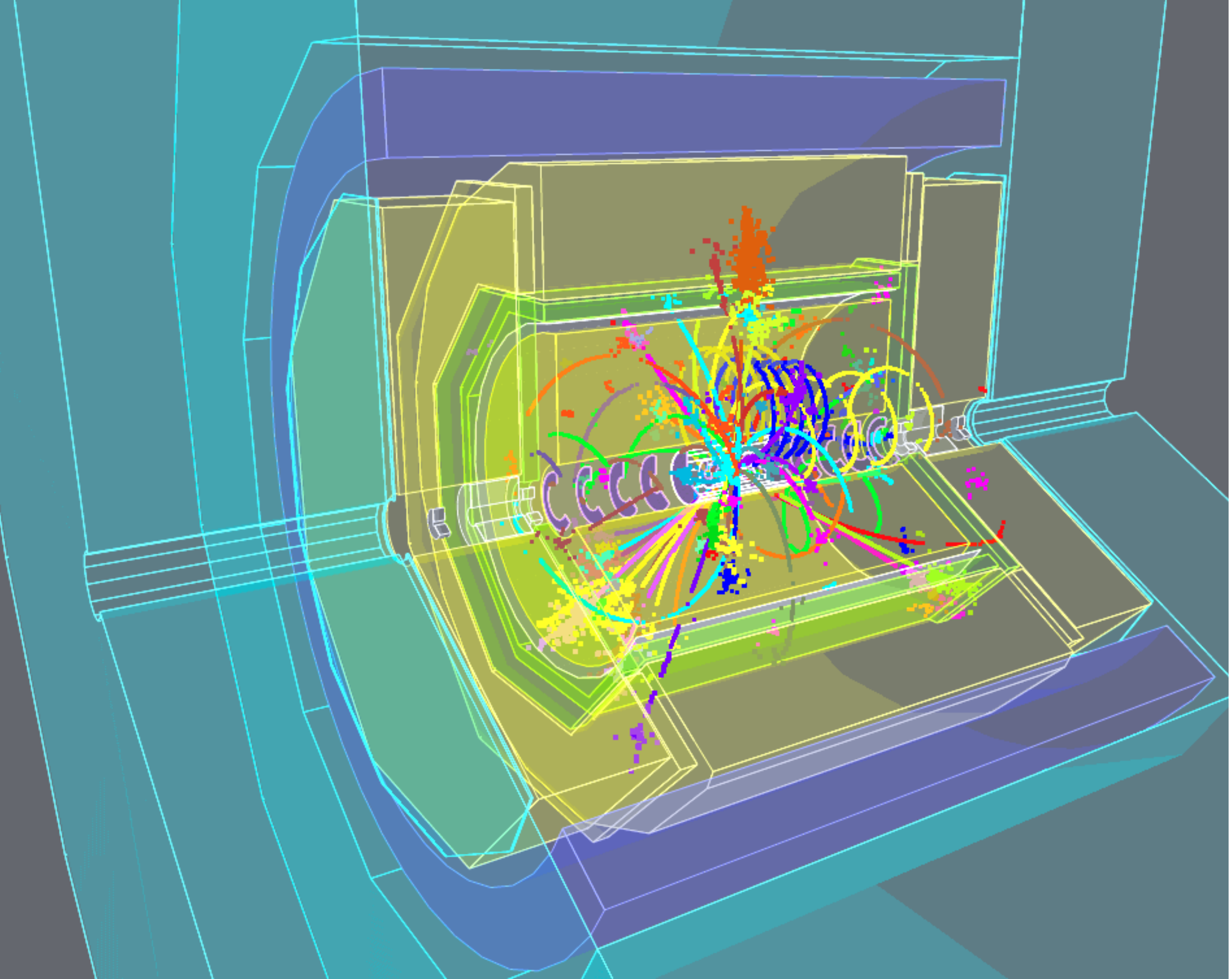

News from ILD

J. List
Arlington
LCWS 2018
October 22, 2018

Outline

- Overview
- ILD Performance:
  Understanding and Optimizing
  - Basic Performance
  - Physics Performance
- Conclusions

The ILD Concept

From key requirements from physics:

- **p_t resolution** (total ZH x-section)
  $\sigma(1/p_t) = 2 \times 10^{-5}\ \mathrm{GeV}^{-1} \oplus 1 \times 10^{-3} / (p_t \sin^{1/2}\theta)$
- **vertexing** (H → bb/cc/ττ)
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- **jet energy resolution** 3-4%
  (H → invisible)
- **hermeticity** $\theta_{min} = 5$ mrad
  (H → invis, BSM)

To key features of the **detector**:

- **low mass tracker:**
  - main device: **Time Projection Chamber** (dE/dx !)
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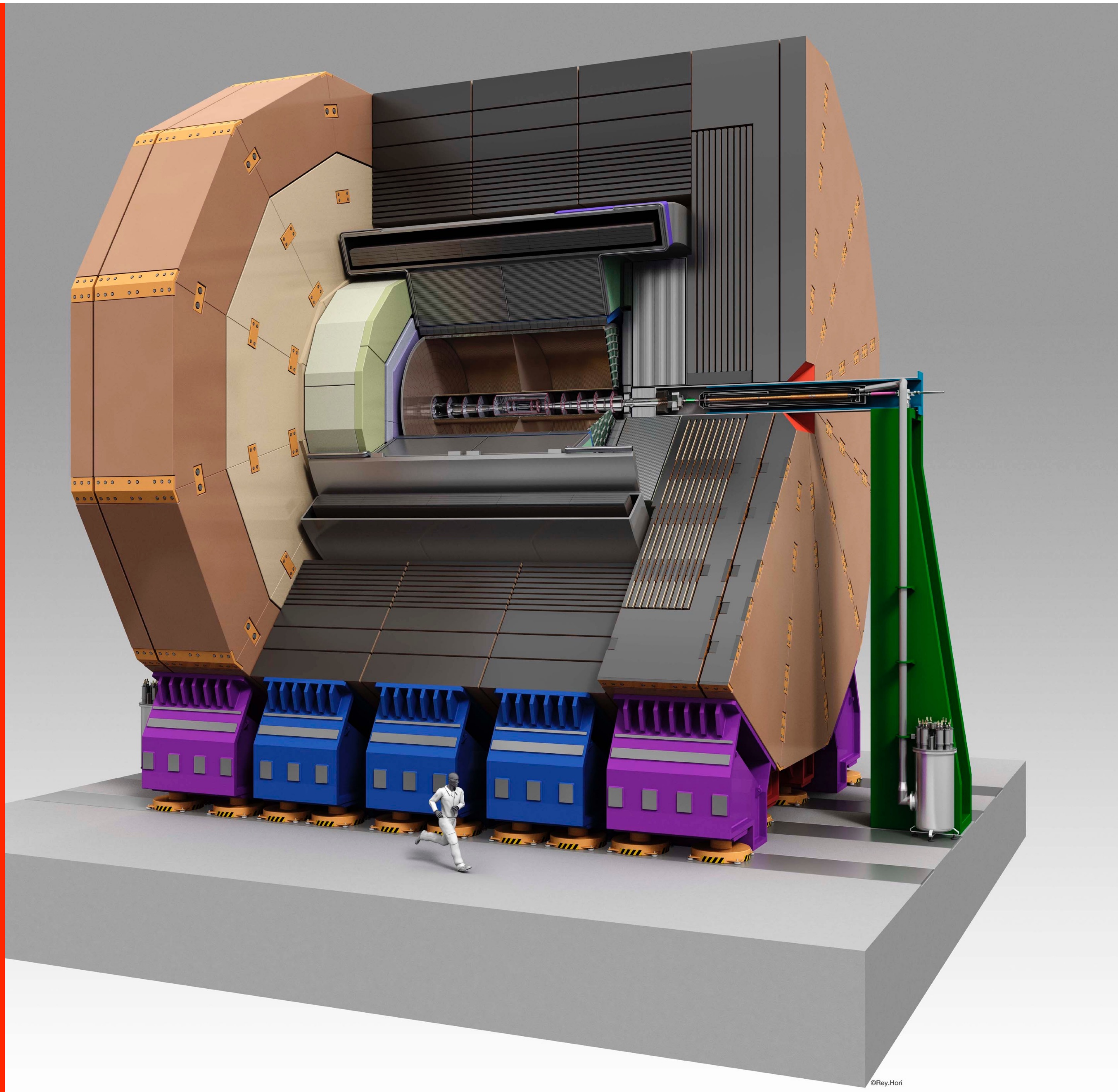

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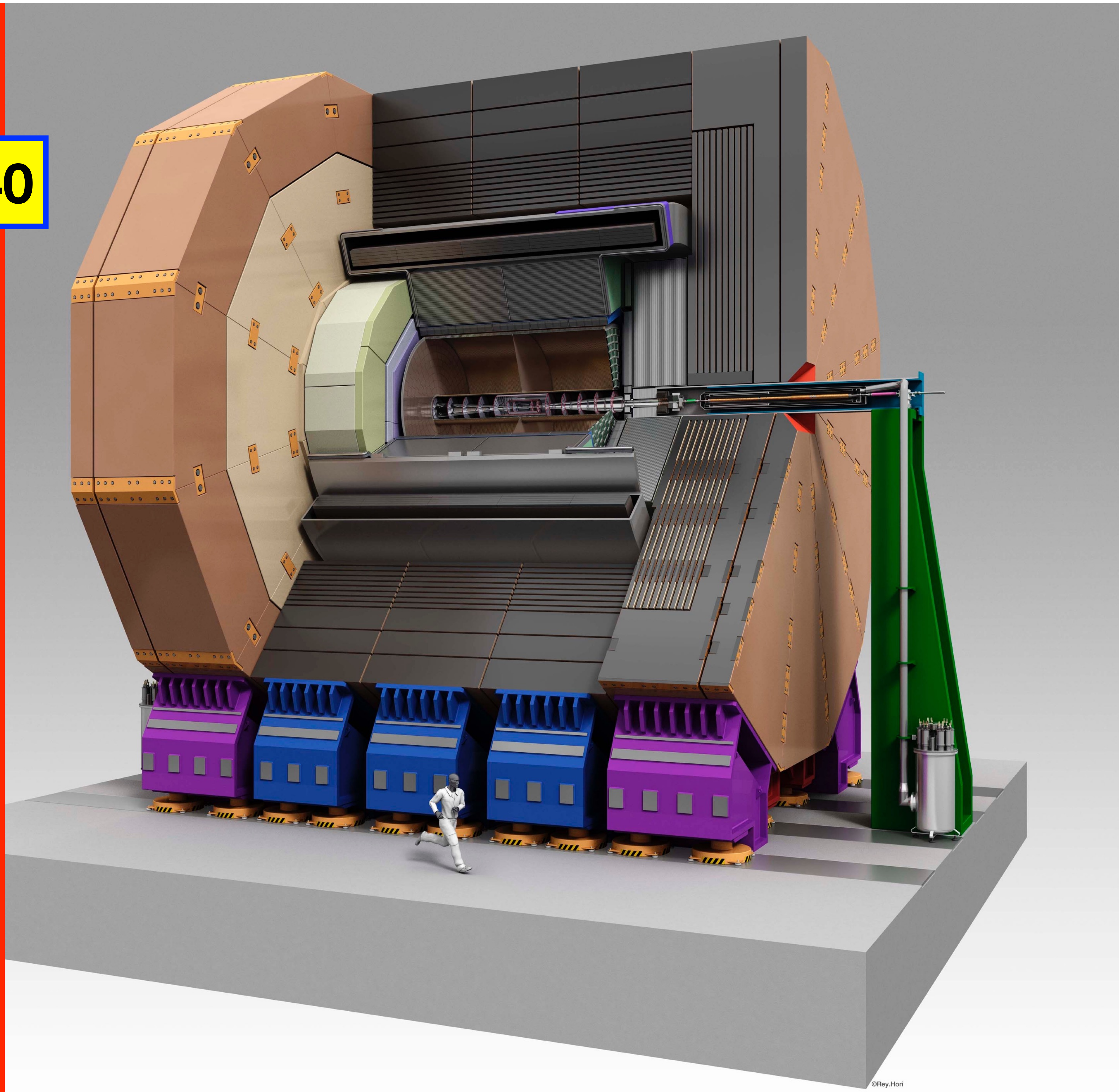

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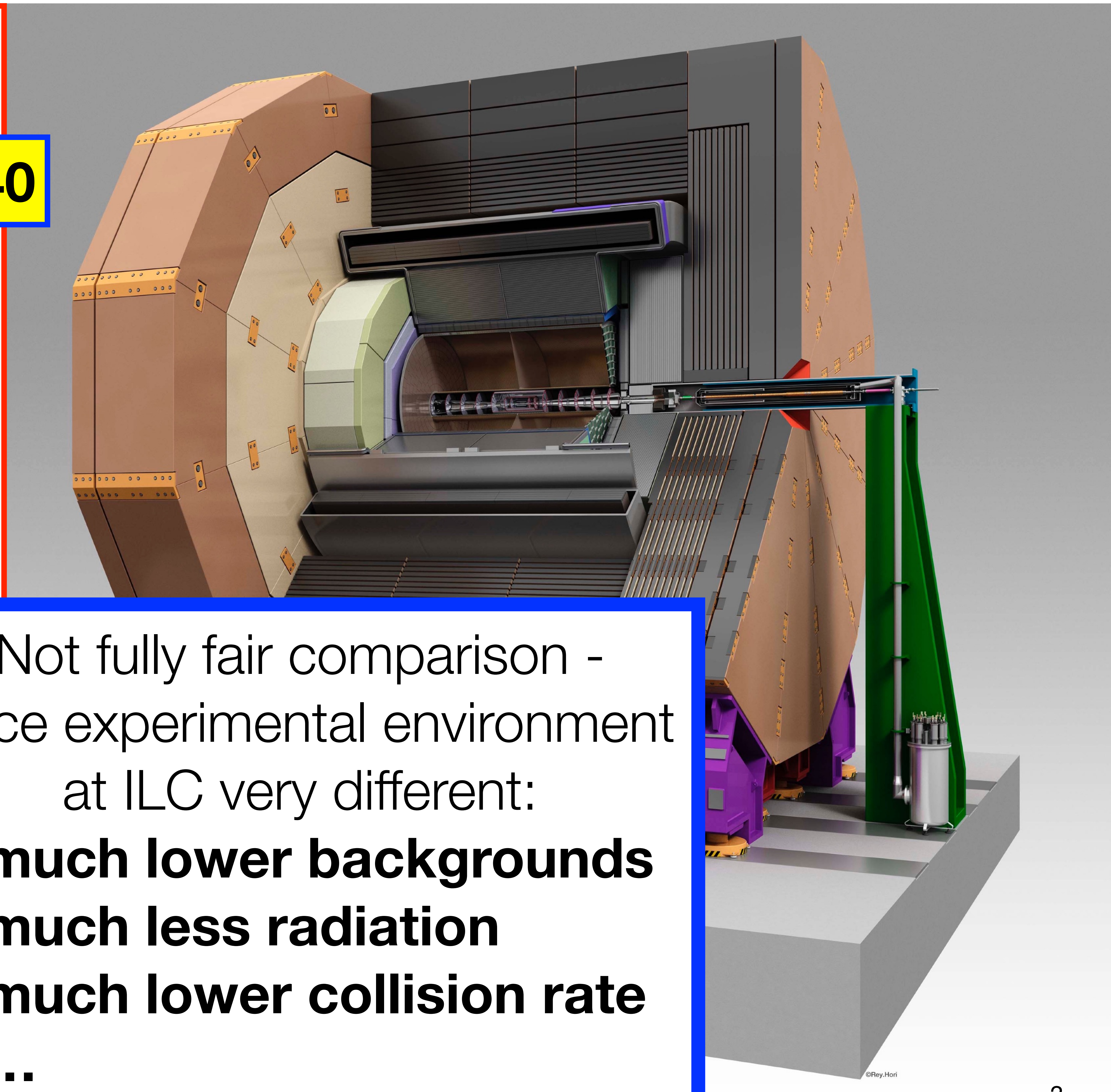

Not fully fair comparison - since experimental environment at ILC very different:

- **much lower backgrounds**
- **much less radiation**
- **much lower collision rate**
- **…**

ILD Members & Activities

68 institutes signed up

ILD Meeting 2018 in Ichinoseki

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Next ILD goal: ILD Design Report = "IDR"

- comprehensive document describing ILD
- especially all developments since the DBD
- basis for real call for LoIs - or legacy documentation?
- executive summary => ILD input to European Strategy
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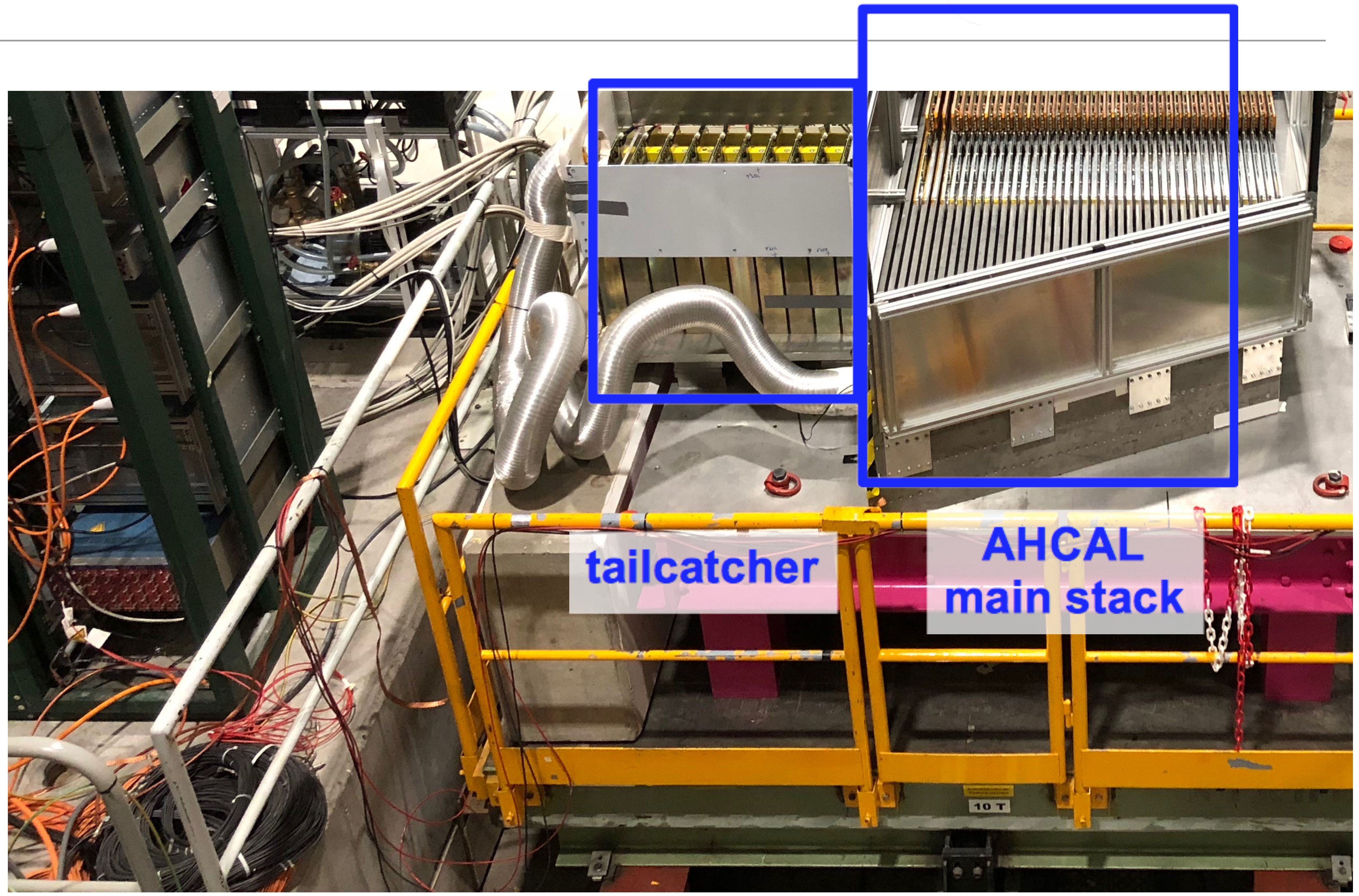
ILD Meeting 2018 in Ichinoseki

Oct 19-21, UT Arlington:
ILD Benchmarking Days

Highlight of Detector R&D: Calorimeter Testbeams

AHCal: 3 weeks at CERN-SPS with new large prototype



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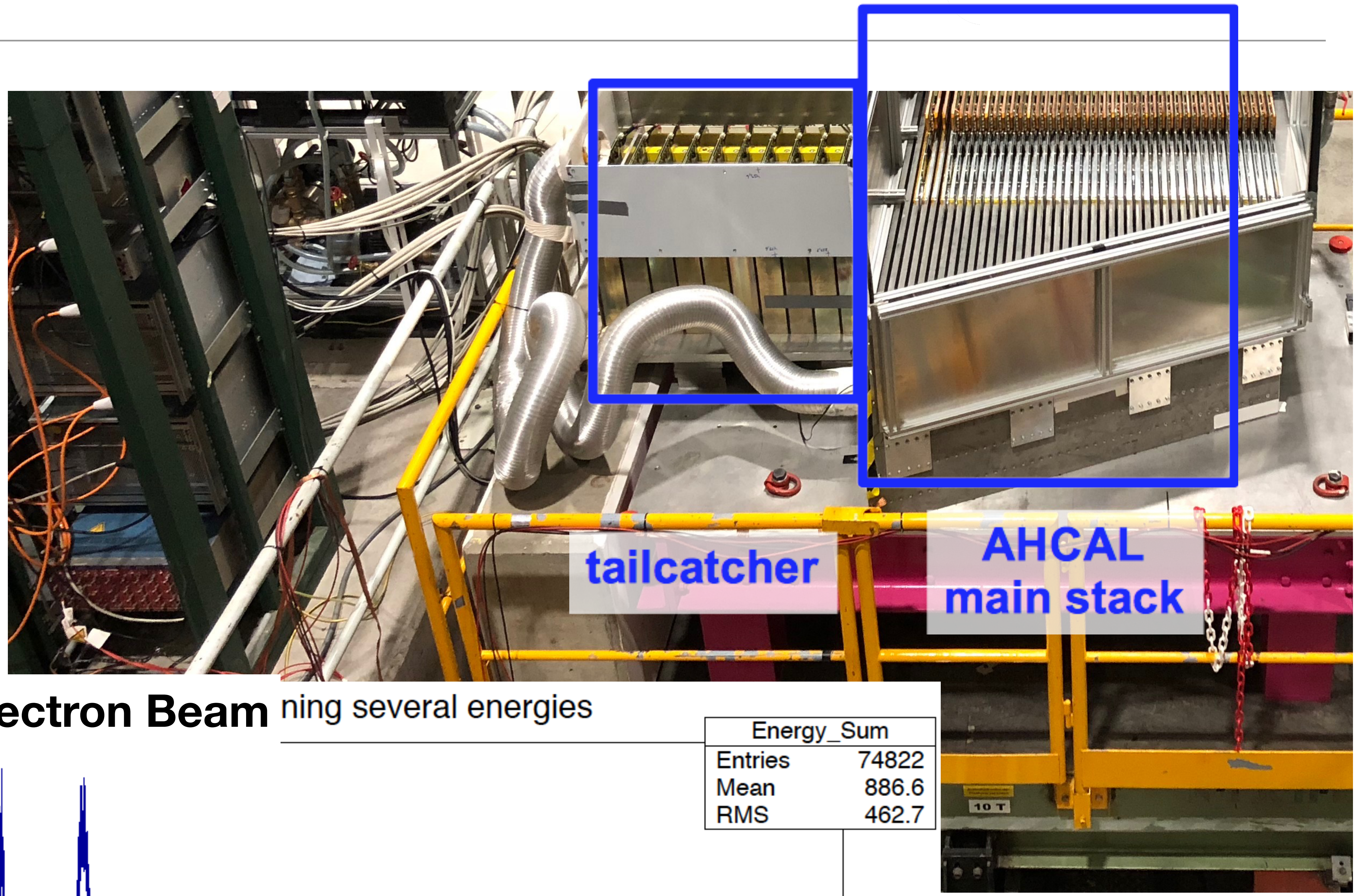

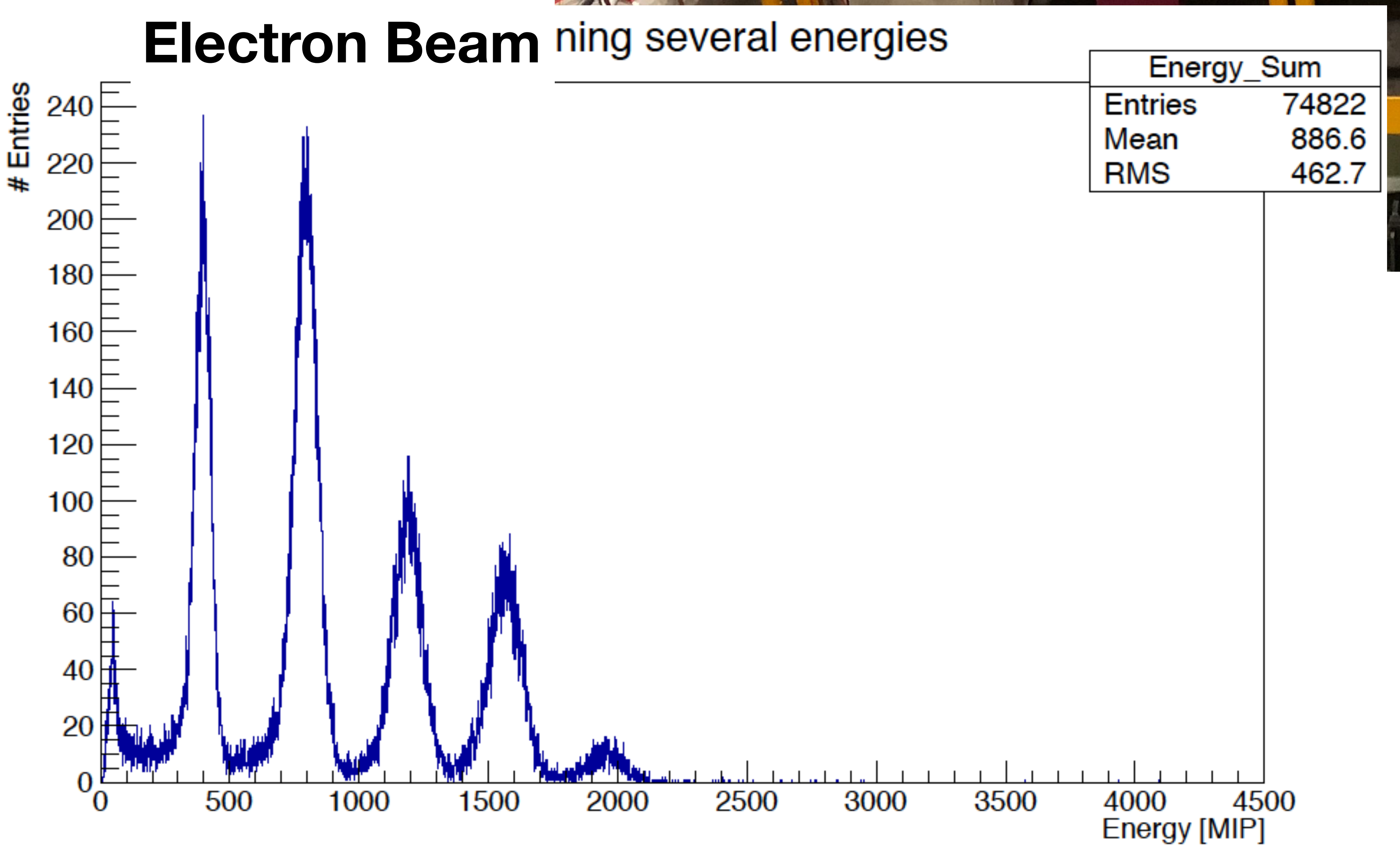

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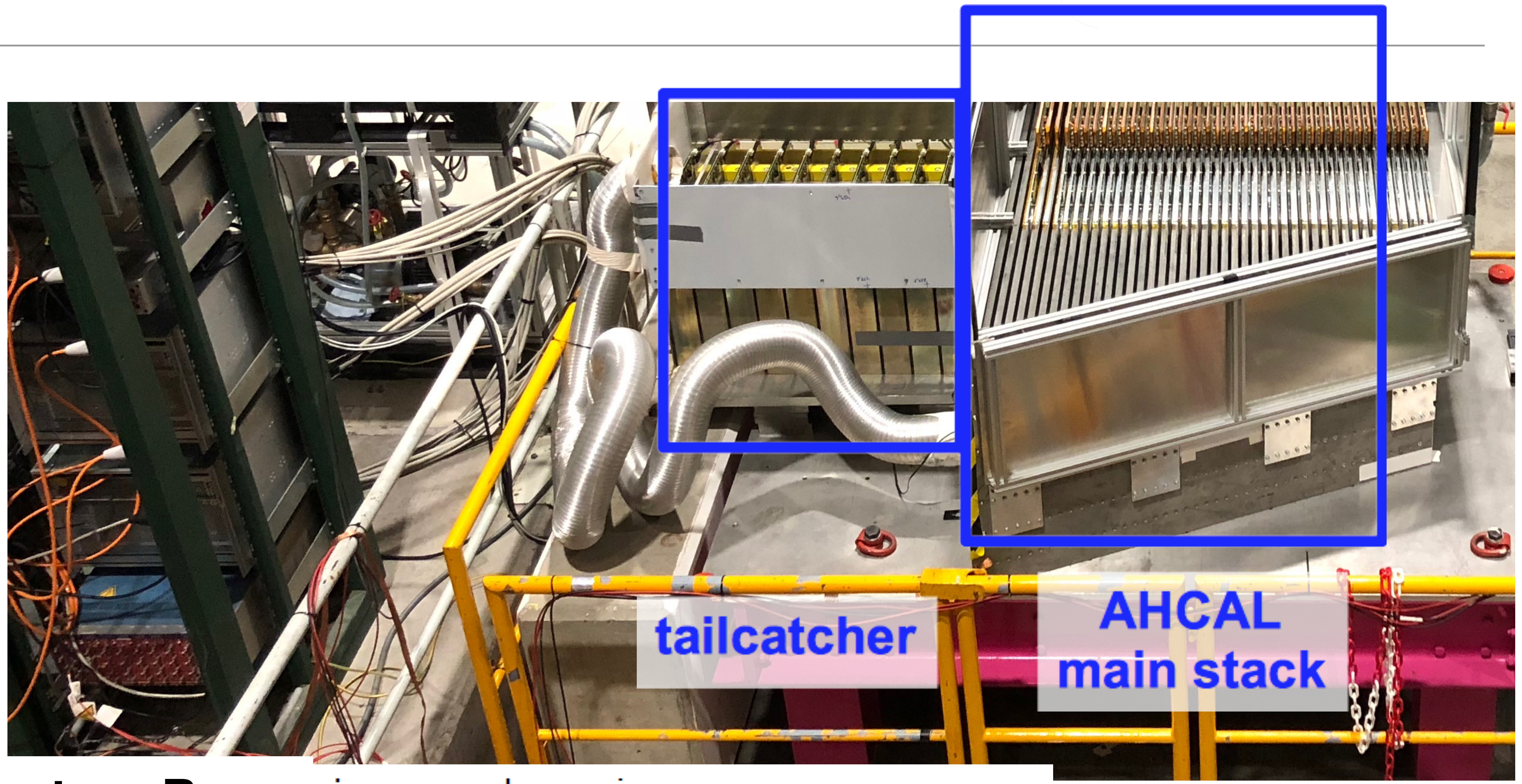

