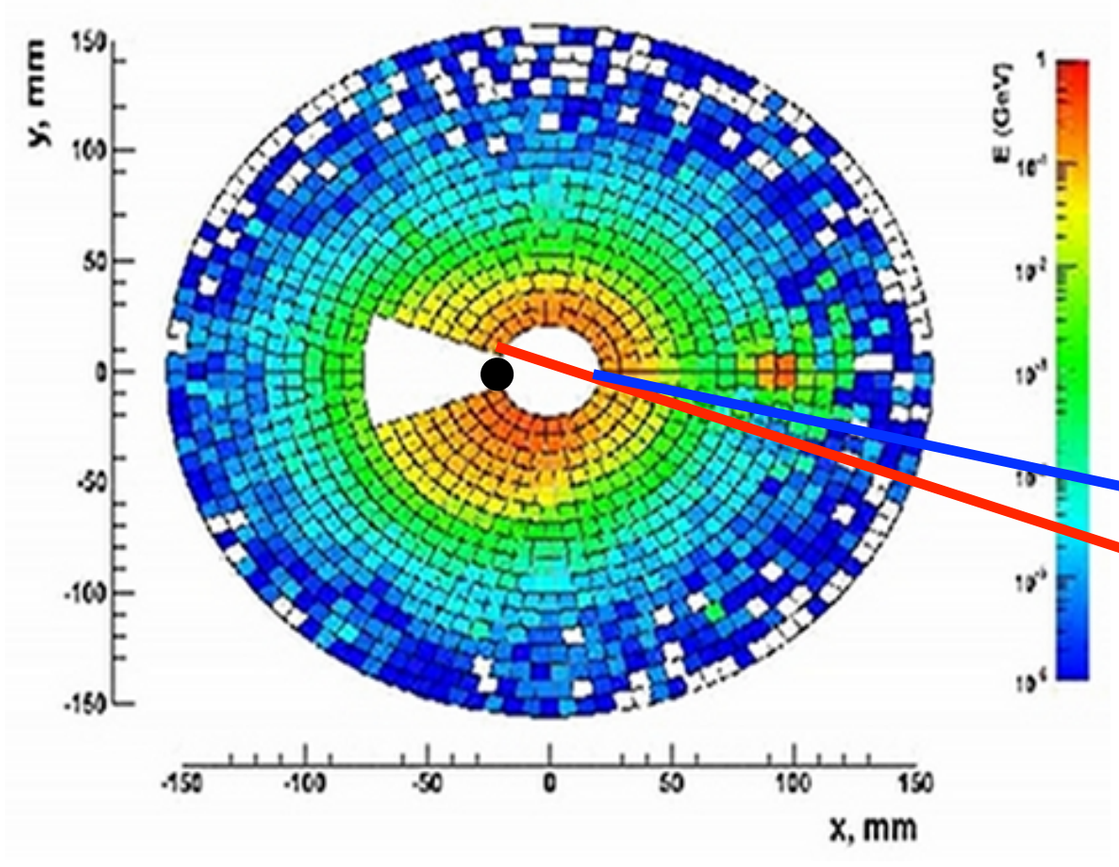


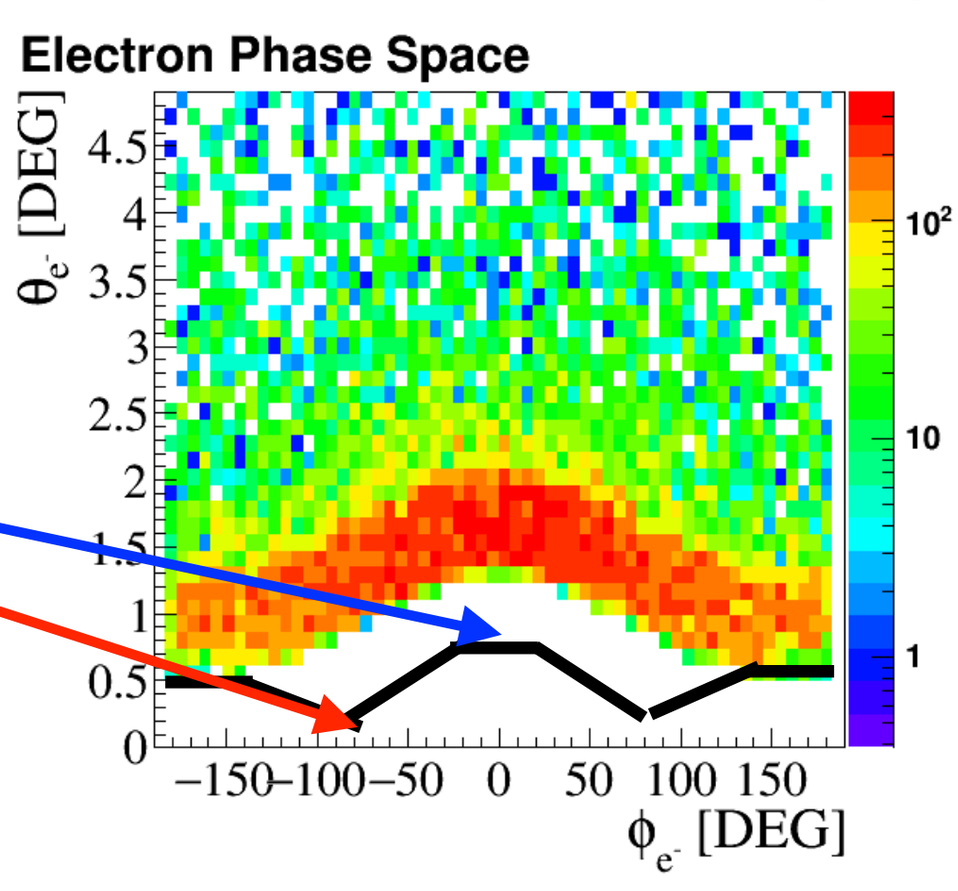


Bhabha veto in BeamCal

- ILD DBD efficiency for detecting single high-energy electrons in BeamCal (particle gun, E=75,150,250GeV)
- effect on Bhabha's?
  => Full energy and angular spectrum!

