Impact of ILD optimisation on the TPC

—from physics performance point-of-view

(see Mikael’s talk for detailed detector performance)

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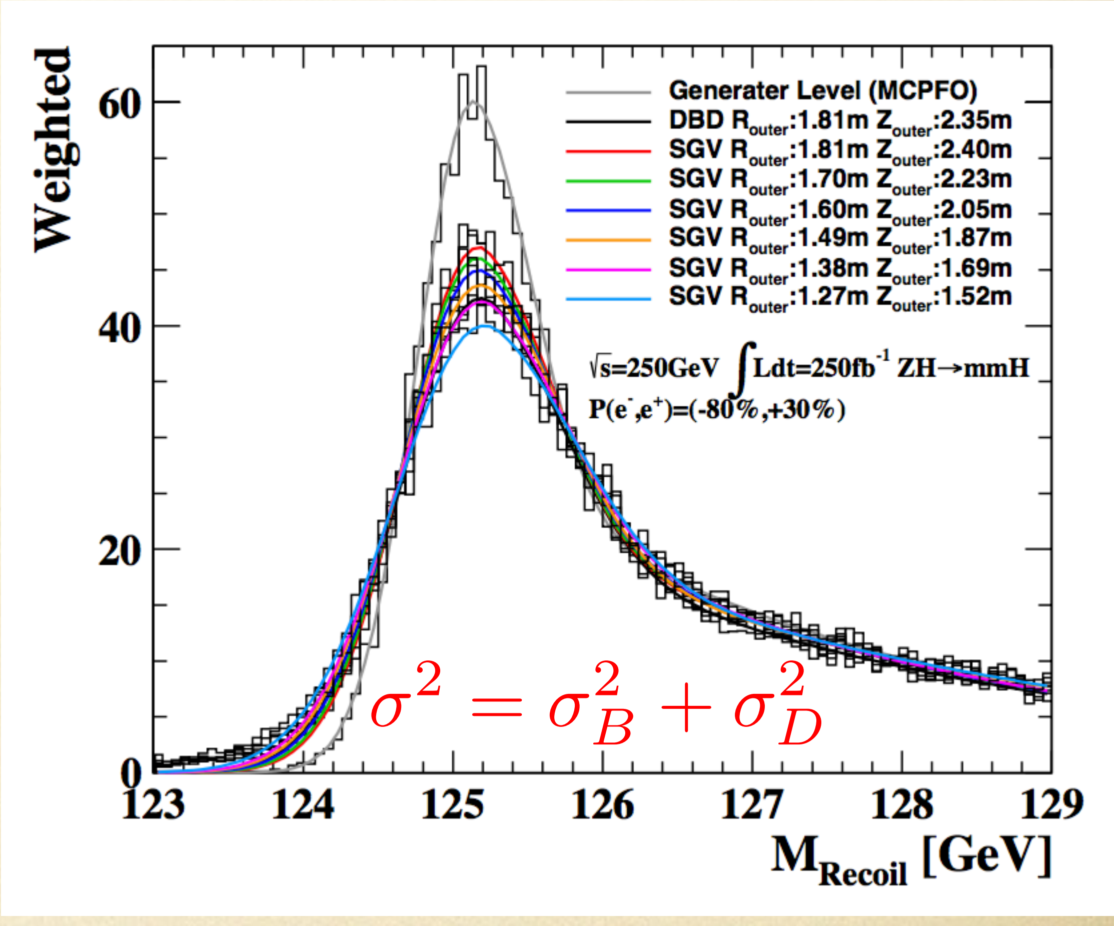
Apr. 20-24, 2015 @ ALCW15, Tsukuba

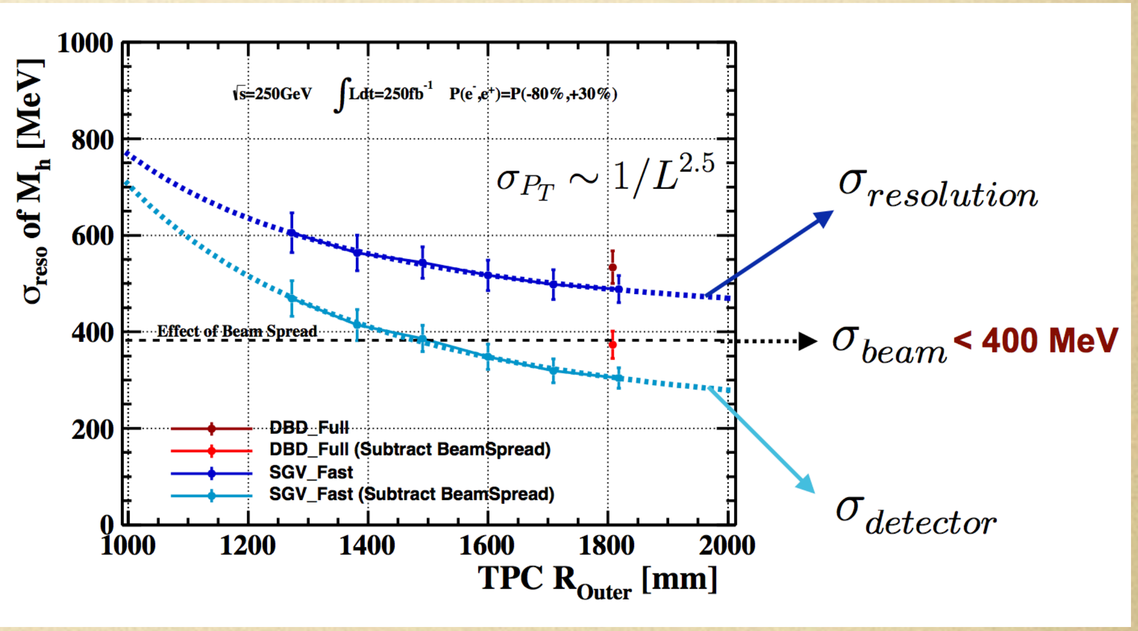
so far most of the optimisation studies focus on sub detector performance, only few of them have looked into overall physics performance. I try to categorize TPC related studies as follows