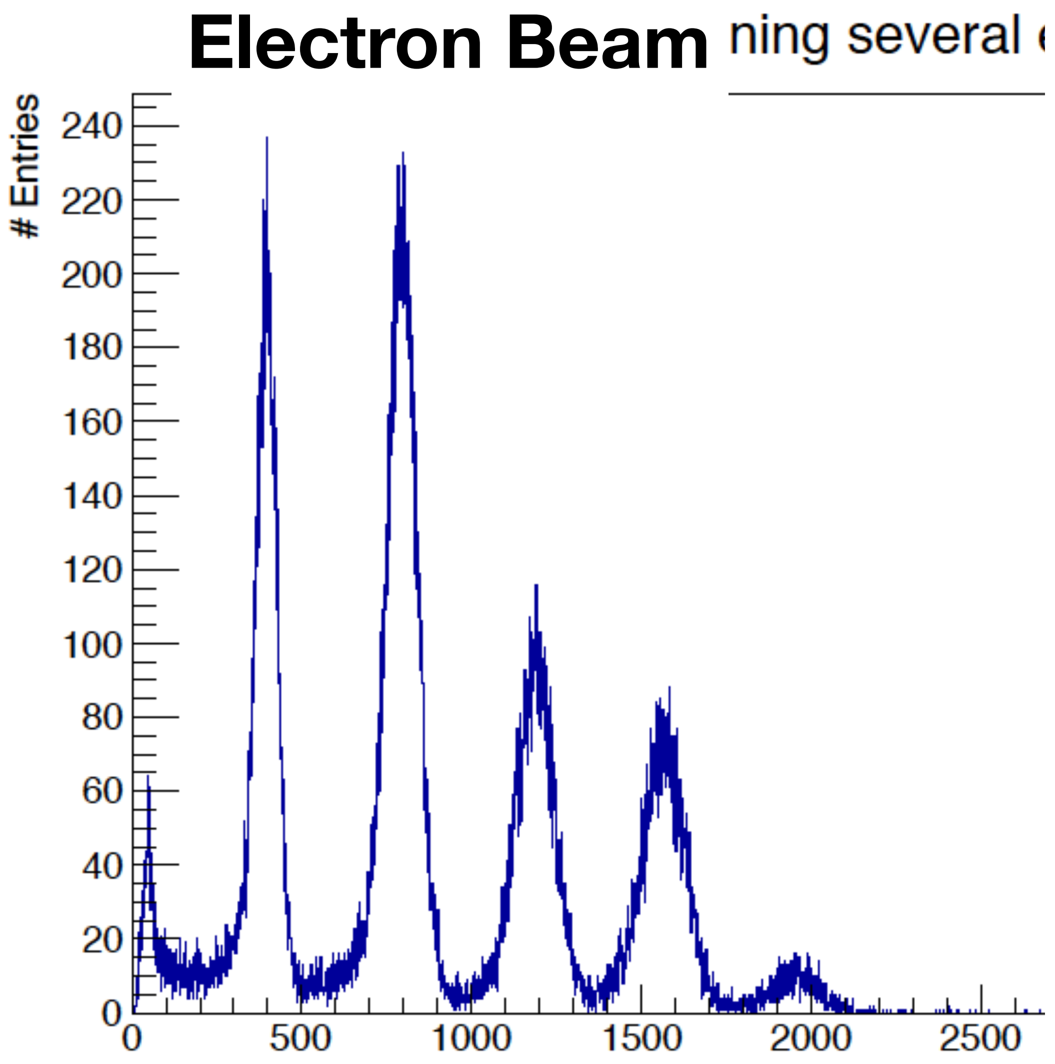

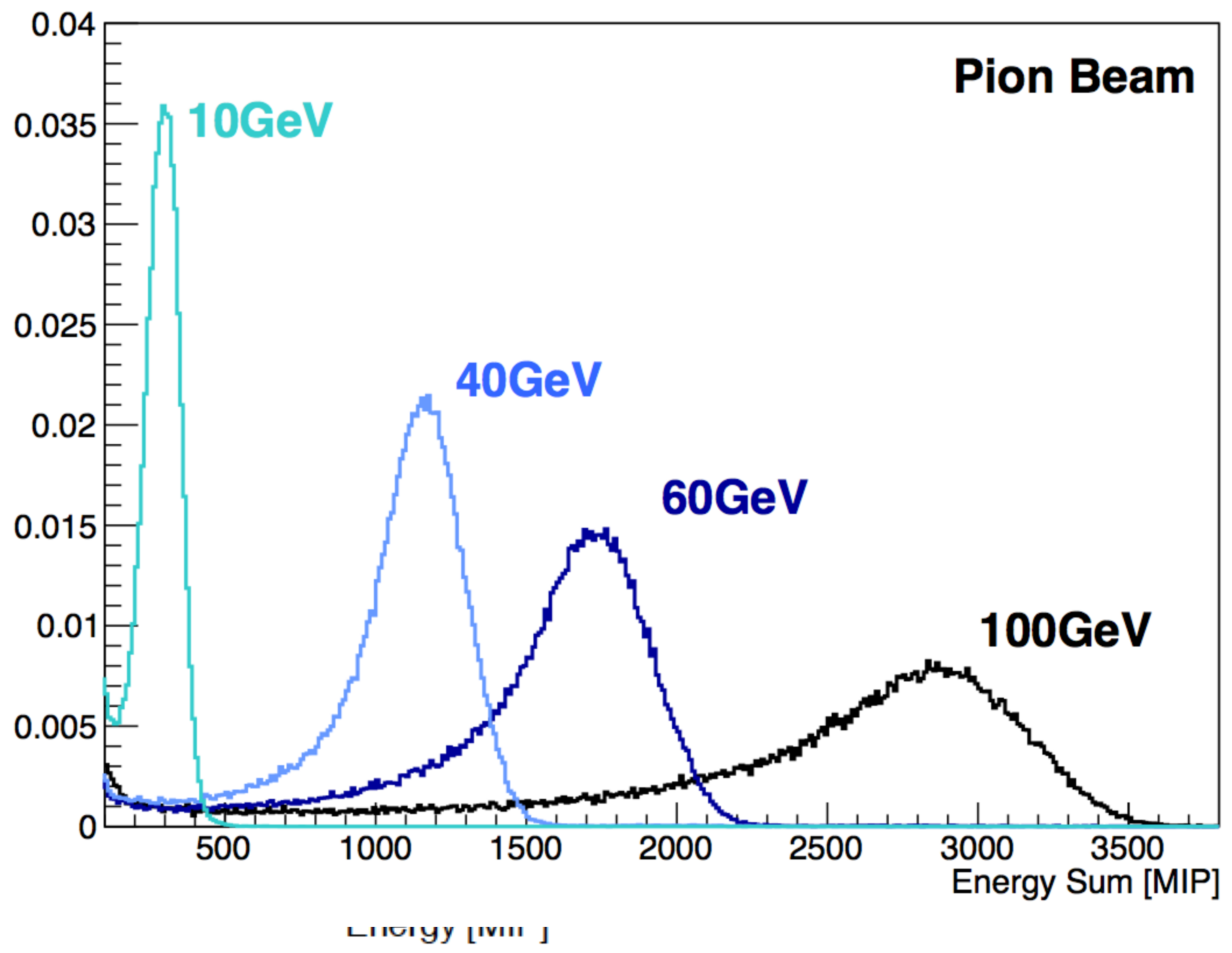

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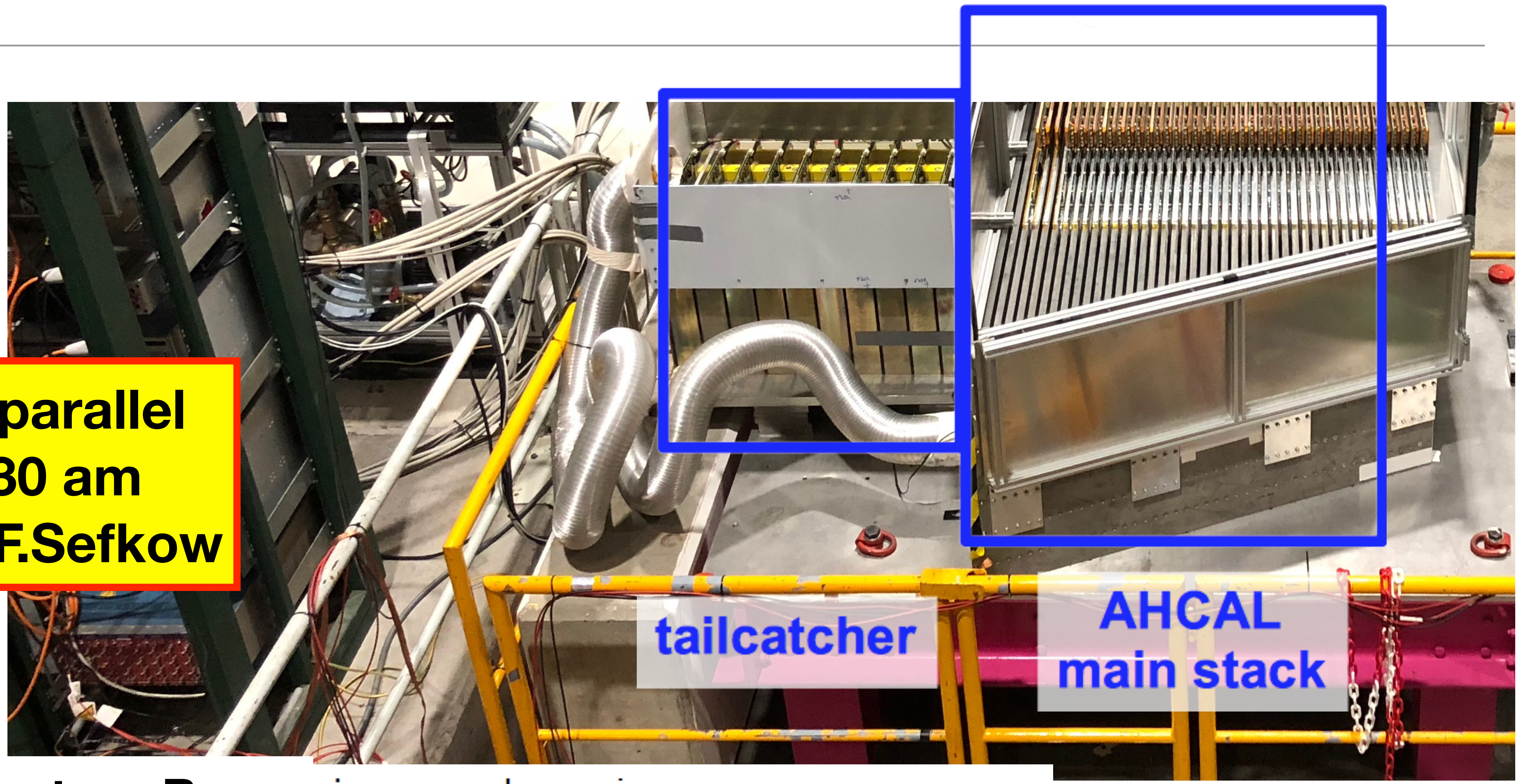
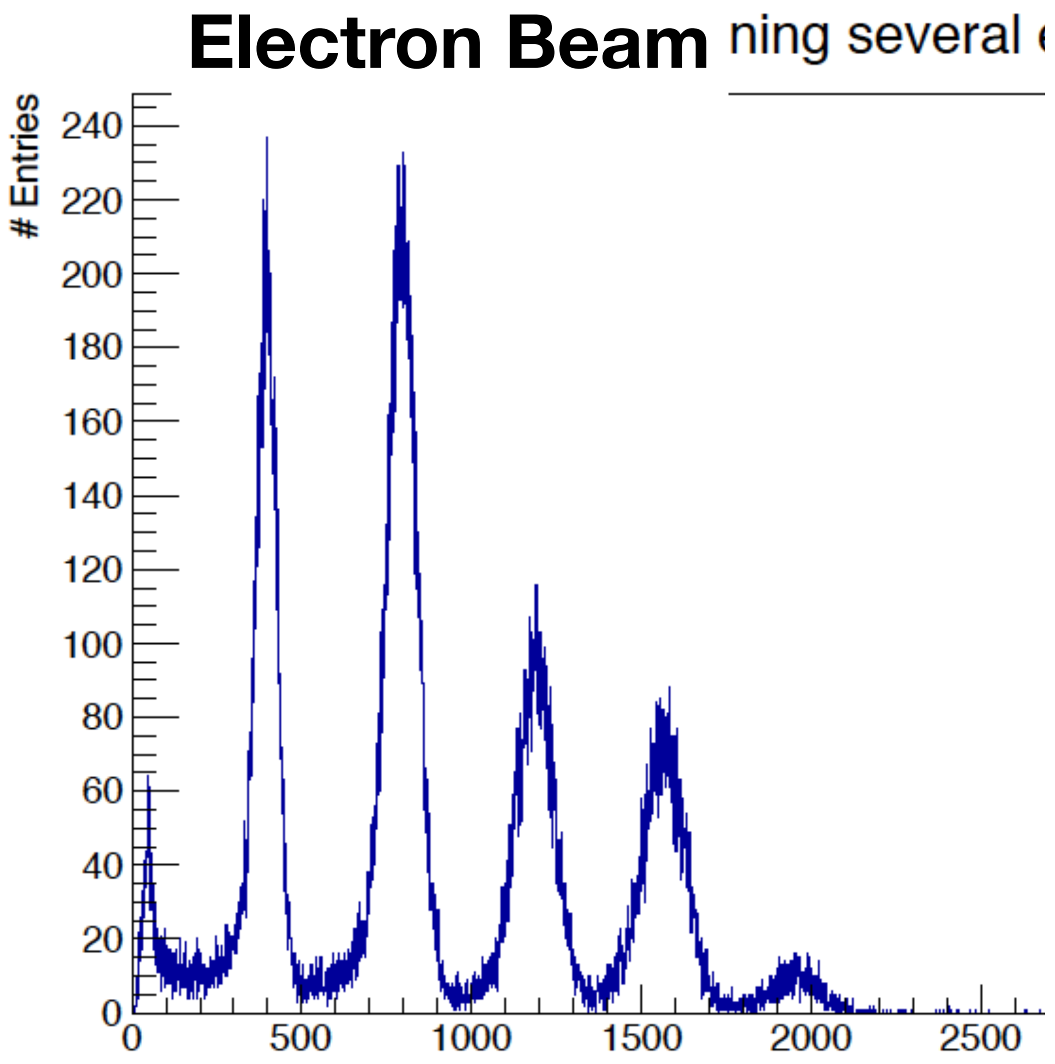
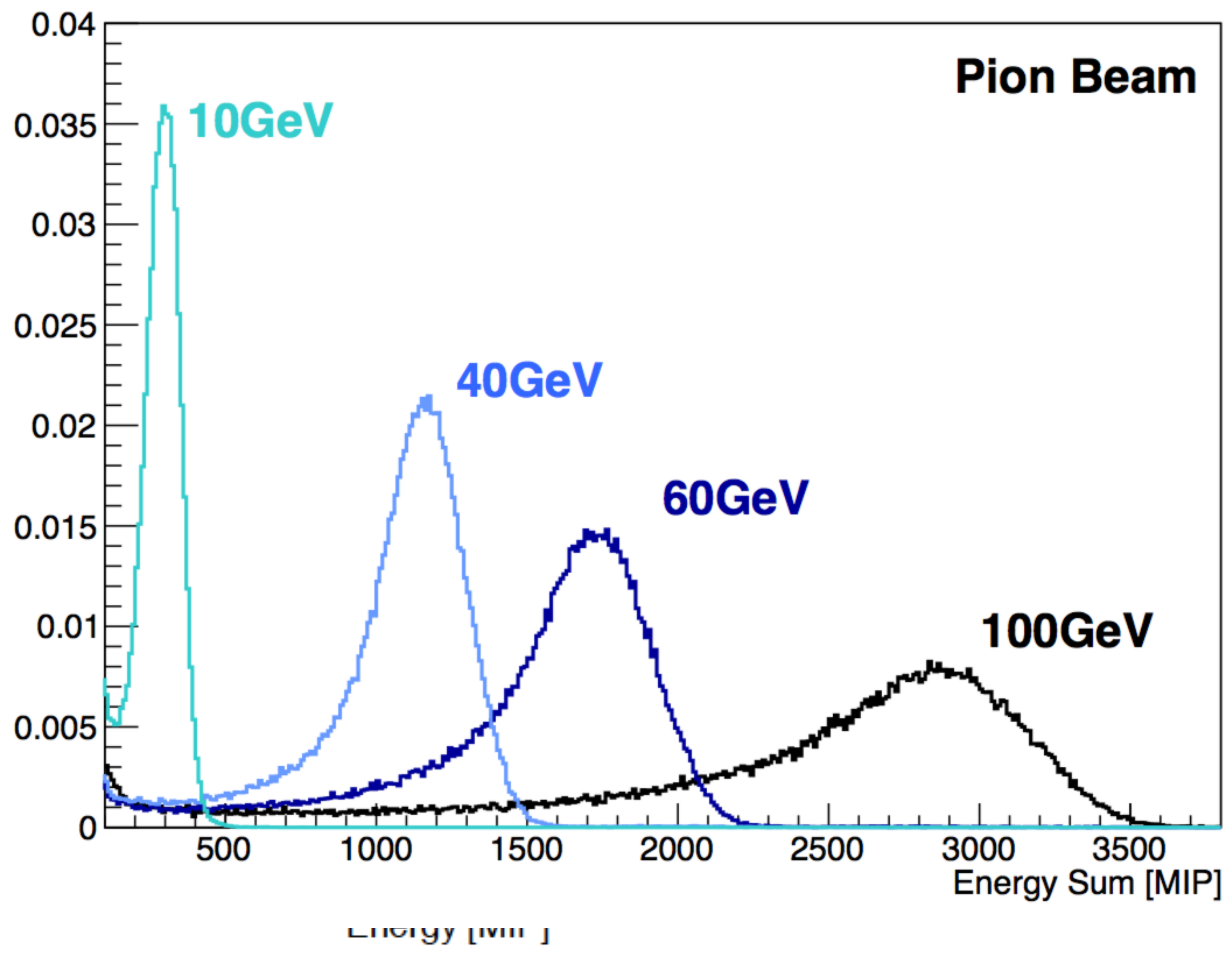
c.f. Calo parallel Wed 8:30 am K.Krüger, F.Sefkow







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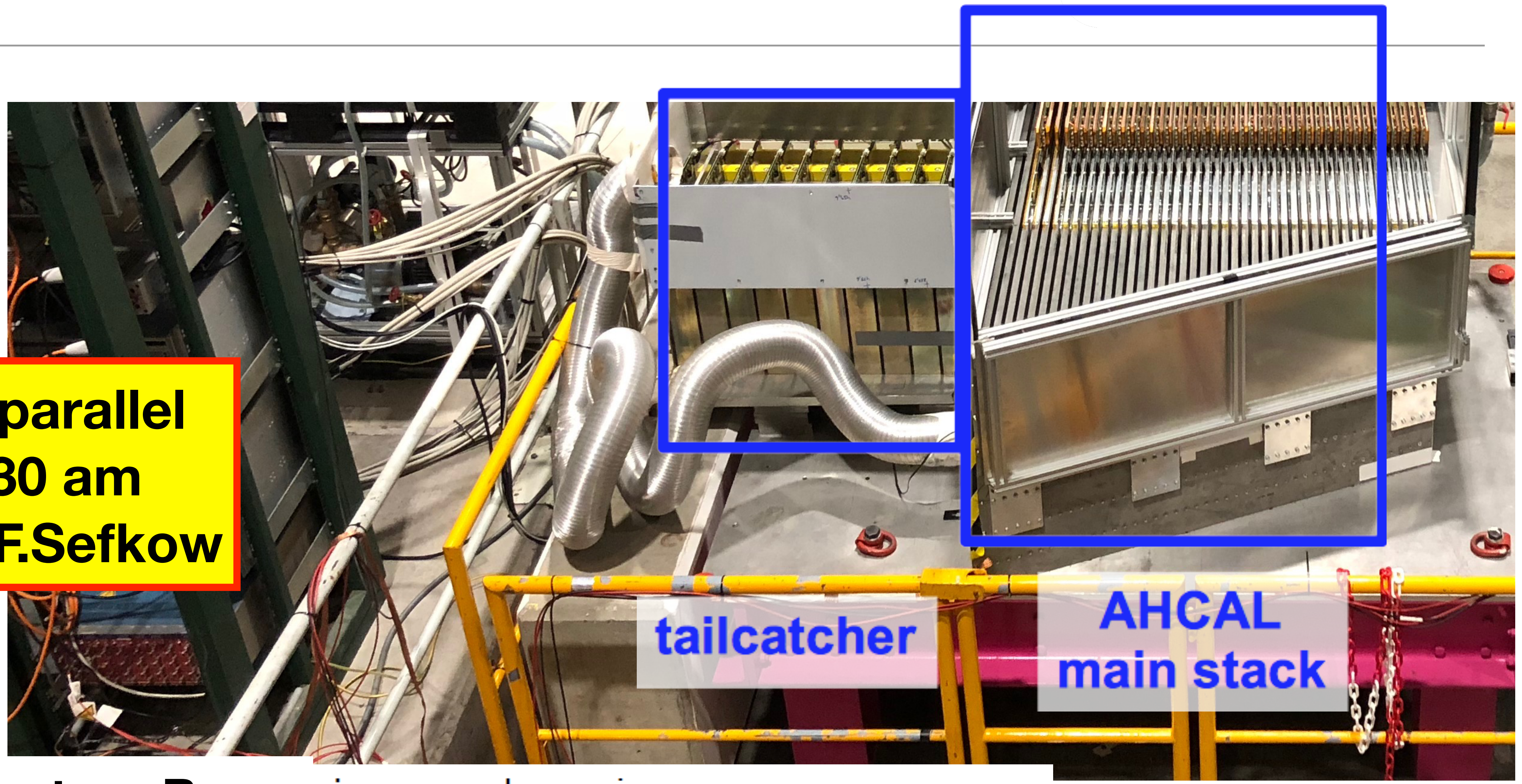

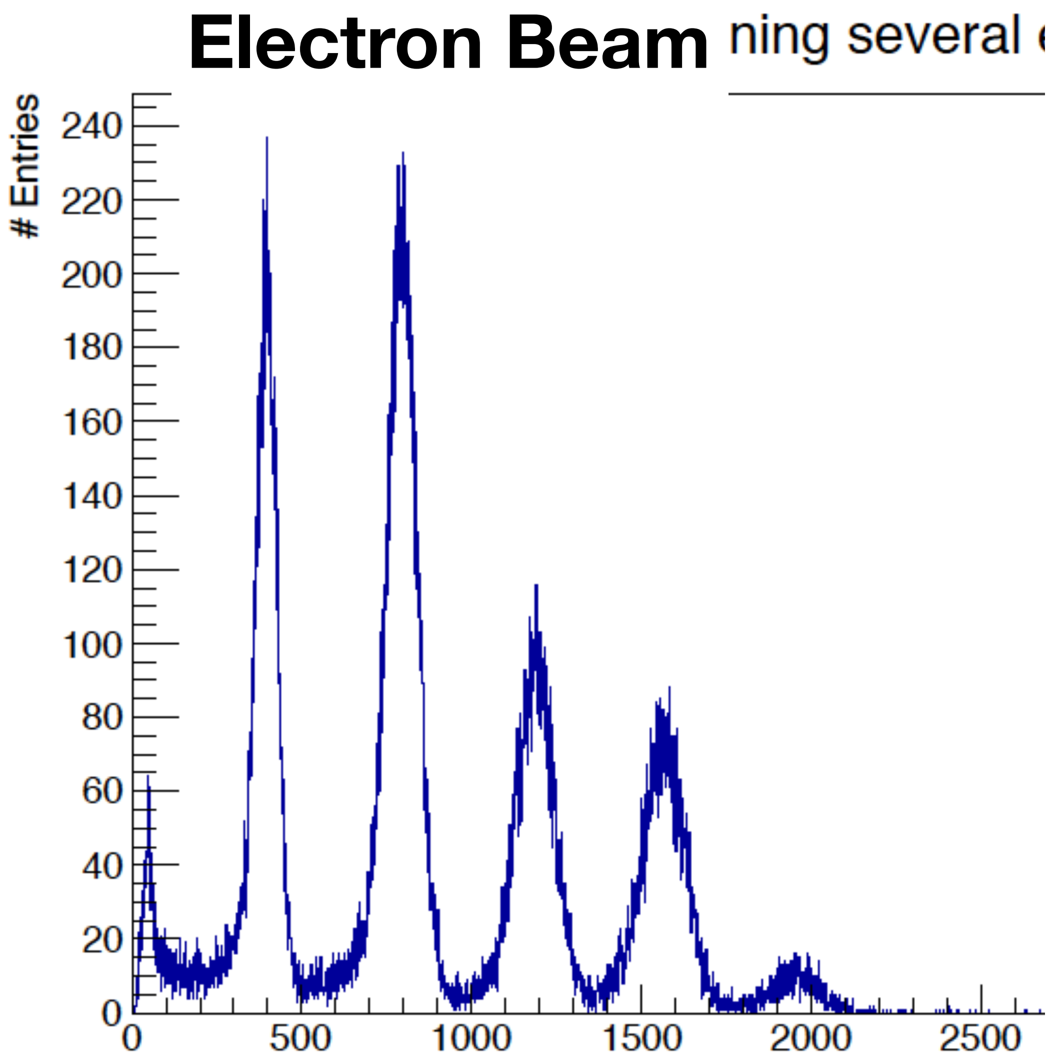

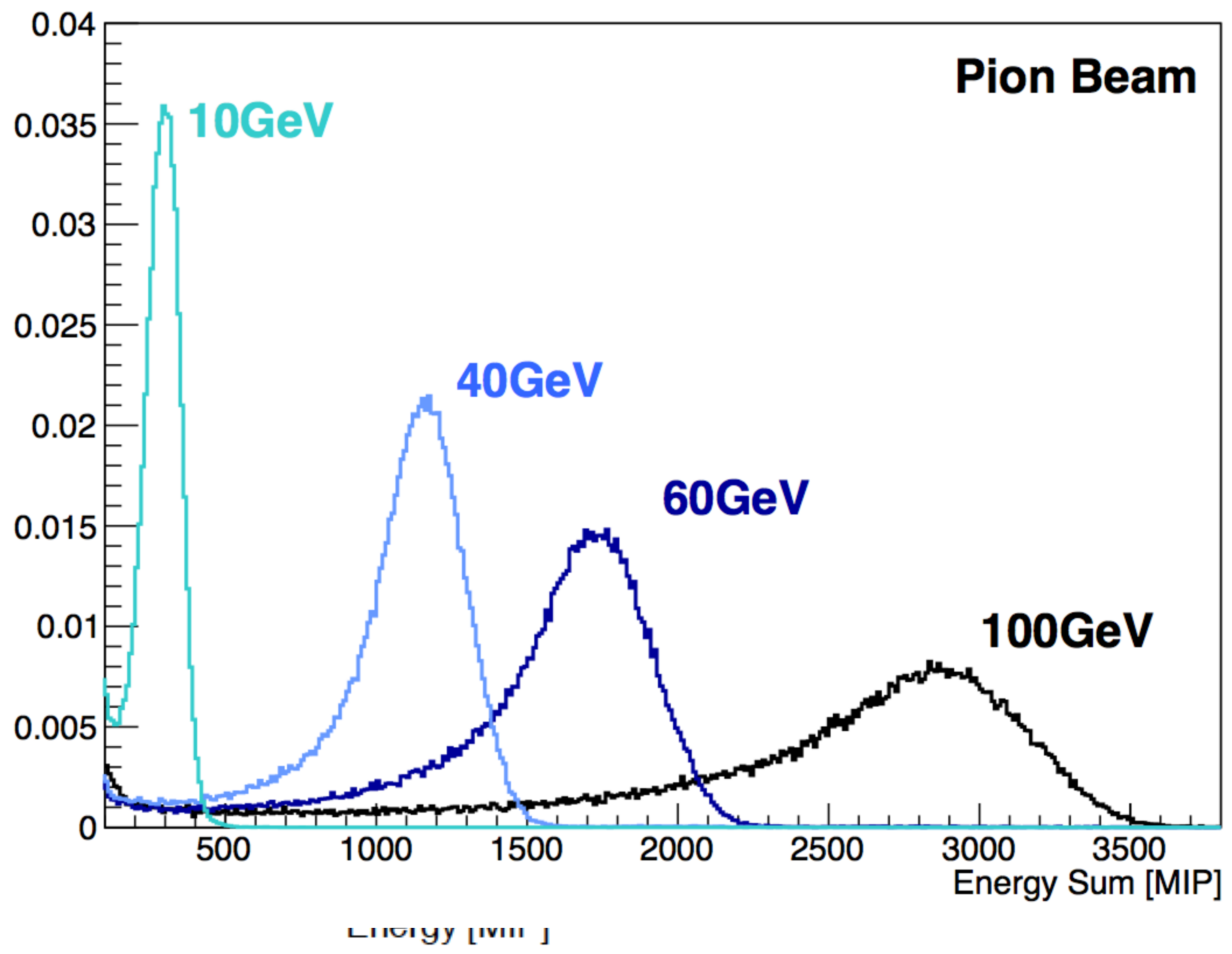

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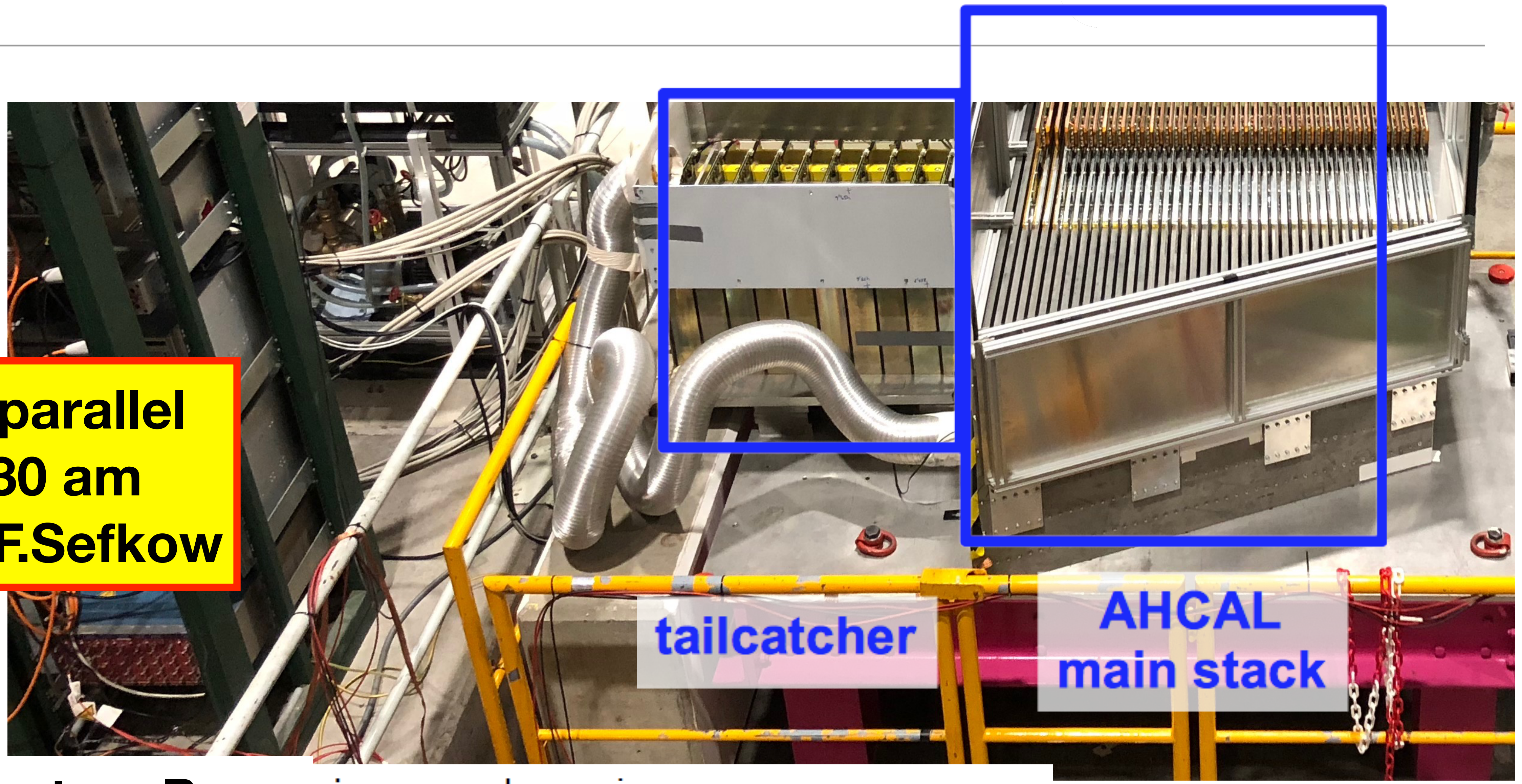
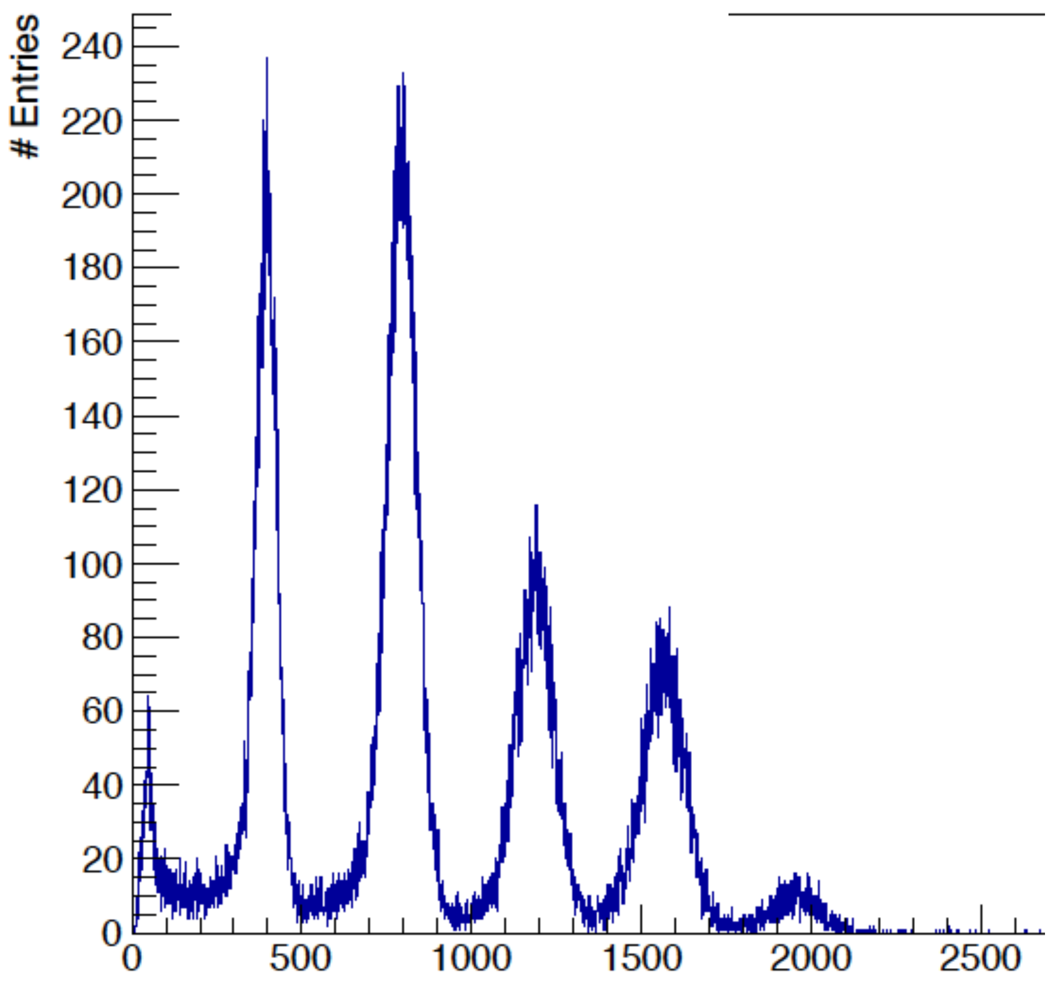
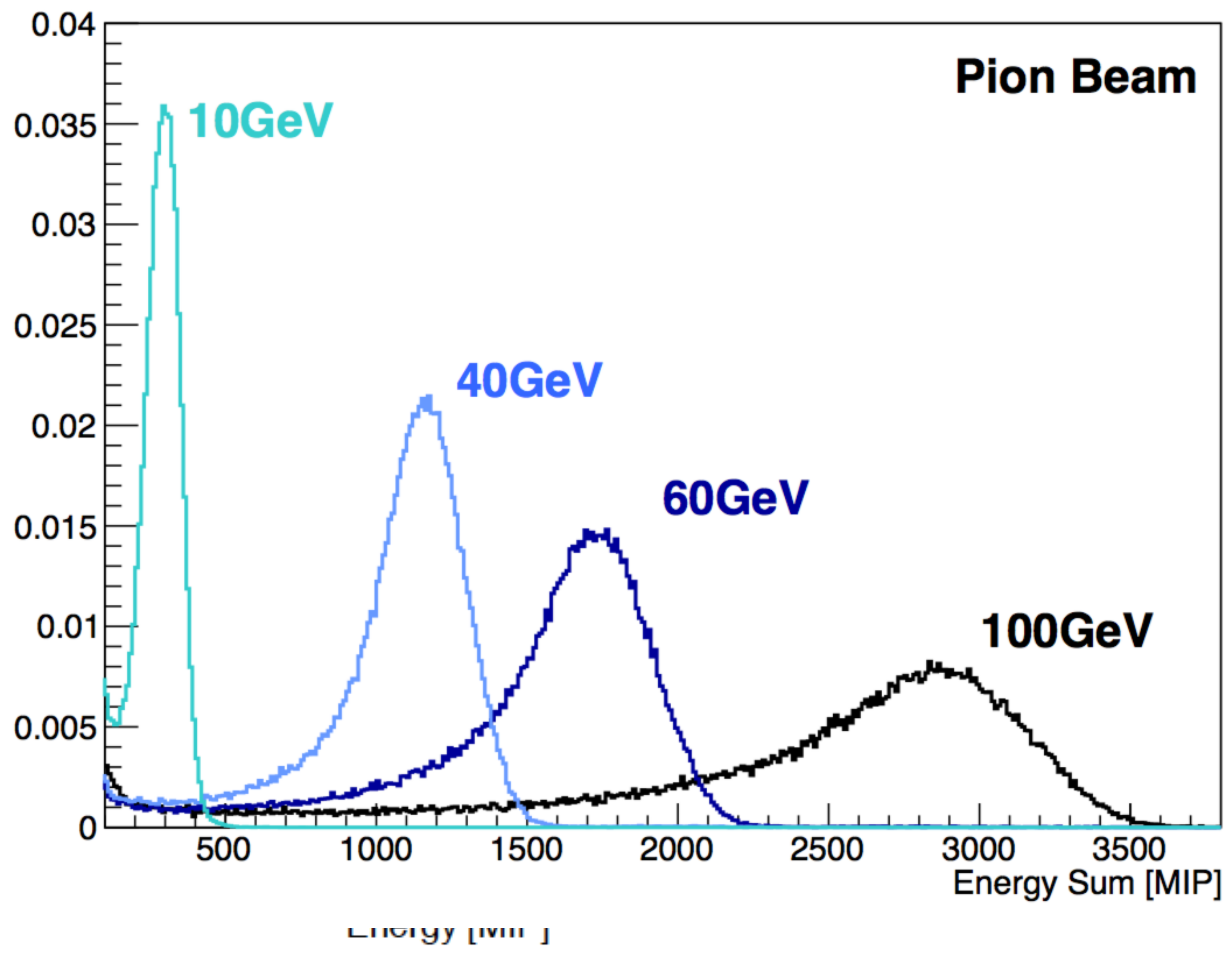


c.f. Calo parallel Tue 2 pm

Electron Beam ning several





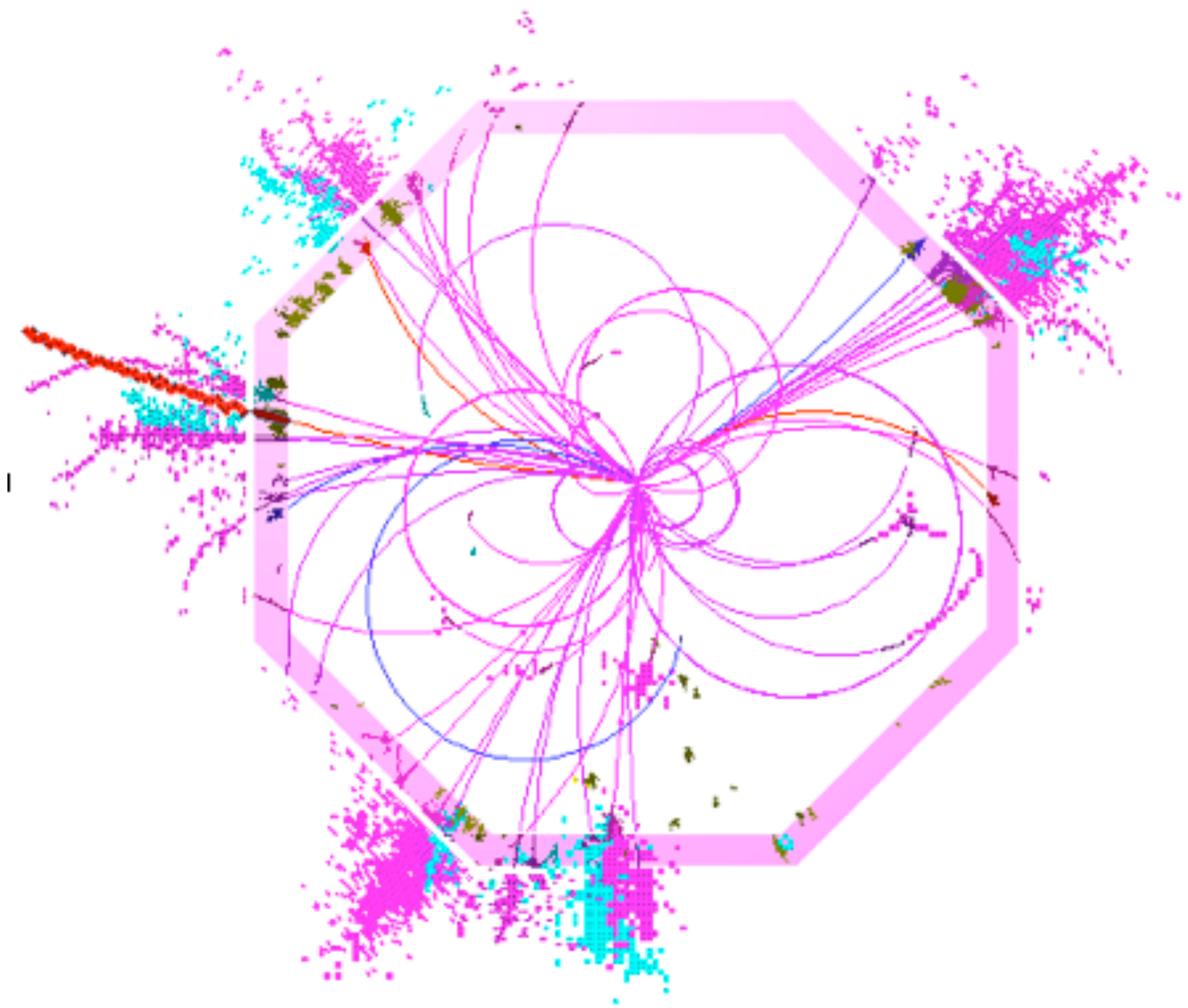
ILD Performance:
Understanding and Optimising

Motivation

ILD as in the DBD

- **is well thought-through detector design**
- **delivers the required physics performance**

=> why bother about optimisation?



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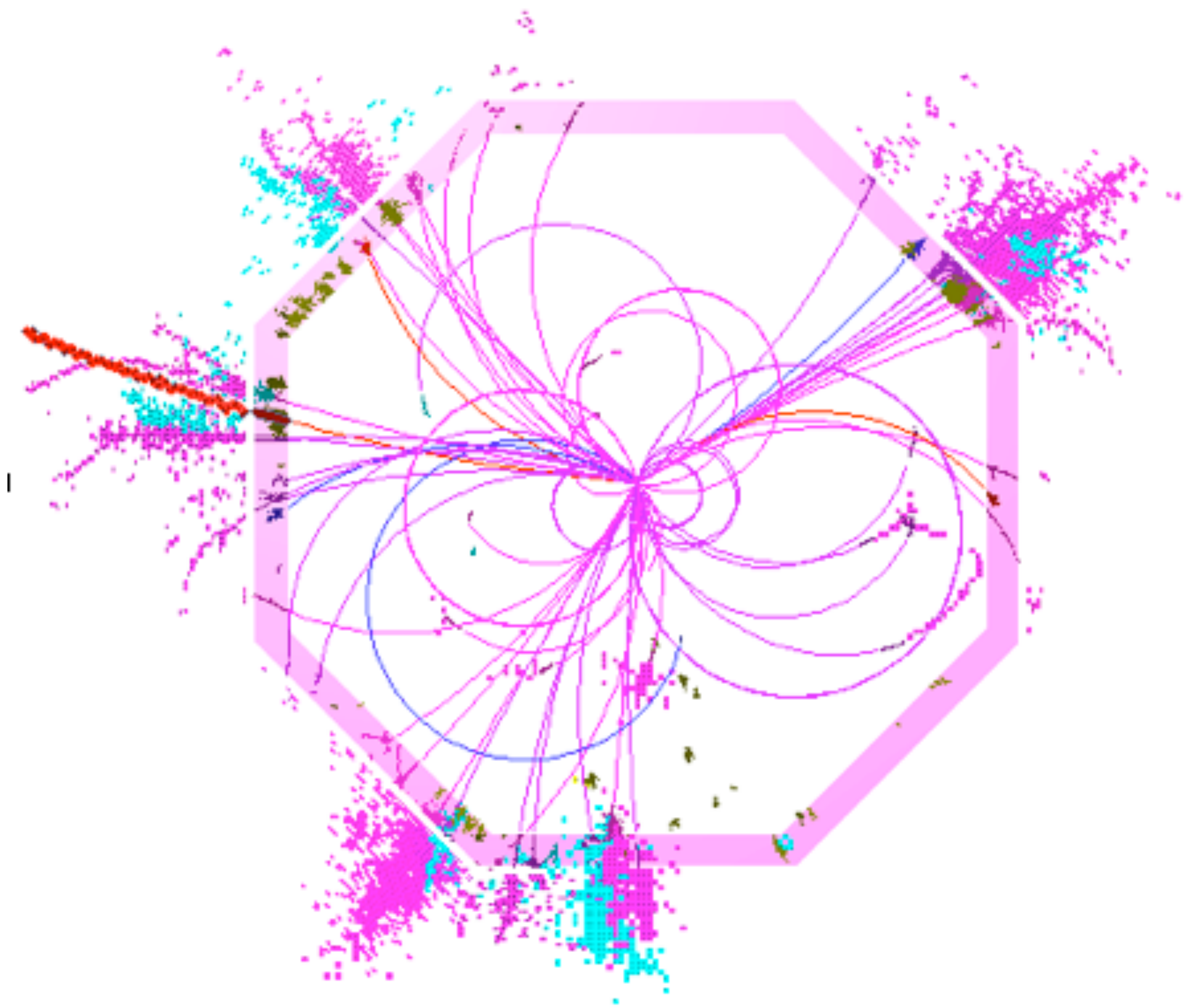
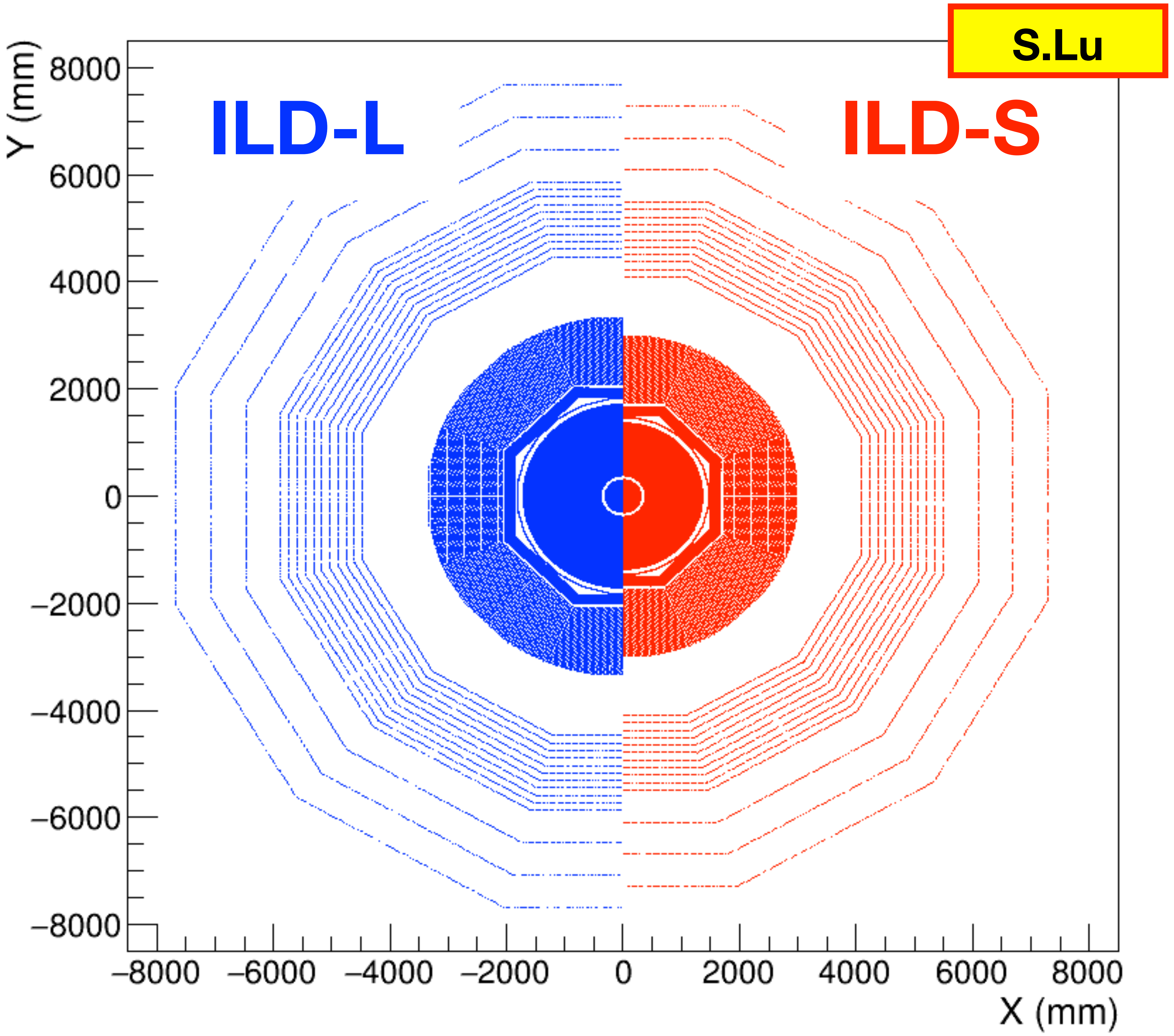