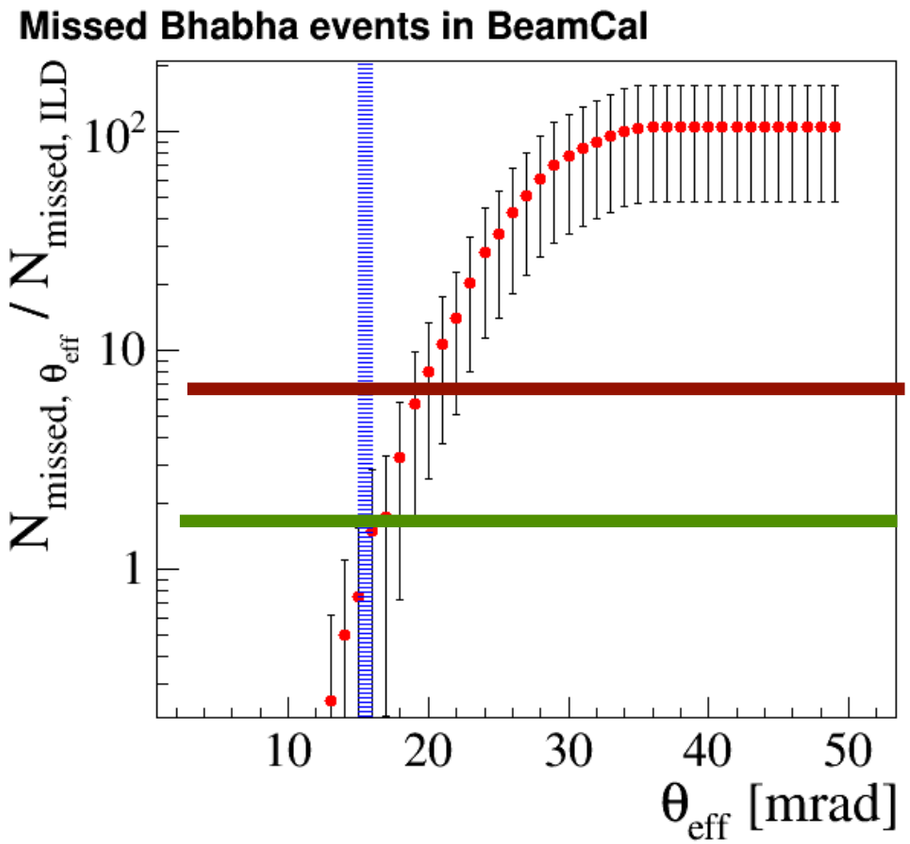






Effect on WIMPs?

- no full sim of new forward region yet
  => look at "effective" θ_{eff}: assume 100% efficiency above and 0% below that angle, such that Bhabha background is the same in DBD configuration
- study effect of varying θ_{eff}
- preliminary estimate of impact (old MC):
  several 100 GeV



BeamCal 40cm further in

current ILD

both with antiDID!

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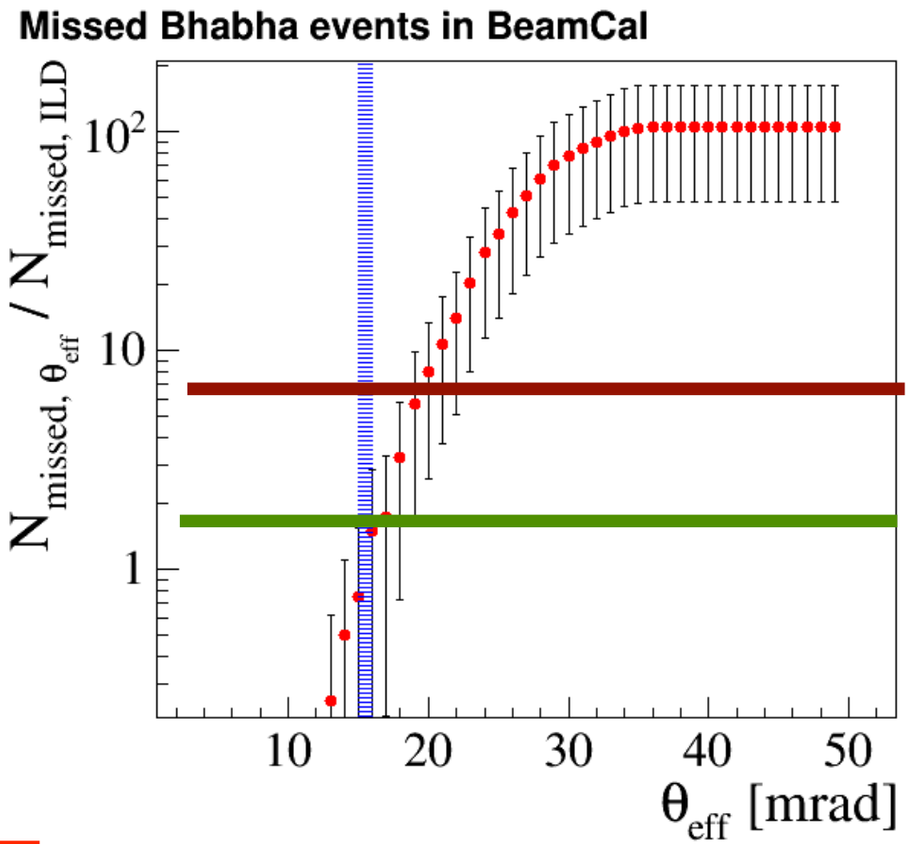

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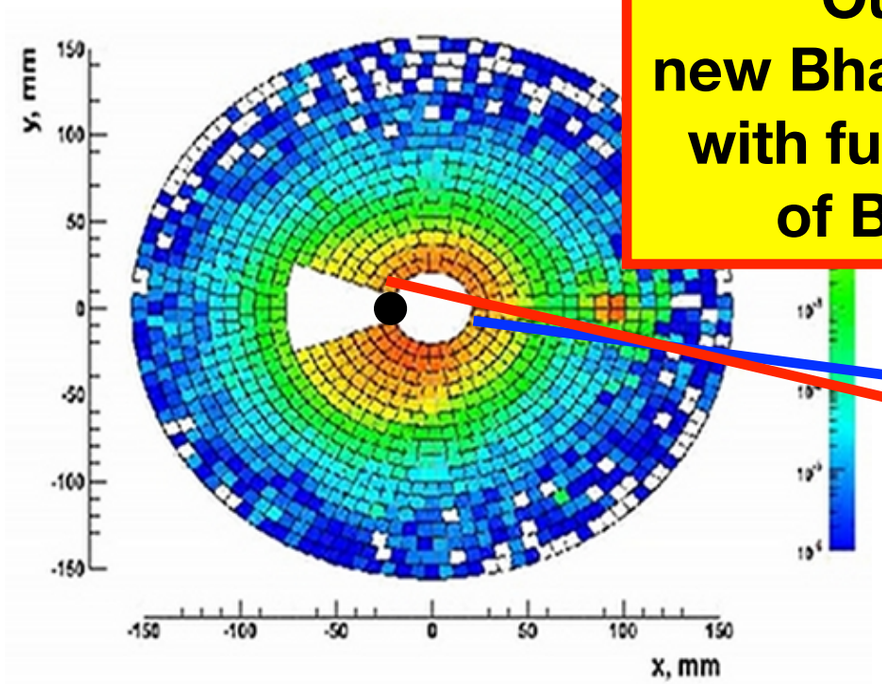
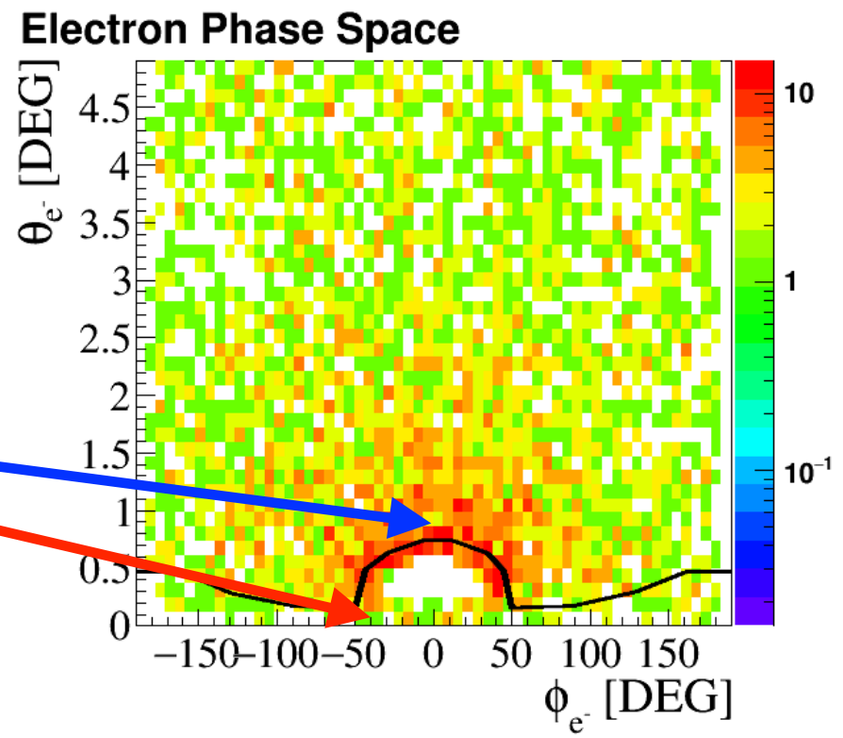
Outlook:
new Bhabha sample with full coverage of BeamCal