- impact of high momentum tracking
- impact of low momentum tracking
- benchmark of two tracks separation
- use of dE/dx and continuous tracking

impact of high momentum tracking

- what matters here is TPC outer-radius ($\sigma_{P_t} \sim 1/L^{2.5}$)
- the most relevant physics case here is the flagship measurement at ILC: leptonic recoil mass measurement
- peak width not only from momentum resolution but also beam energy spread
- TDR σ_B ~ 400 MeV < RDR (560 MeV)
- σ_D ~ 300 MeV at R=1.8m, not much smaller than σ_B (at R=1.4m, $\sigma_D > \sigma_B$)
- so even at ecm=250GeV, Higgs mass precision already becomes sensitive to track momentum resolution, therefore to TPC outer-radius

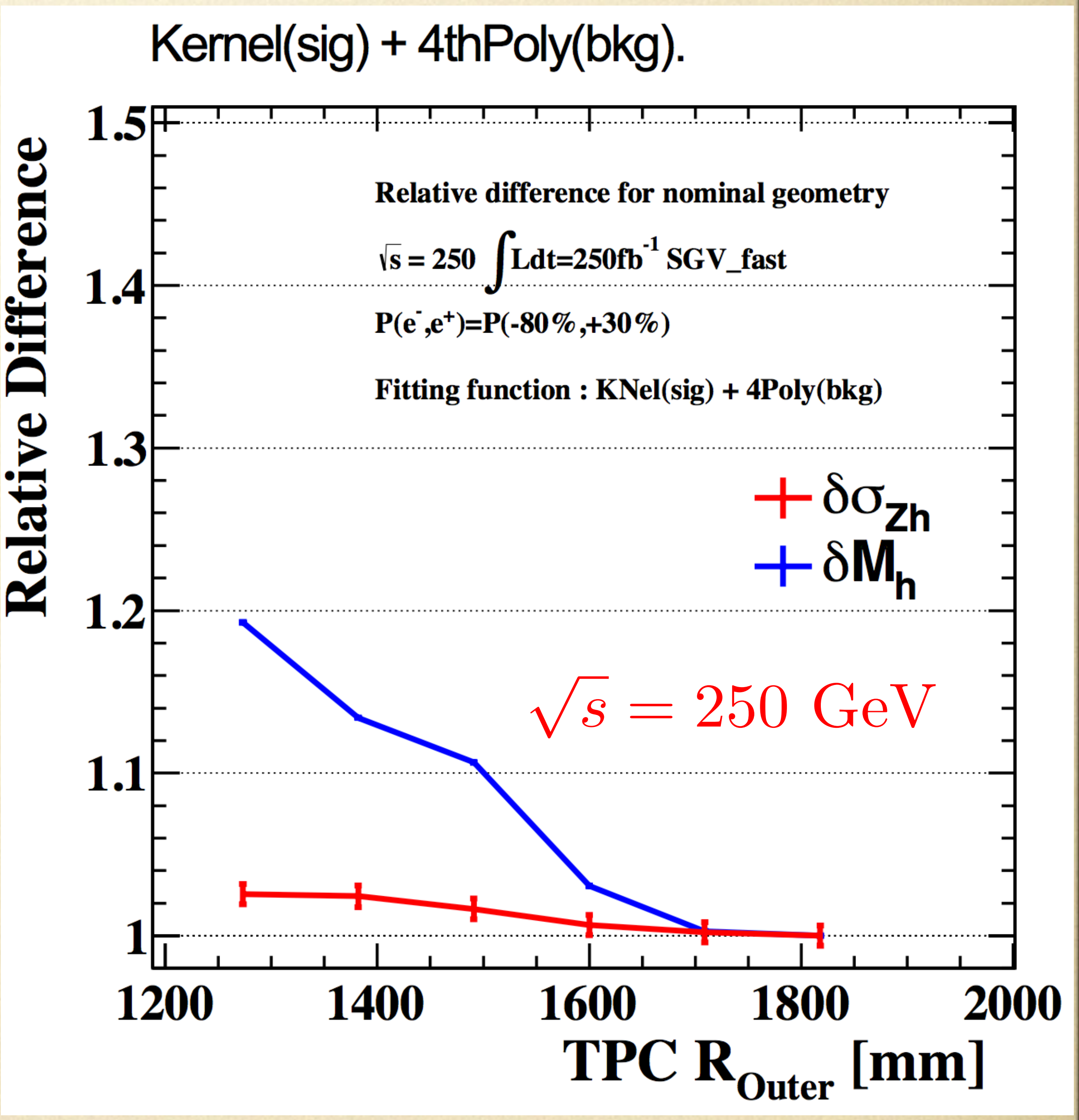




(T. Ogawa @ 7th ILD Opt. Meeting)