Goals of current optimisation process:

- **how large is "Large"?**
- understand better the **dependence of physics performance on** various (high-level) **detector performance** aspects
- **quantify** expected **gain** from possible **improvements** of the detector, e.g. ToF, new vertex geometry, …
- **identify limiting factors** in detector design and/or reconstruction and quantify their impact

2018 MC Production for Detector Optimisation

- **completely new detector simulation** based on DD4HEP:
  - **large detector "ILD-L": R_{TPC} = 1.8 m, B = 3.5 T**
  - **small detector "ILD-S": R_{TPC} = 1.46 m, B = 4 T**
- general **overhaul of reconstruction**
- … and adding further realism
- Spring 2018: first large scale MC production
  => thanks to ILD MC production team!
- **full SM @ 500 GeV,** plus some 1 TeV, **both detectors**
- based on events generated for DBD (Whizard 1.95)



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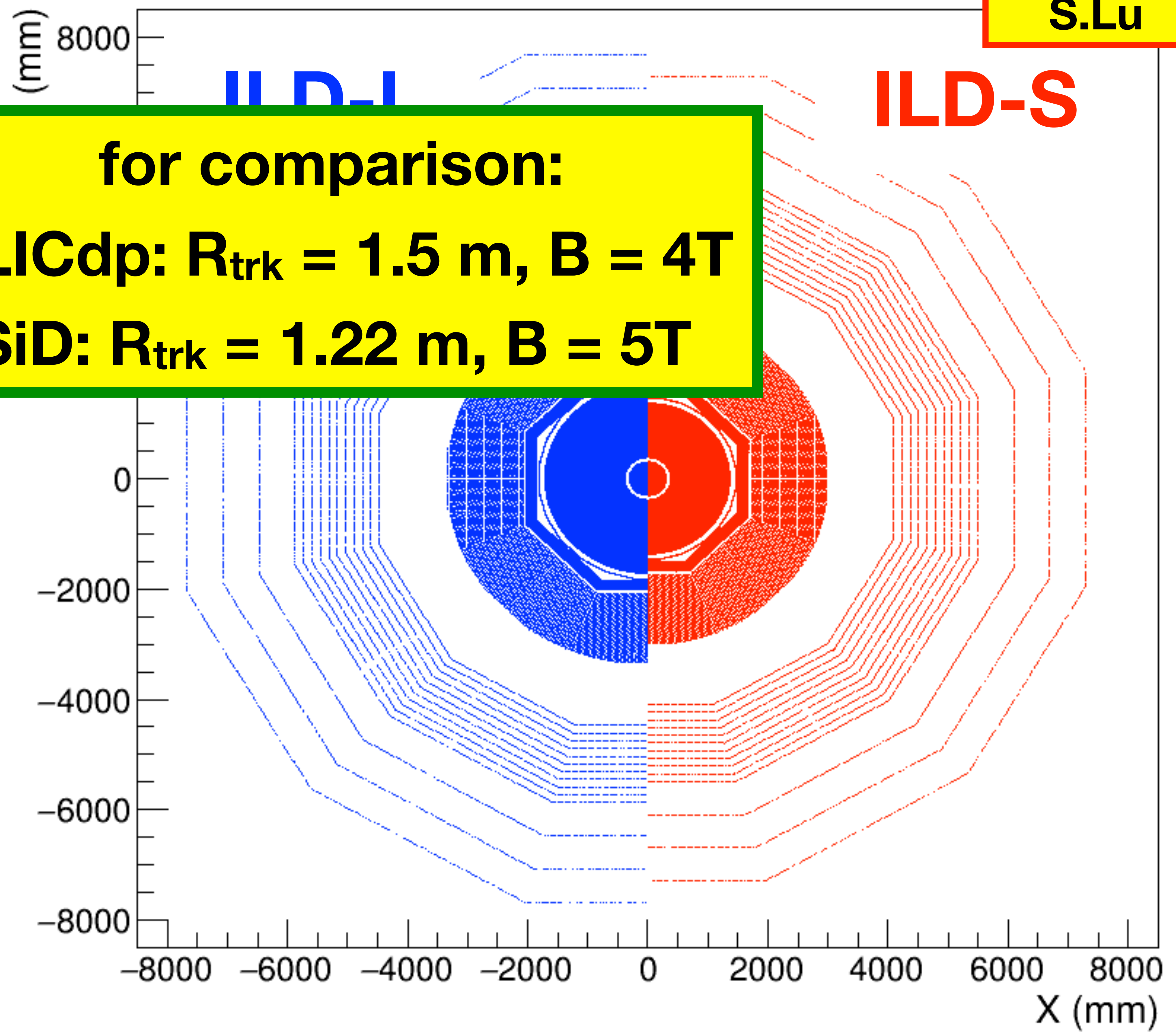

for comparison:
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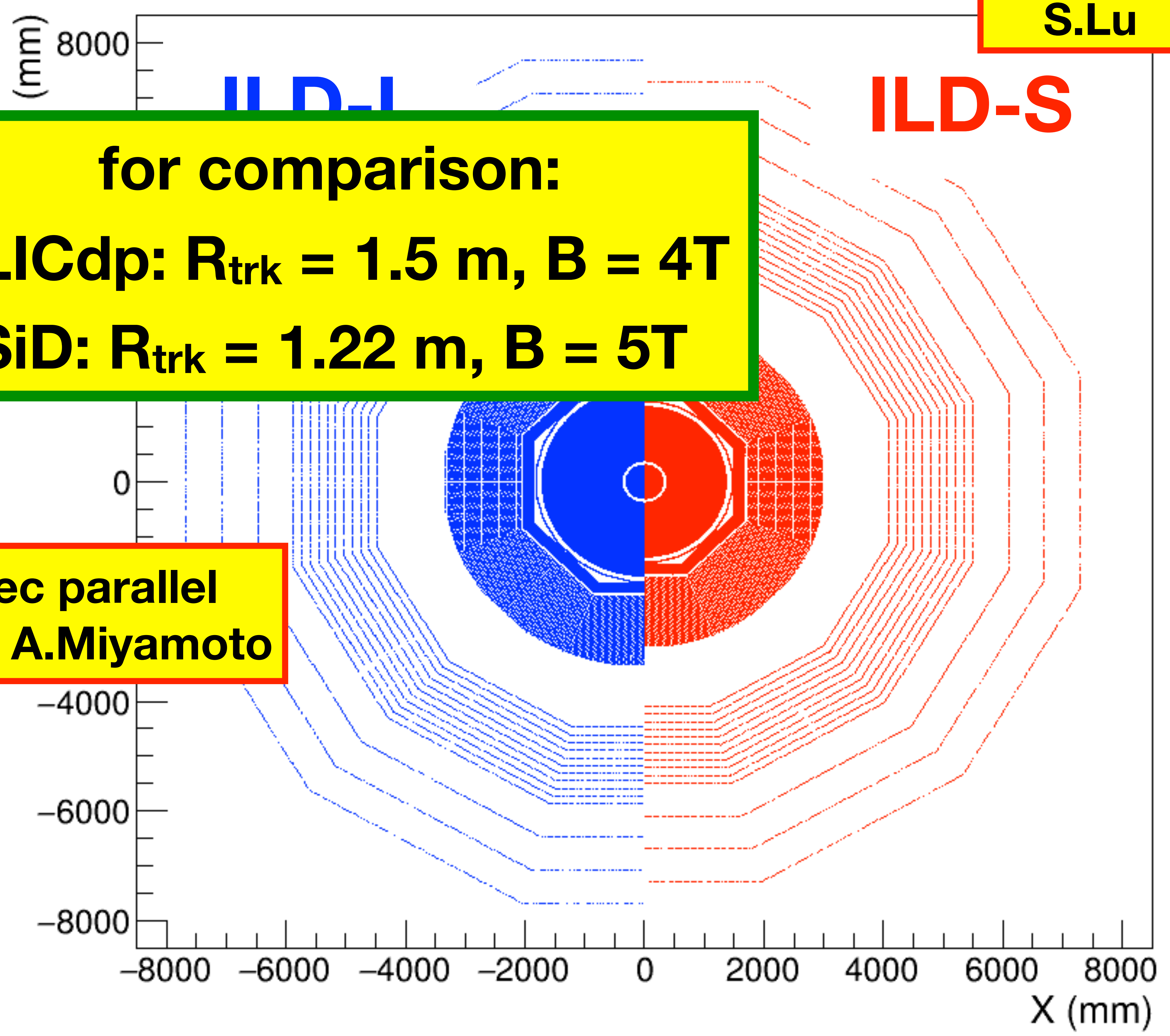

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Tue 4:30 pm, A.Miyamoto

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next step (post-IDR): 250 GeV with Whizard 2

c.f. Sim/Rec parallel
Tue 4:30 pm, A.Miyamoto

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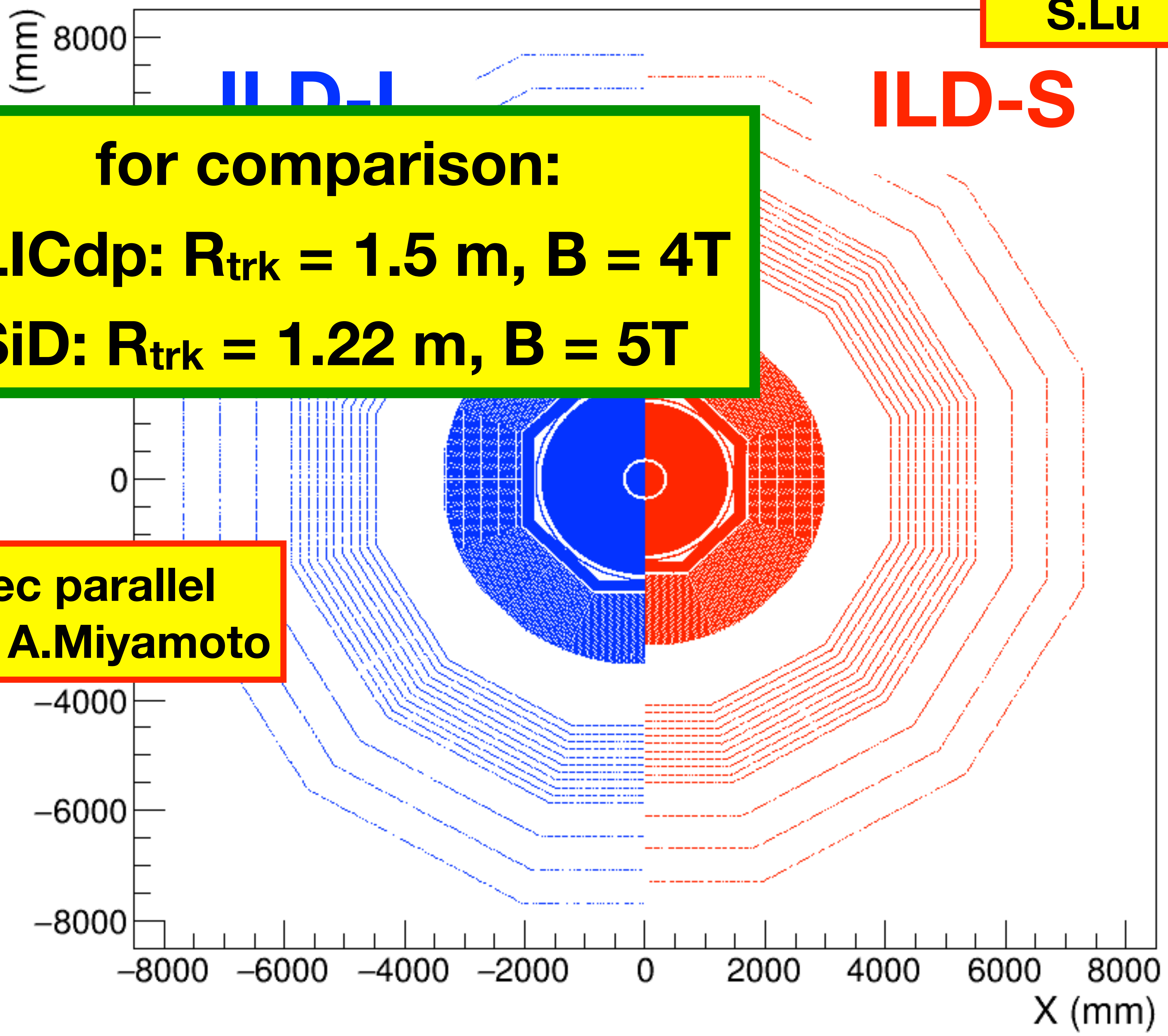


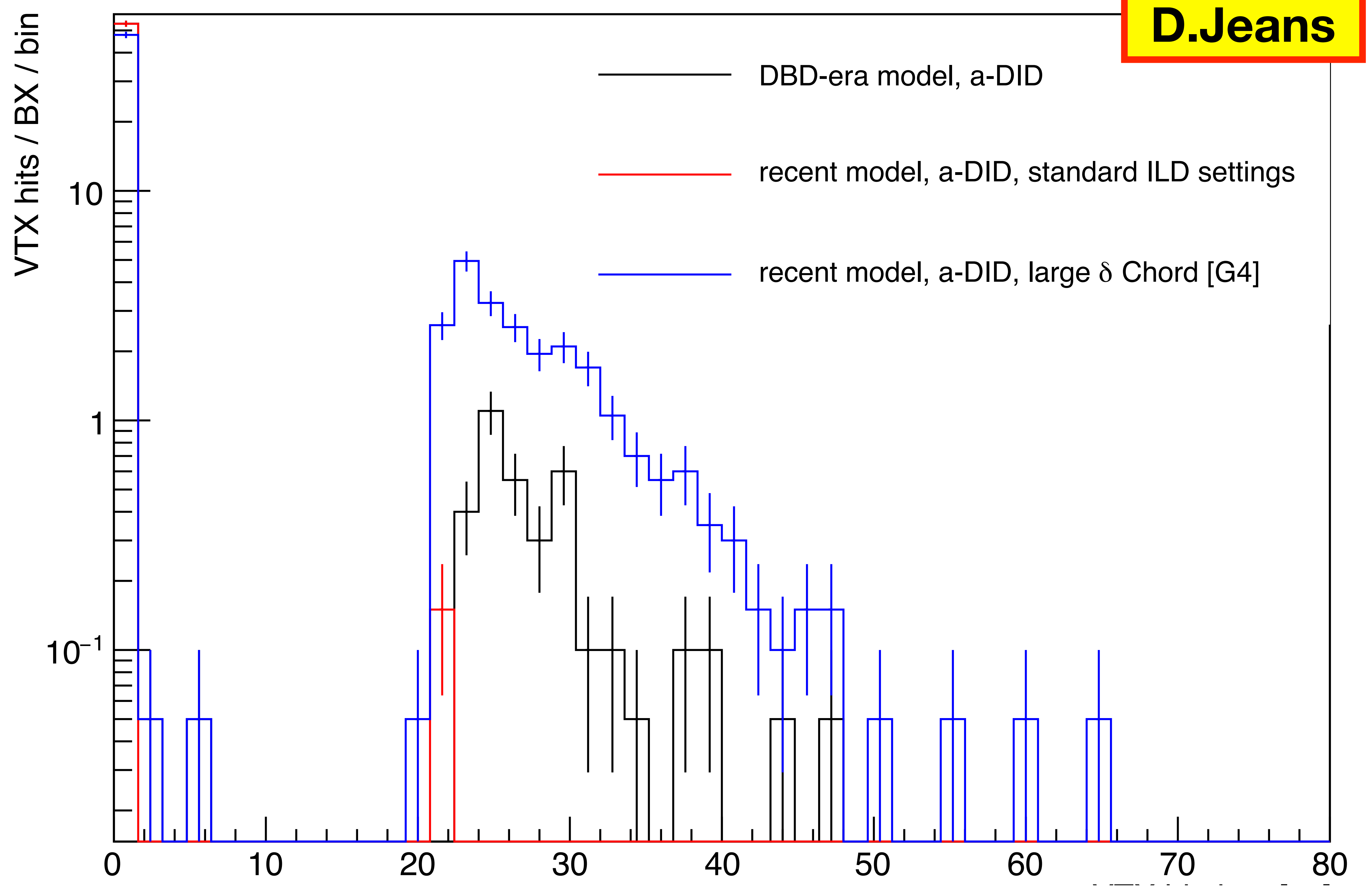
Design of forward region: antiDID or no antiDID?

DBD-ILD includes an antiDID field

- guides e^+e^- pairs from beamstrahlung down the beam pipe
- reduces "blind region" of BeamCal -> hermeticity!
- reduces back-scatter into vertex detector

Question: really needed / worth the effort?

D.Jeans



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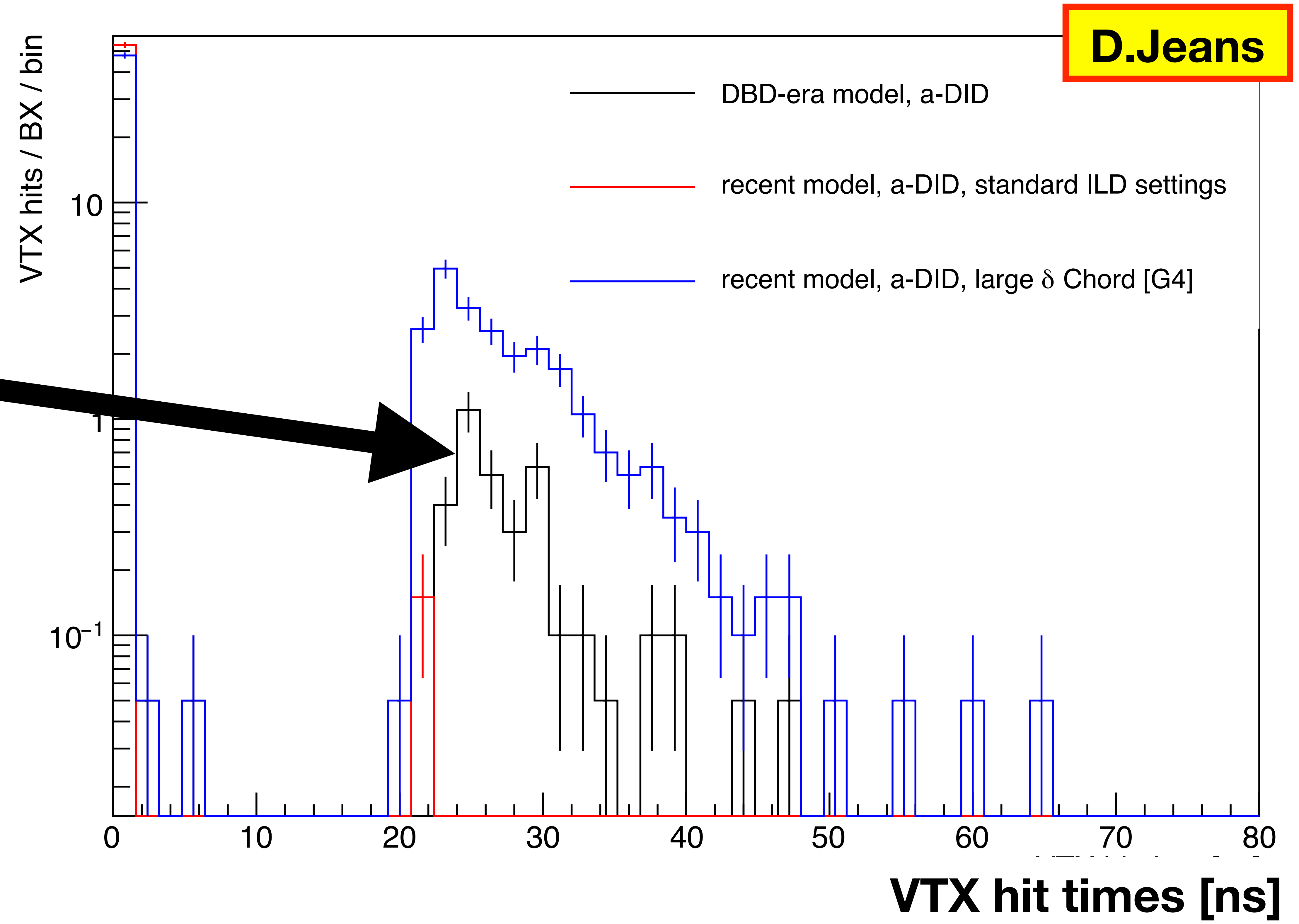

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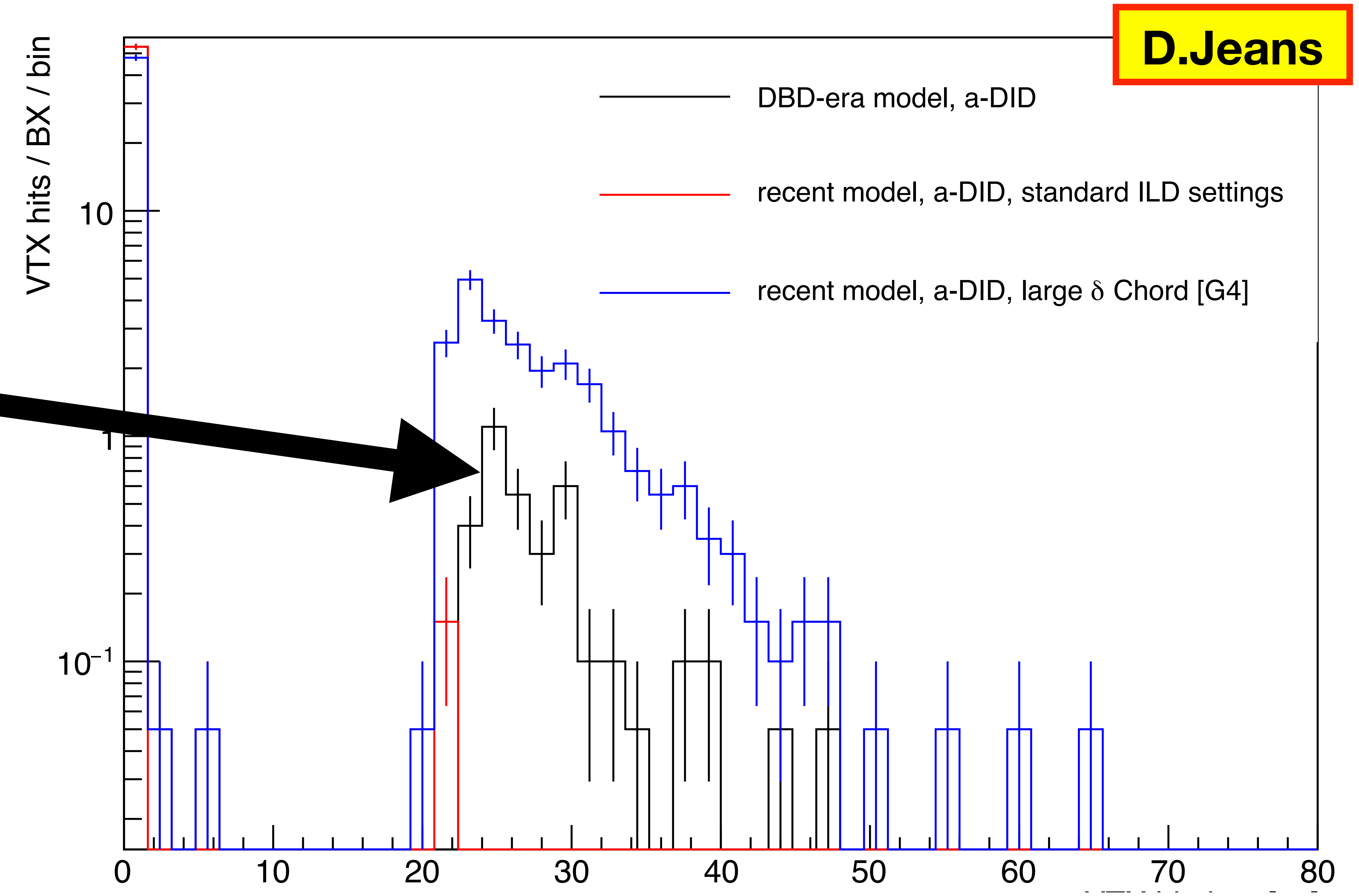

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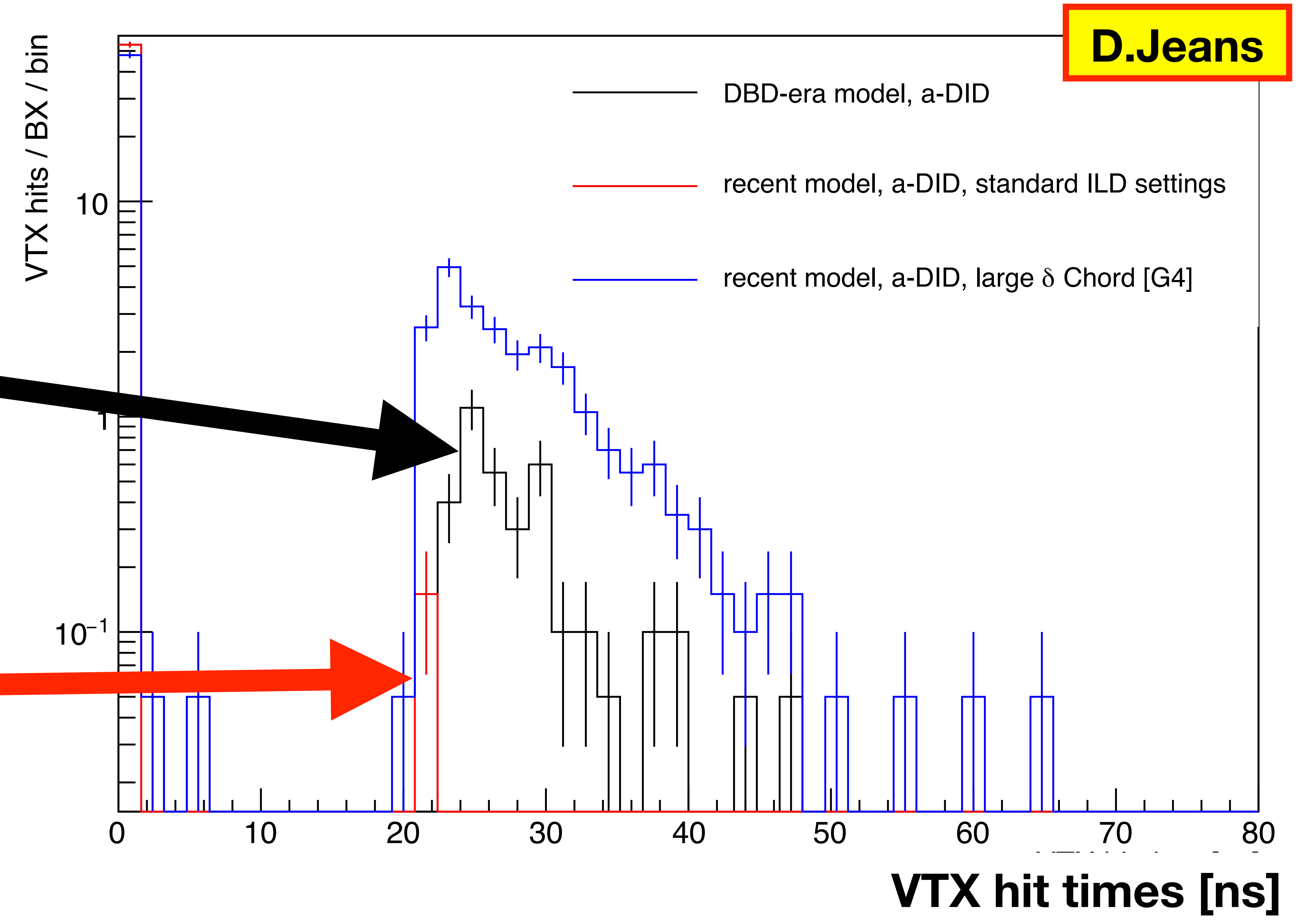

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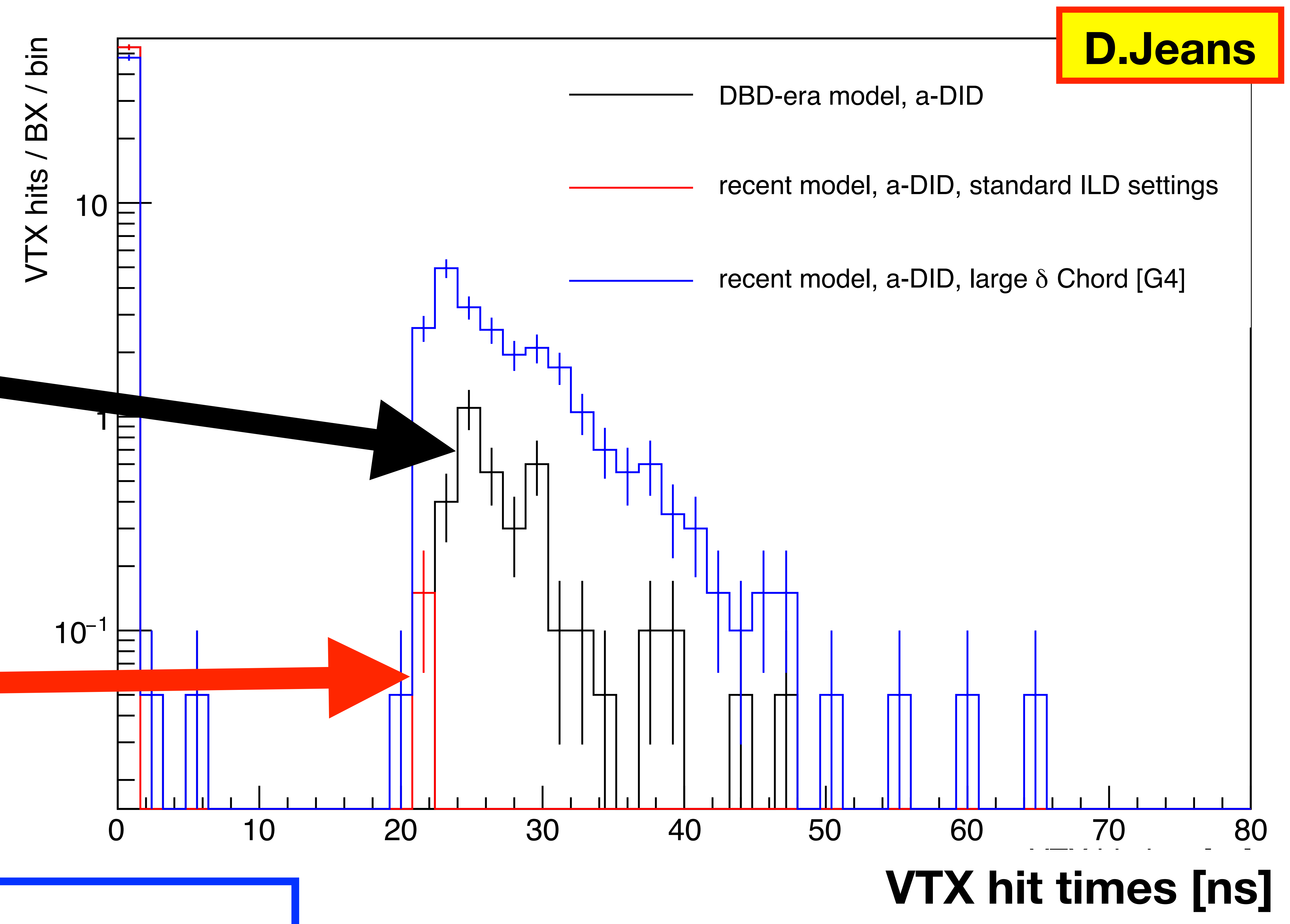

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- makes curling **particles stop artficially**
- post-DBD results shown at previous meetings need to be revisited

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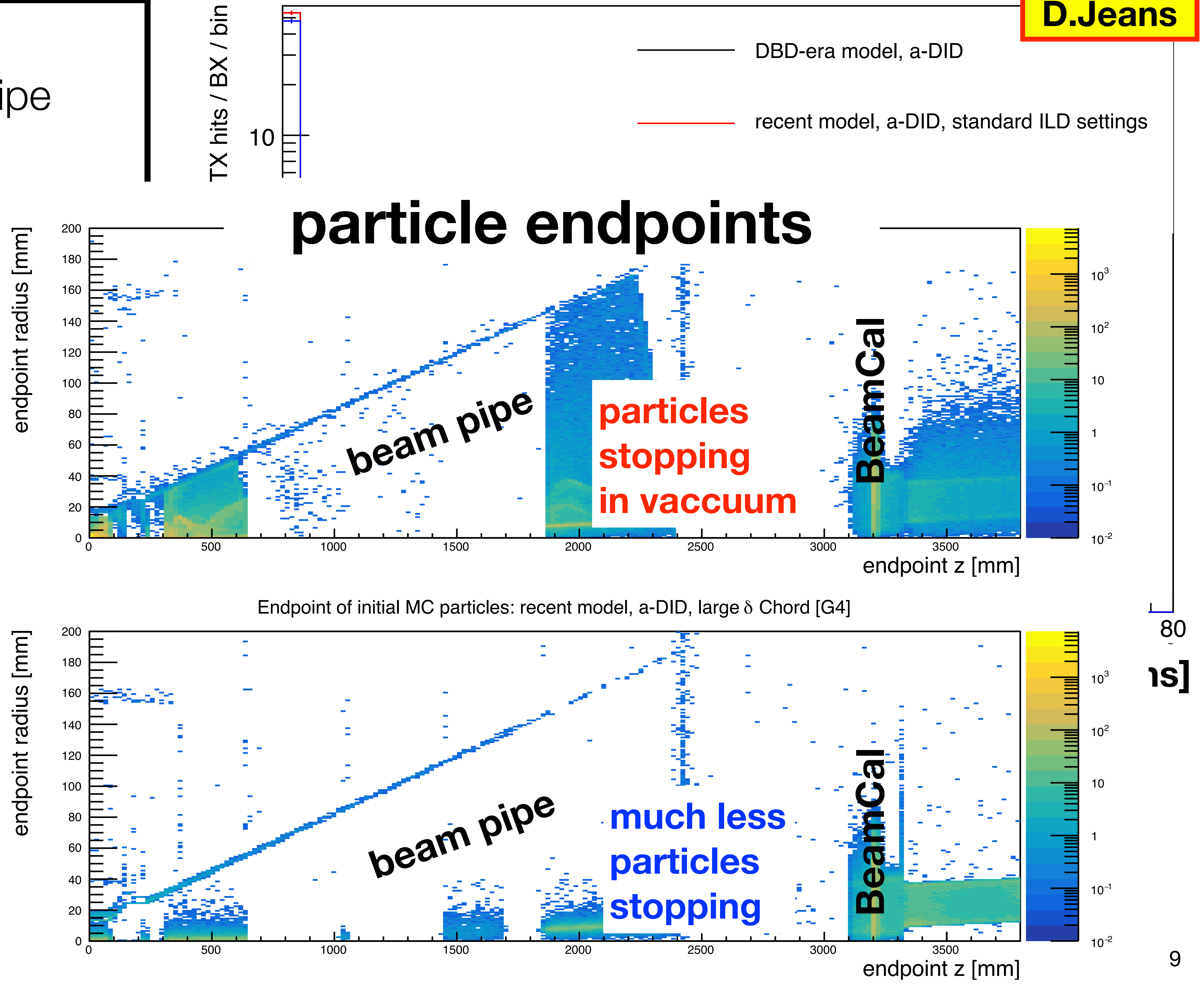

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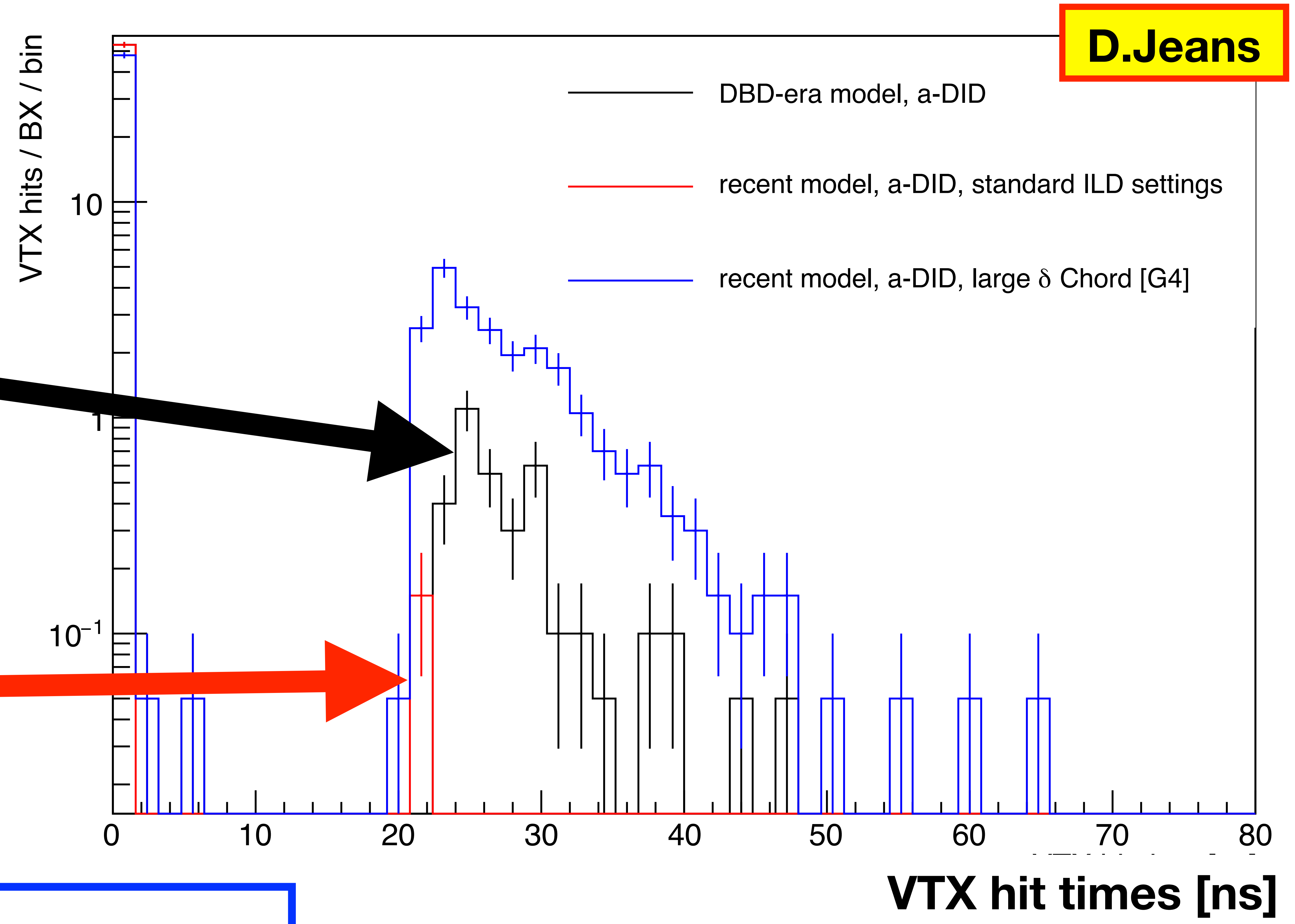

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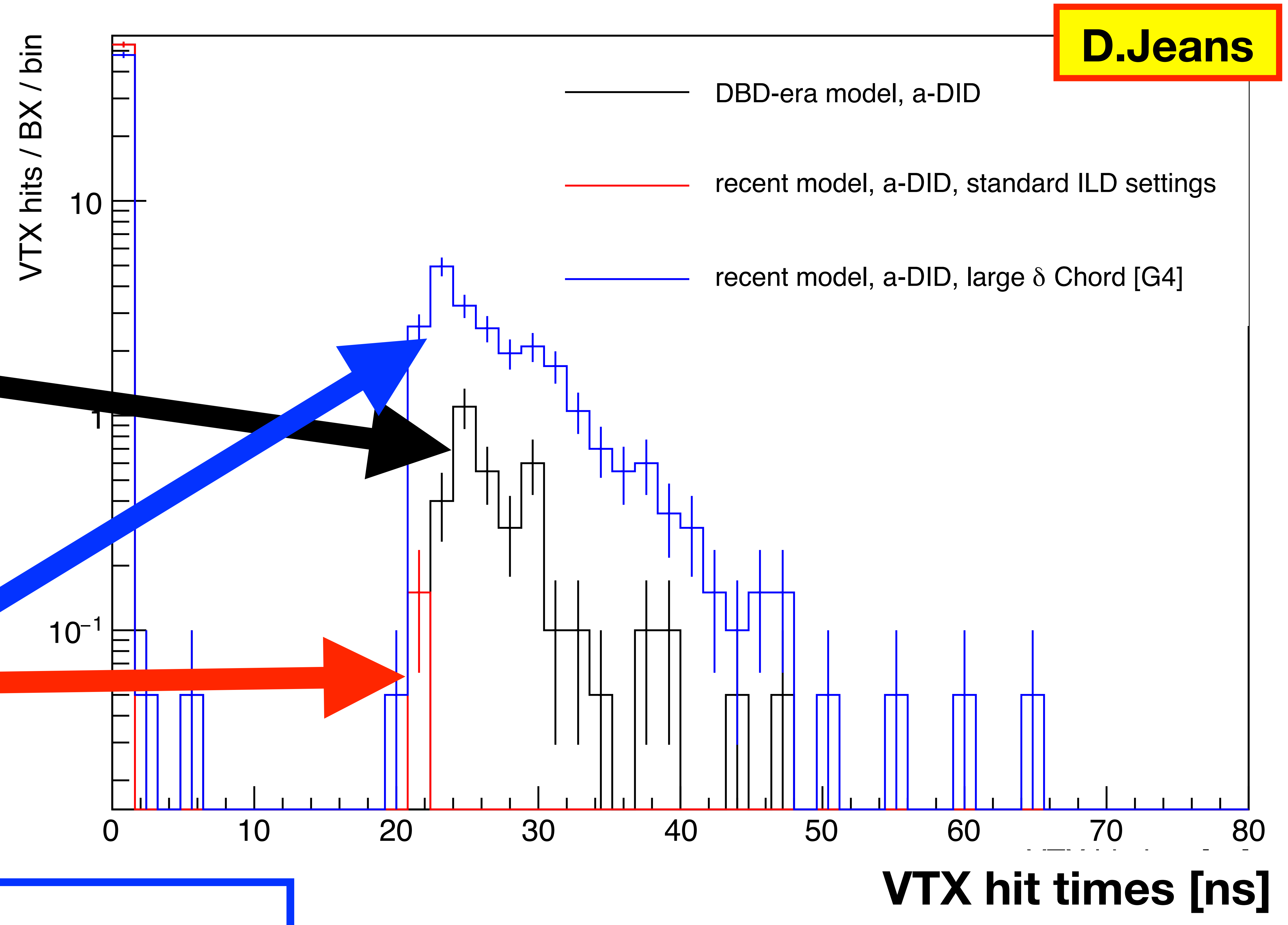

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Still needs further investigations before final conclusions can be drawn!