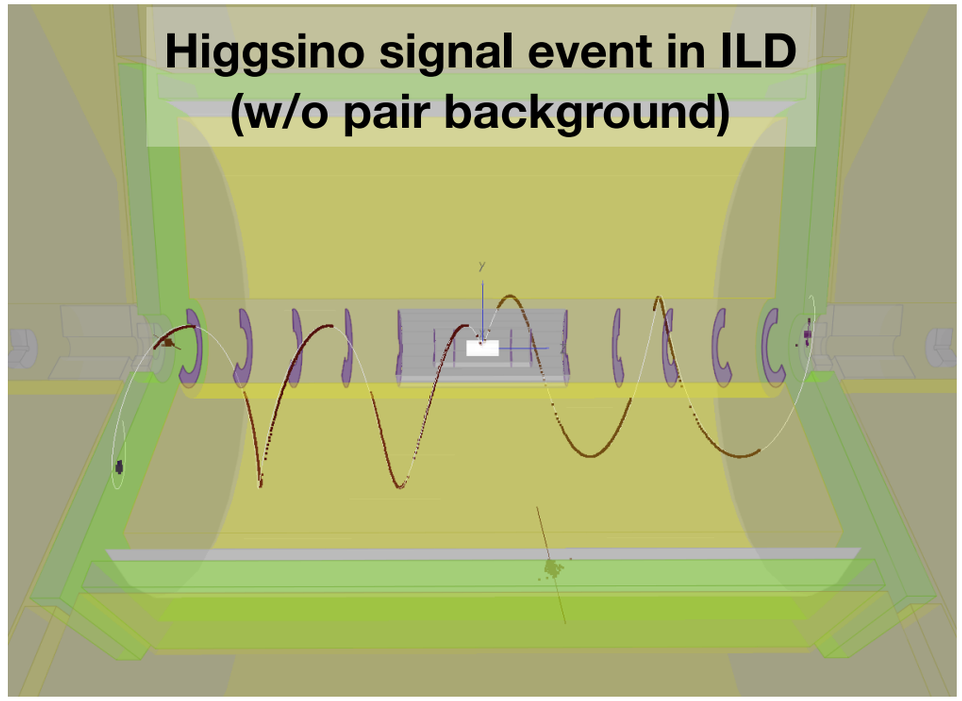


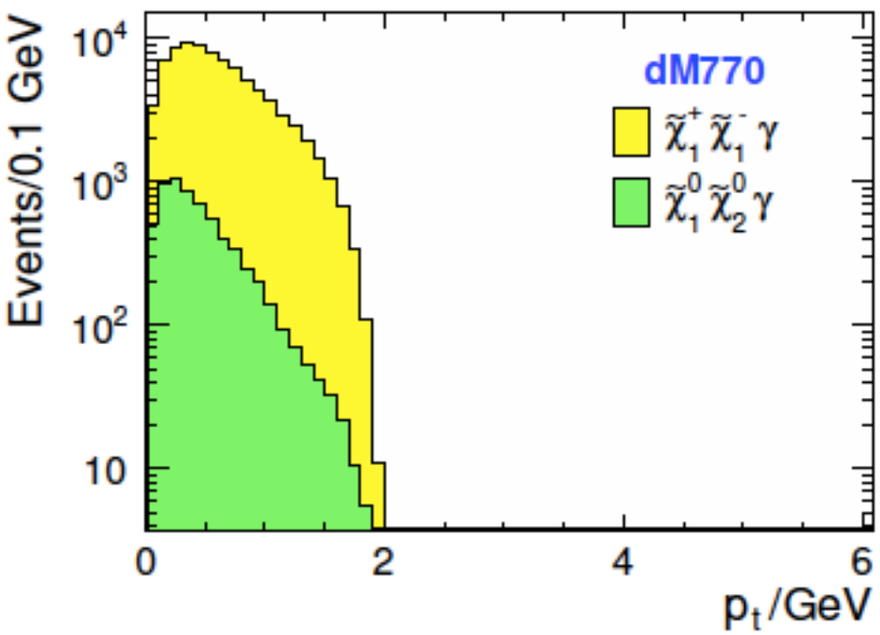


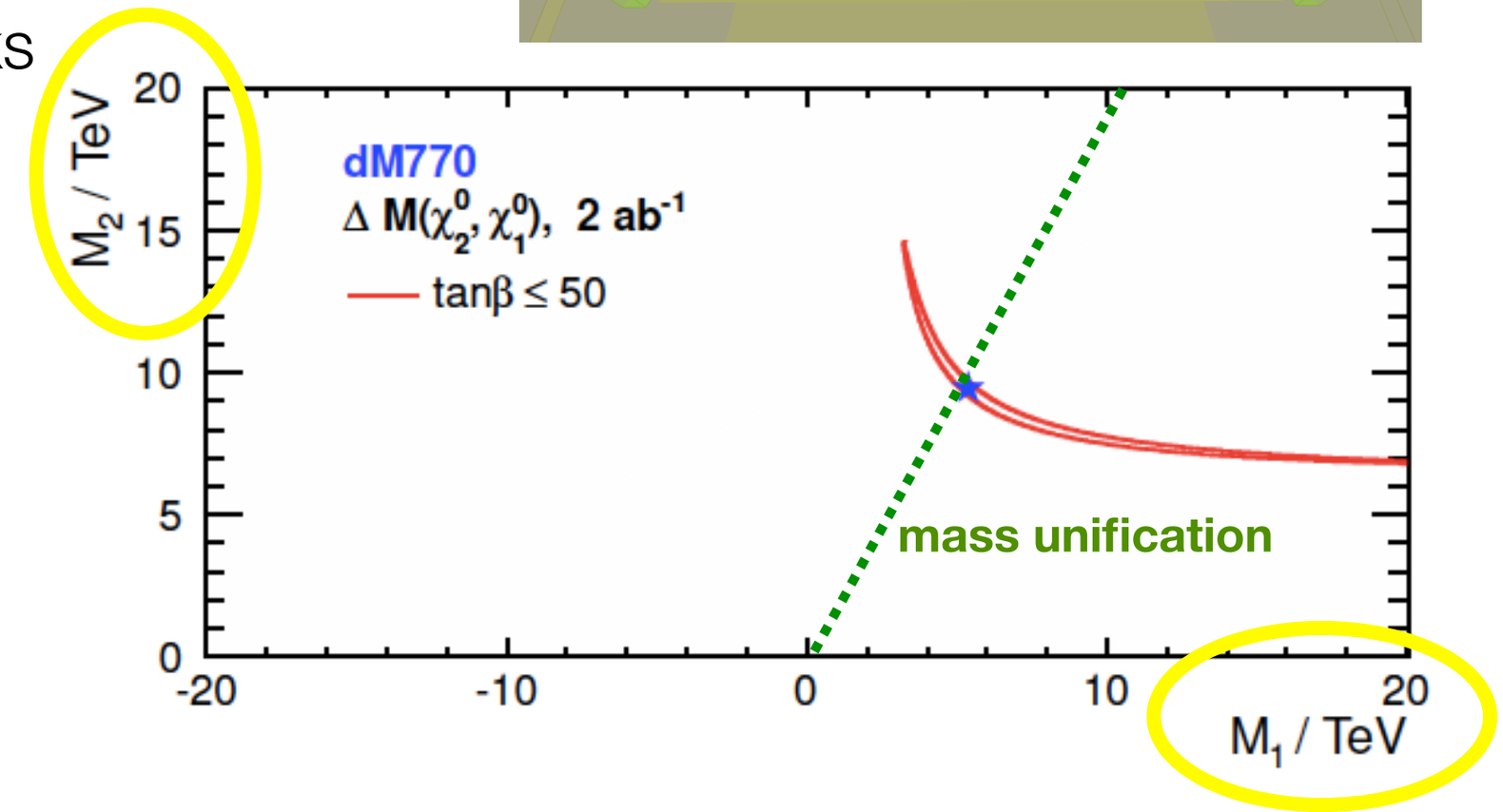
Physics with low-pt tracks

Near-degenerate New Particles (e.g. Higgsinos)

- "blind spot" of LHC
  => ILC direct discovery potential
- ILC precision spectroscopy allows determination of gaugino masses even if in multi-TeV regime