impact of high momentum tracking on ΔM_H and σ_{ZH}

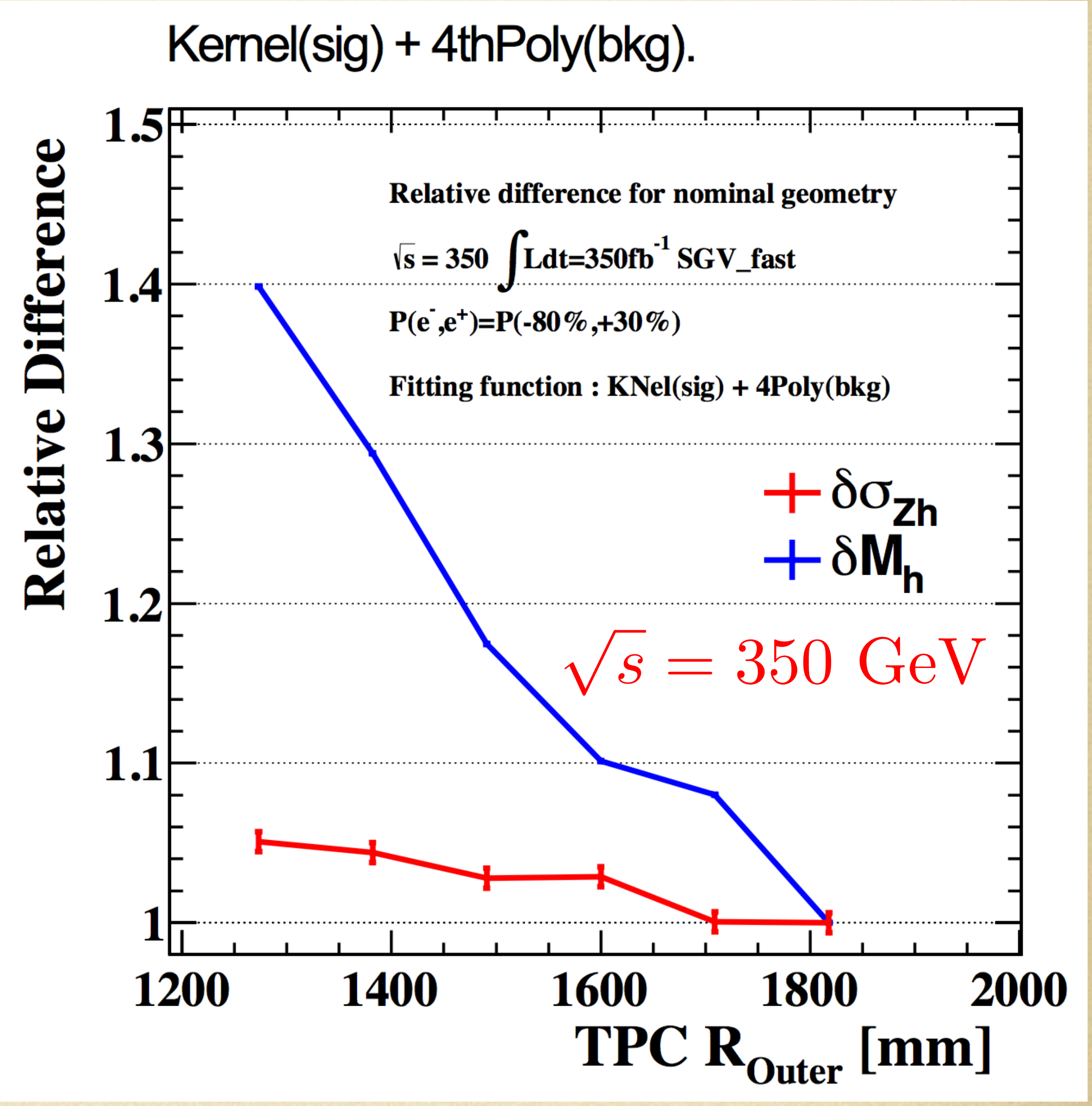
- ΔM_H gets worse by 12% when TPC outer radius is reduced from 1.8m —> 1.4m
- which means to get same precision 25% more integrated luminosity is needed
- ΔM_H will eventually be one of the theoretical errors to all the Higgs couplings (20MeV —> 0.2% uncertainty)
- running scenario from ILC Parameter WG suggests 2000 fb^{-1} @ 250 GeV
- so 25% more data means additional 500 fb^{-1} (~2 years of High Lumi ILC running)
- running scenario from ILC Parameter WG suggests 2000 fb^{-1} @ 250 GeV
- σ_{ZH} gets worse by ~5%; certainly we need evaluate all other measurements to conclude on impact of TPC outer radius



(T. Ogawa @ 7th ILD Opt. Meeting)

impact of high momentum tracking on ΔM_H and σ_{ZH}

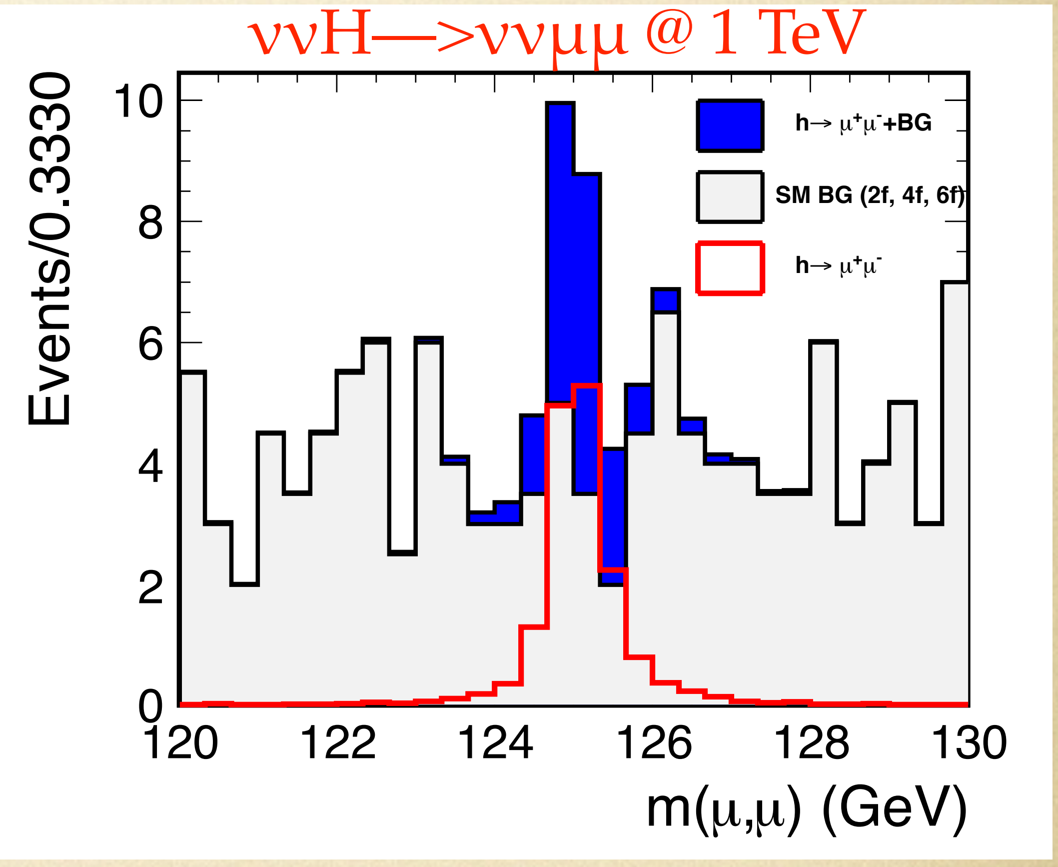
- impact gets more significant if ILC is going to run more at 350 GeV then at 250 GeV; σ_D dominant
- ΔM_H gets worse by 30% when TPC outer radius is reduced from 1.8m —> 1.4m
- σ_{ZH} gets worse by ~5%