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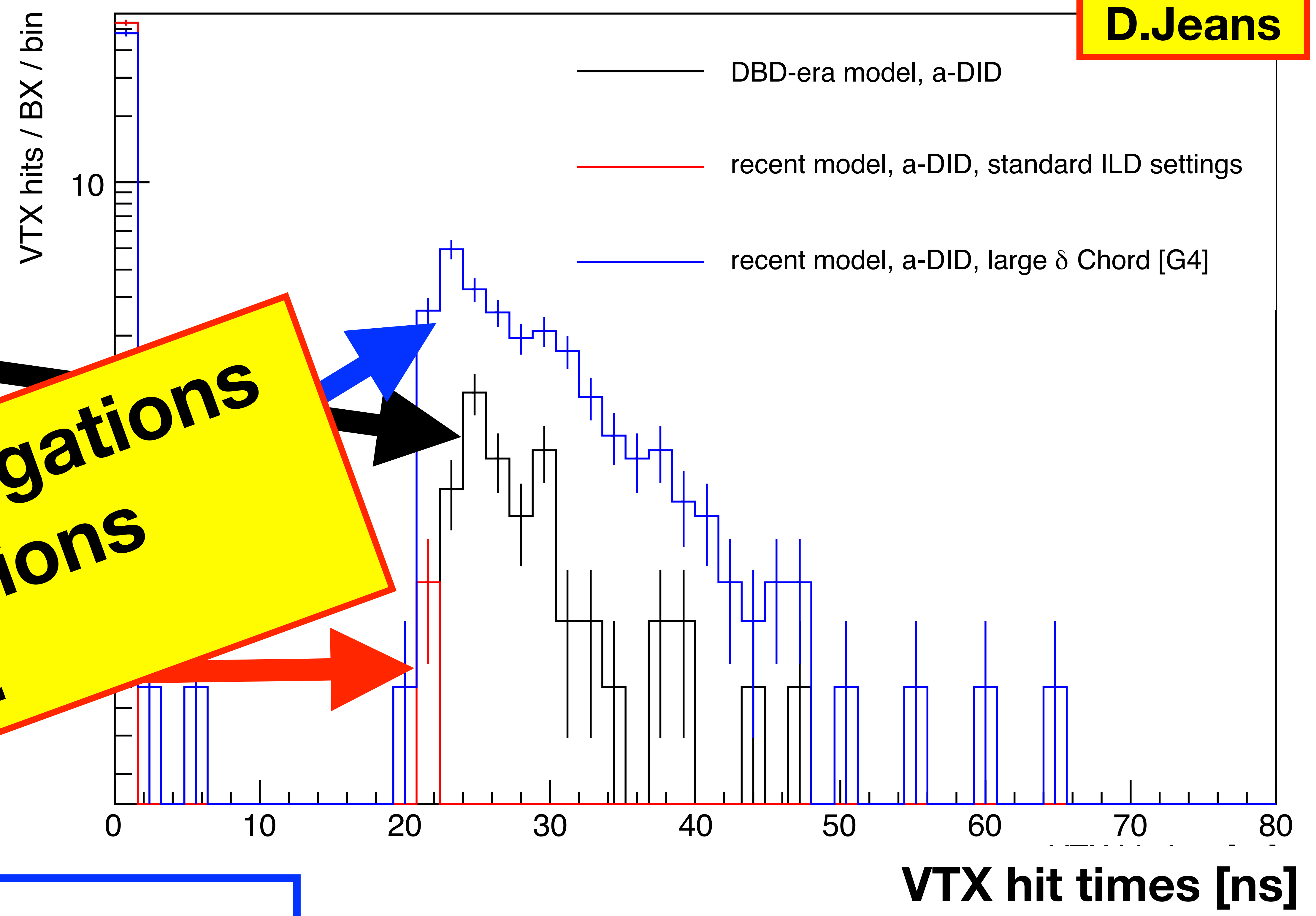


Documentation

Significant effort to improve documentation w.r.t. previous rounds of detector optimisation:

- an overview on each benchmark on ILD webpages
- general ilcsoft and ILD specific documentation on github
- code, scripts, macros, README on github
- public ILD note or paper (with internal review process)
- and finally the IDR…

Pages /… / ILD Physics Working group

Benchmarks for physics-driven detector optimisation

Jenny List posted on 02. Mar. 2018 08:37h - last edited by Jenny List on 03. Jul. 2018 09:38h

For a full list and questions to be addressed for each benchmark see presentation by J.List at ILD Workshop 2018

Higgs/EW Working Group

- **Higgs mass from H→bb.** Details.
- **branching ratio H→mu+ mu-.** Details.
- **limit on H→invisible.** Details.
- **tau polarisation, A_FB, A_LR, decay modes in e+e- → tau+ tau-.** Details.
- **W mass, TGCs, beam polaristion from e+e- → WW → qq lnu.** Details.
- **QGCs e+e- → nunu qqqq.** Details.
- **A_LR, JES calibration from e+e- → gamma Z.** Details.

Top / Flavour tag Working Group

- **A_LR, A_FB from tt →bb qqqq.** Details.
- **hadronic branching ratios of the Higgs: H→bb/cc/gg.** Details.

BSM Working Group

- **ge, cross-sections, masses for low delta M Higgsinos.** Details.
- **ge, mass, cross-section, operator type for WIMPs in mono-photon channel.** Details.
- **ge for low mass extra Higgses in e+e- → Zh.** Details.

itors of benchmark reactions: click here

R.Ete & Y.Wang

ILDAnaSoft

International Large Detector for ILC - Analysis

https://confluence.desy.de/display/ILD/ILD

Repositories 17 | People 7 | Teams 0 | Projects 0 | Settings

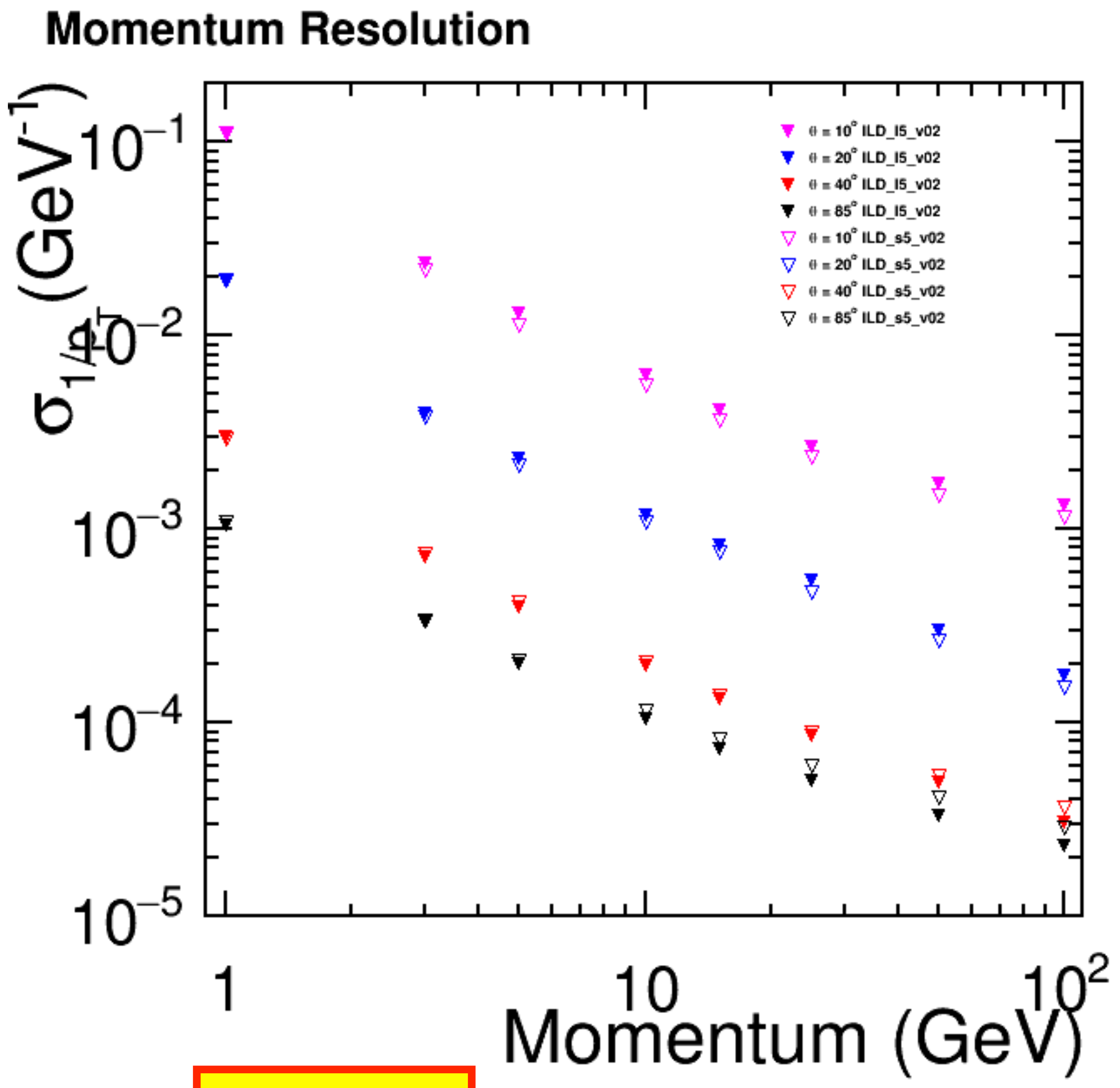
Pinned repositories

ILDDoc
General documentation for running ILD software and analyses
Python ★1 4

Skeleton
ILD skeleton repository to create new analysis repositories
C++ ★1 1

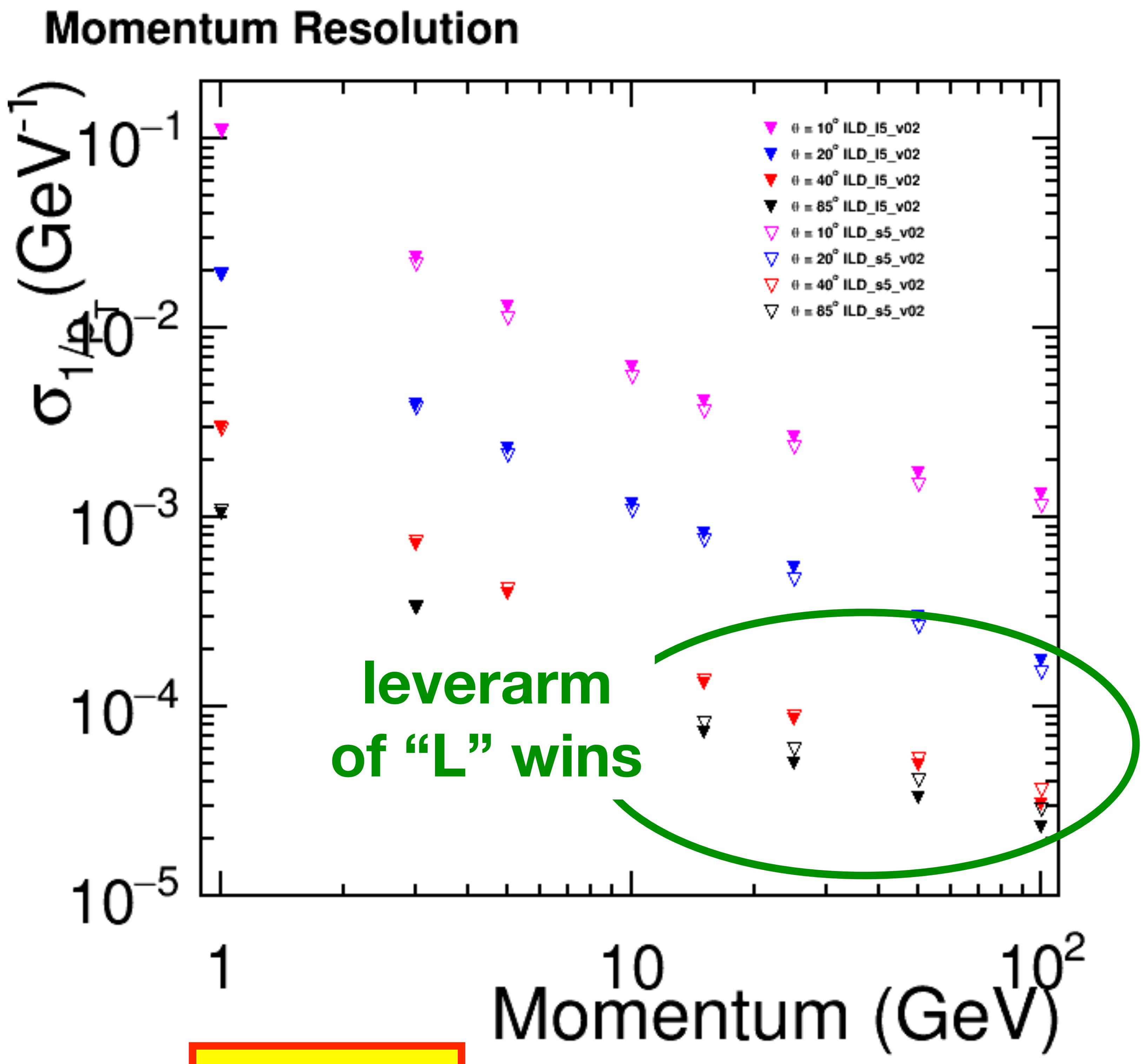
Basic Performance

Tracking - Large vs Small



S.Lu

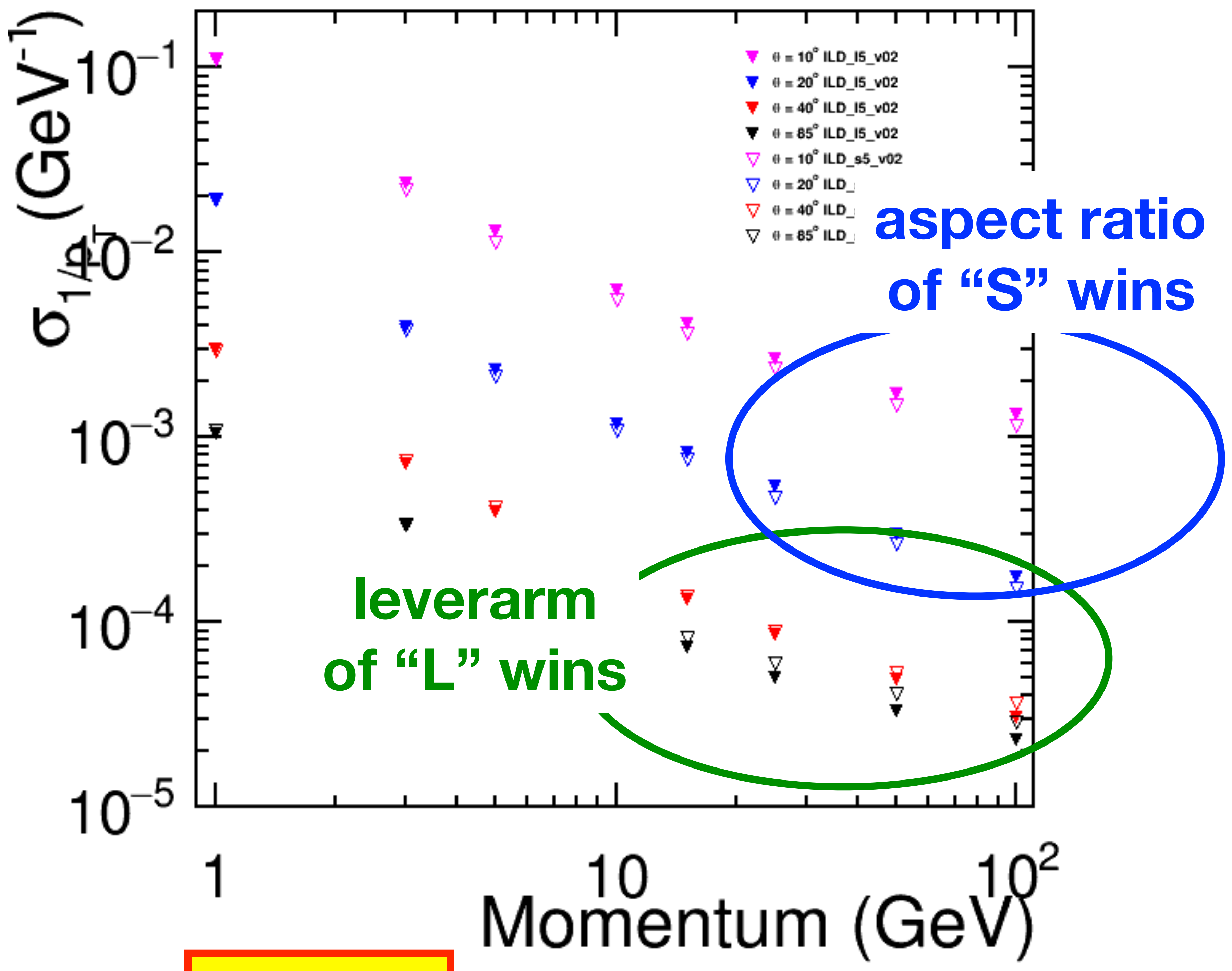
Tracking - Large vs Small



S.Lu

Tracking - Large vs Small

Momentum Resolution



S.Lu

Tracking - Large vs Small

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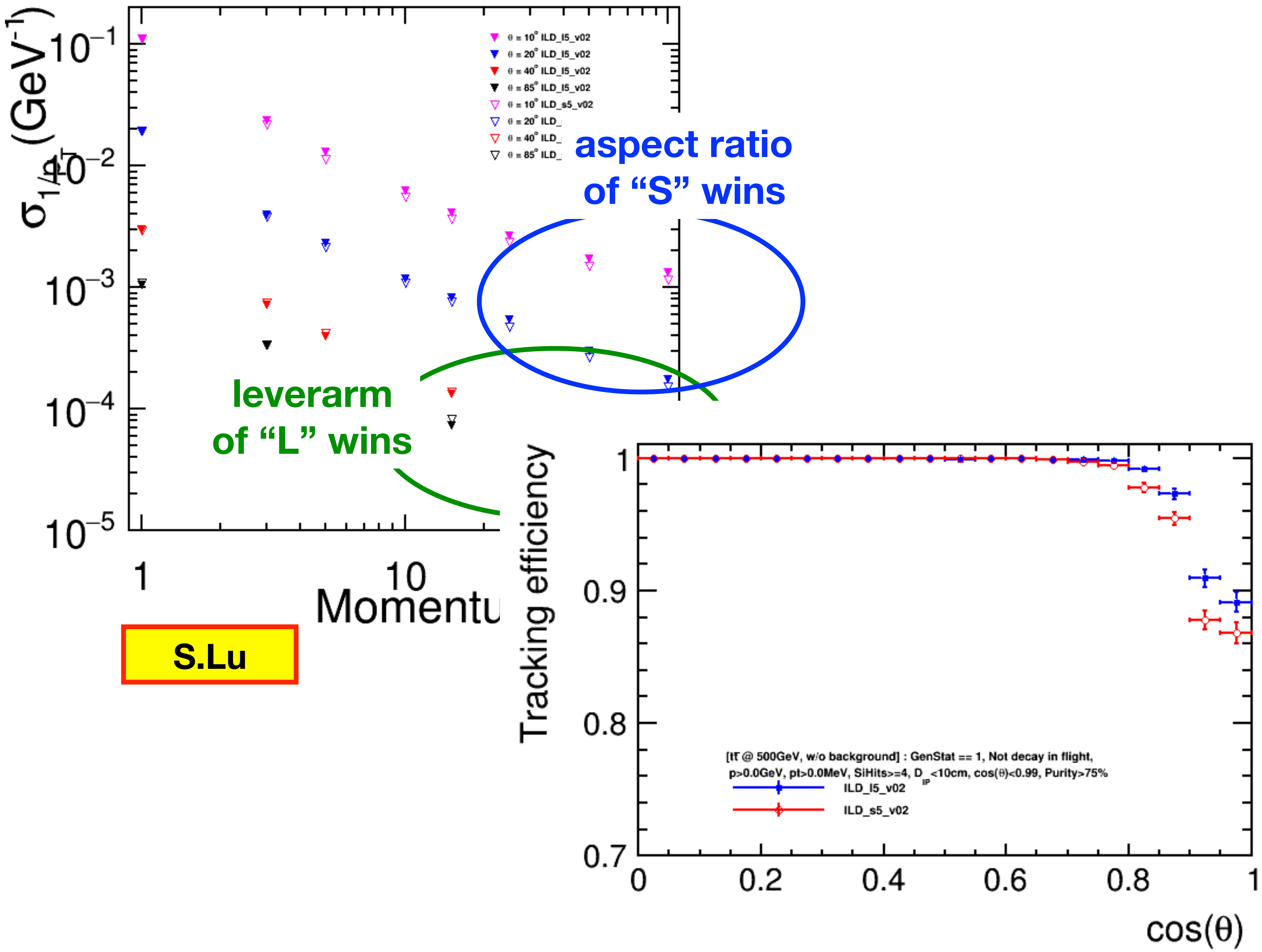
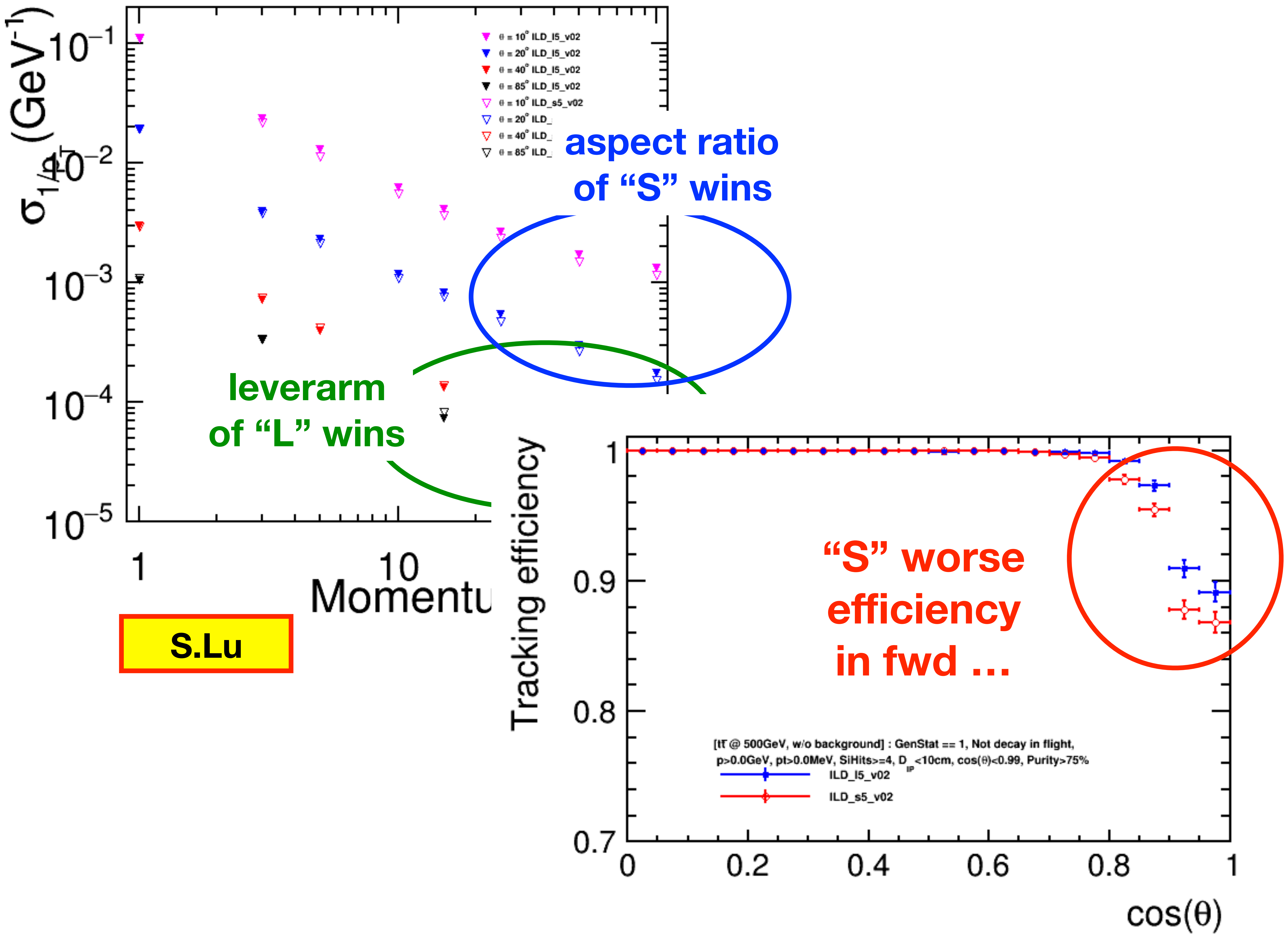


S.Lu

Tracking - Large vs Small

Momentum Resolution



S.Lu

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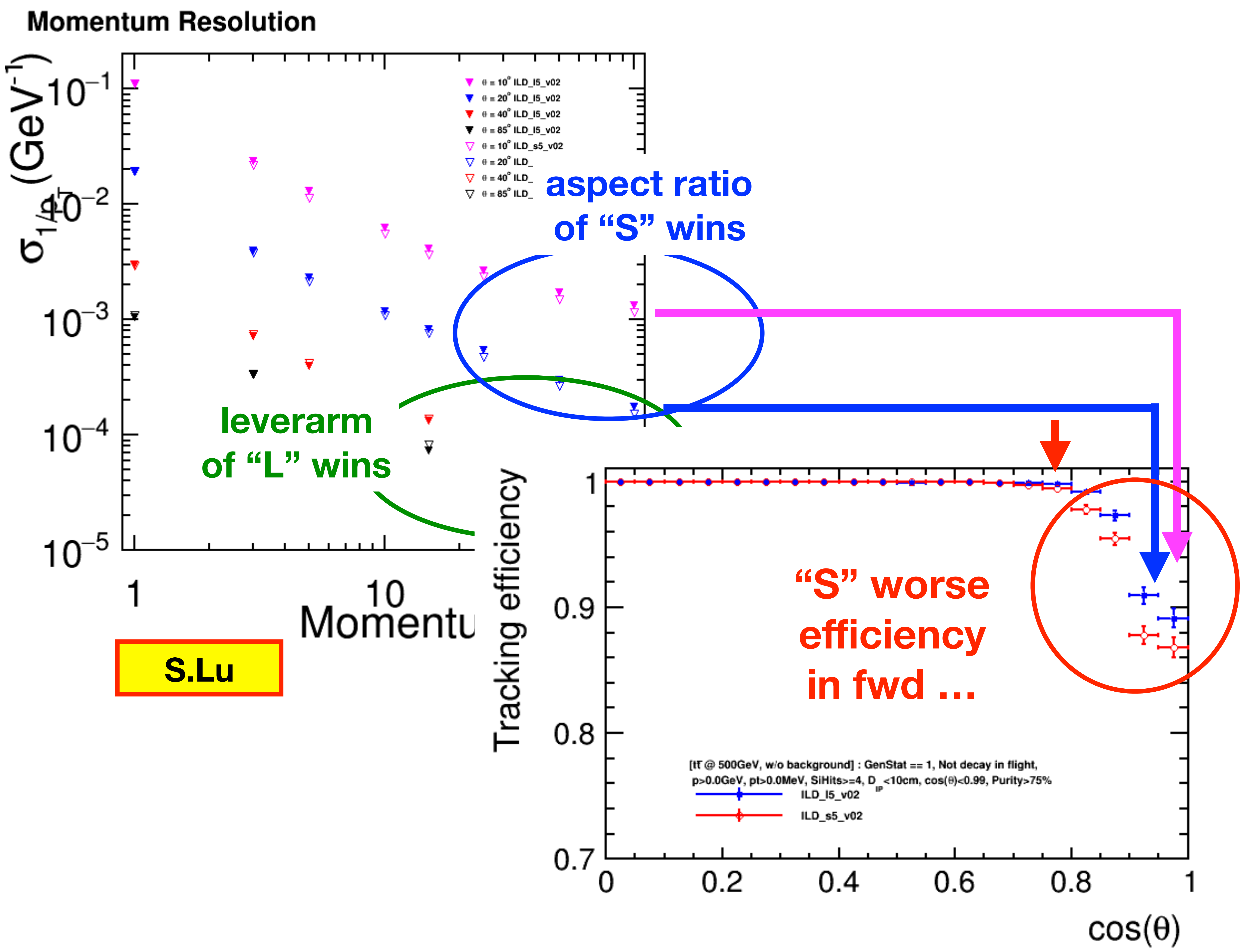

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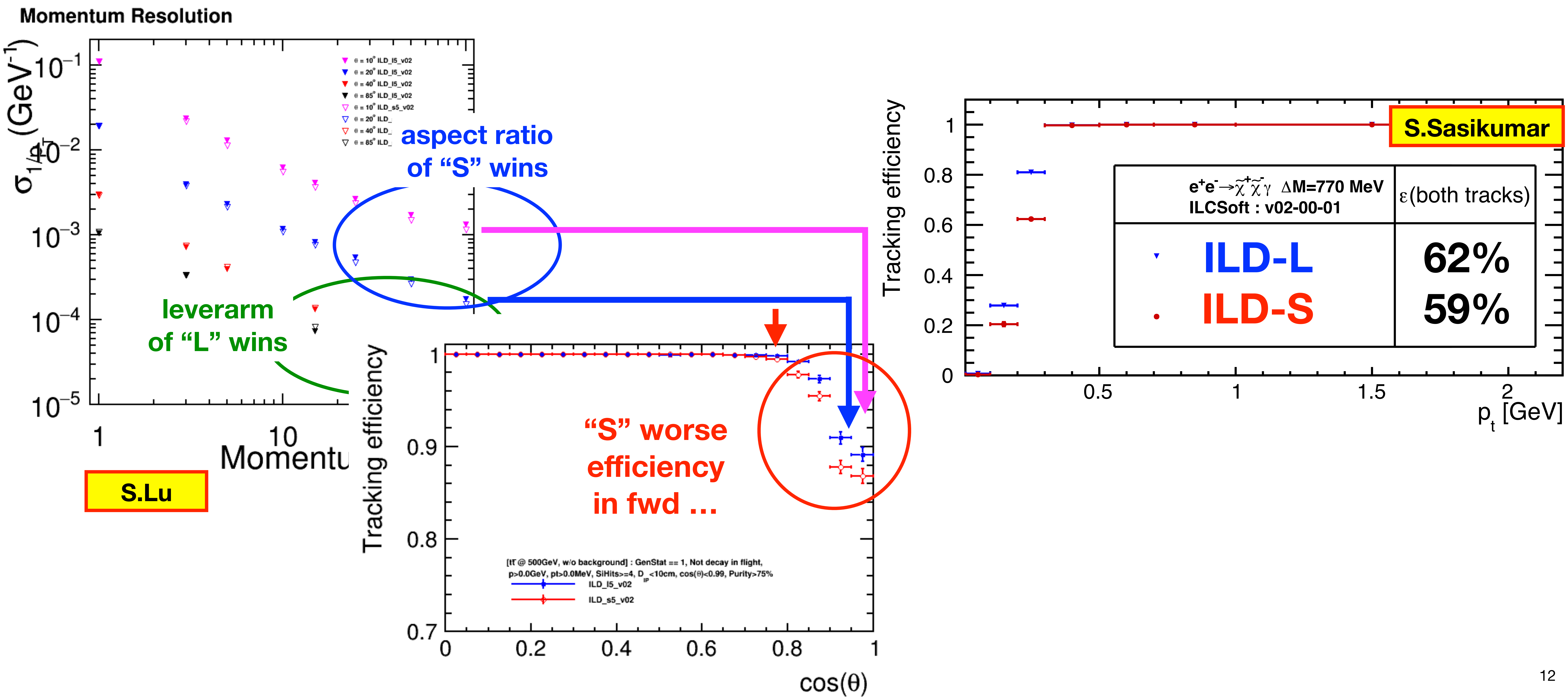

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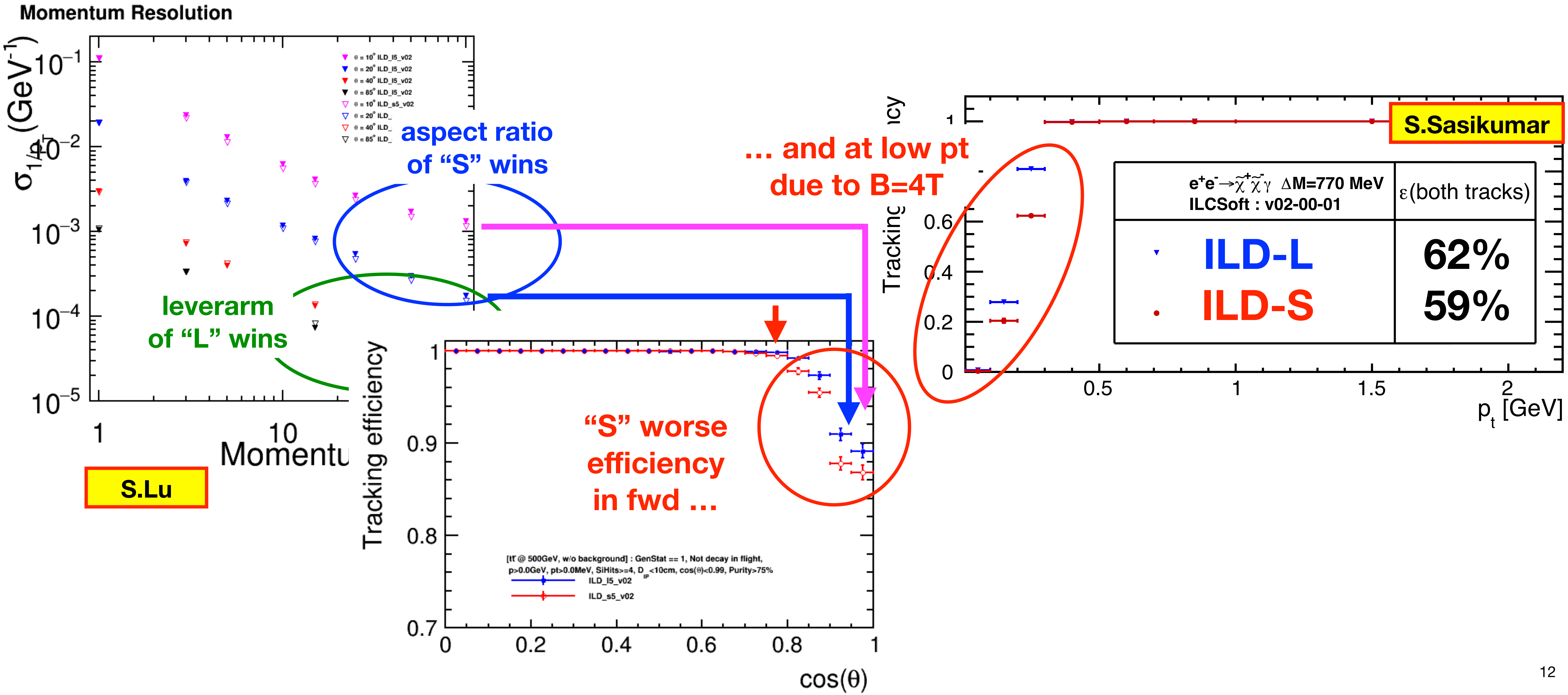
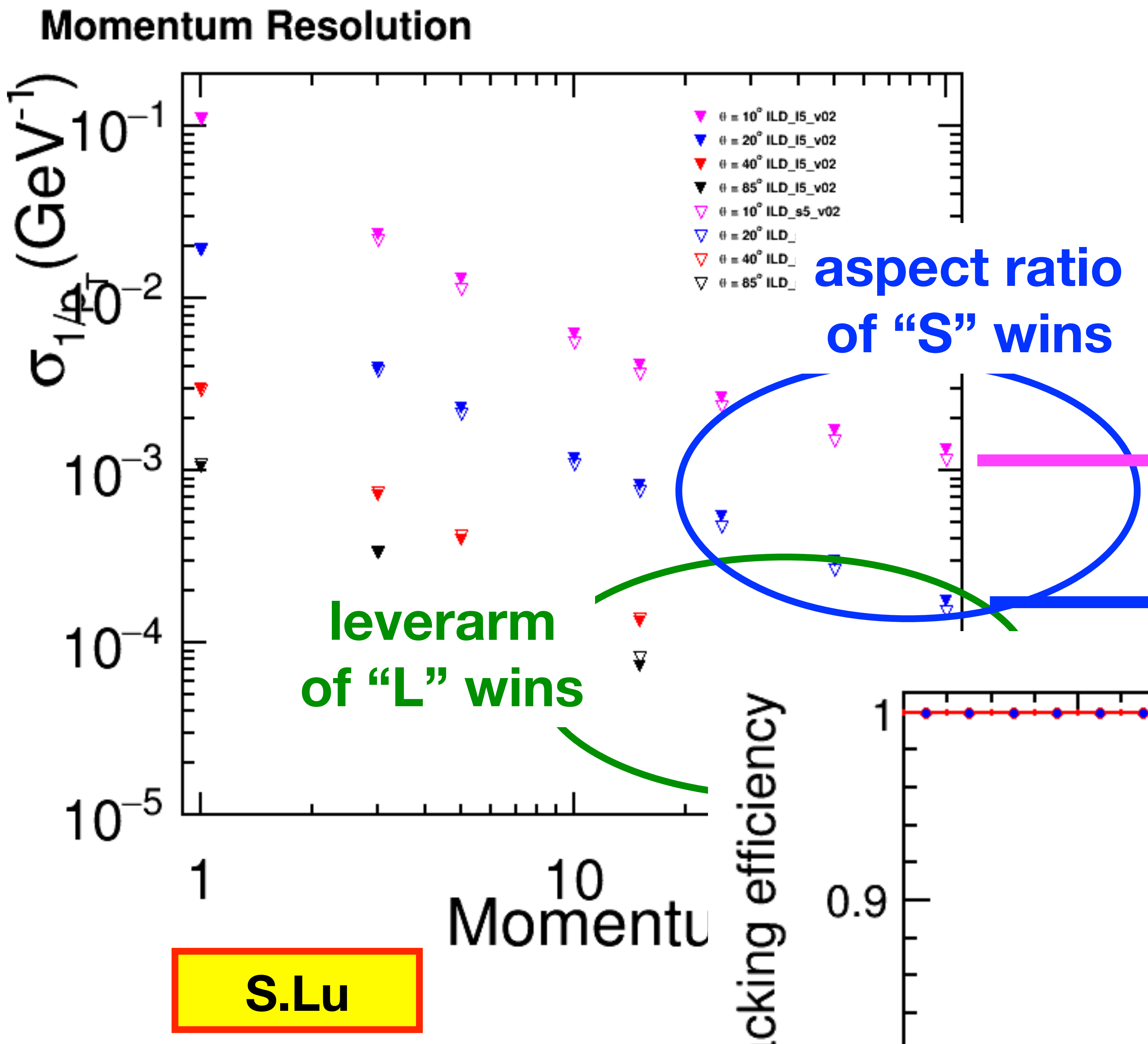
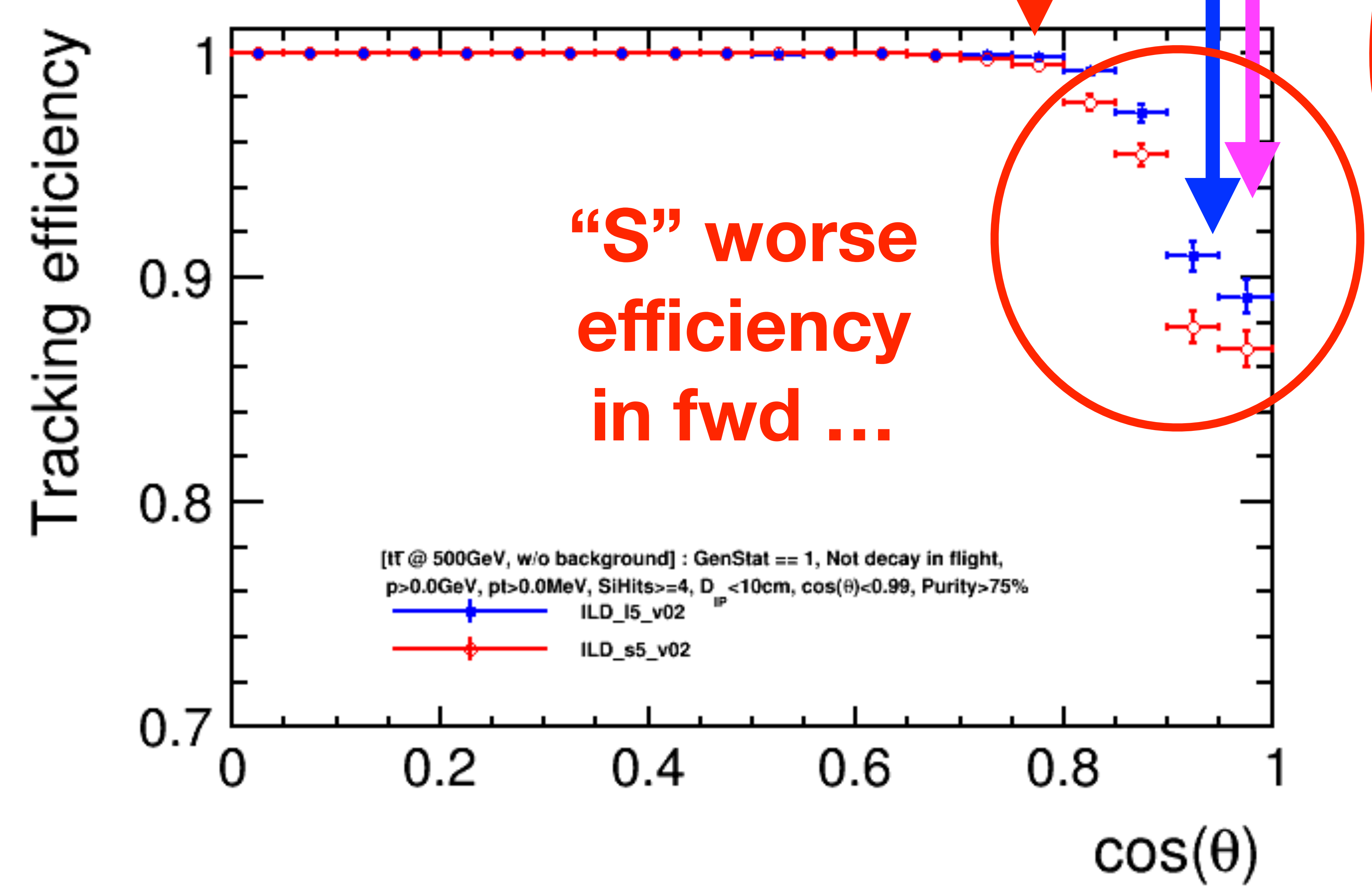
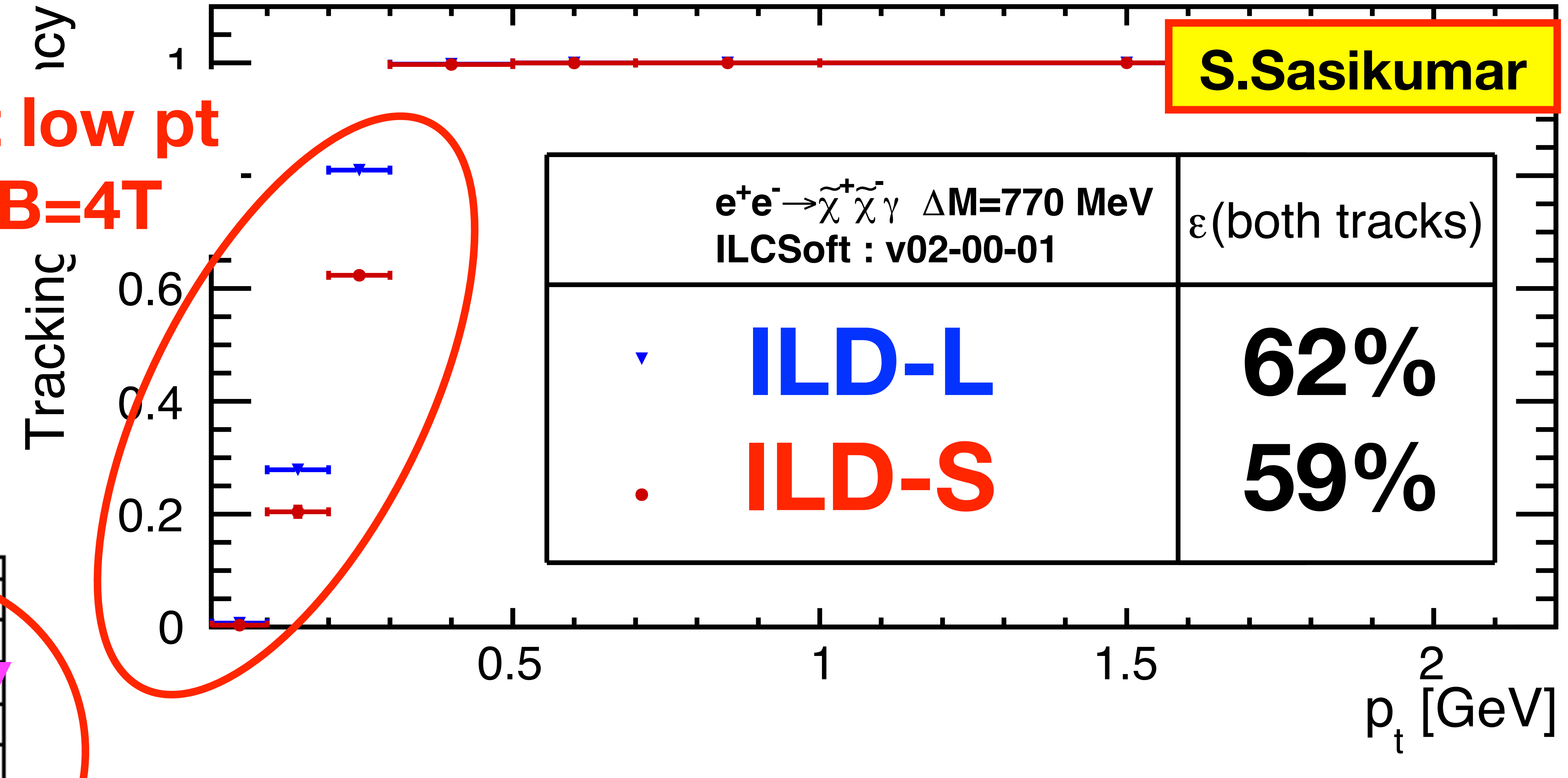