- visible part of event:
  - very few, very soft tracks







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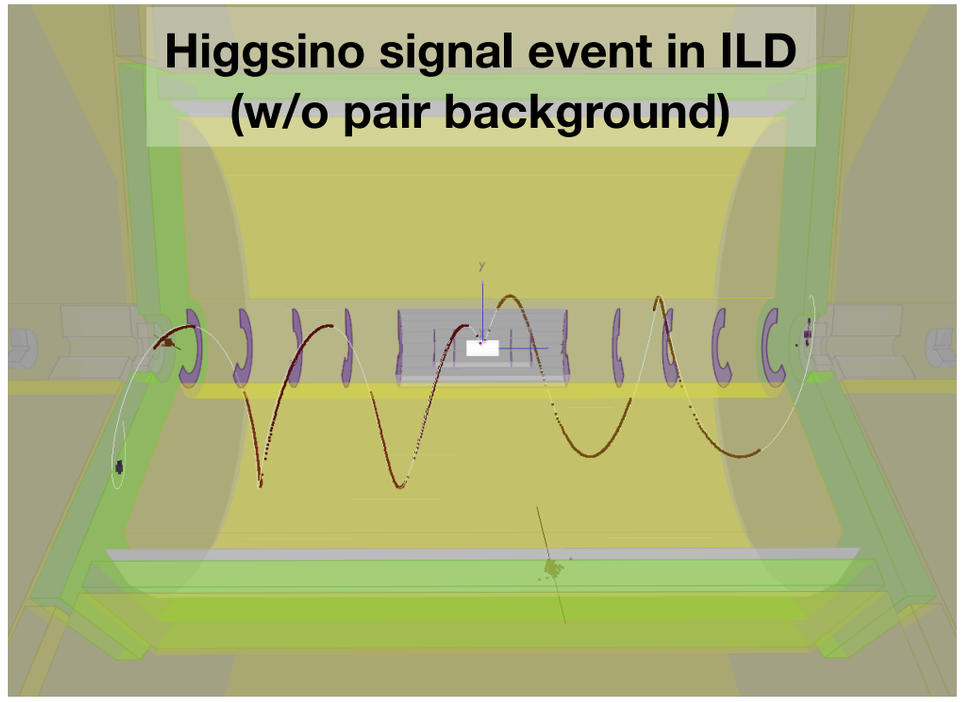
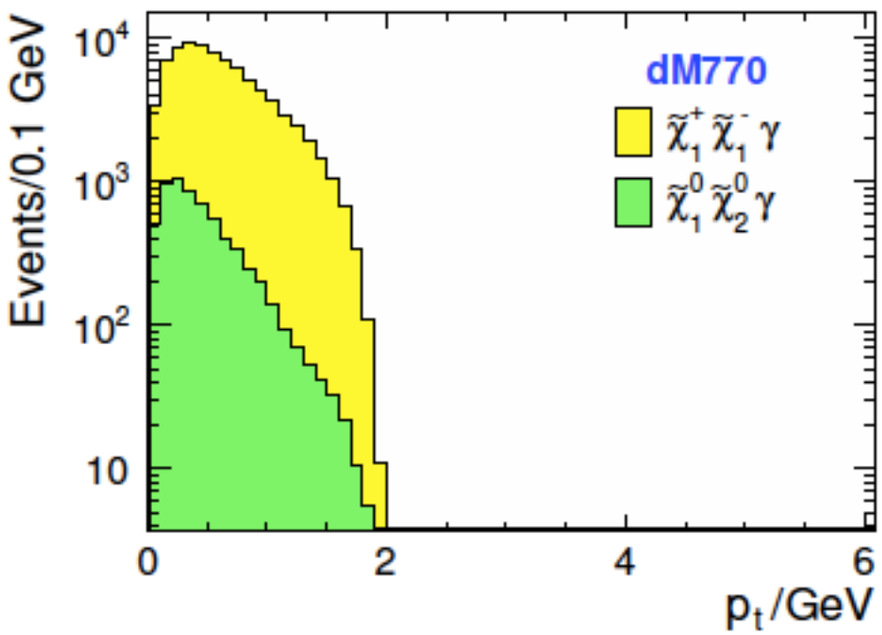
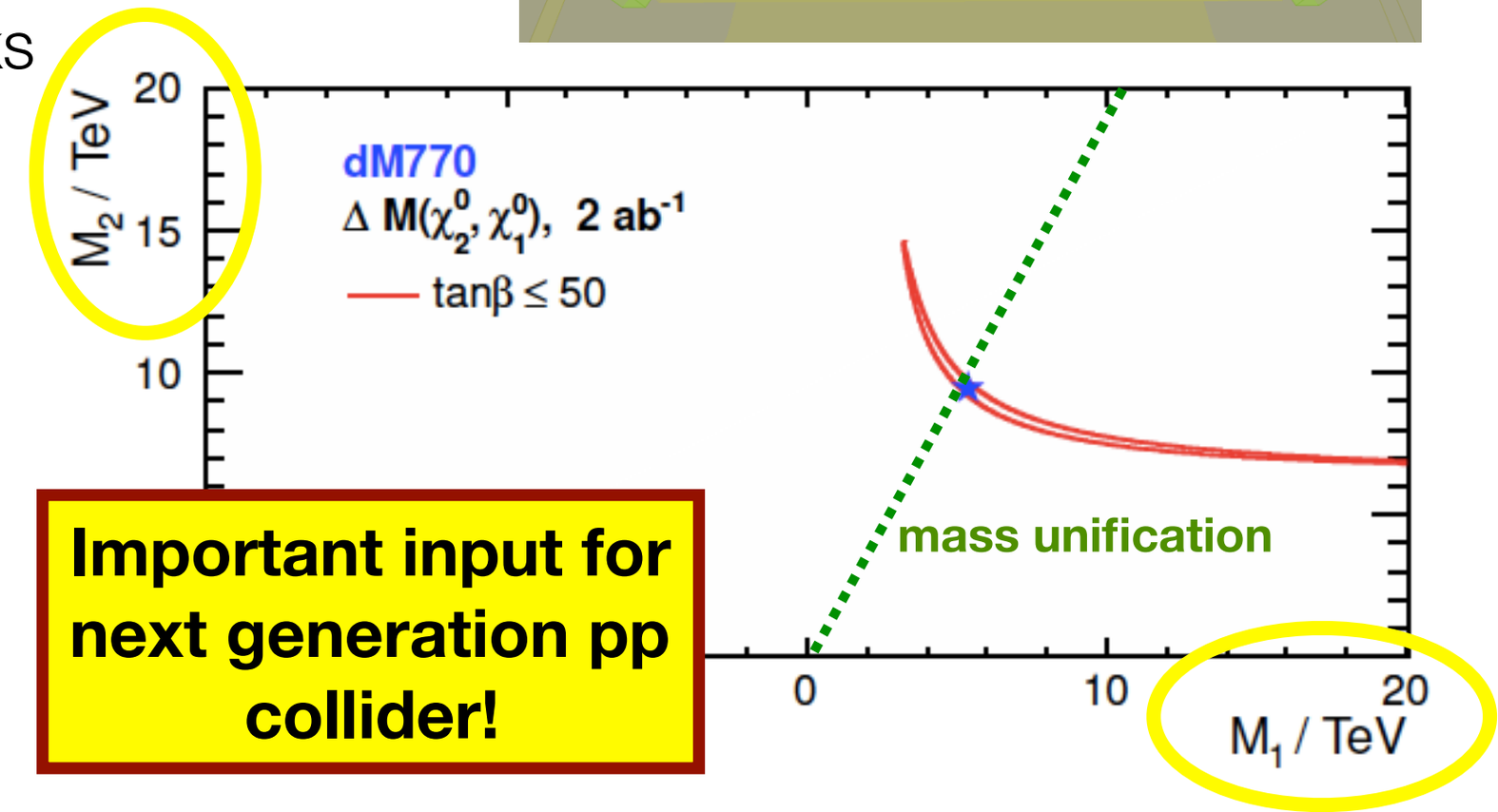
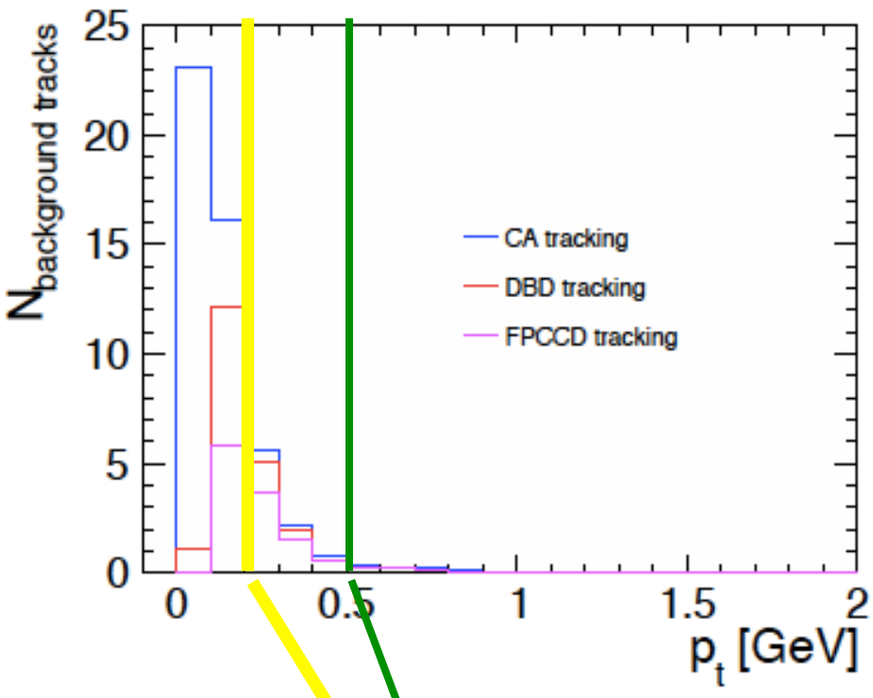