(T. Ogawa @ 7th ILD Opt. Meeting)

other benchmarks for high momentum tracking

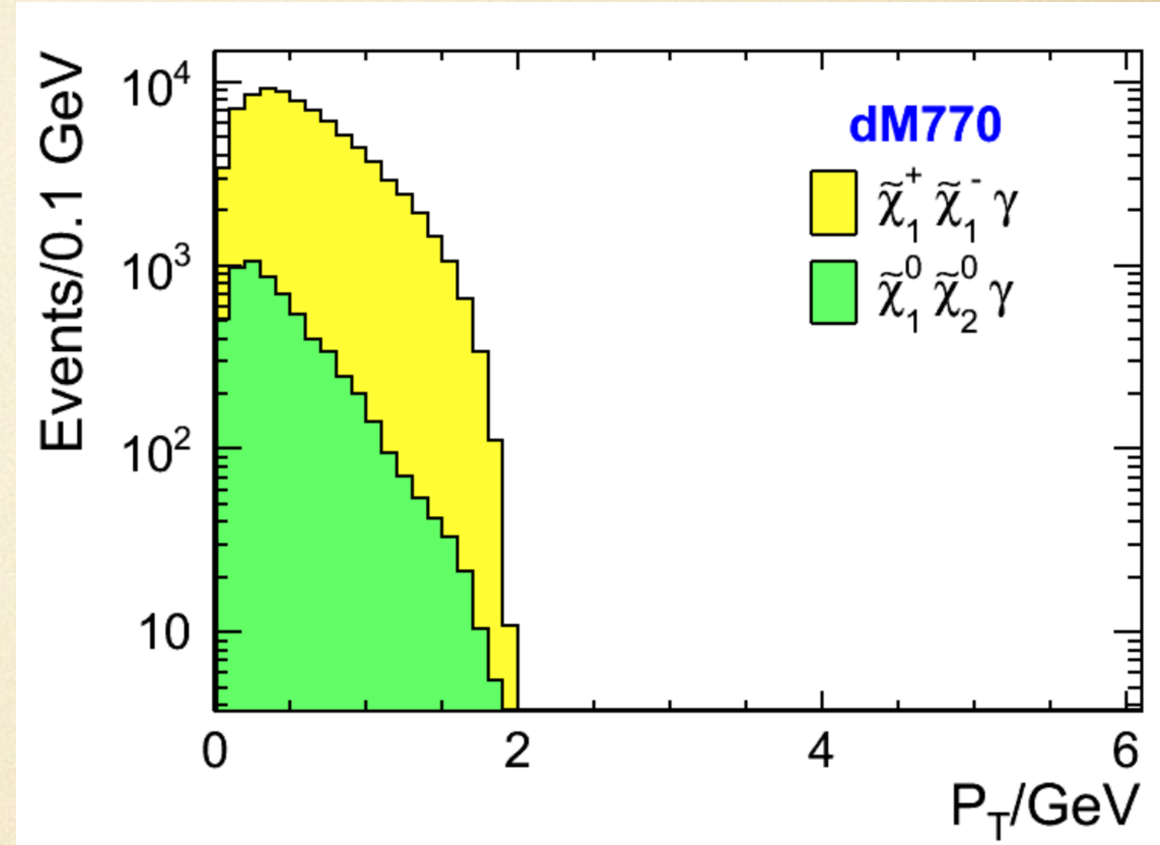
- H—>μμ: detector effect only, would be more sensitive to high momentum resolution; DBD analysis was done by Tino, now Rashid is working on the evaluation of dependence with radius.
- sensitivity to search of Z'—>μμ would also be an interesting benchmark
- but $\sigma_{Pt} \sim 1/(BL^{2.5})$, can be increase B-field when radius is reduced? That depends…