Tracking - Large vs Small

Physics example: low ΔM new particles!
eg Higgsinos ΔM=770 MeV
c.f. BSM parallel Tue 2 pm







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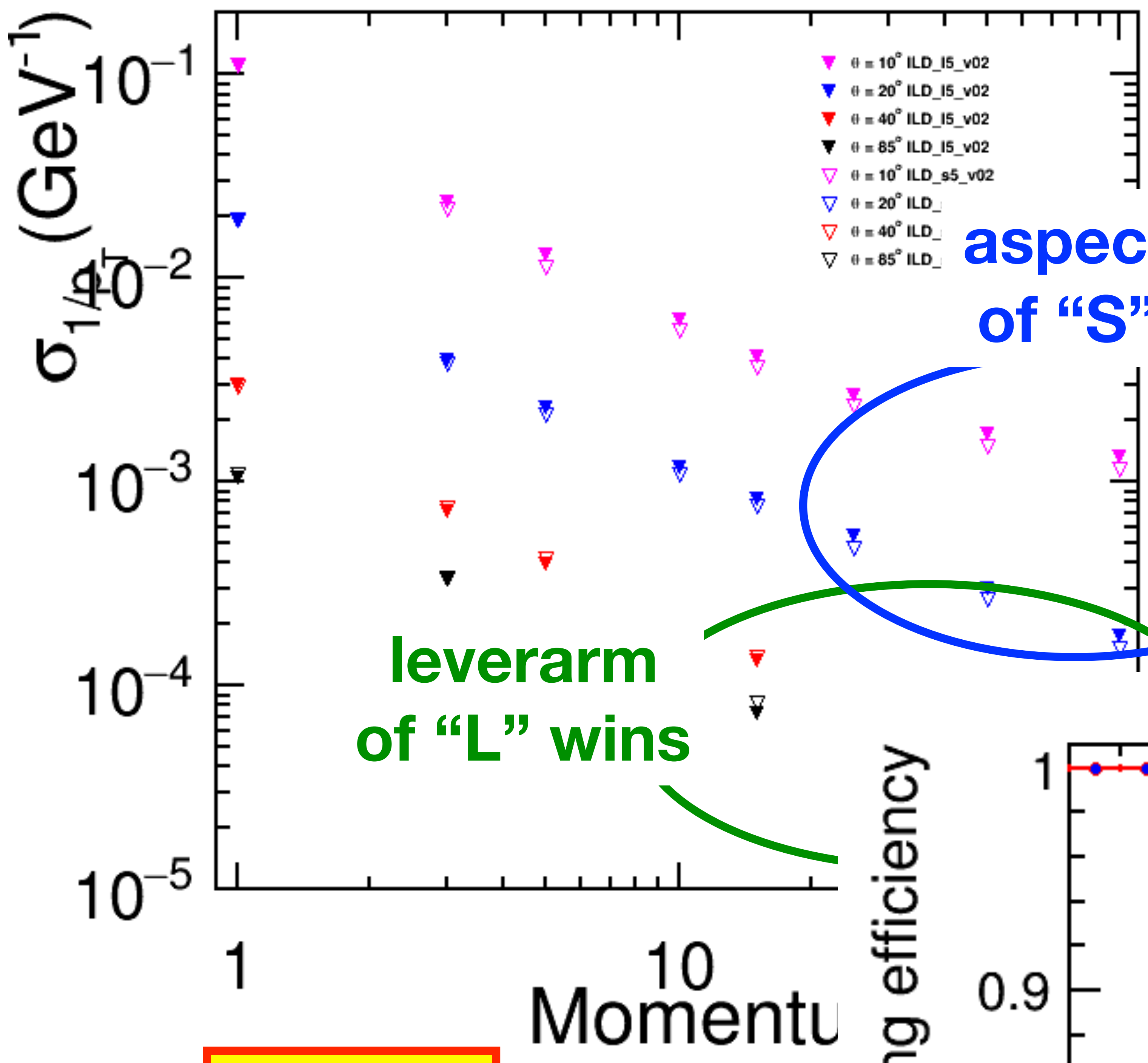
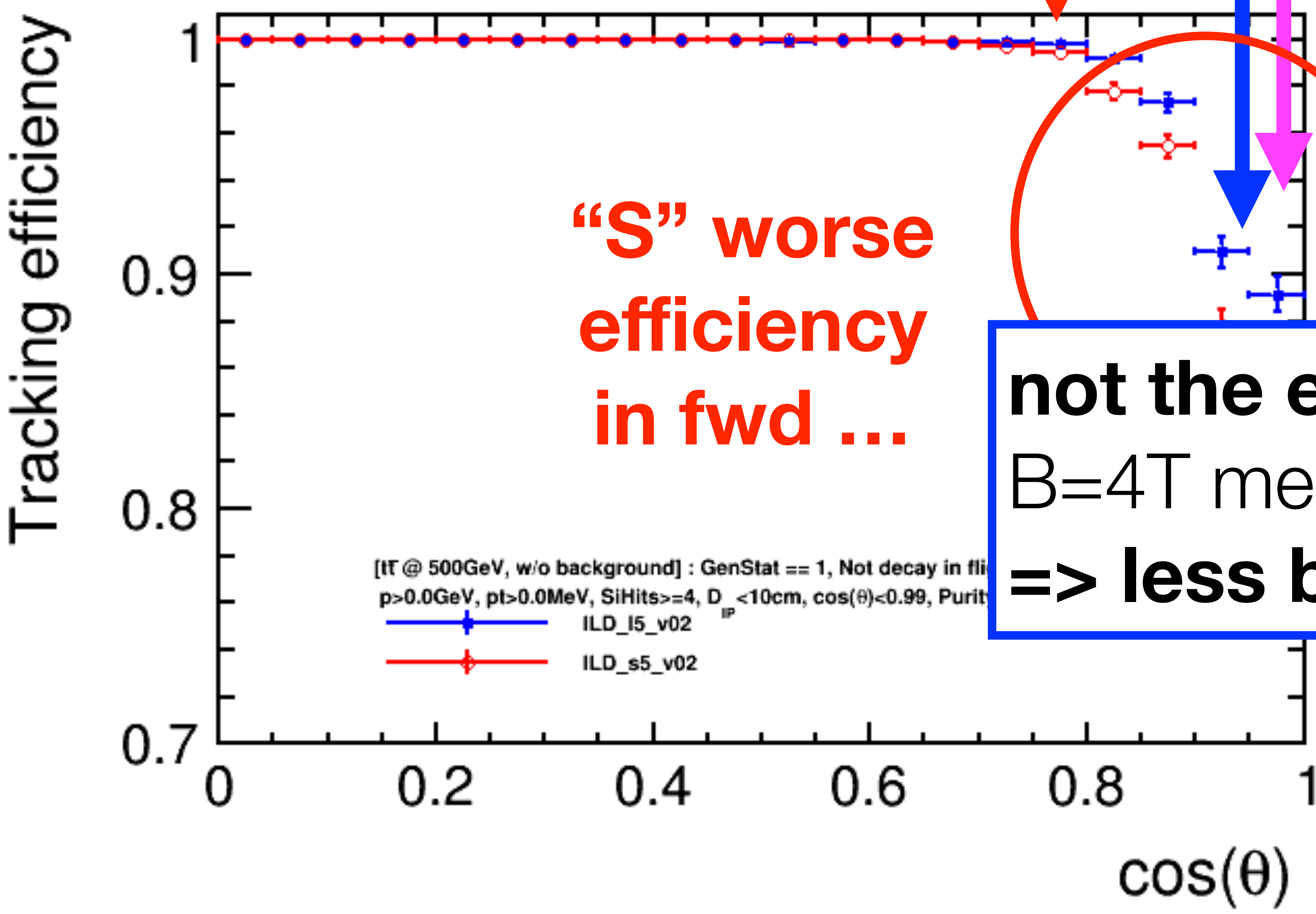


S.Lu

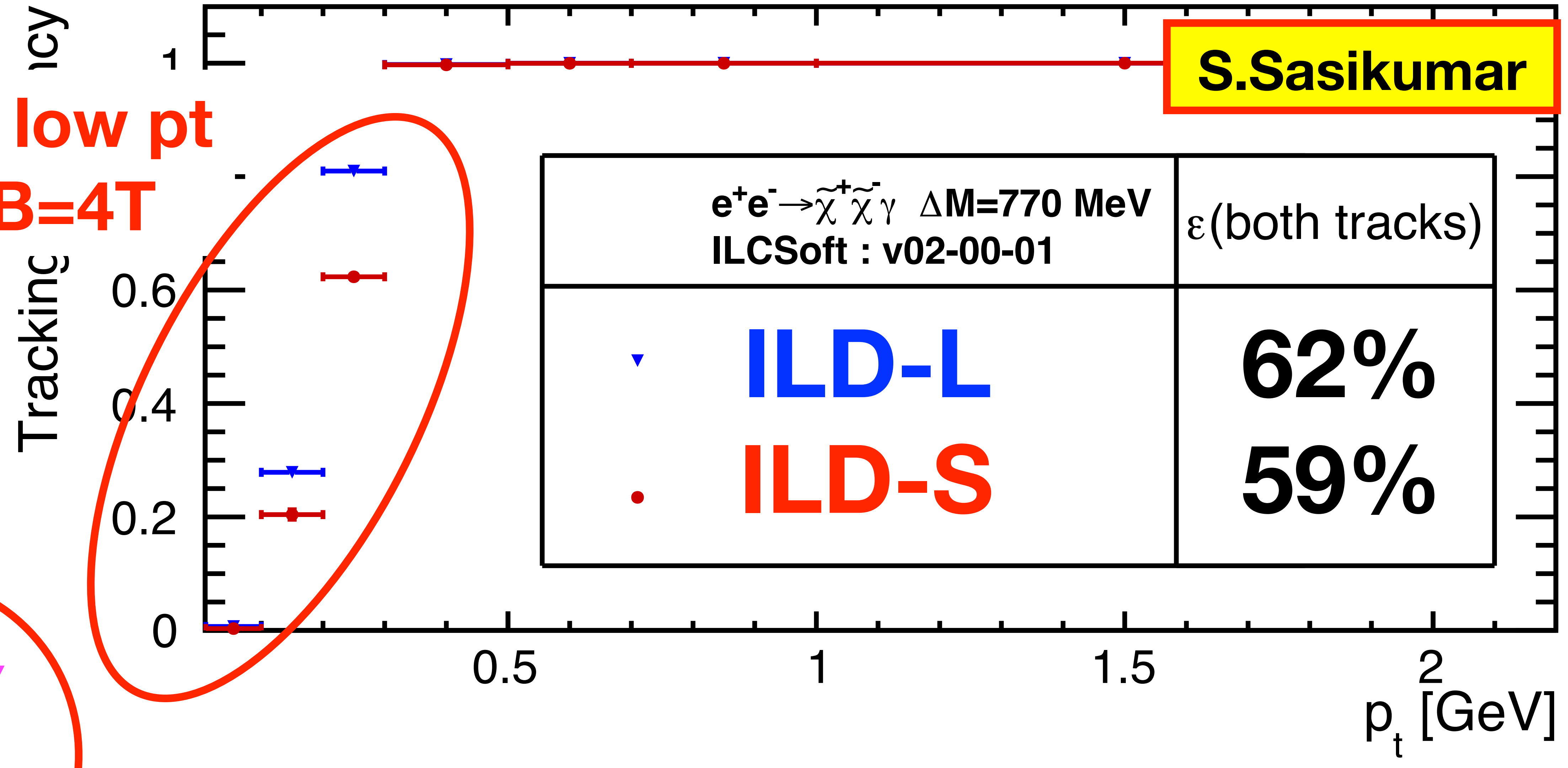
aspect ratio of "S" wins

leverarm of "L" wins



"S" worse efficiency in fwd …

… and at low pt due to B=4T



S.Sasikumar

not the end of the story:
B=4T means stronger focus of pair background hits in VTX
=> less background - or 1st layer closer to IP ?

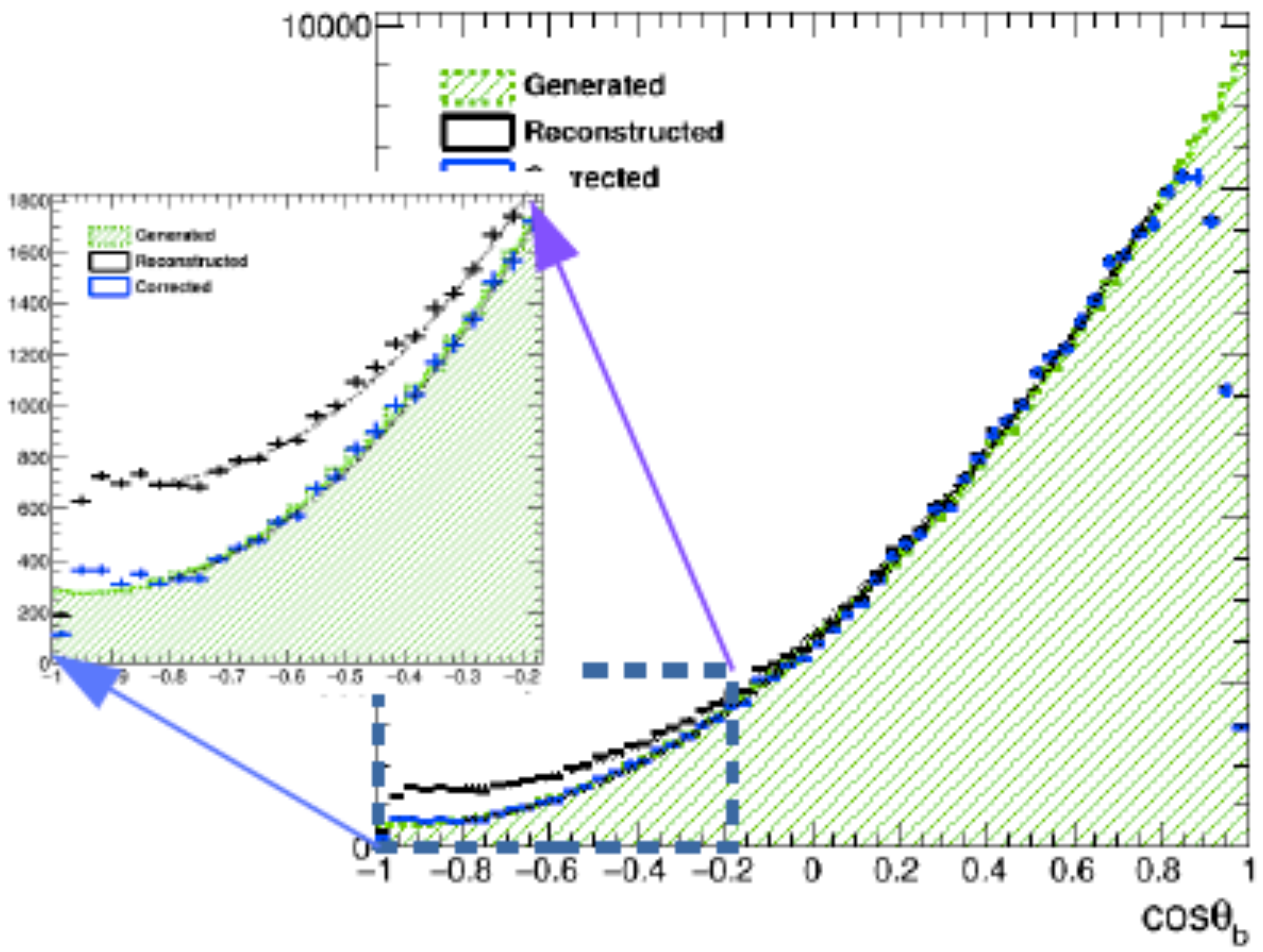
Opportunities to improve ILD - Vertexing in forward direction

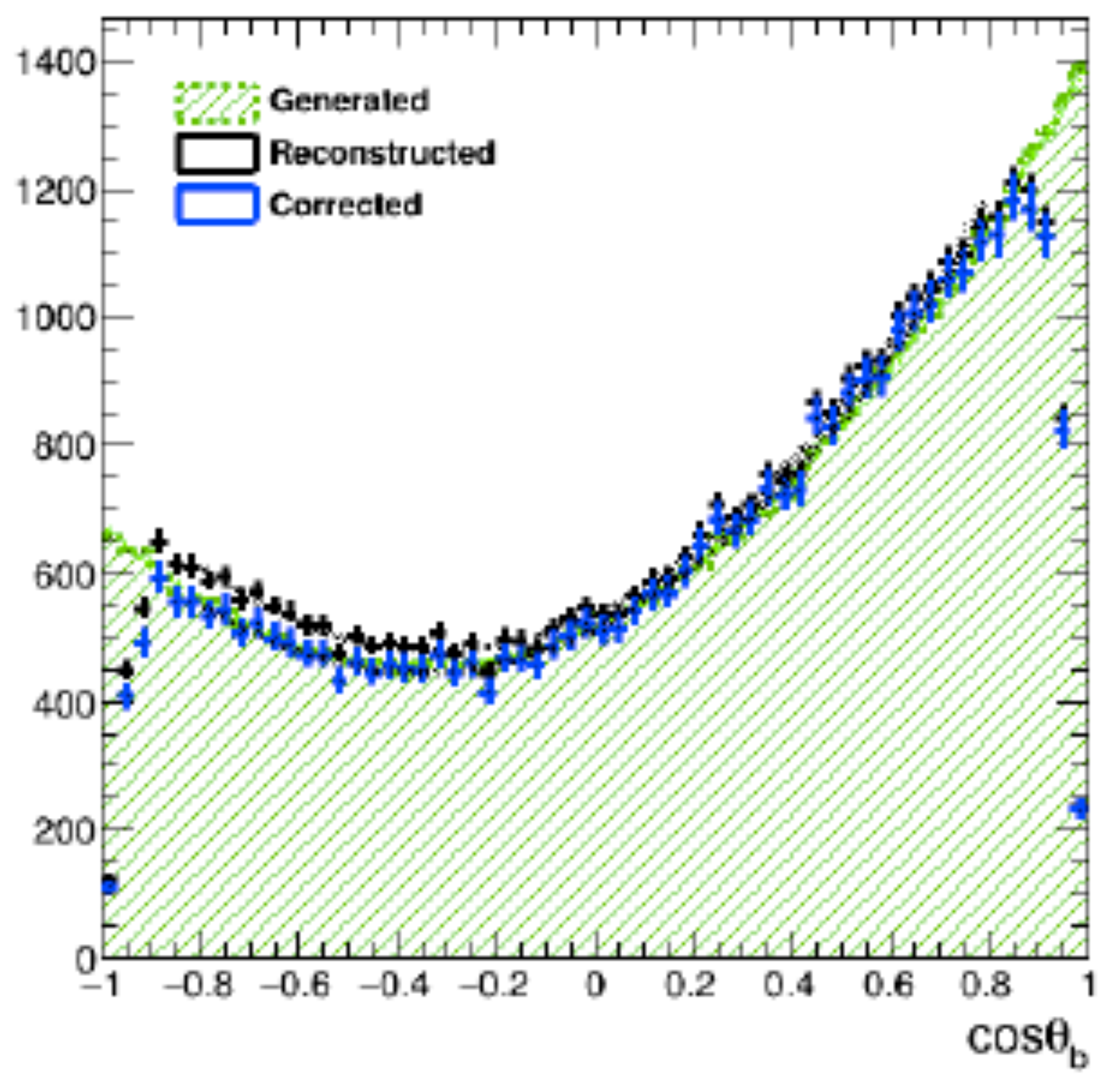
S.Bilokin

Polar angle reconstruction

$L = 250\,\mathrm{fb}^{-1}$

$e^-_L e^+_R \rightarrow b\bar{b}$ $\qquad$ $e^-_R e^+_L \rightarrow b\bar{b}$





$A^{rec}_{fb}/A^{gen}_{fb} = 100.7\% \pm 0.62\%$ $\qquad$ $A^{rec}_{fb}/A^{gen}_{fb} = 104.9\% \pm 1.9\%$

Physics example:
A_{FB}(b) from e^+e^- -> bb @ 250 GeV
clarify LEP vs SLD discrepancy

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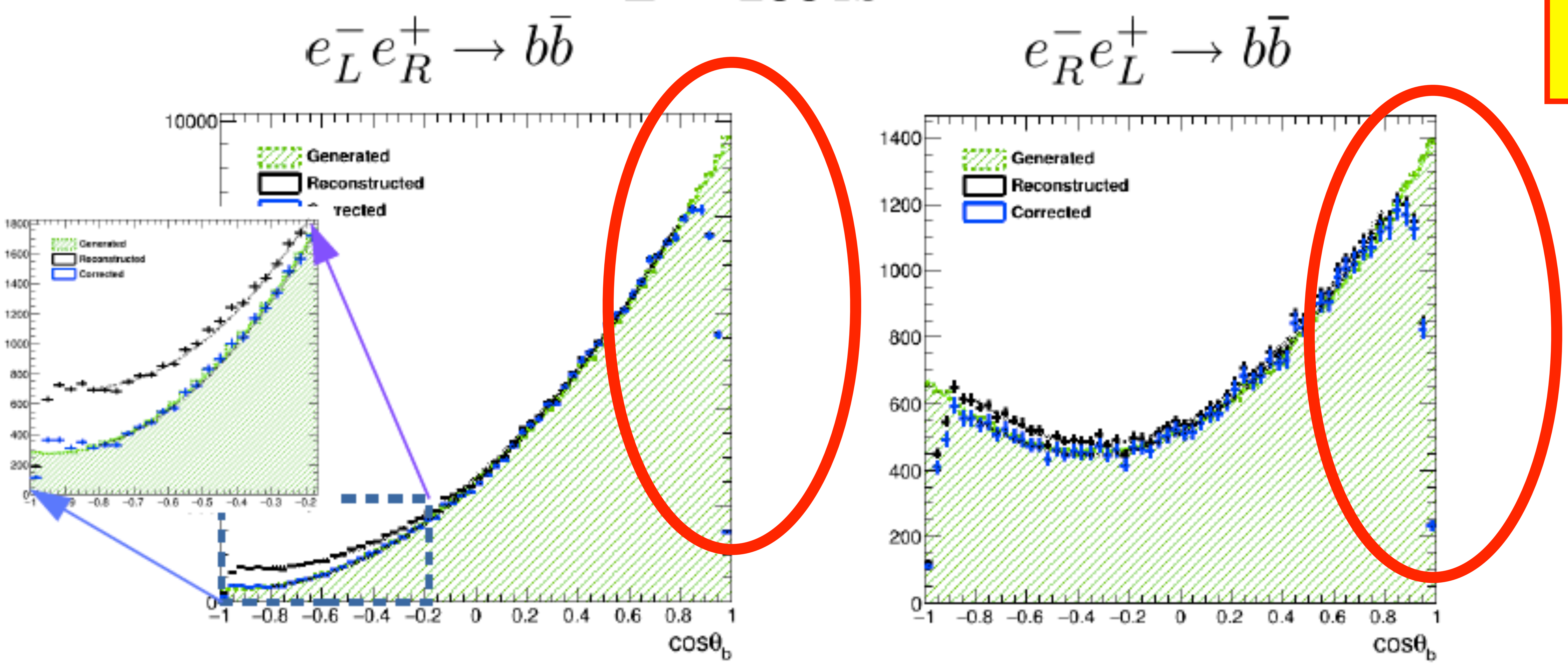

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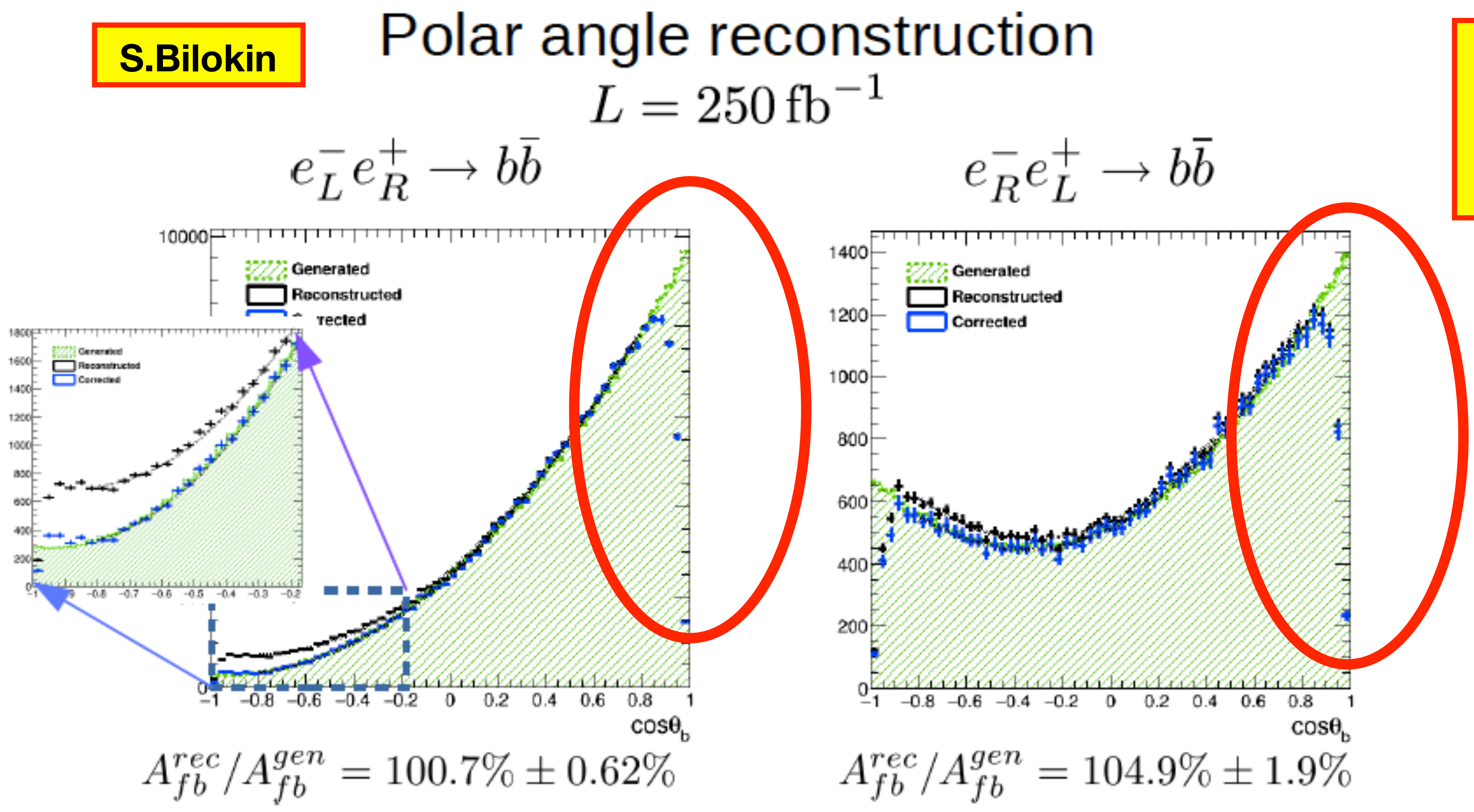

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deficiency in vertex finding for cos(θ) > 0.8

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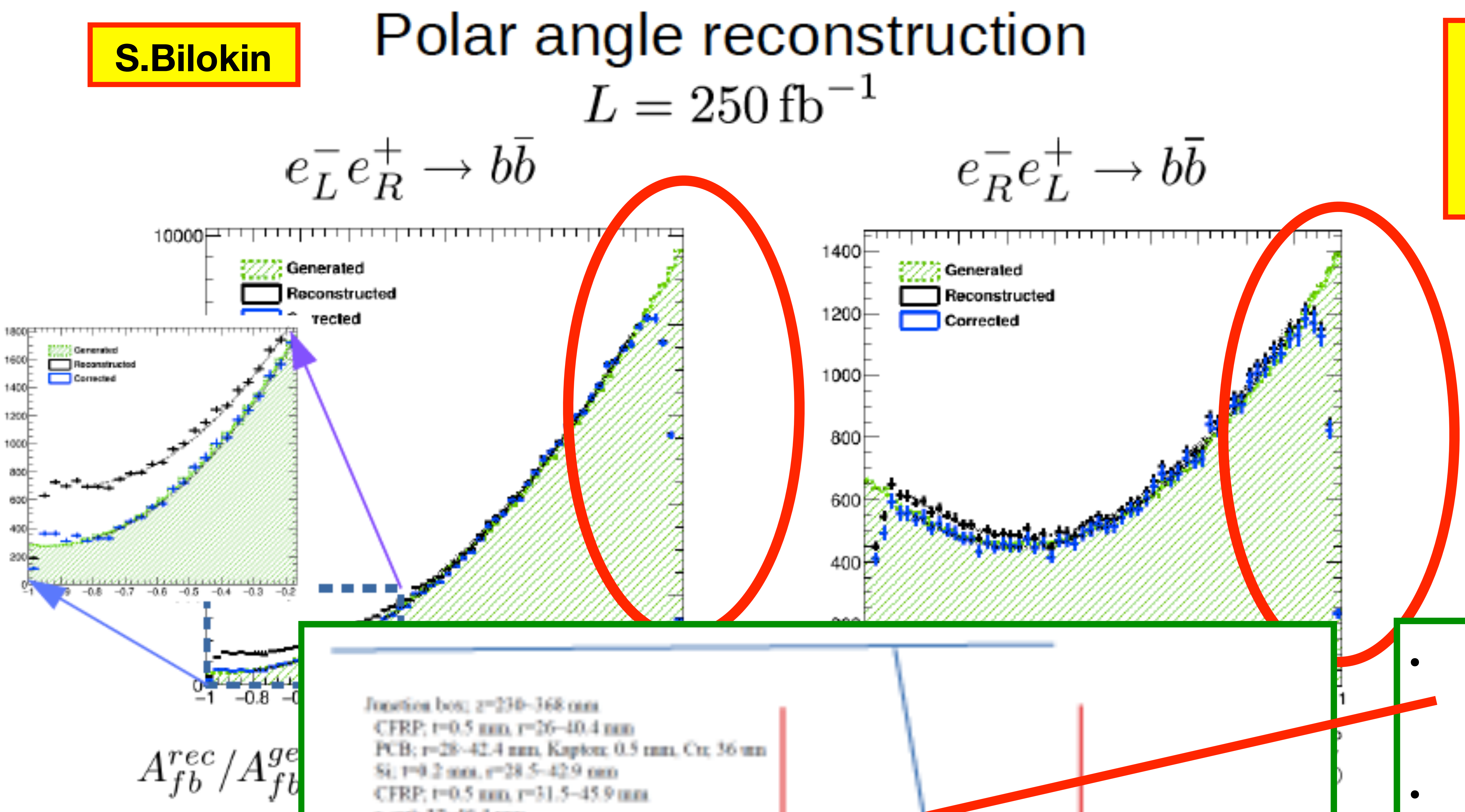