Important input for next generation pp collider!

Tracking in presence of pair background



VTXD types	DBD VTX		Fast CMOS VTX		Ideal VTX (1 BX)	
Layers	$\sigma_{spatial}(\mu m)$	$\sigma_{time}(\mu s)$	$\sigma_{spatial}(\mu m)$	$\sigma_{time}(\mu s)$	$\sigma_{spatial}(\mu m)$	$\sigma_{time}(\mu s)$
Layer 1	3/6	50/10	3/6	50/2	3/6	0.6/0.6
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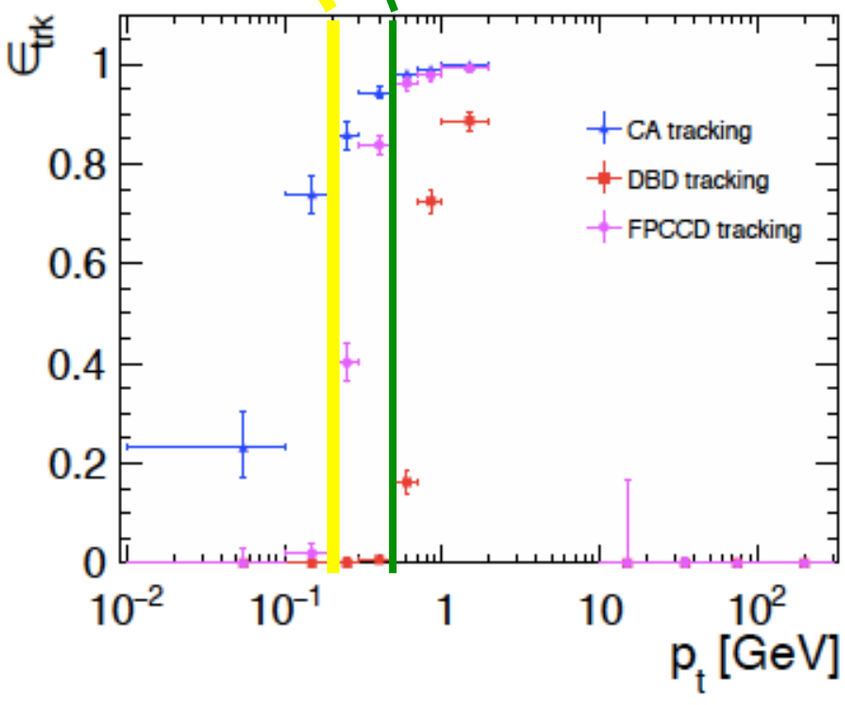
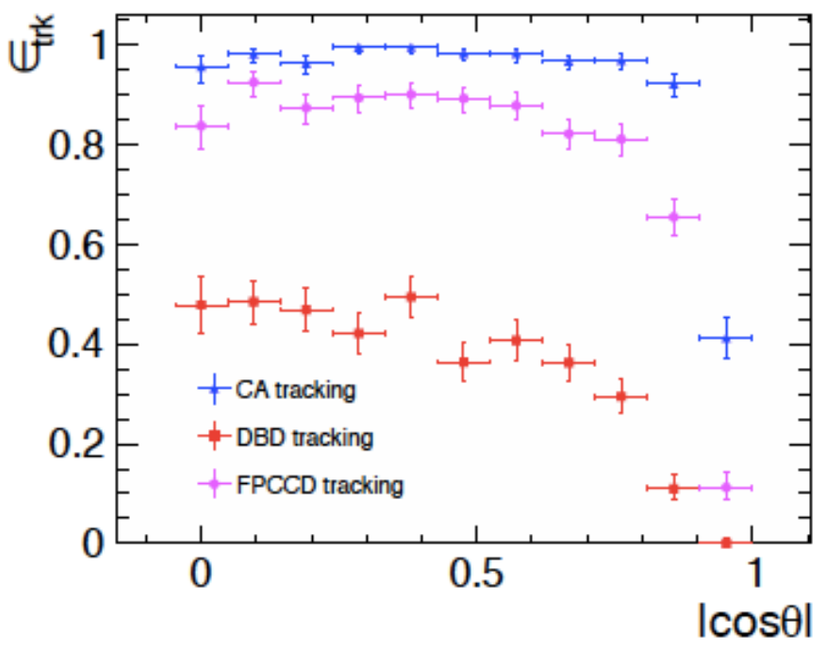
Higgsinos + pair background for **“fast CMOS VTX”** and 3 different tracking algorithms