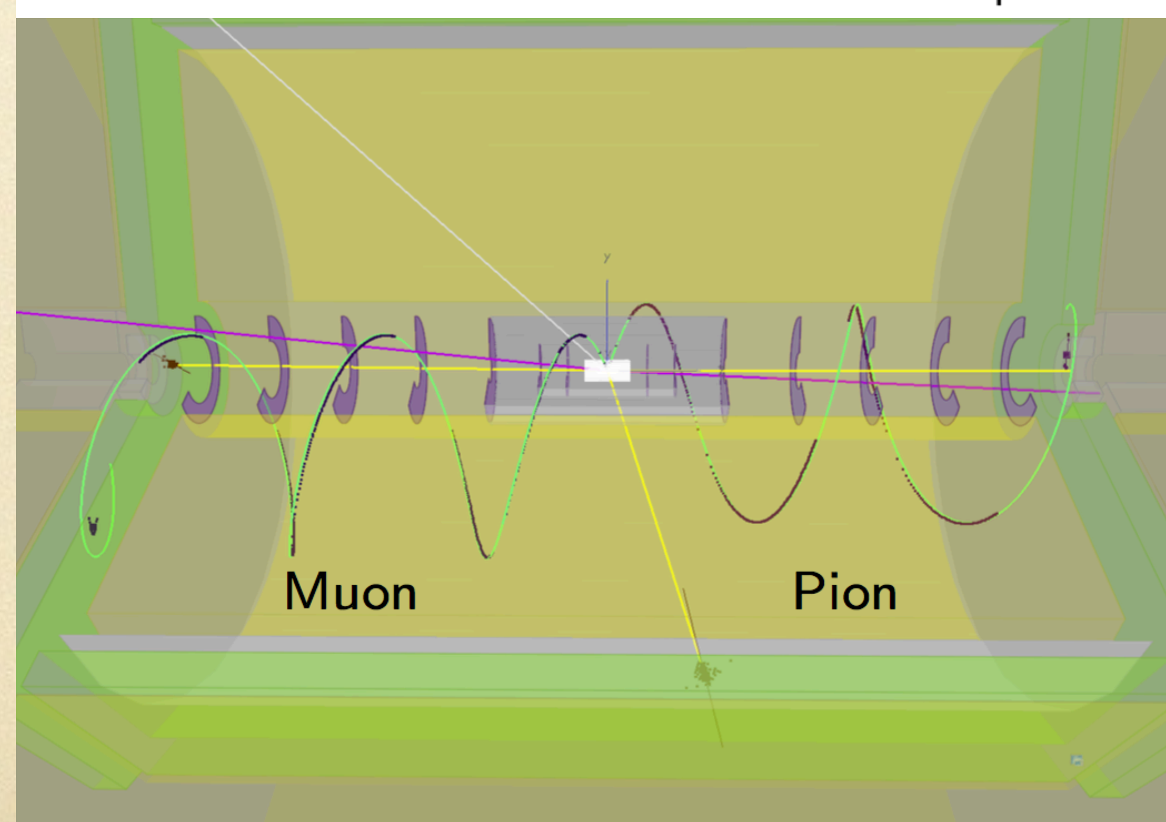


(C. Calancha, LC-REP-2013-006)

impact of low momentum tracking

- what matters here is efficiency of low momentum tracking
- the most relevant physics case here is SUSY particle discovery at ILC: Light Higgsino scenario
- where $\Delta(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0)$ & $\Delta(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$ $\sim$ (sub) GeV
- very soft and forward tracks
- TPC with continous tracking helps
- But it's not good to increase B-field (reconstruction efficiency is already only ~50% for ILD DBD)
- see talk on Friday by Yorgos





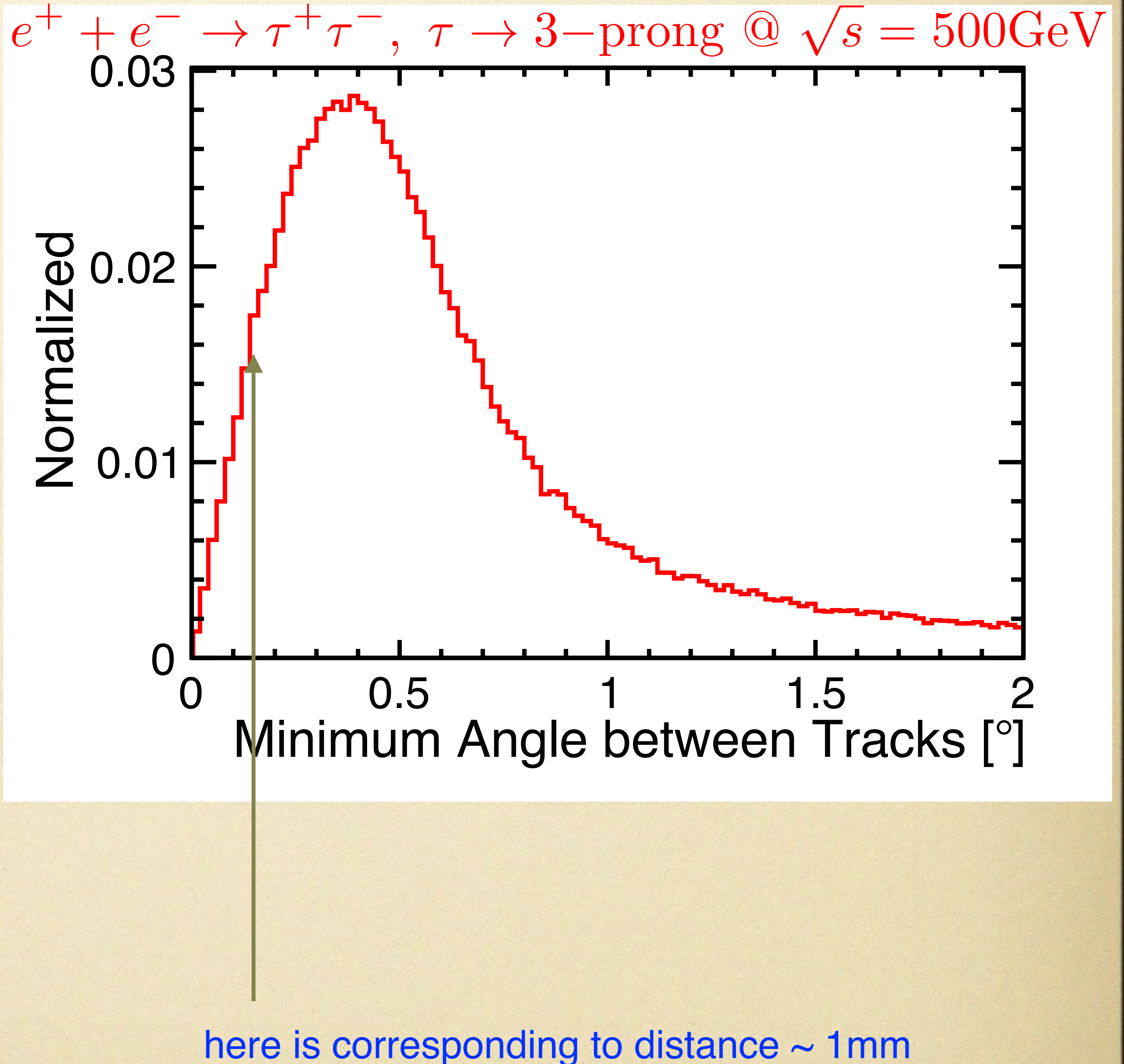
(H. Sert at ILD analysis/software meeting, Mar. 15)