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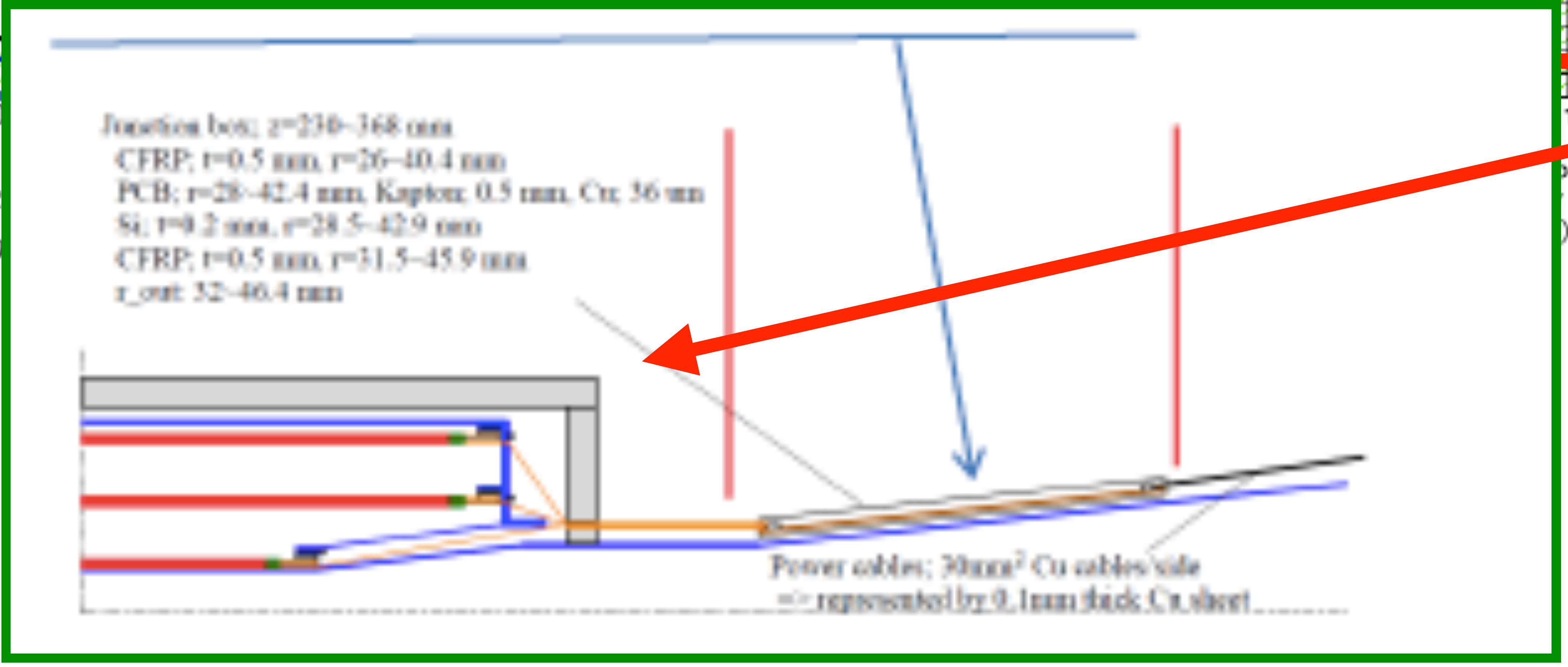
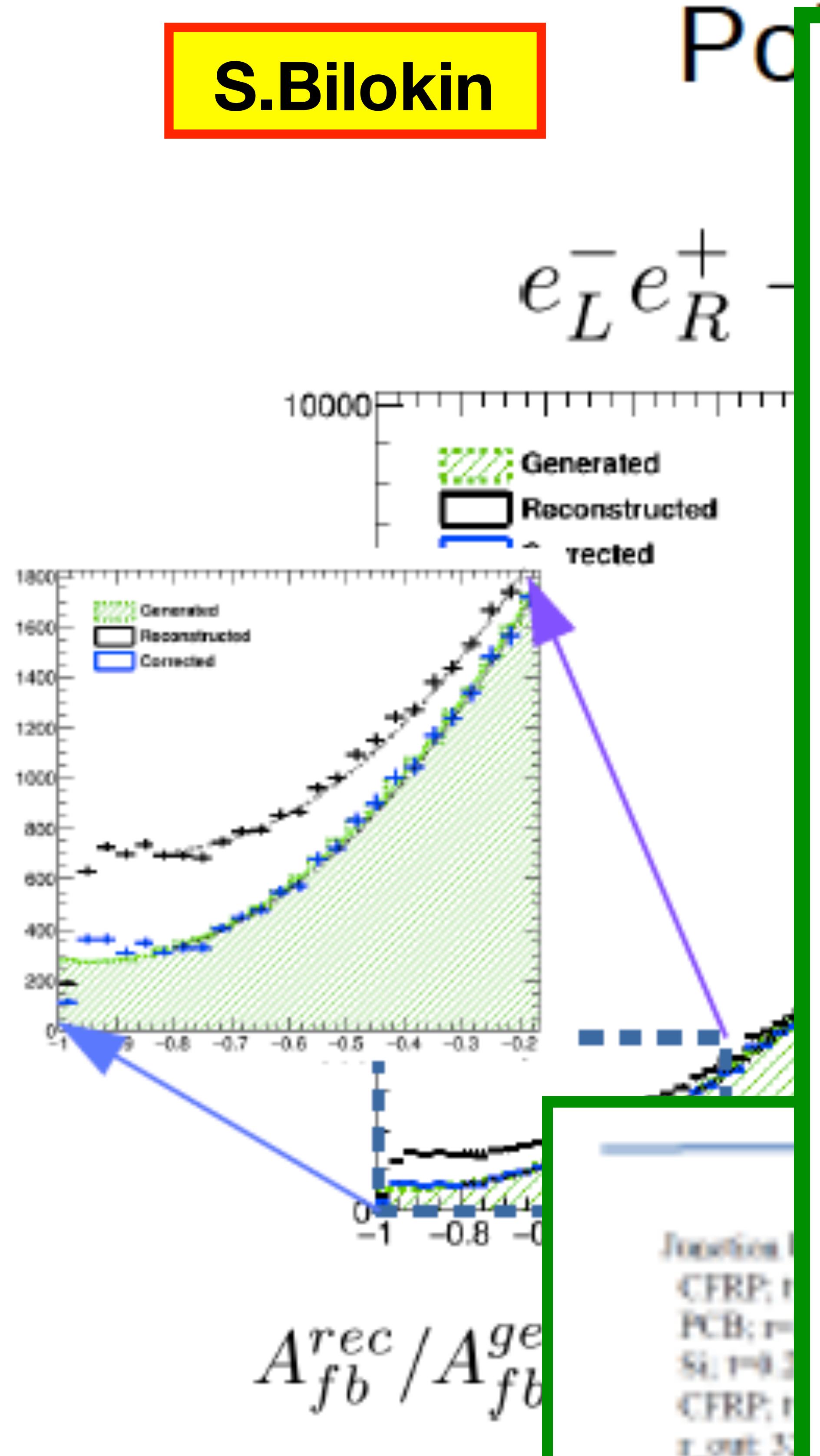
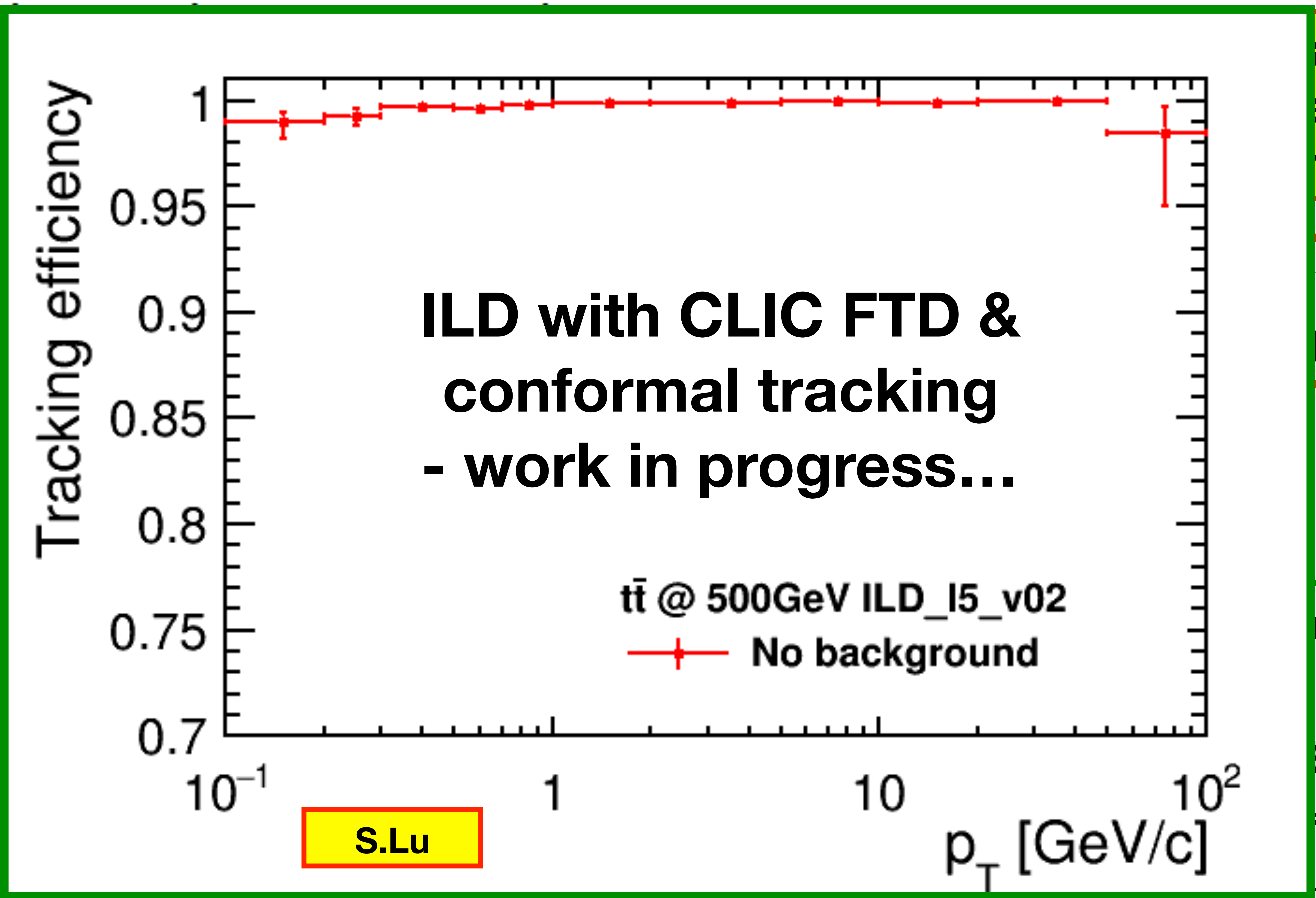


- **Currently O(10cm) gap between end of VTX barrel and first FTD disk**
- Close / reduce gap?
- Or include a disk in VTX?
- Or make FTD all-pixel ?
- **Or consider CLIC-like FTD ?**

Opportunities to improve ILD - Vertexing in forward direction

S.Bilokin





S.Lu

…sics example:
e+e- -> bb @ 250 GeV
…vs SLD discrepancy

…vertex finding
…(θ) > 0.8

…cm) gap between end …nd first FTD disk

…gap?

…k in VTX?

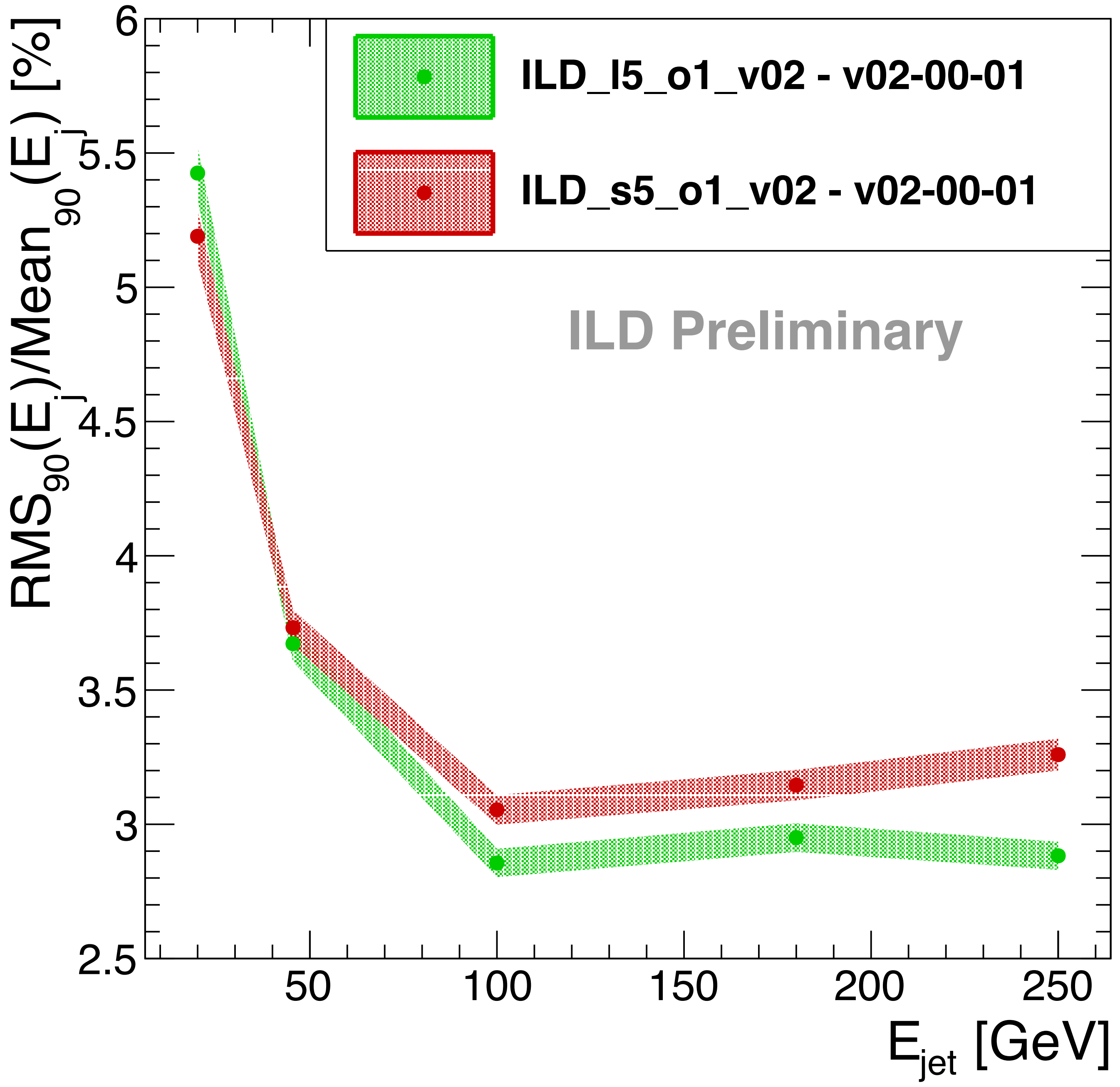
…-pixel ?

- **Or consider CLIC-like FTD ?**

Particle Flow Performance

Standard definition of Jet Energy Resolution / Scale (JER/JES):

- dijet events with light quarks: **ee -> uu / dd / ss**
- **fixed E_{CM} = 2 E_{quark}**;
  no ISR, no beam energy spectrum
- observable: total visible energy - **no jet finding**



R.Ete

ILD-S

ILD-L

Particle Flow Performance

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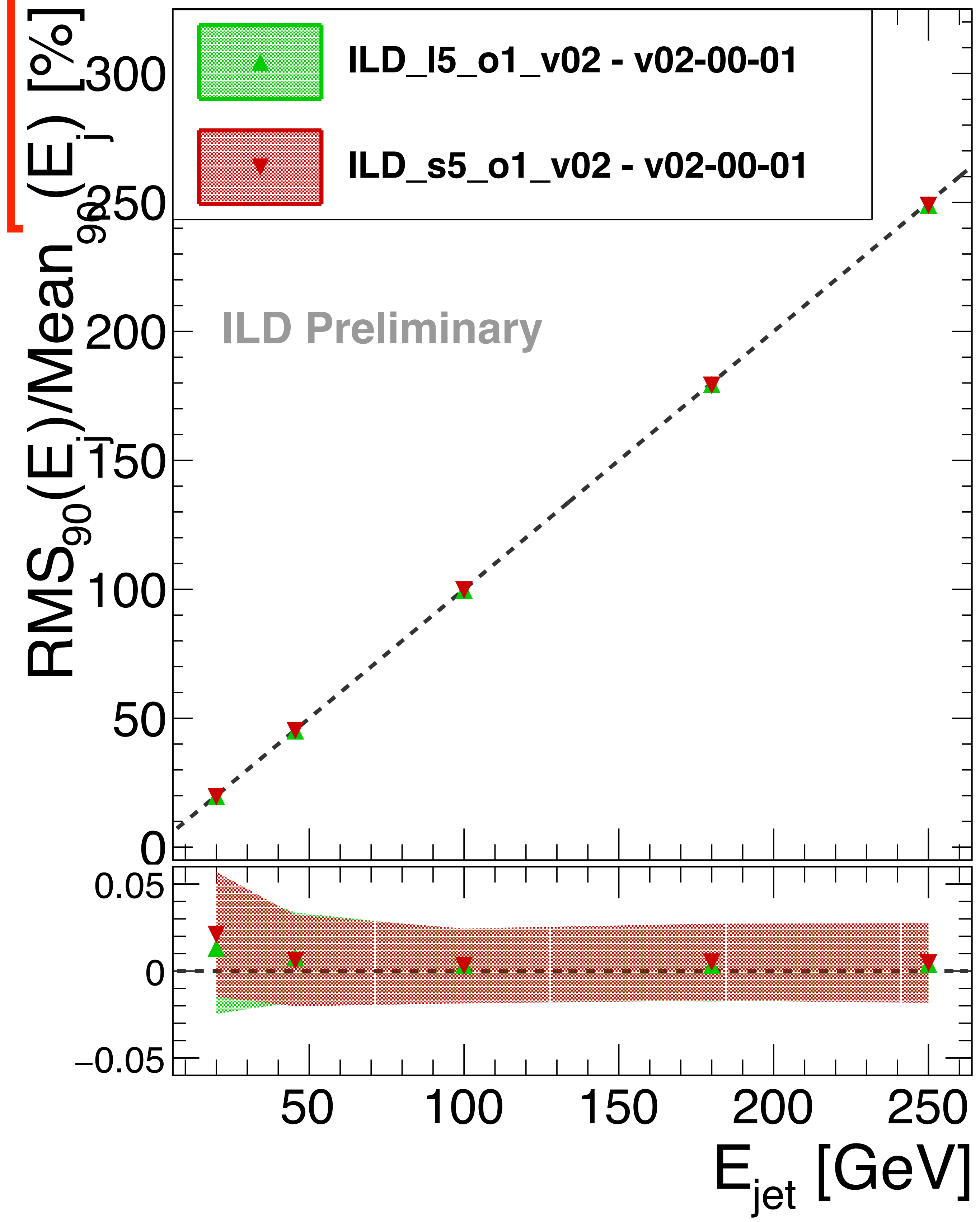
n

o jet finding



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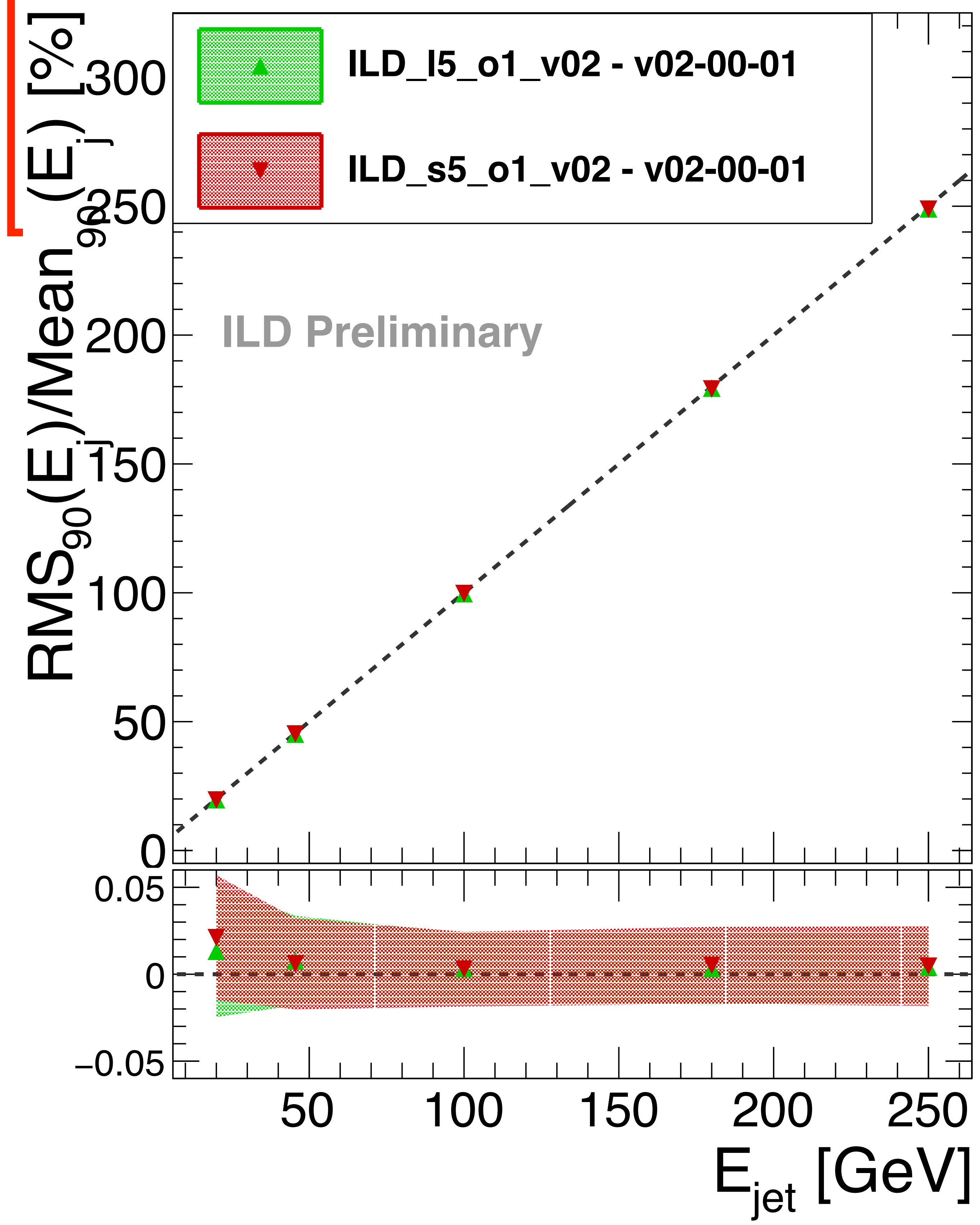

Visible on *physics* events?

R.Ete

ILD-S

ILD-L

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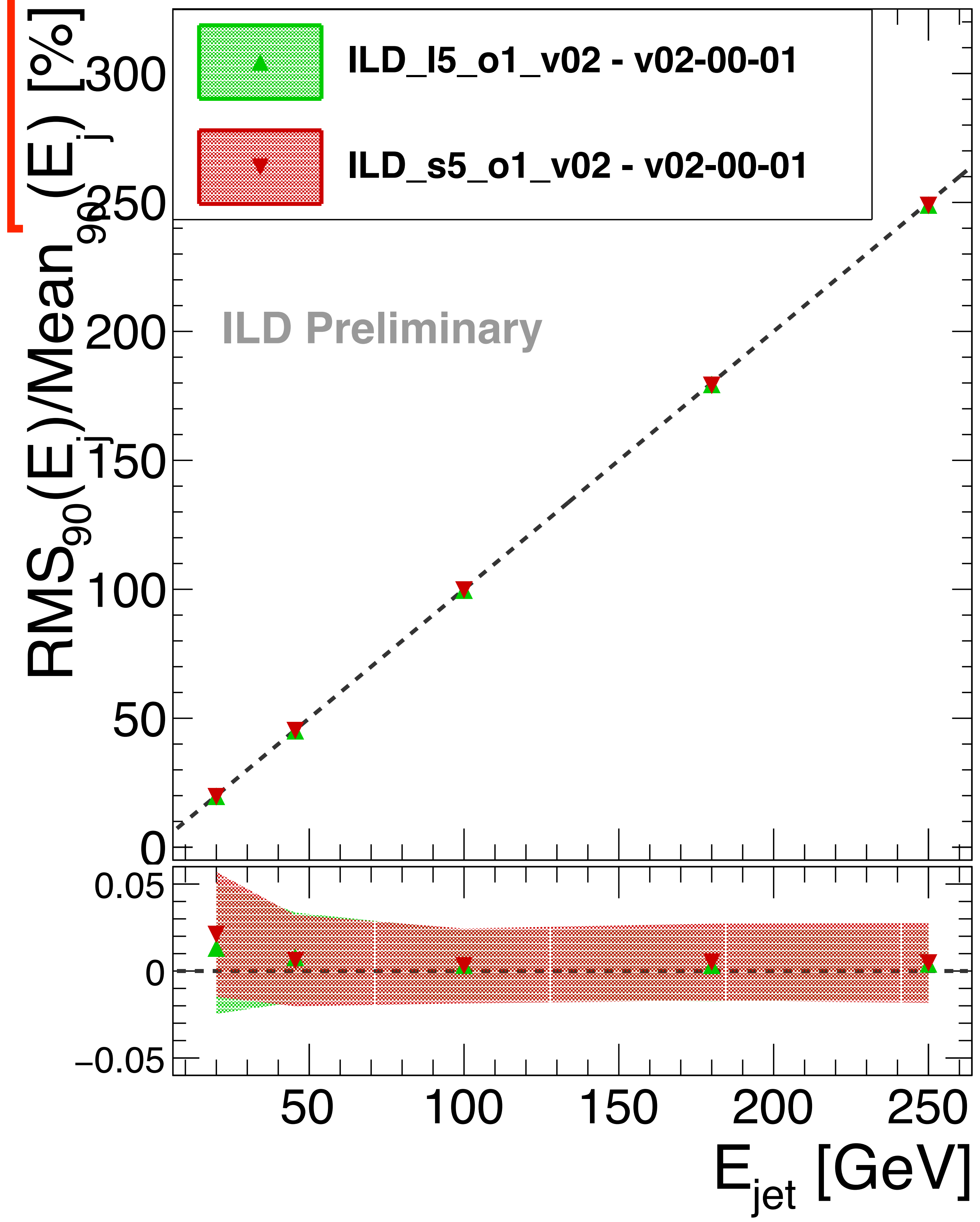


R.Ete

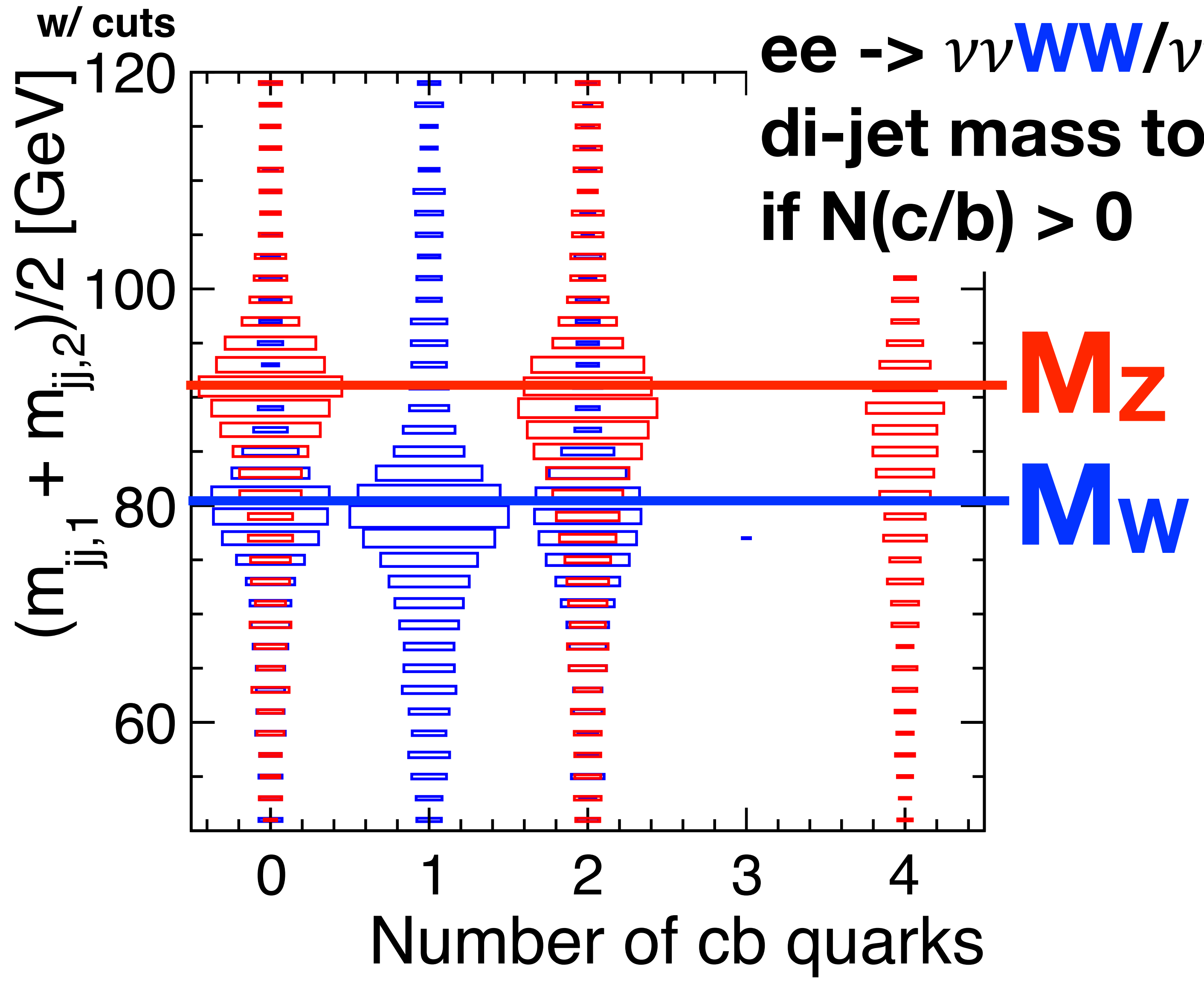
ILD-S

ILD-L

Visible on *physics* events?

ee -> $\nu\nu$WW/$\nu\nu$ZZ ->$\nu\nu$qqqq:
di-jet mass too low
if N(c/b) > 0

J.Beyer



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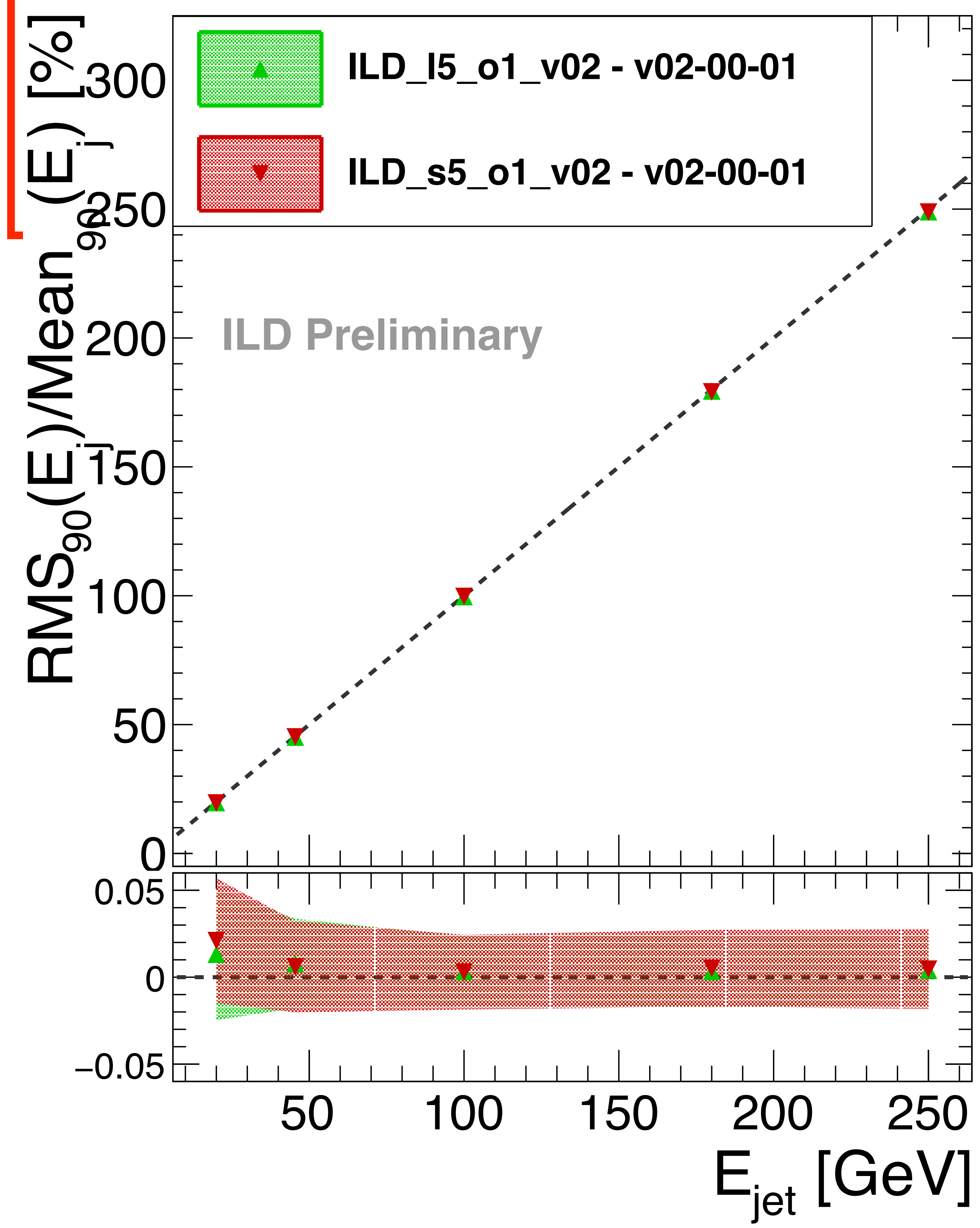

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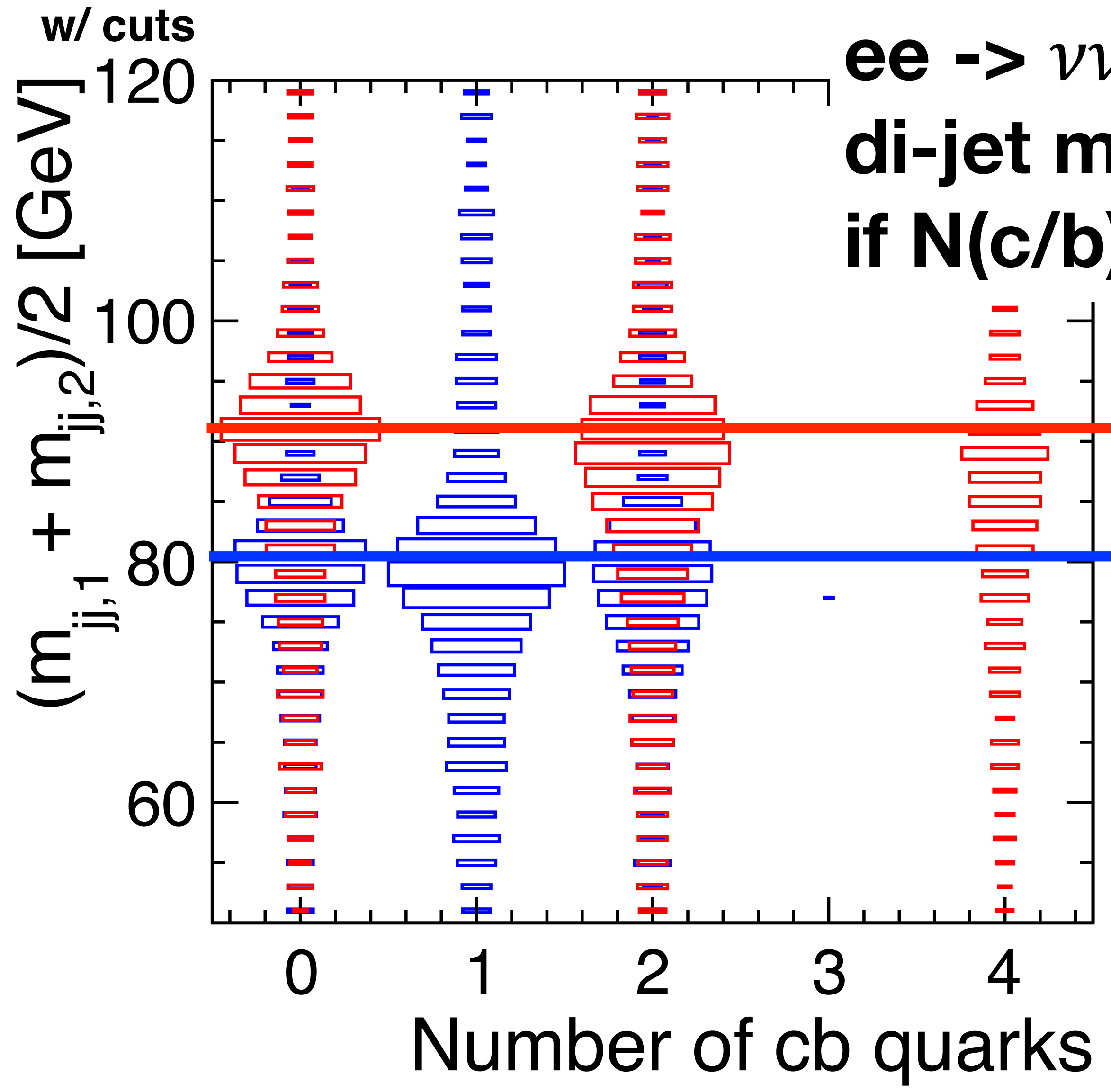

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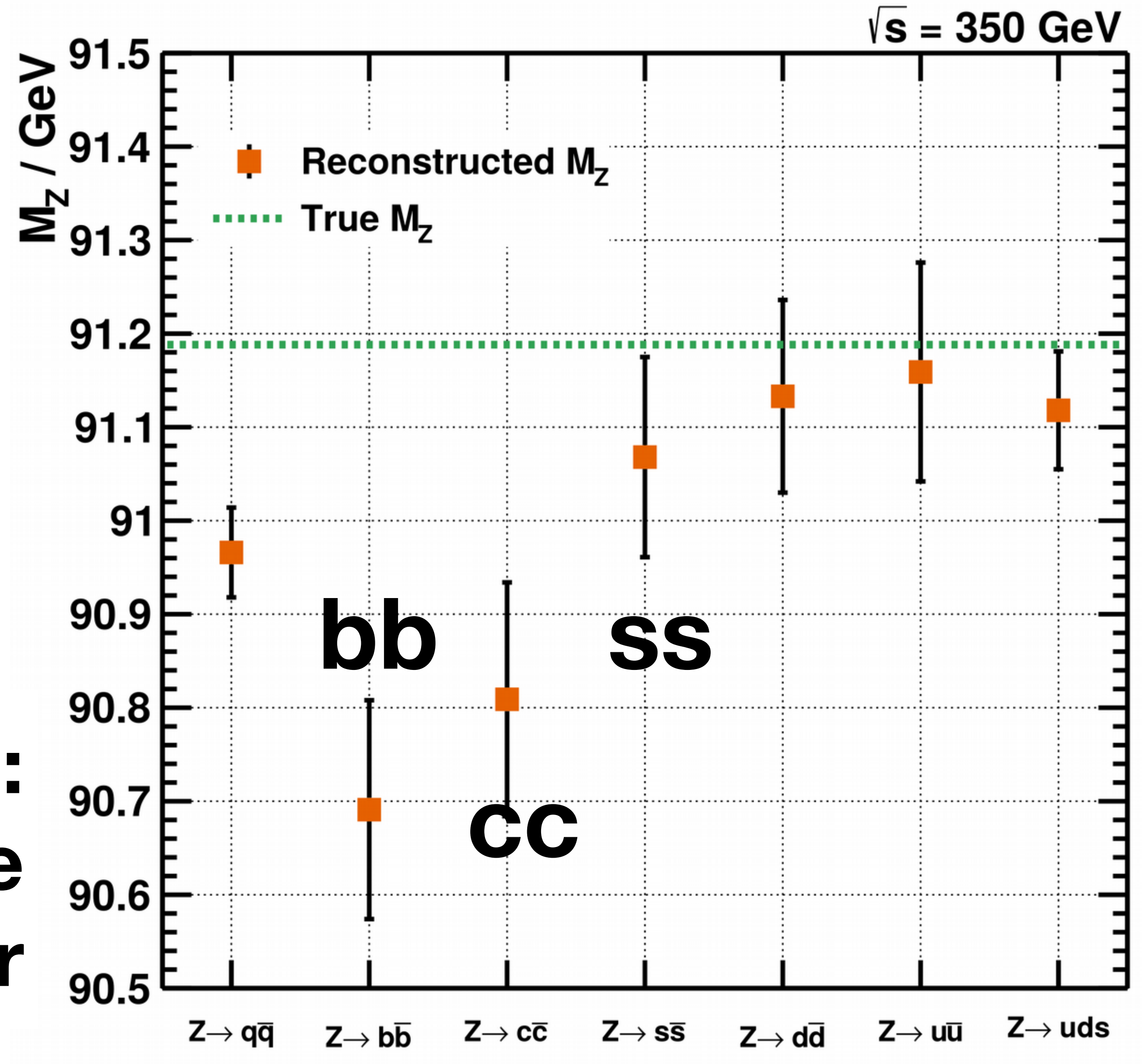
J.Beyer

M_Z

M_W

A.Ebrahimi

ee -> HZ ->qqqq:
Z mass dependence
on quark flavour



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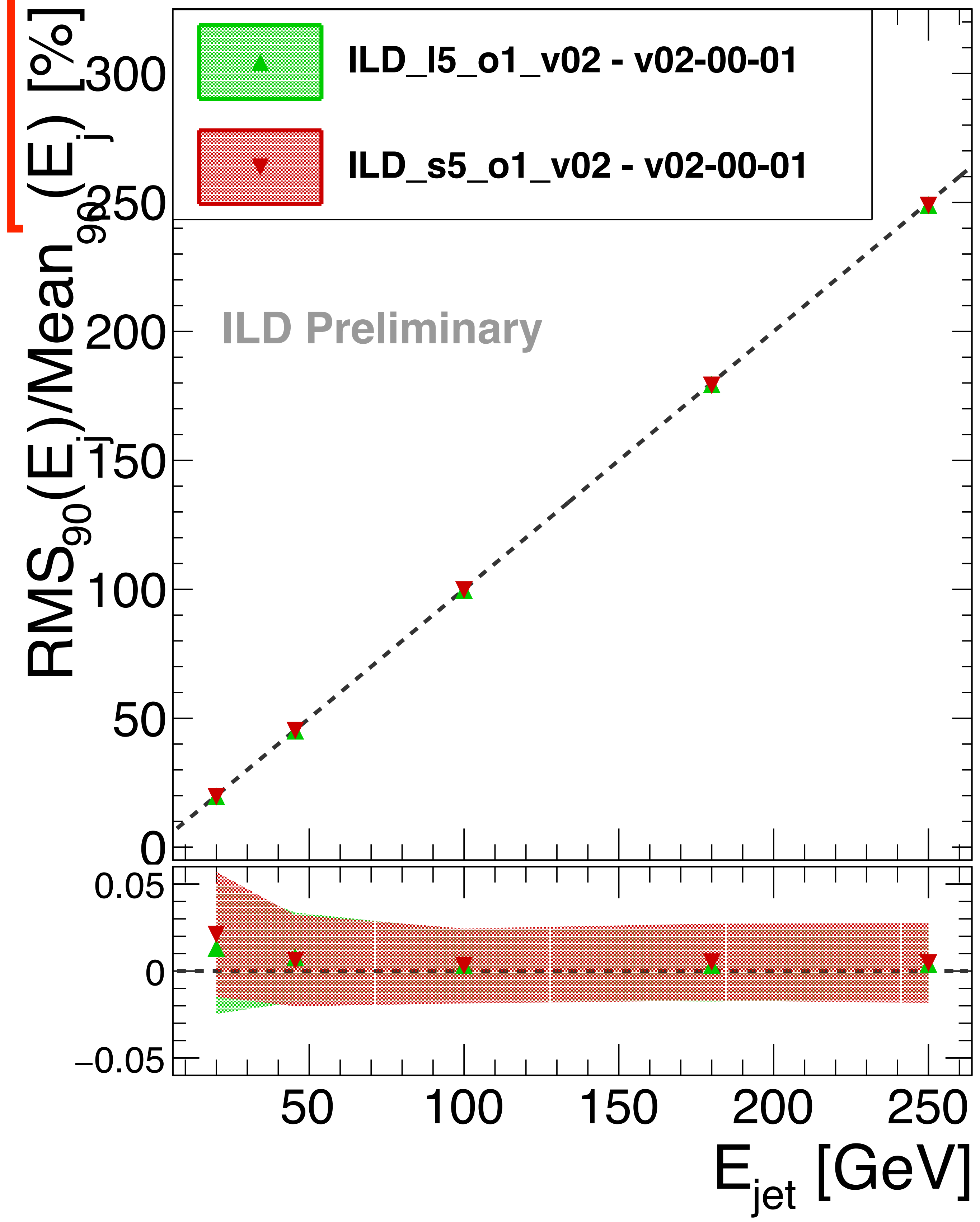