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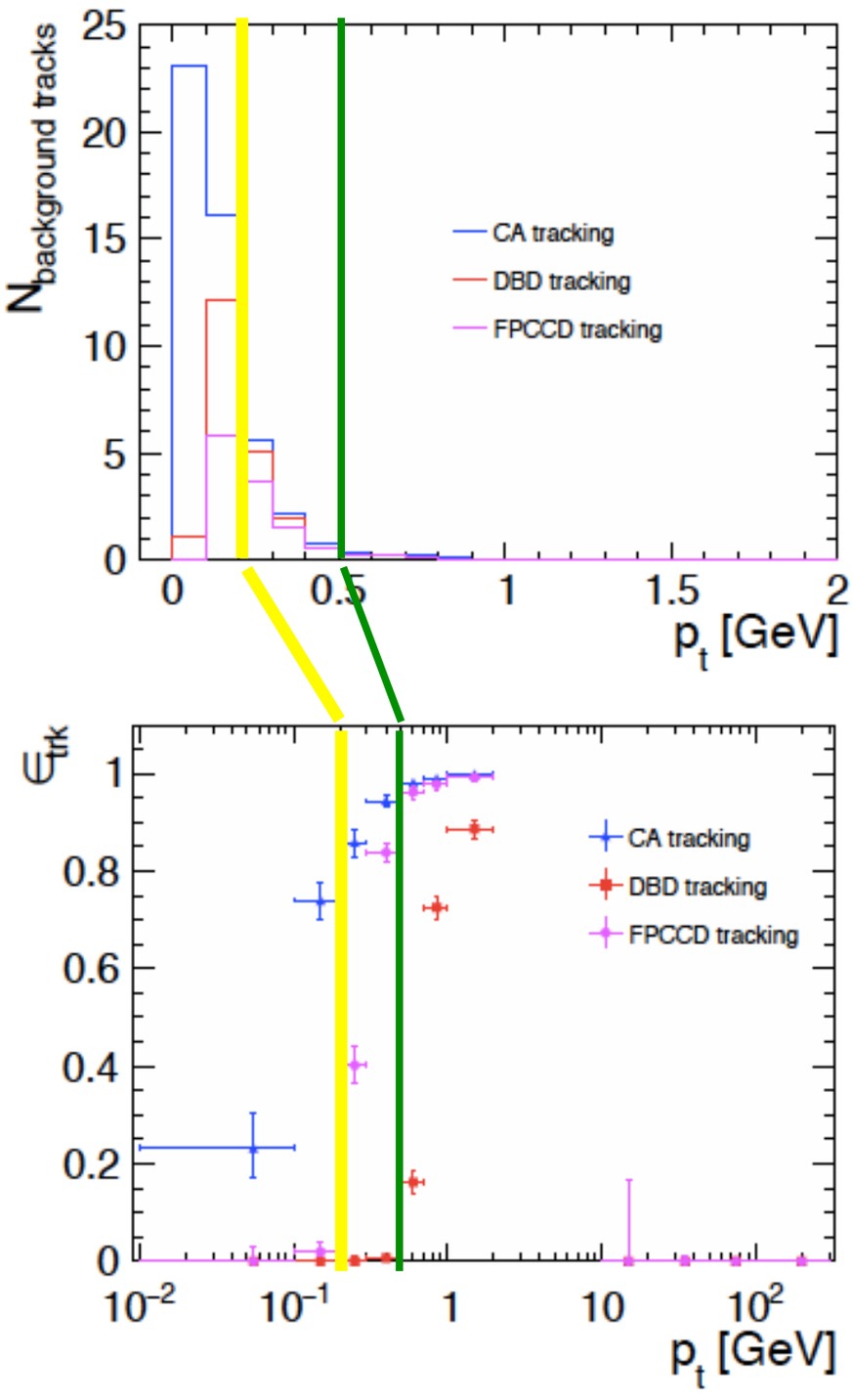

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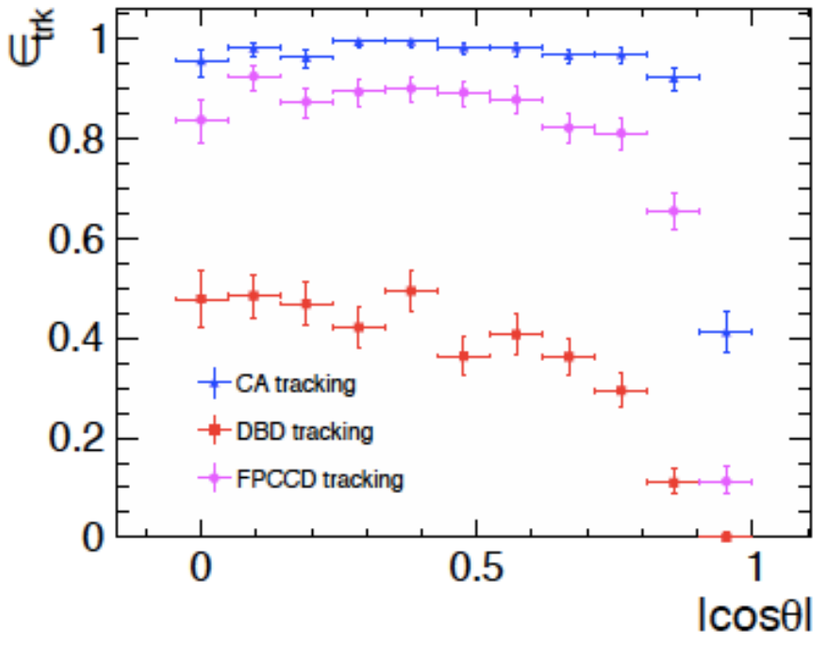

- 5-10 tracks from pairs in signal range
- studies stopped at this point due to lack of person power
- **obvious that a factor x more of pair background is a severe challenge to this type of signatures**

Outlook & Conclusions

For MC production with new L* we need:

- **new forward region design and implementation**
- **new detailed maps of main and fringe fields** for:
  - realistic solenoid
  - QD0 (+ potentially more of beamline)
  - anti-solenoids
  - antiDID
- **new simulation of pair background** for each centre-of-mass energy
  - occupancies / radiation doses
  - **realistic tracking efficiencies / purities**
  - **realistic BeamCal response**
- study of all field inhomogeneities on tracking, alignment, …

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Each of these tunable in magnitude!