impact of low momentum tracking

- low momentum tracks carry important information such as charge and impact parameter.
- may play an important role in high-level reconstructions, such as vertex charge and flavor tagging.
- quick proposal: check the components which contribute to vertex charge, and randomly remove some low momentum track to see how performance goes
- similar proposal to evaluate the low momentum track contribution to flavor tagging.
- a good physics benchmark can be A_{FB} in tt-bar

benchmark for two tracks separation

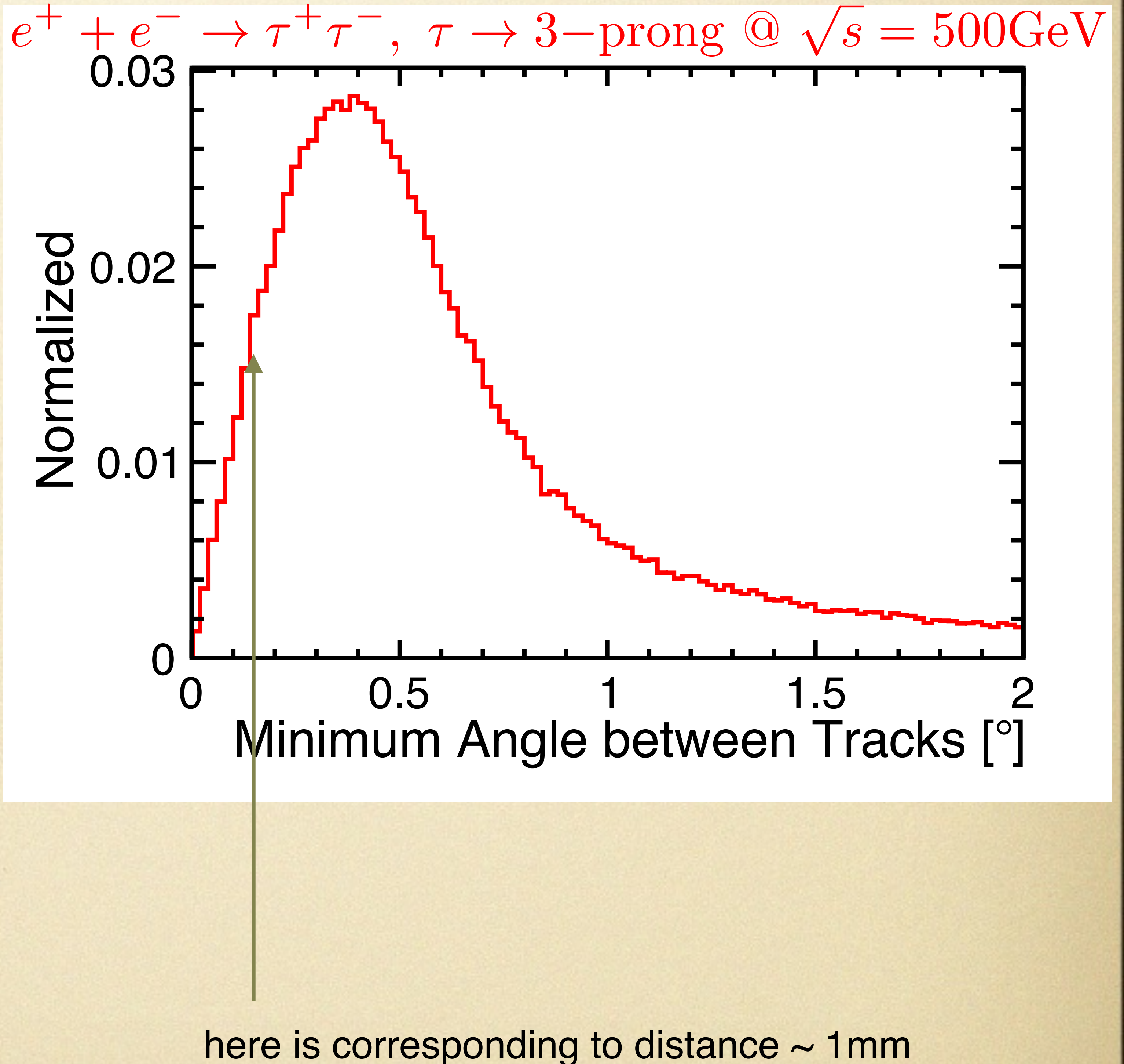
- the physics process that requires extreme two tracks separation would be e^+e^- —> $\tau^+\tau^-$, τ —>3-prong
- taking example at 500 GeV, tau is highly boosted —> 3 tracks are almost collinear —> plot the minimum angle between them.
- at the TPC inner radius ~ 40 cm, assuming 0.1 degree between two tracks —> distance at the most inner layer is ~ 0.7 mm (our pad width is just good?)