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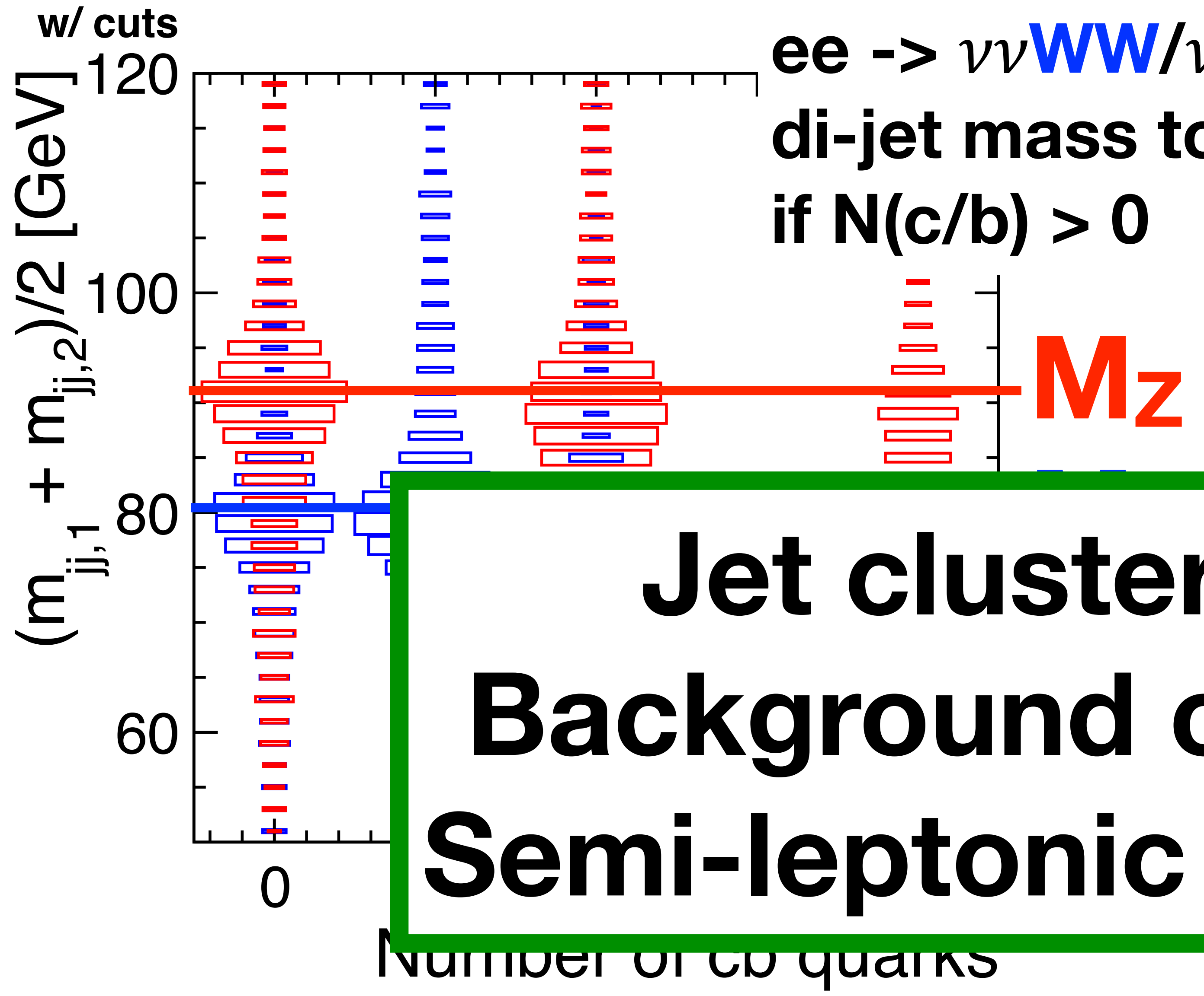
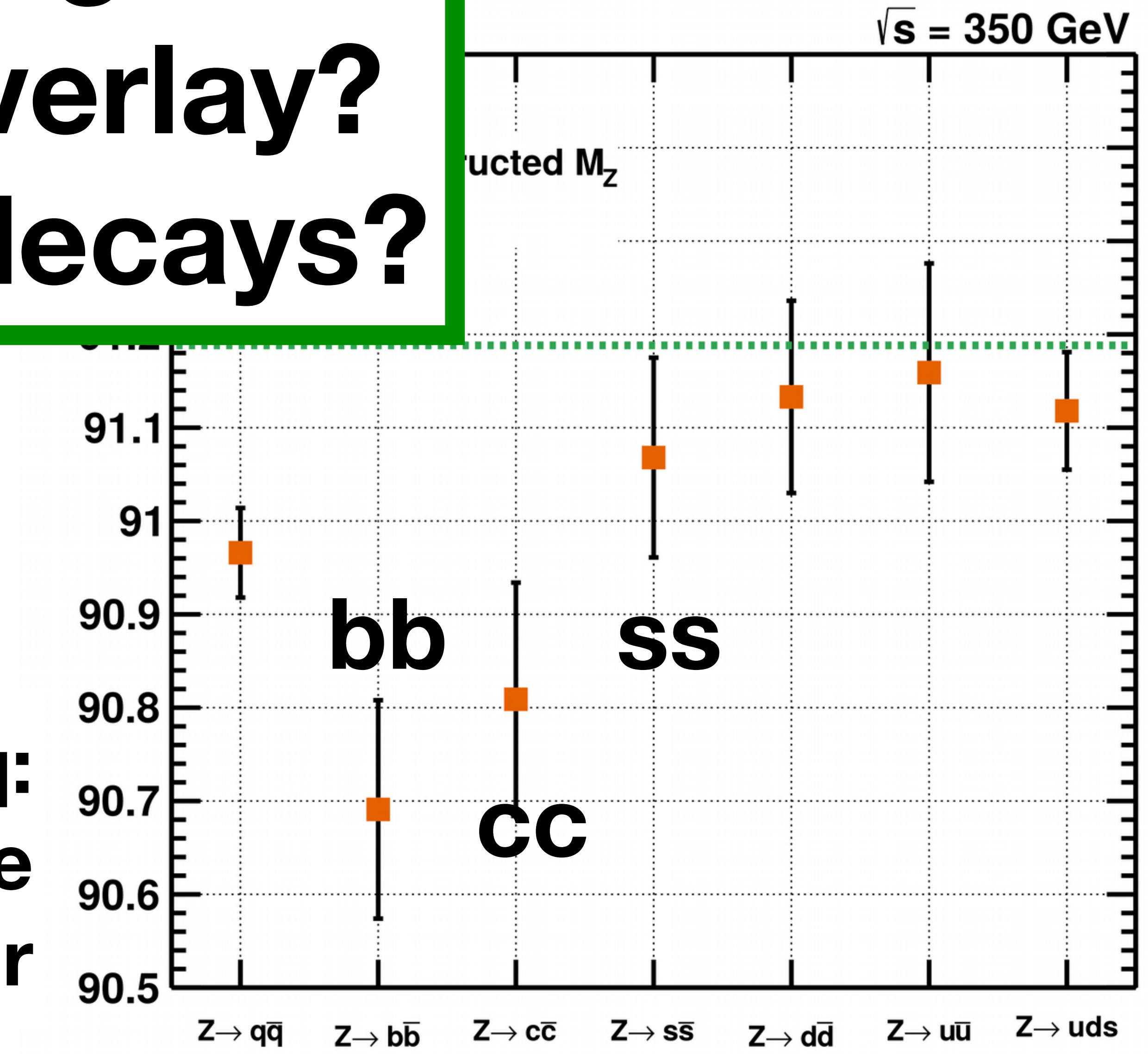


Jet clustering?
Background overlay?
Semi-leptonic decays?

A.Ebrahimi

ee -> HZ ->qqqq:
Z mass dependence
on quark flavour



Particle Flow for heavy quark jets

- **using new ee -> cc / bb** analogously to uds samples **Y.Radkhorrami**
- differences in
  - fragmentation
  - number /energy of neutral hadrons
  - but cheating neutrinos

cause **huge** degradation of c/b - JER/JES

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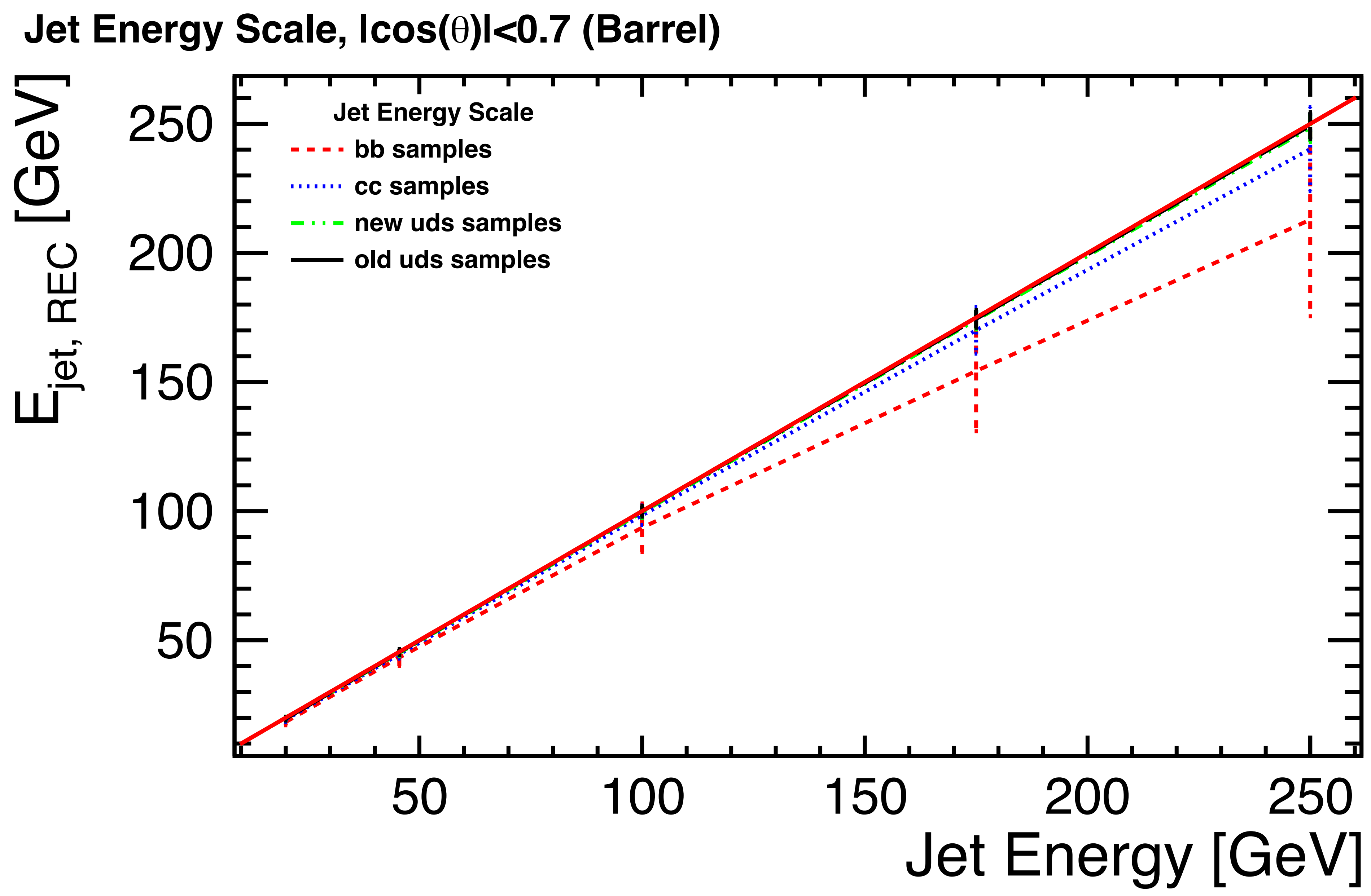

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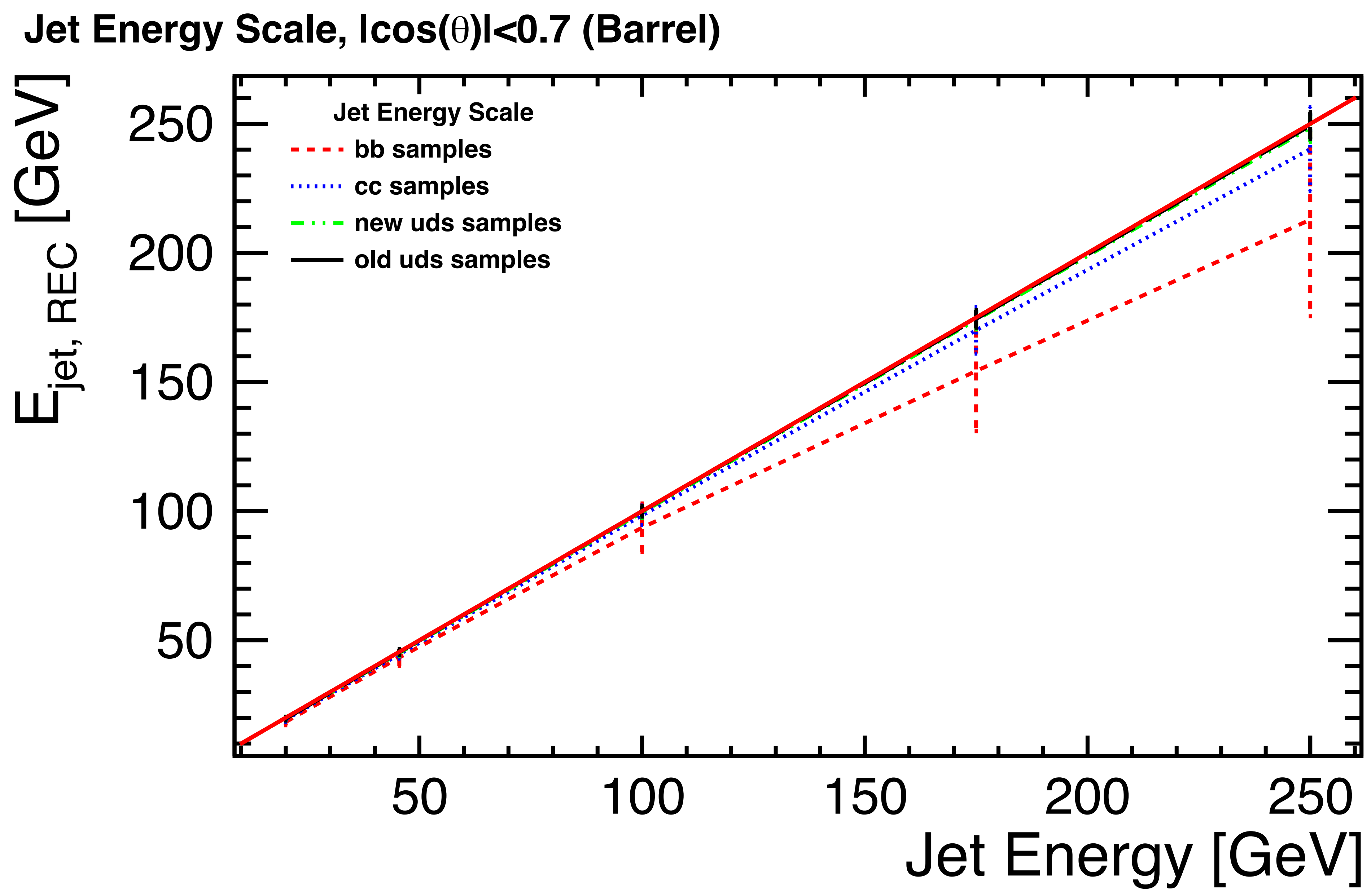

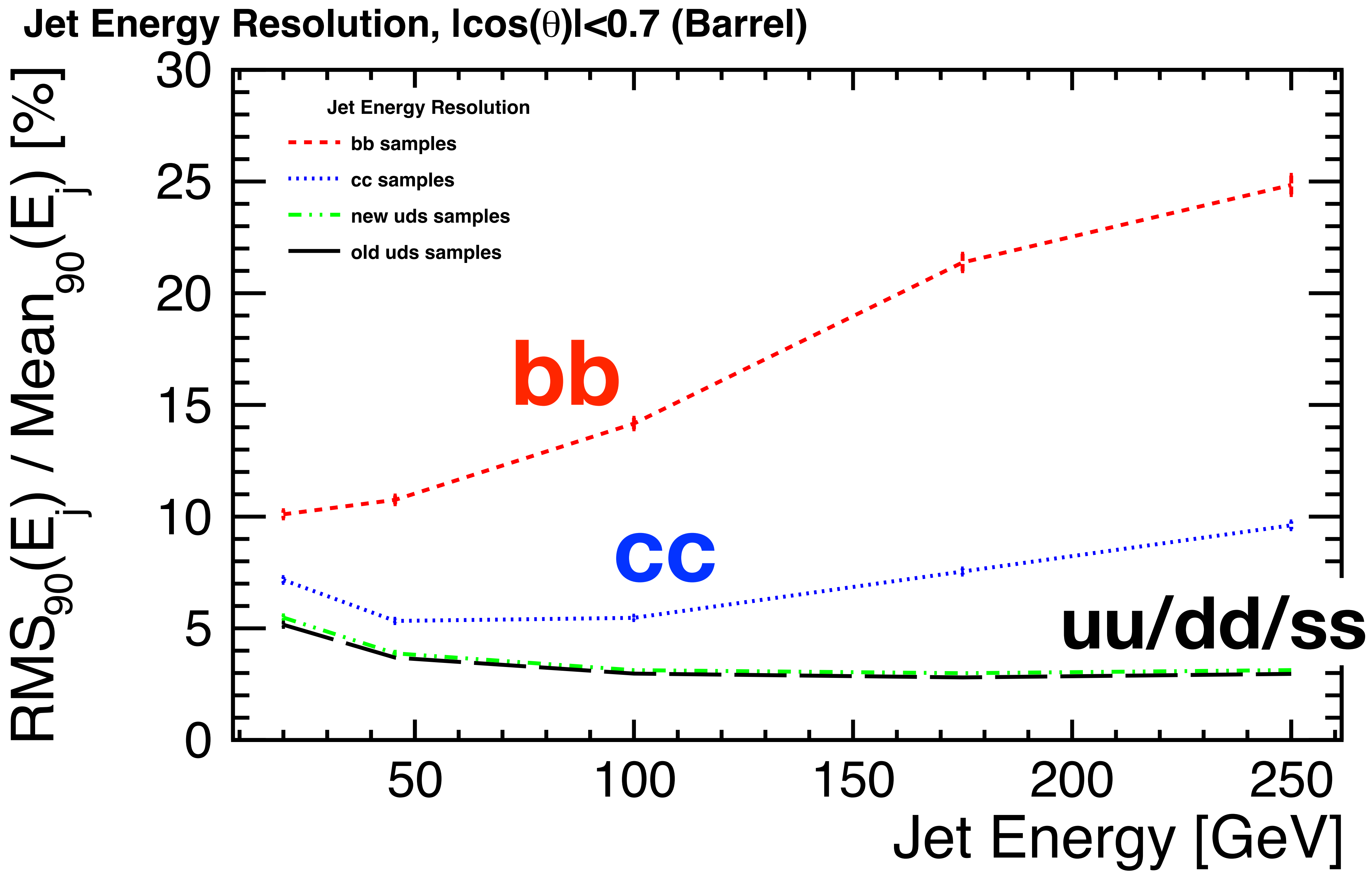

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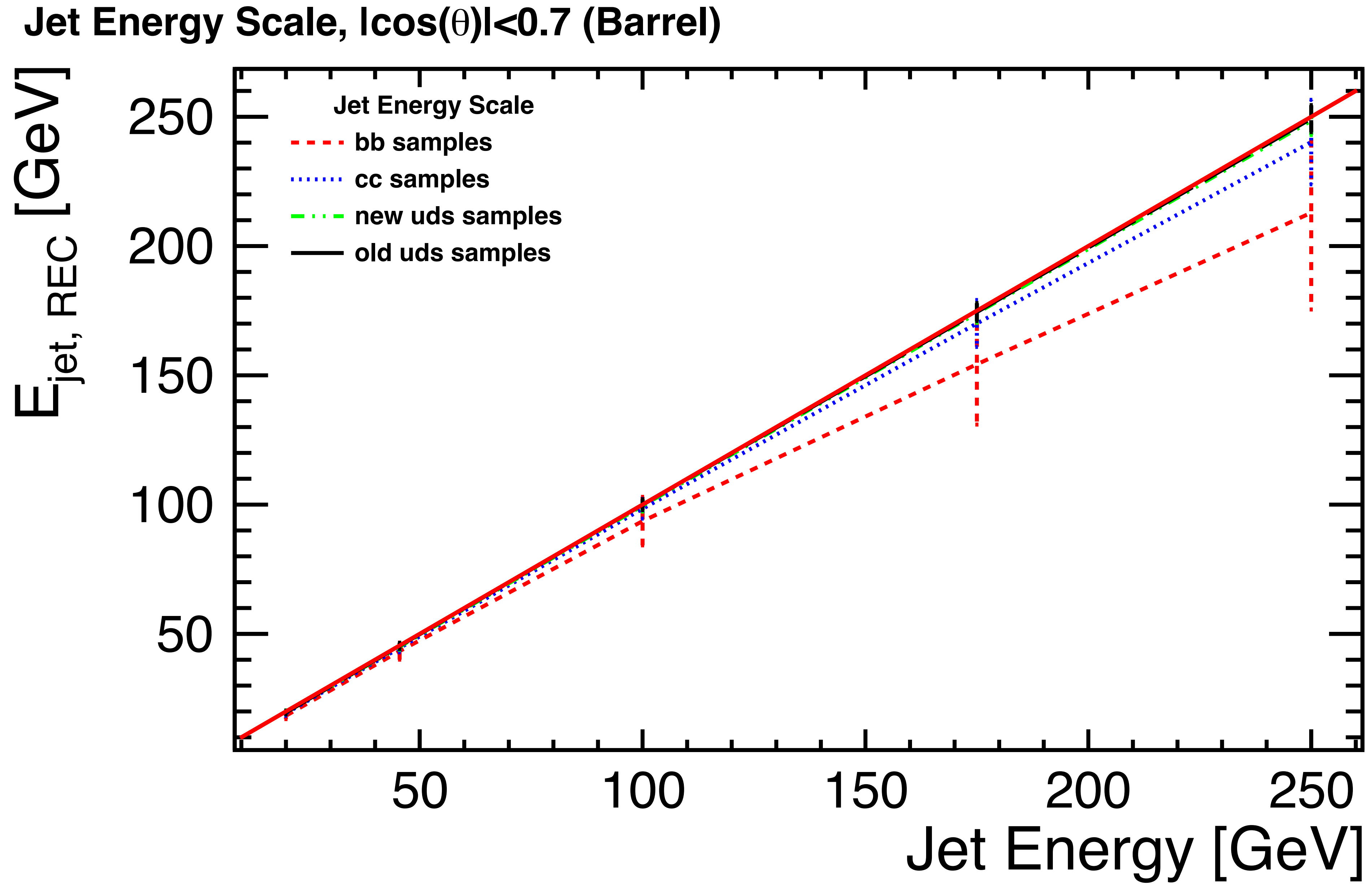

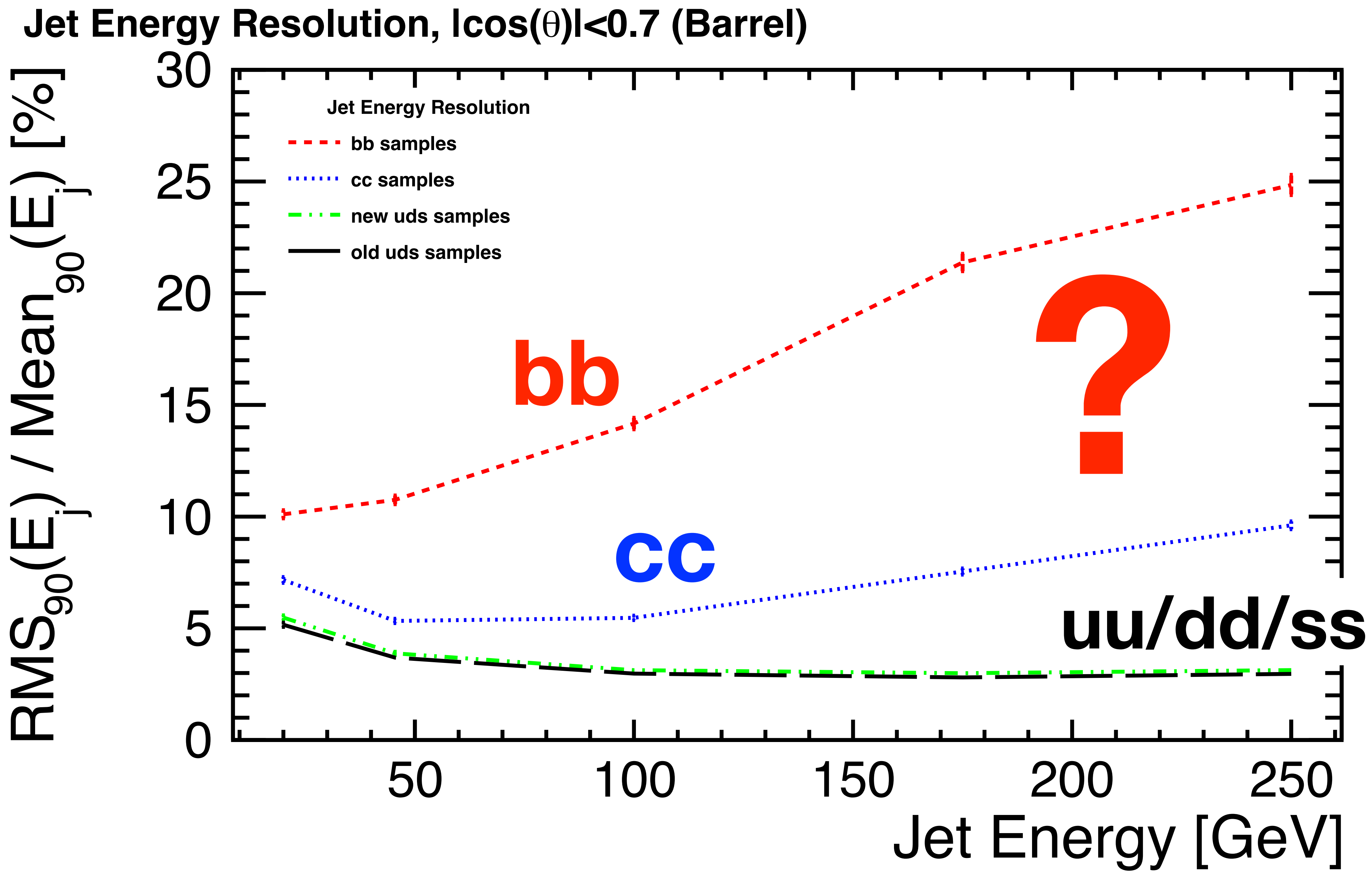

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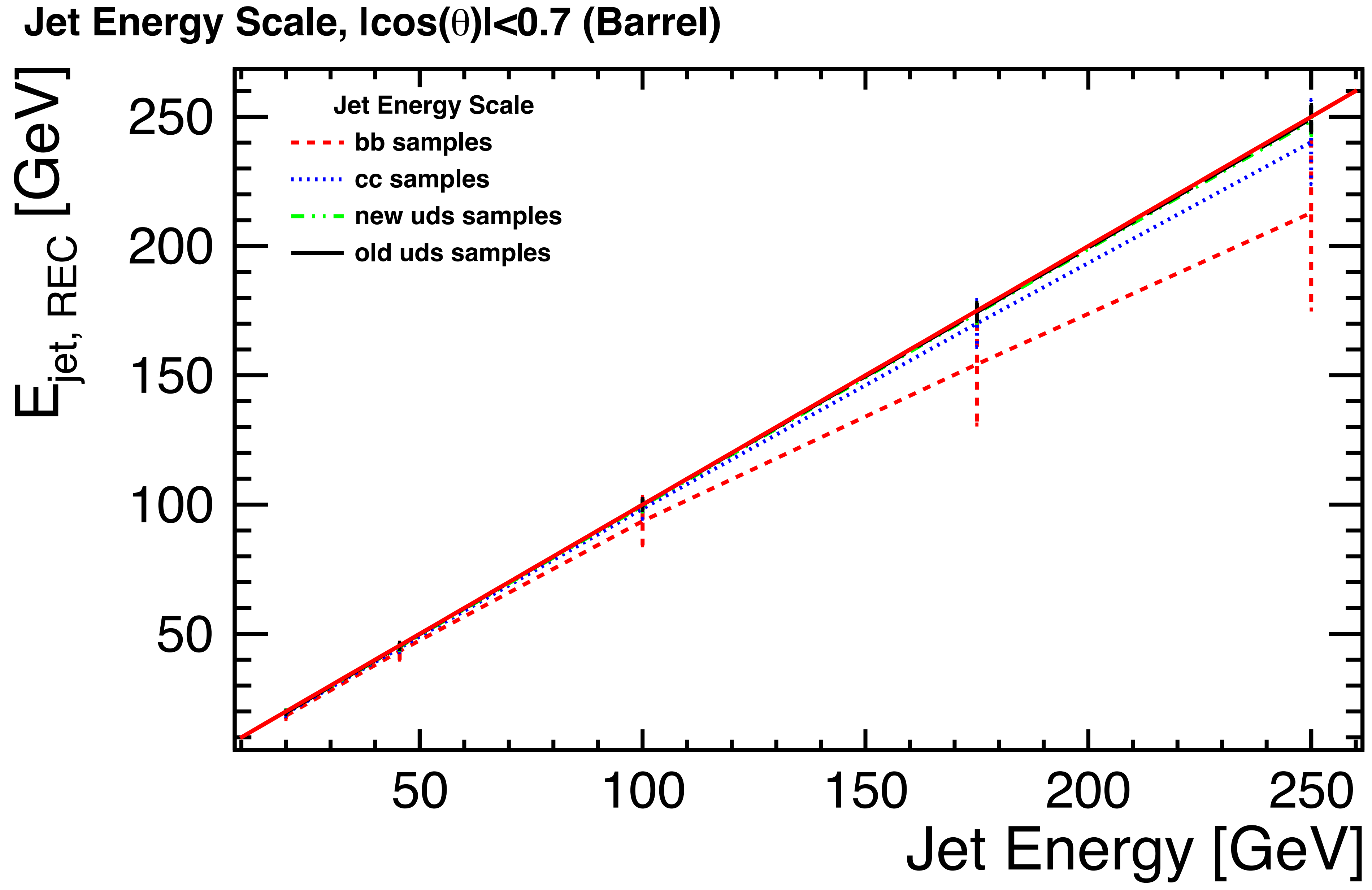

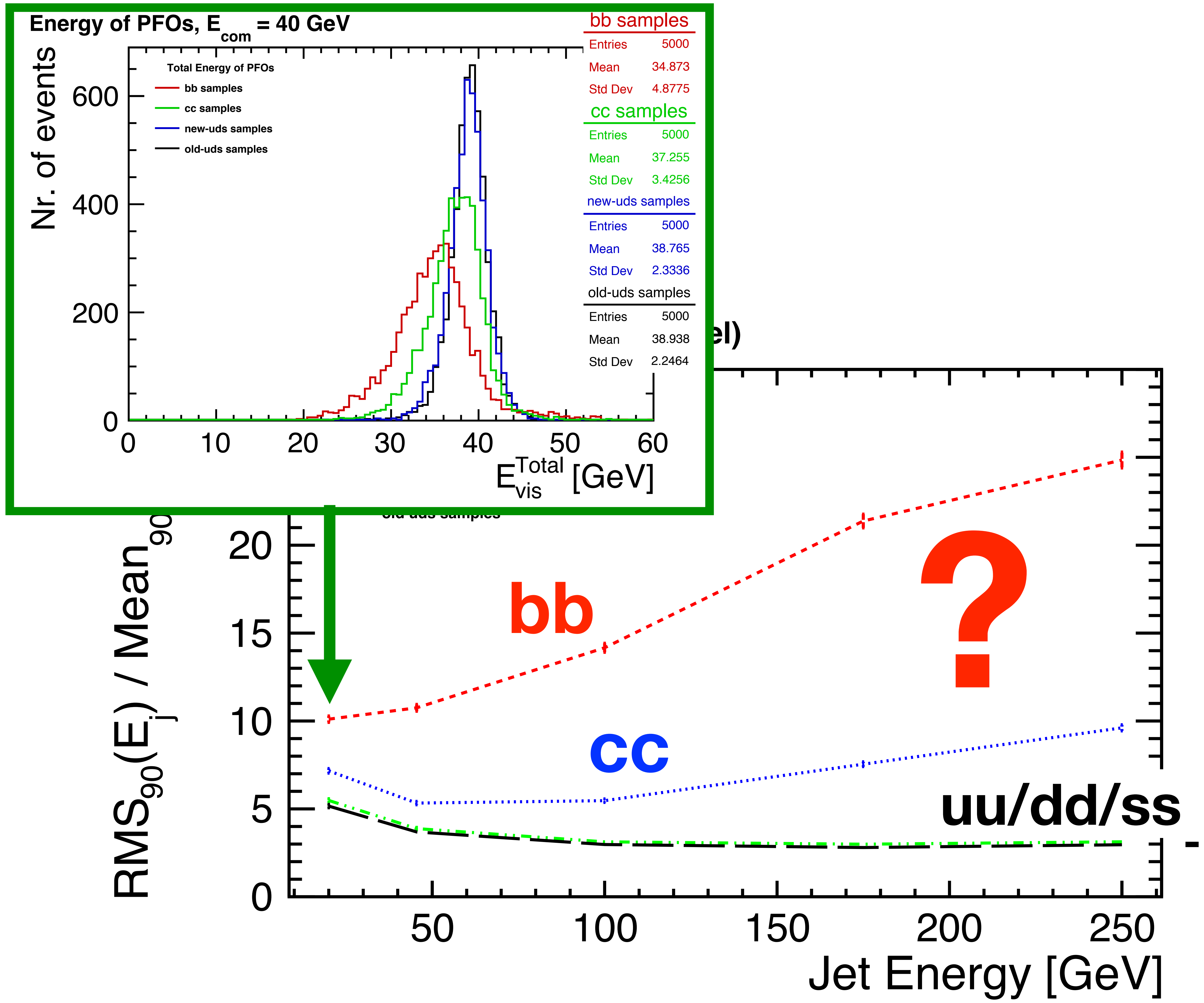

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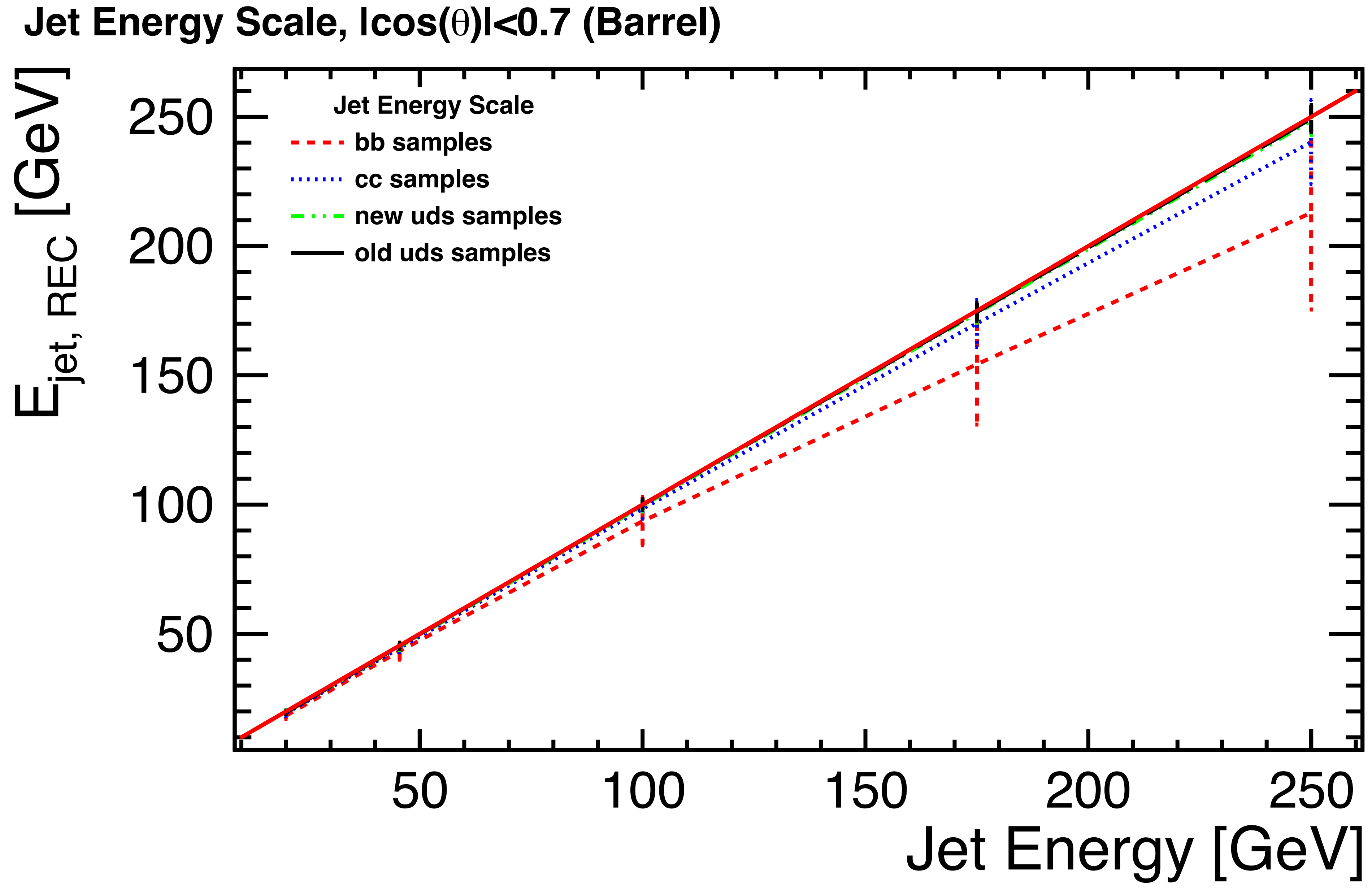