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Conclusions

- **with antiDID: detector and physics performance profit a lot**
  - hermeticity, e.g. WIMPs, low-deltaM SUSY, …
  - low momentum signatures, e.g. Higgsinos, natural SUSY, …
  - charm tagging… (n)ever tested with full pair background…?
- **no antiDID: would hurt the physics case where it is most complementary to LHC!**
- antiDID *by far* not the only source of B field inhomogeneity (solenoid fringe, anti-solenoid, …) => alignment, ExB etc in non-perfect solenoid field needs to be understood *anyway*
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=> no (fundamental) reason to remove the antiDID, but good reasons to keep it !

Backup

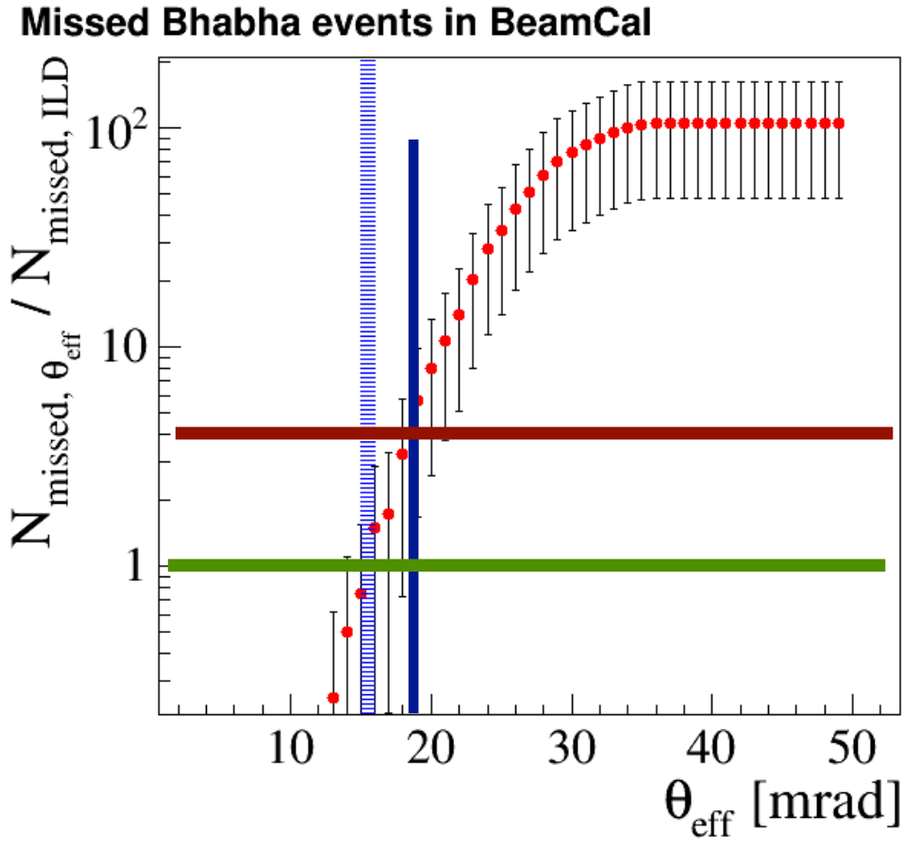
Light, near-degenerate Higgsinos @ 500 GeV

- observables:
  - polarised cross sections for charginos & neutralinos
  - masses and mass differences
- main performance aspects:
  - low momentum
  - PID
  - hermeticity of forward region
- completed studies:
  - H.Sert, SGV
  - H.Sert, Y.Voutsinas: single aspects in full sim.
- open issues:
  - full analysis in full sim?
  - $\gamma\gamma$ -> low p_t hadron removal
  - pair background
- expected improvements:
  - PIDTools
  - Si tracking
  - new $\gamma\gamma$ -> low p_t hadron simulation
- current status:
  - **S.Sasikumar: $\gamma\gamma$ -> low p_t hadron removal**
  - **new student in Tokyo? (tbc)**

Mono-photons ($\chi\chi\gamma$) @ 500 GeV

- observables:
- main performance aspect:
  - hermeticity in forward region: Bhabha veto
  - energy scale and resolution for high-energy photons
  - systematics: beam energy spectrum
- completed studies: C.Bartels @ LoI, re-interpretation by A.Chaus
- open issues:
  - **suitable generator for radiative Bhabha's which works efficienctly in signal region (E>10 GeV photon in detector, e+e- down the beam pipe)**
  - anit-DID ? L* ?

- expected improvements:
  - much better Bhabha veto from new BeamCal reconstruction
- current status: **ongoing analysis** based on Whizard2 + Mokka **by M. Habermehl, will need replacement eventually T.Tanabe?**



BeamCal 40cm further in

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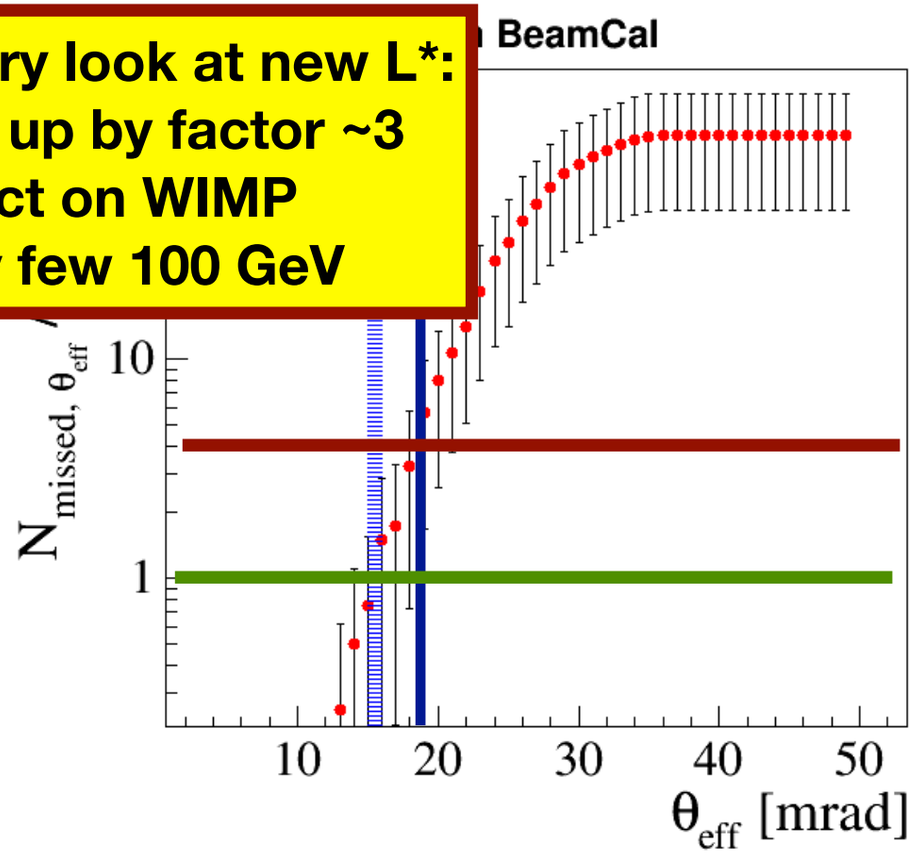
very preliminary look at new L*: Bhabha bkg up by factor ~3 => impact on WIMP sensitivity few 100 GeV