(a very preliminary check after yesterday's dinner…)

benchmark for two tracks separation

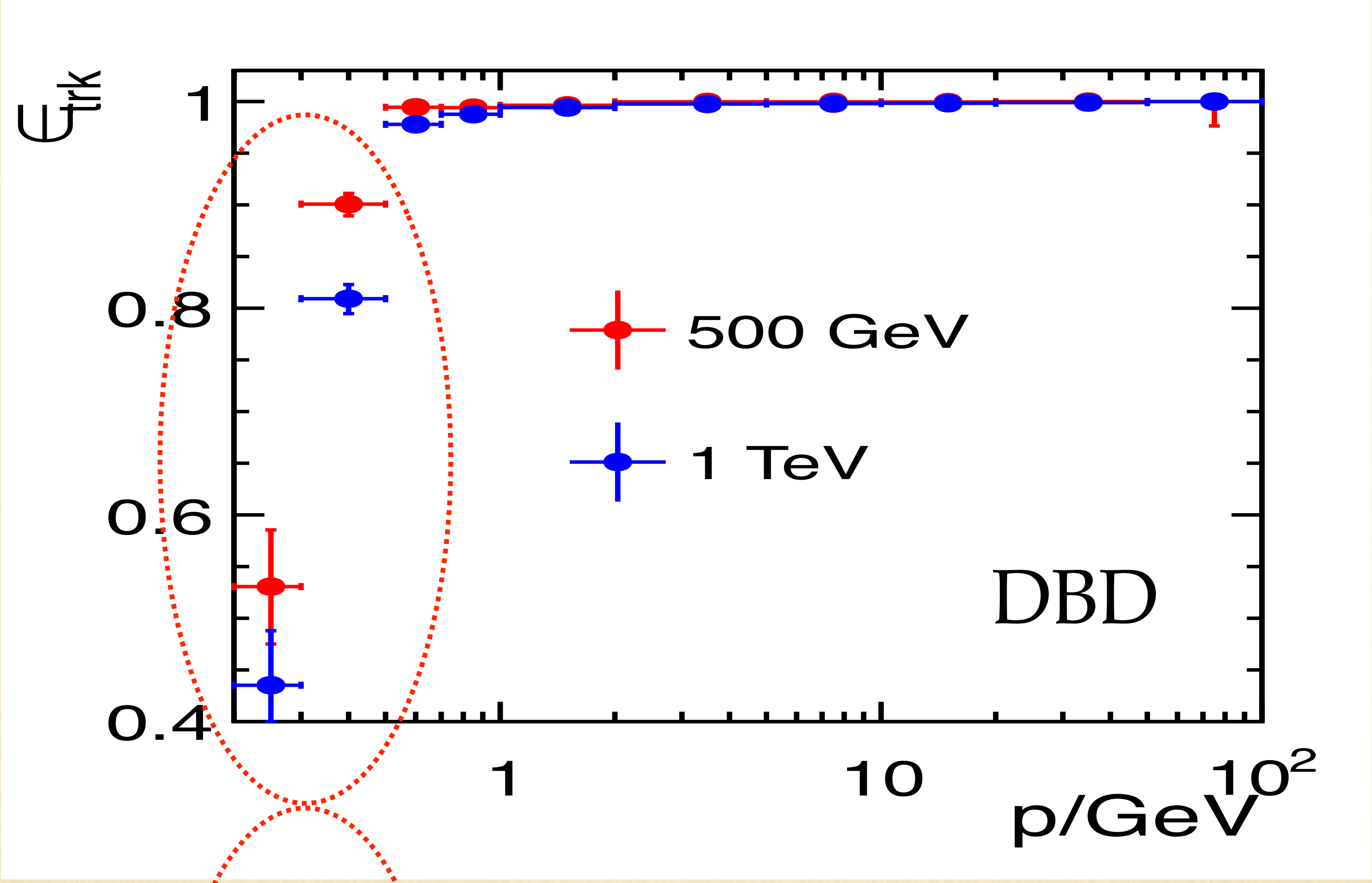
- certainly properer way is to look directly at the closest points, not simply minimum angle (there's magnet!)
- detailed evaluation has to check the minimum distance as a function of τ momentum and polar angle
- H—>ττ is certainly a physically more important benchmark though probably less boosted
- another interesting benchmark would be photon conversion in H—>γγ, γ—>e+e-
- what about the separation in z-direction?