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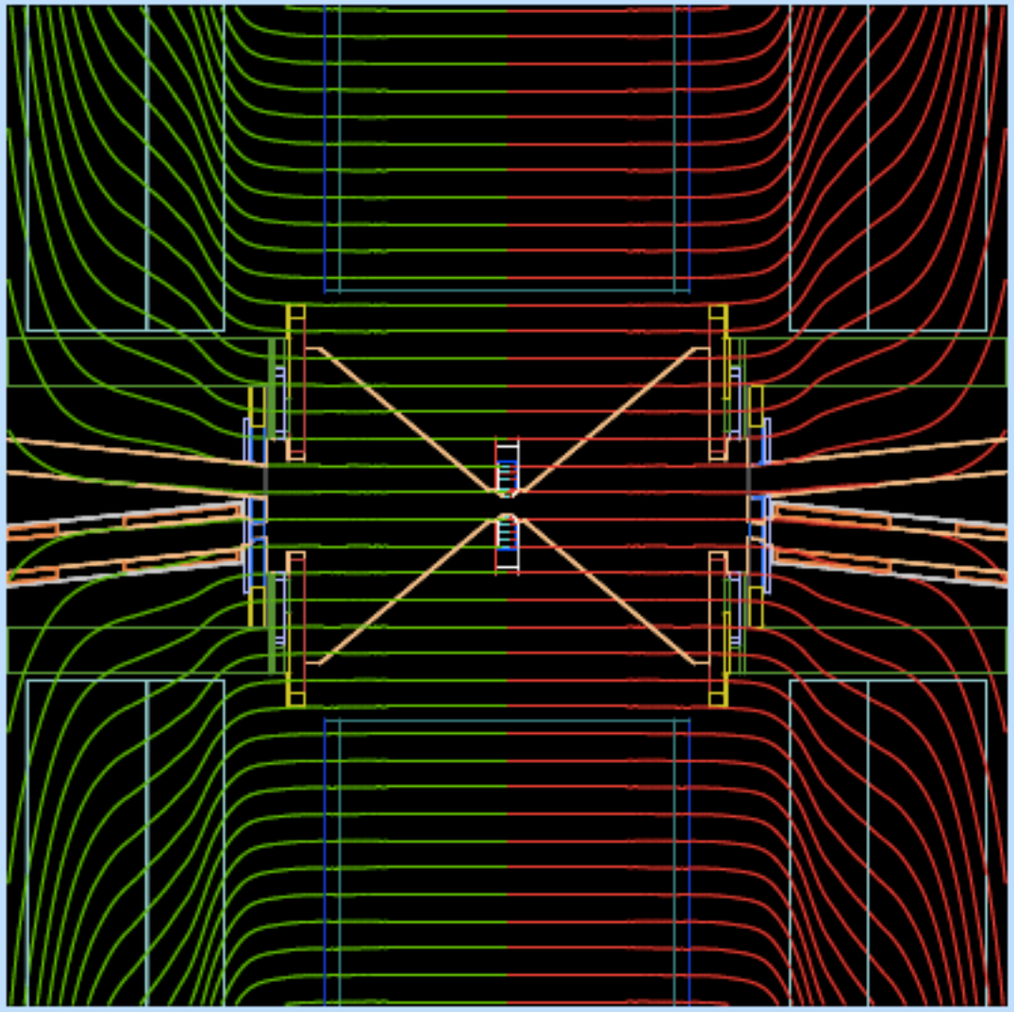
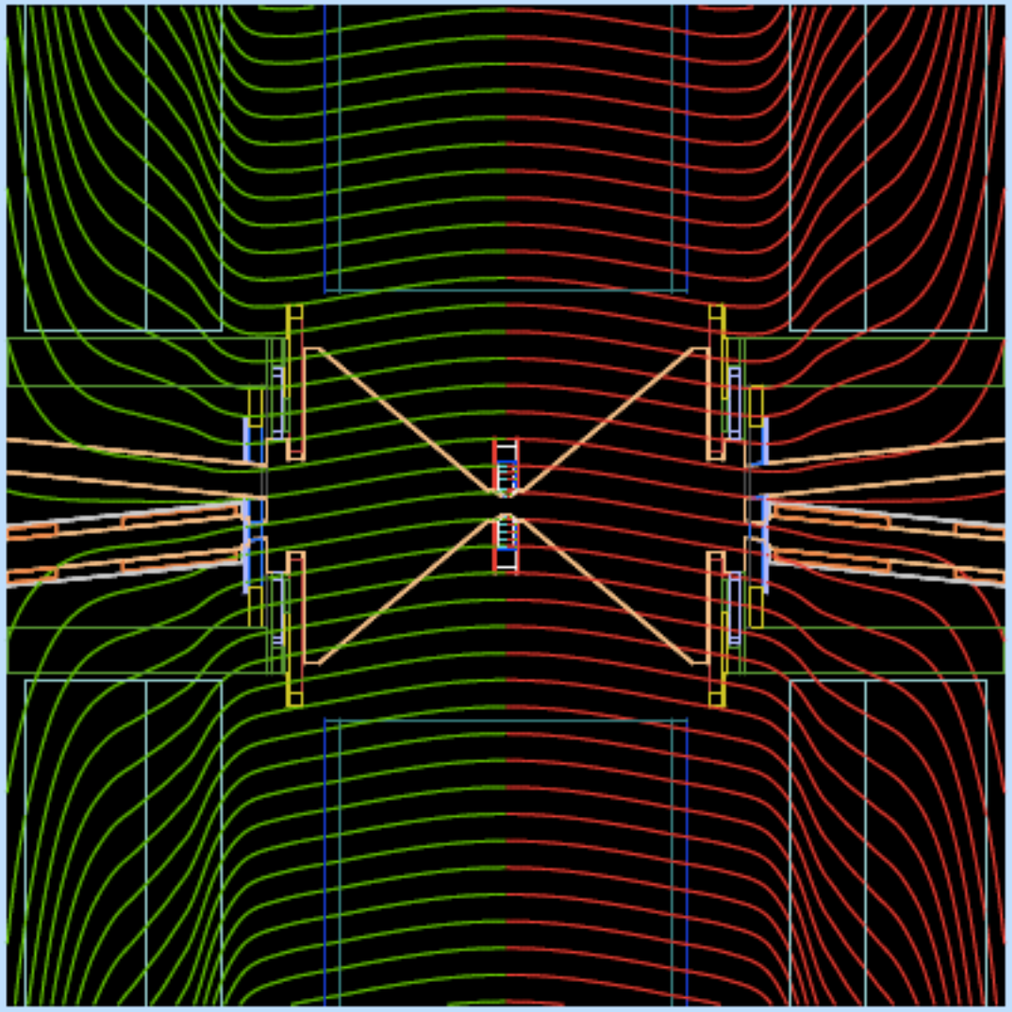
Magnetic Field Maps



Plain solenoid



Solenoid with DID

Realistic field maps (plus simplified quadrupoles)