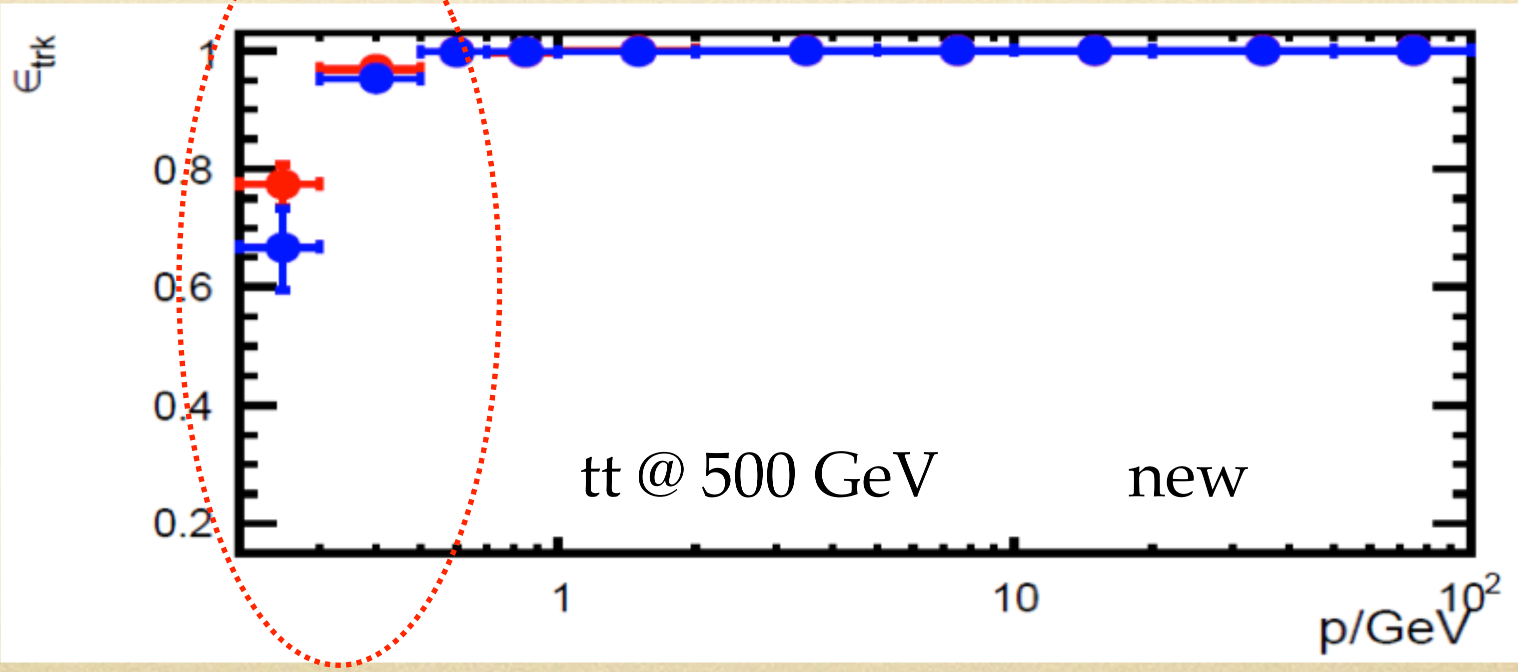


use of dE/dx and continuous tracking

- use of **dE/dx**:
  - many potential applications in physics (M. Kurata).
  - what missing is to provide a bit more realistic simulation to go beyond the assumption of 3~5% dE/dx resolution (by someone from TPC group; verify or improve charge simulation in Mokka; include detector resolution; Astrid @ DESY was working on this, as well as Wenxin @ Saclay?)
- use of **continuous tracking**:
  - curling tracks reconstruction is crucial as seen in light Higgsinos study
  - quasi stable stau in GMSB, stau—>$\tau\chi^0$—>1- or 3-prongs, large parameter space where stau decays in TPC (very interesting signatures, 3 track segments with 2 kinks)

in any case try to improve reconstruction algorithm





Y. Voutsinas / M. Berggen / F.Gaede

summary

- TPC outer radius shows a sensitive impact on Higgs recoil mass measurement. We may need choose between less expensive detector with longer running and more expensive detector with shorter running.

- low momentum tracking is crucial for search of near degenerate Higgsino. This may limit the higher B-field for ILD.

- 2 tracks separation can be mostly accessed using highly boosted τ—>3-prong process.

- we should focus on not only optimisation, but also justification of TPC, in particular use of continuous tracking and dE/dx.

- nevertheless evaluation of detector impact on physics performance needs a full picture, which hopefully will be clear after ILD agreed on several benchmark detector models and full simulations based on those detector models are performed.

backup

Production Processes & Decay Modes

Production Processes

- $e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-$
- $e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_2^0$

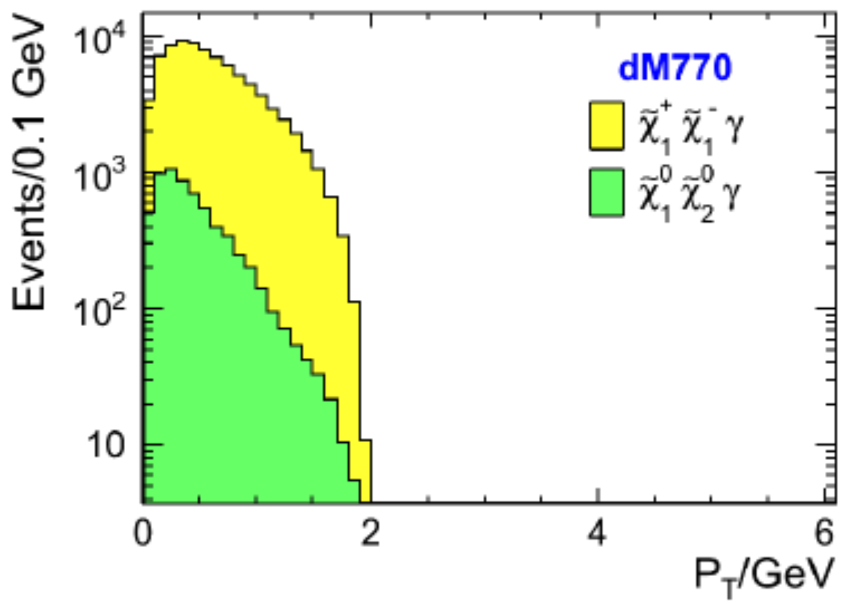
Decay Modes

- $\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 W^{\pm *}$
- $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 Z^{0*}$
- $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \gamma$

Separation of Signal Processes

Exclusive decay modes:

- $\tilde{\chi}_1^+\tilde{\chi}_1^+ \to 2\tilde{\chi}_1^0\ W^{+*}\ W^{-*}$
  - semileptonic final state (35%)
- $\tilde{\chi}_1^0\tilde{\chi}_2^0 \to 2\tilde{\chi}_1^0\ Z^{0*}/\gamma$
  - photonic final state (74%)



P_T dist. of final state particles at generator level

- Muons & Pions are very soft!

In semileptonic decays

- $BR(\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0\ \pi) \approx 60\ \%$
- $BR(\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0\ \mu^-\nu_\mu) \approx 13\ \%$

- Muon & Pion separation plays an important role in this analysis