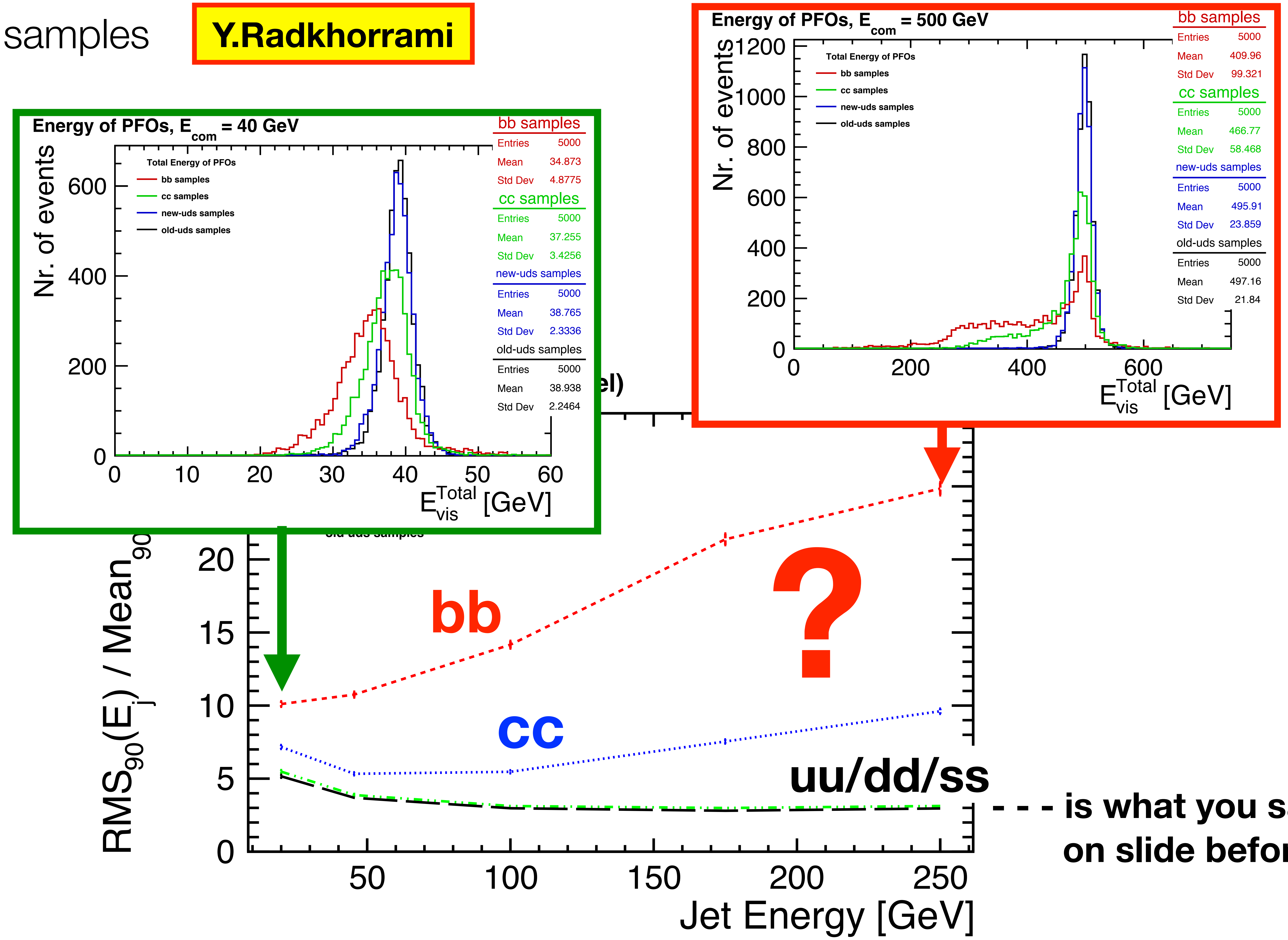

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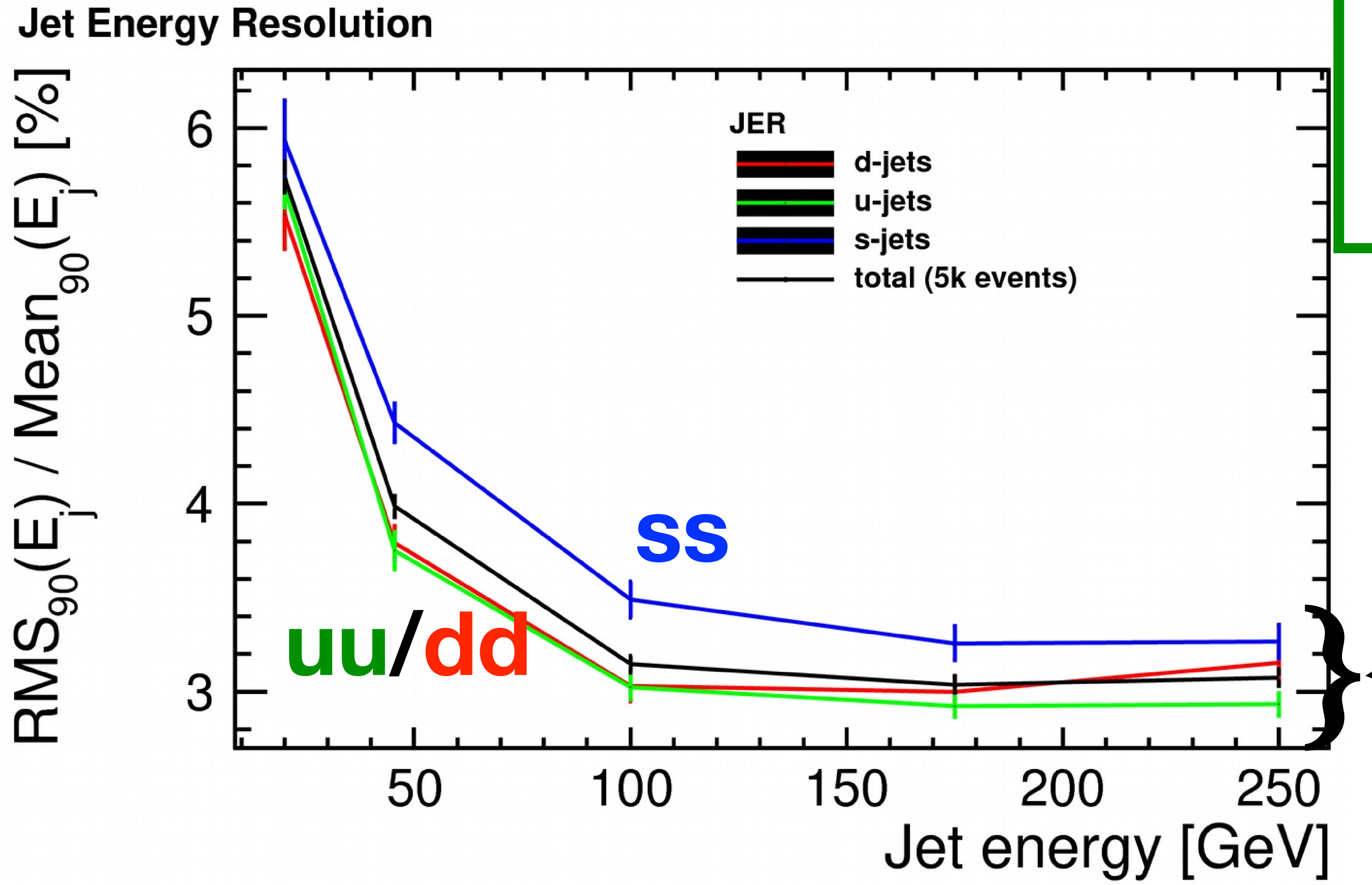

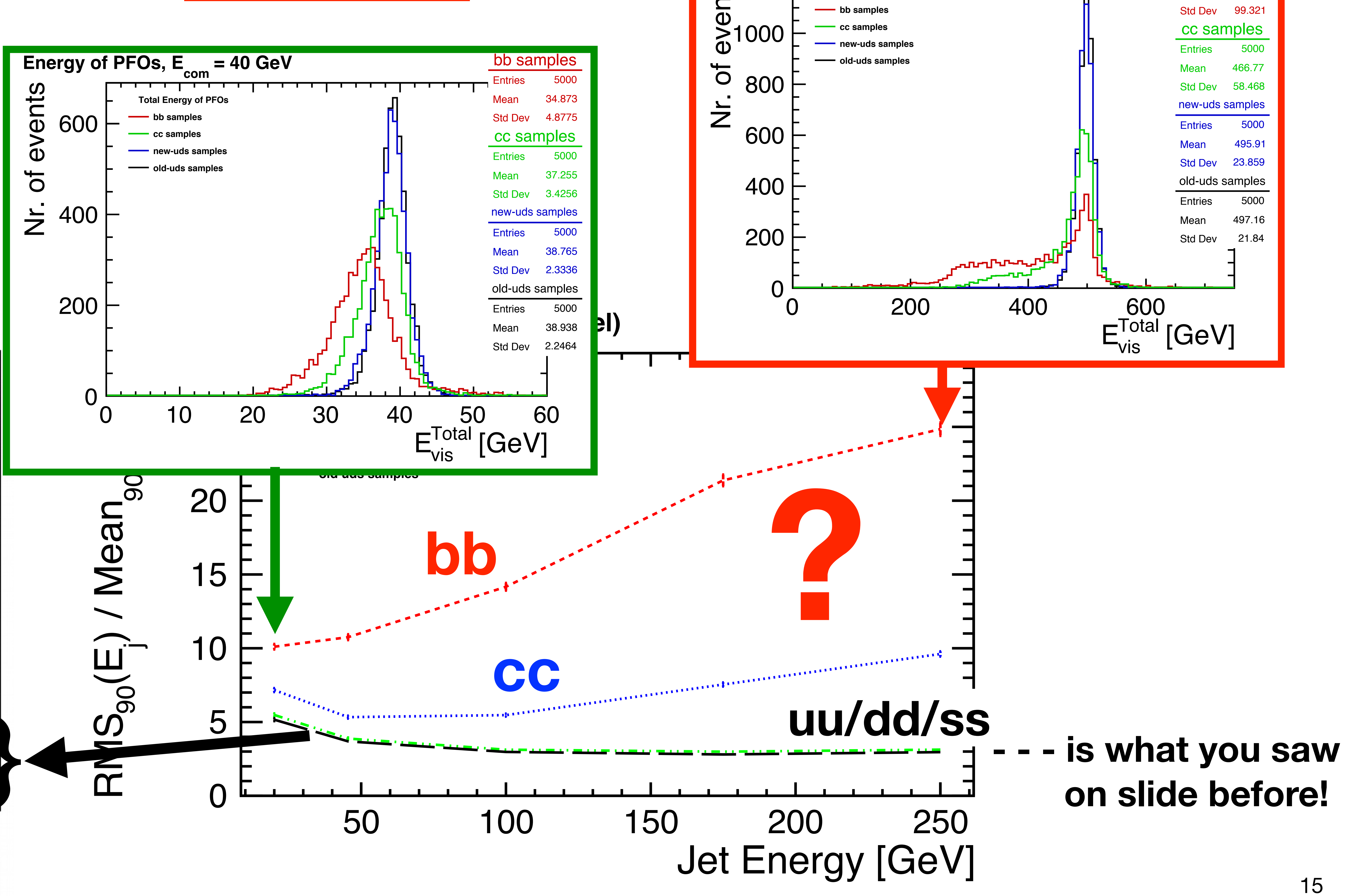

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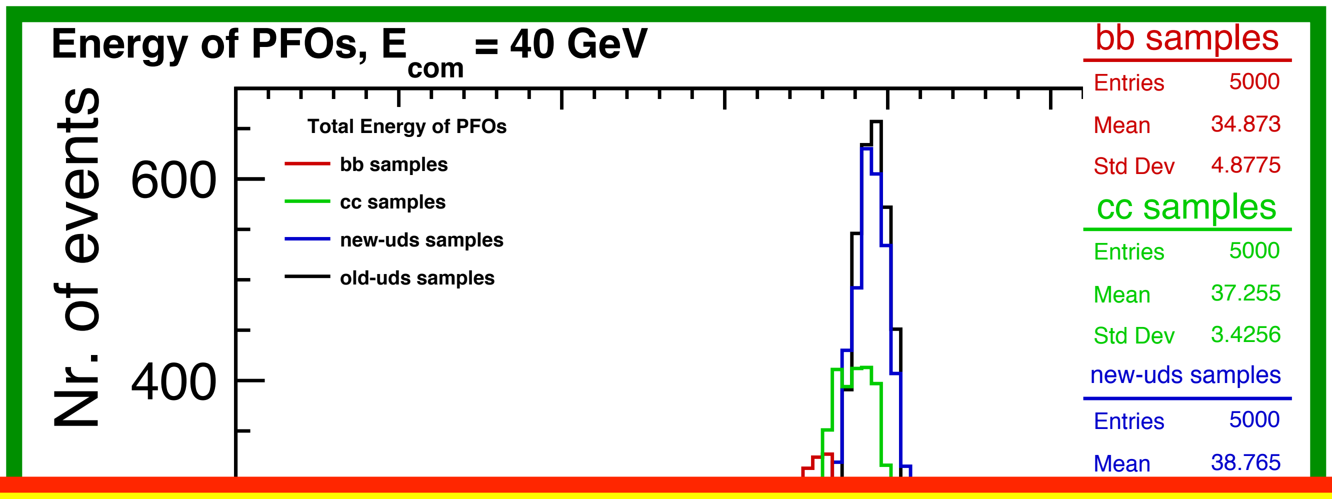
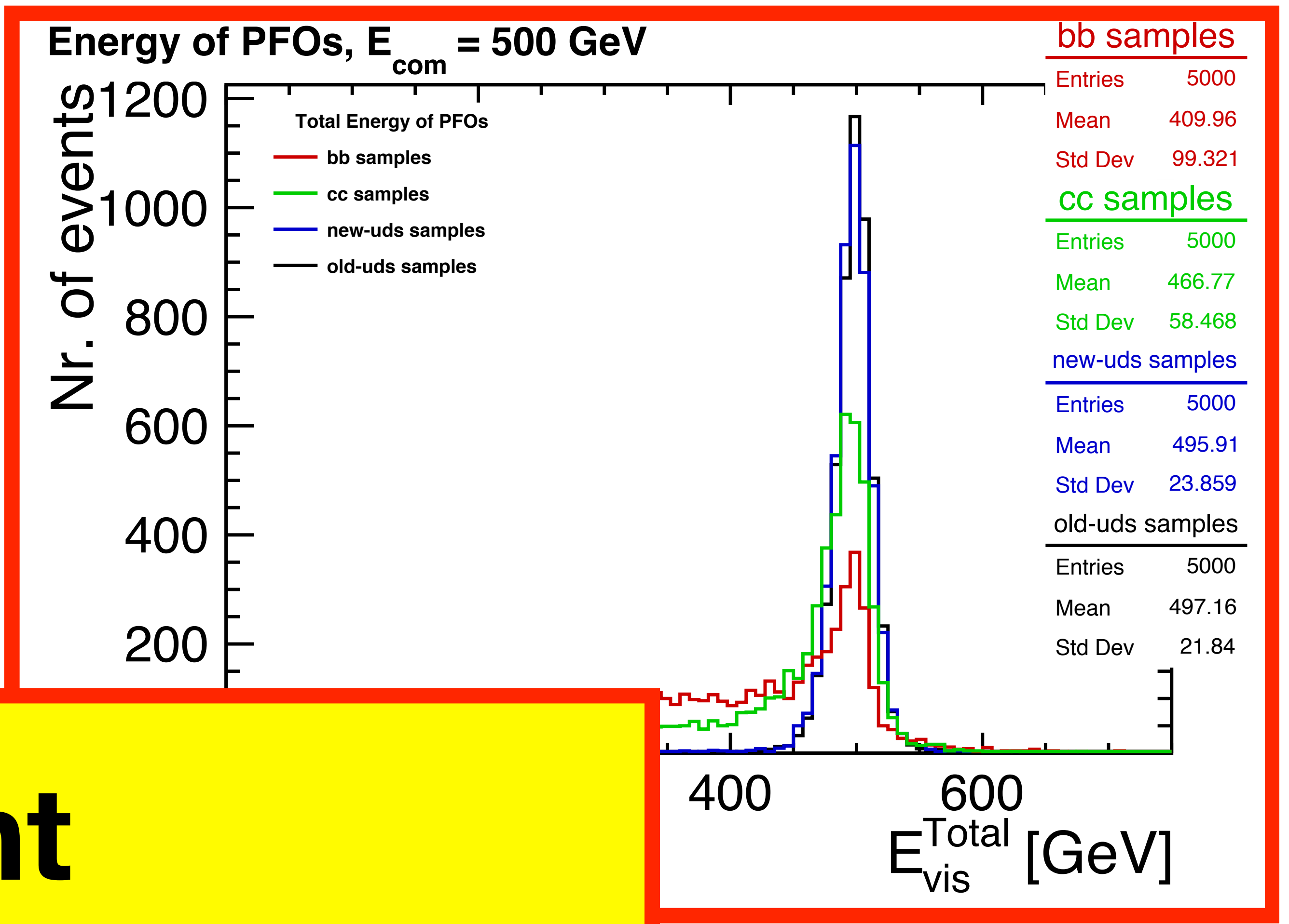
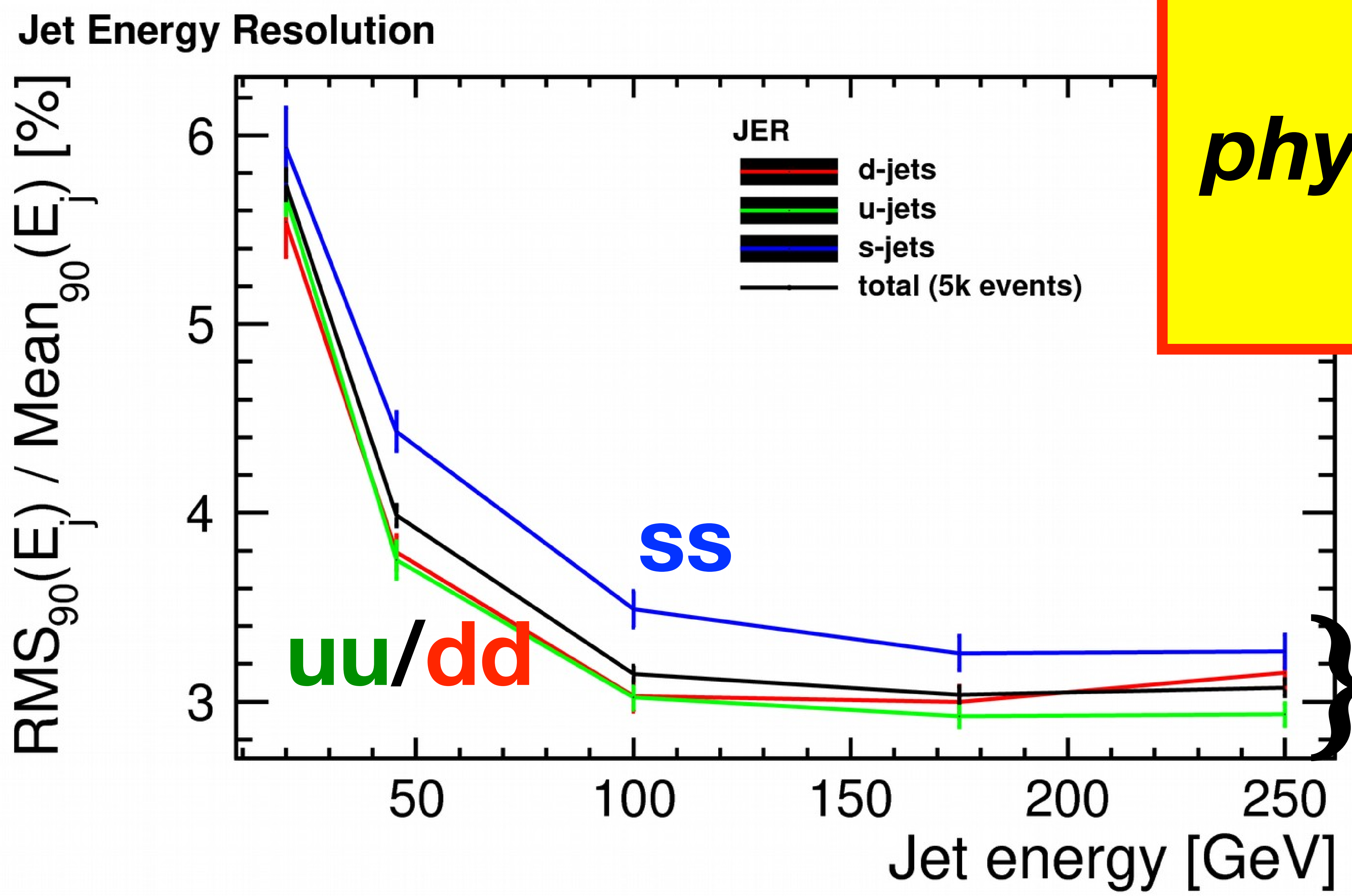
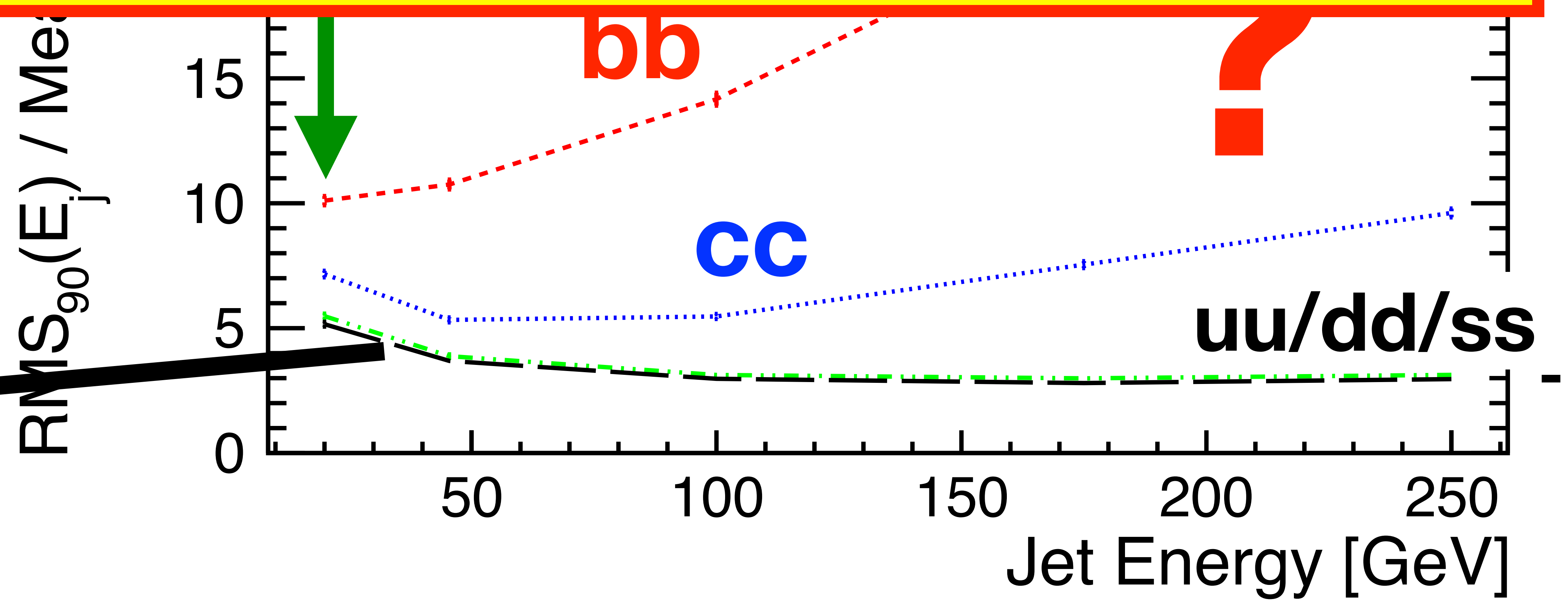




This is what current *physics case studies* are based upon => room for improvement!





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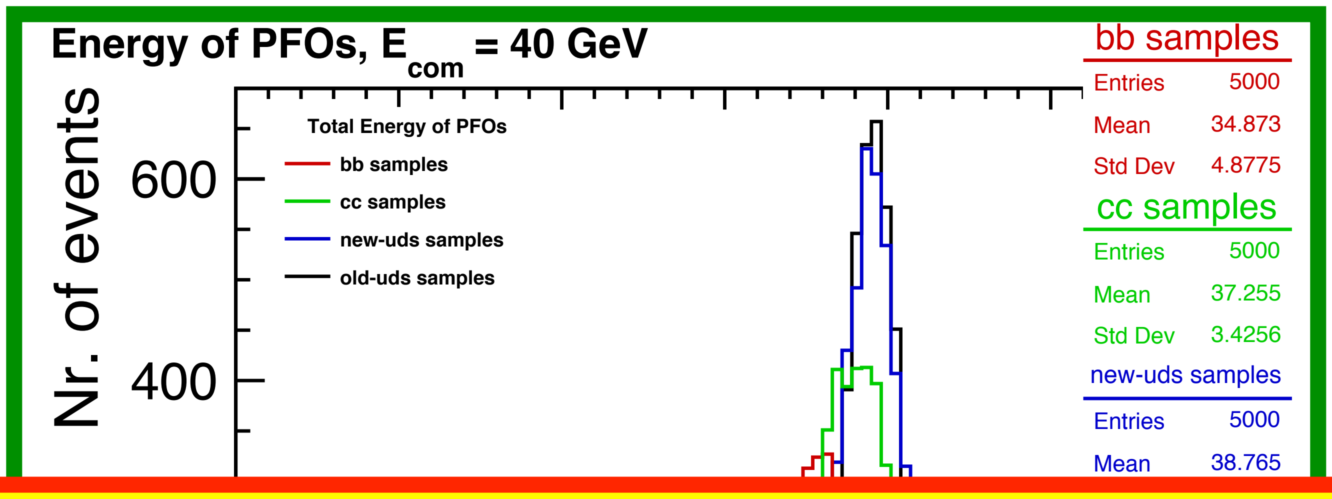

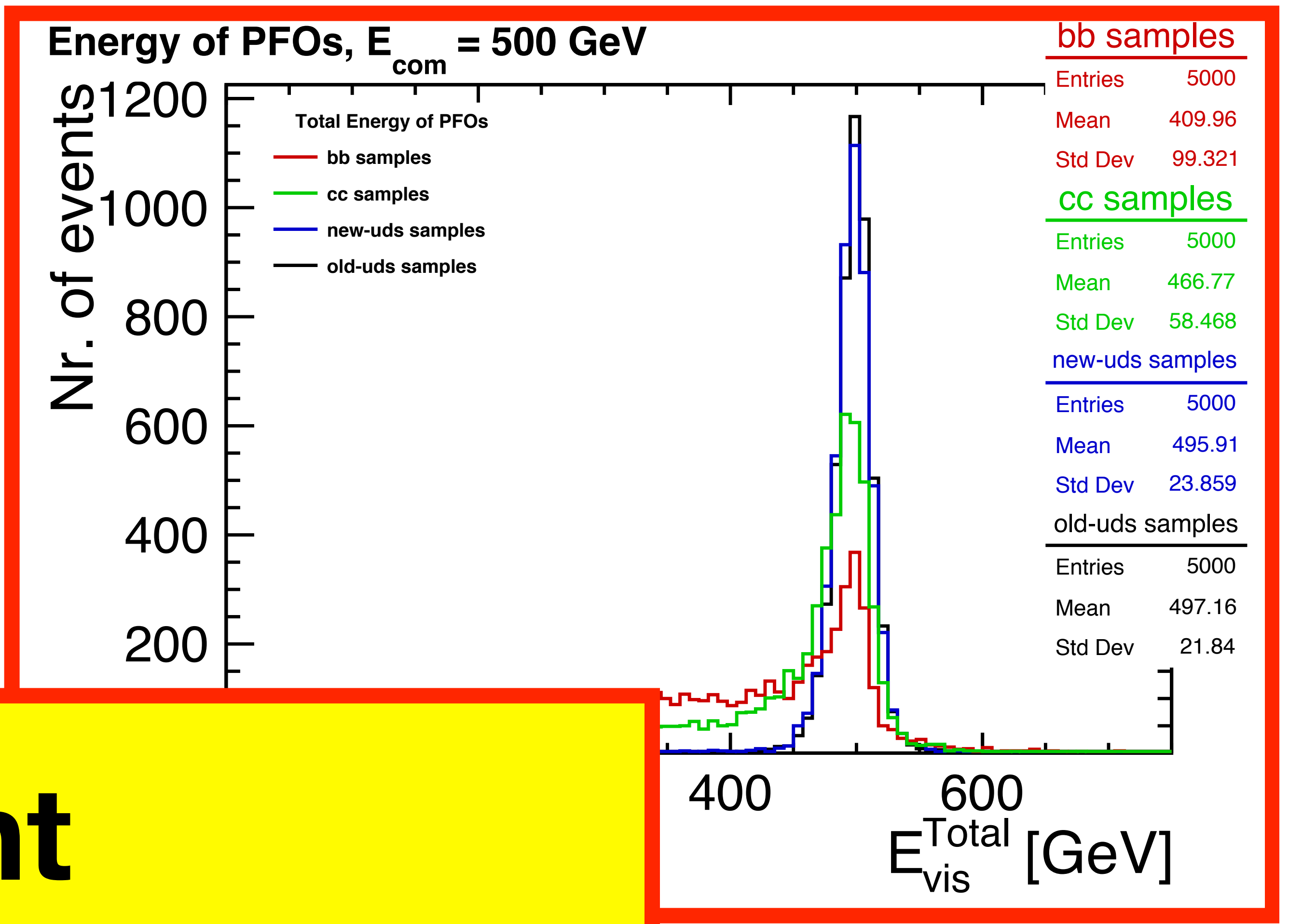

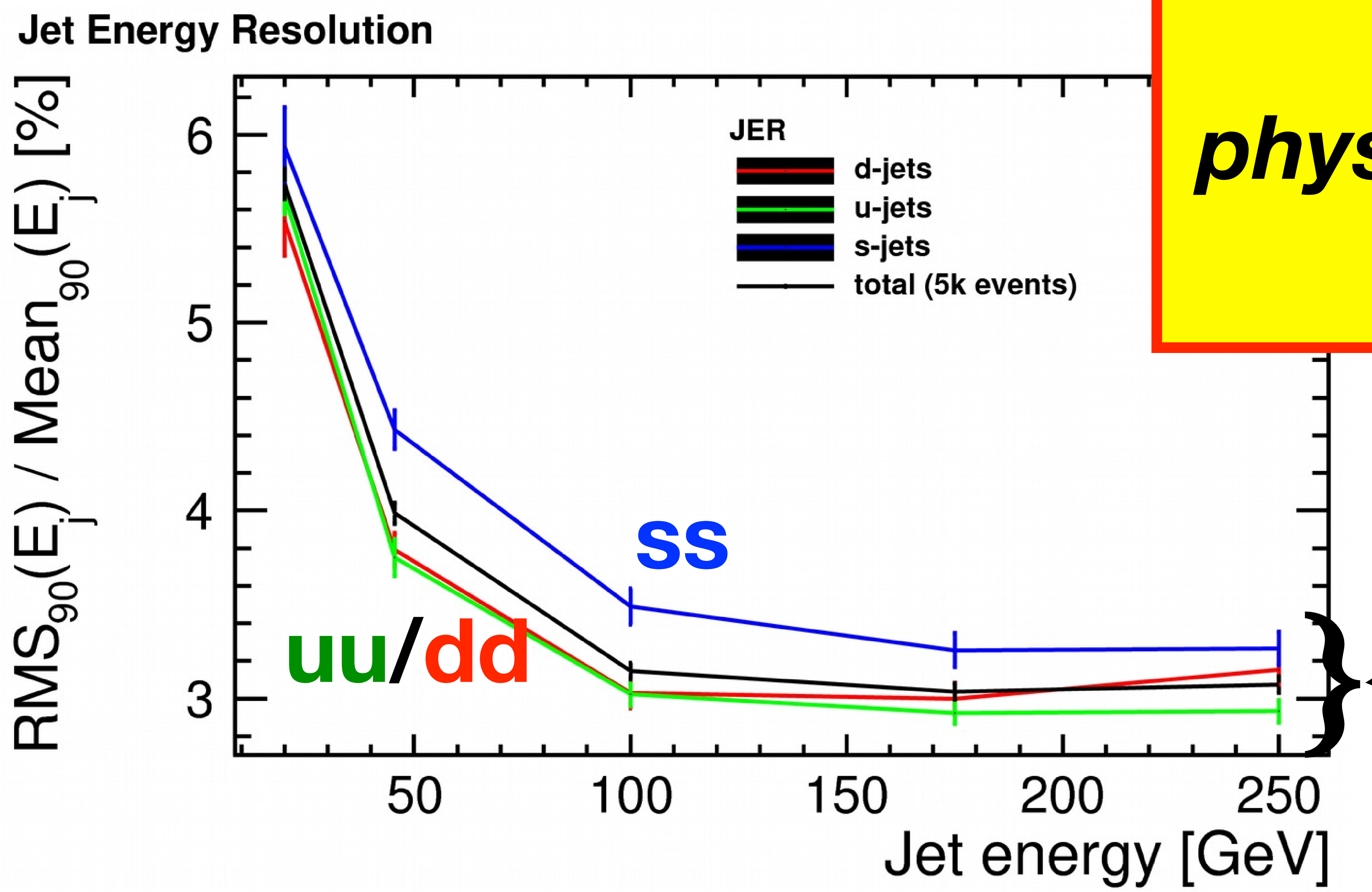

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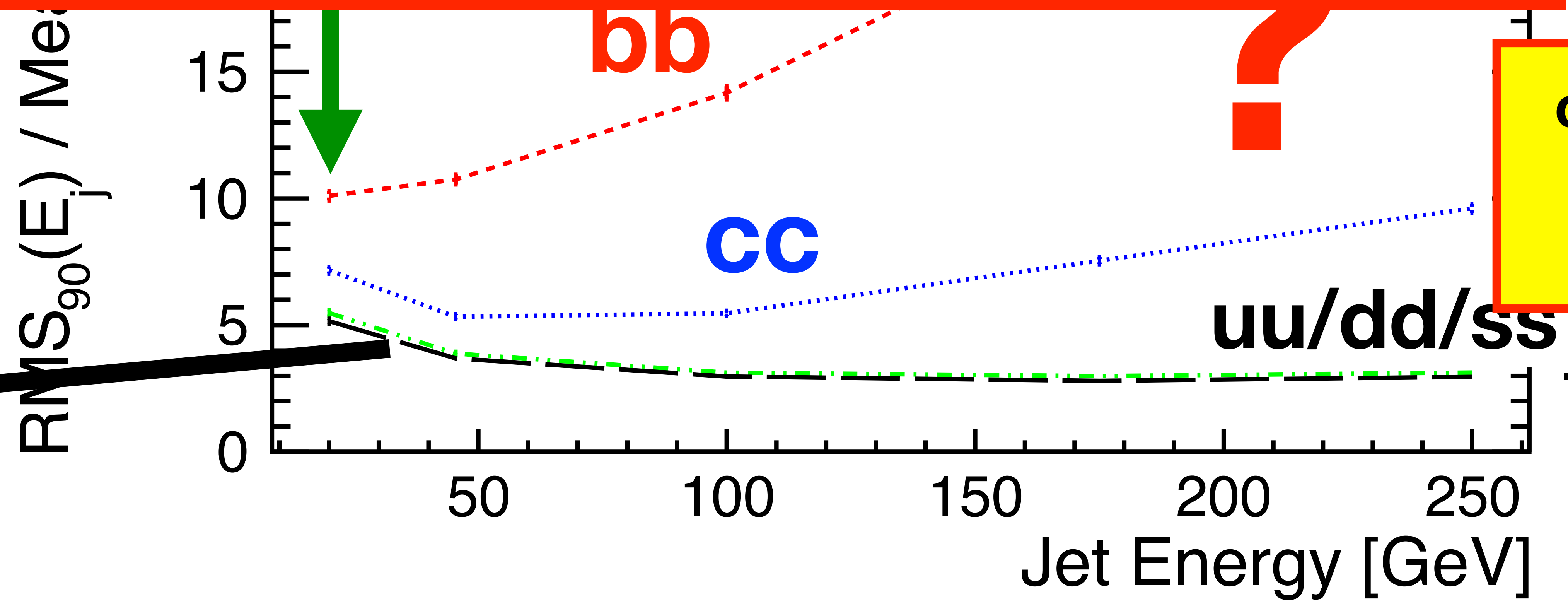


c.f. sim/rec parallel
Thu 11 am
R.Ete

- - - is what you saw on slide before!

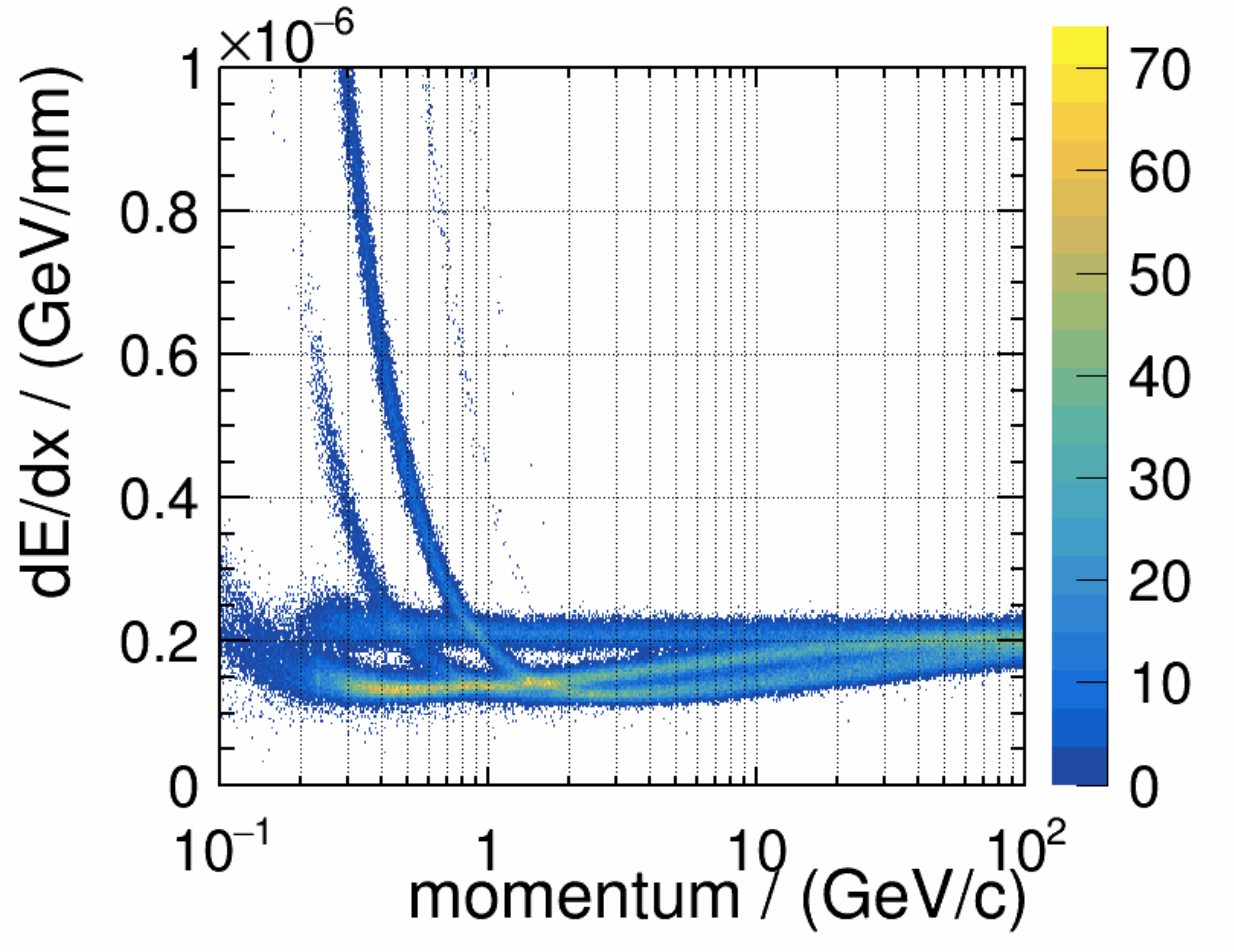
Opportunities to improve ILD - Time of Flight for PID

- ILD baseline: **dE/dx** (TPC) - **resolution**

  ILD-L : 4.4% (sim) vs 4.2…4.7% (testbeam)

  ILD-S: 4.9% (sim) vs 4.8…5.4% (testbeam)

- **NEW**: Studied potential improvement by **time-of-flight** by assuming 10, 50,100 ps resolution on first 10 ECal hits



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  ILD-L : 4.4% (sim) vs 4.2…4.7% (testbeam)

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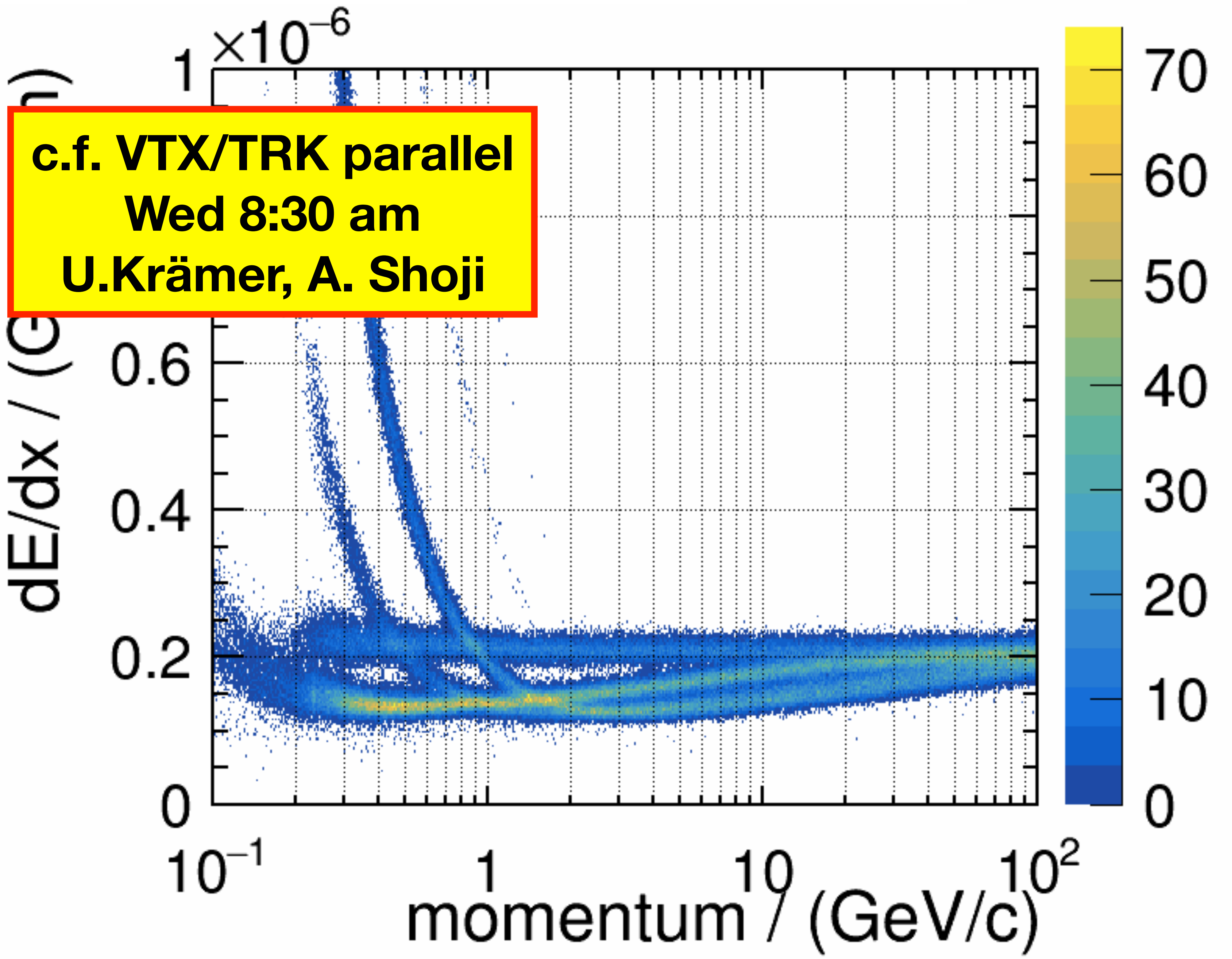
- **NEW**: Studied potential improvement by **time-of-flight** by assuming 10, 50,100 ps resolution on first 10 ECal hits



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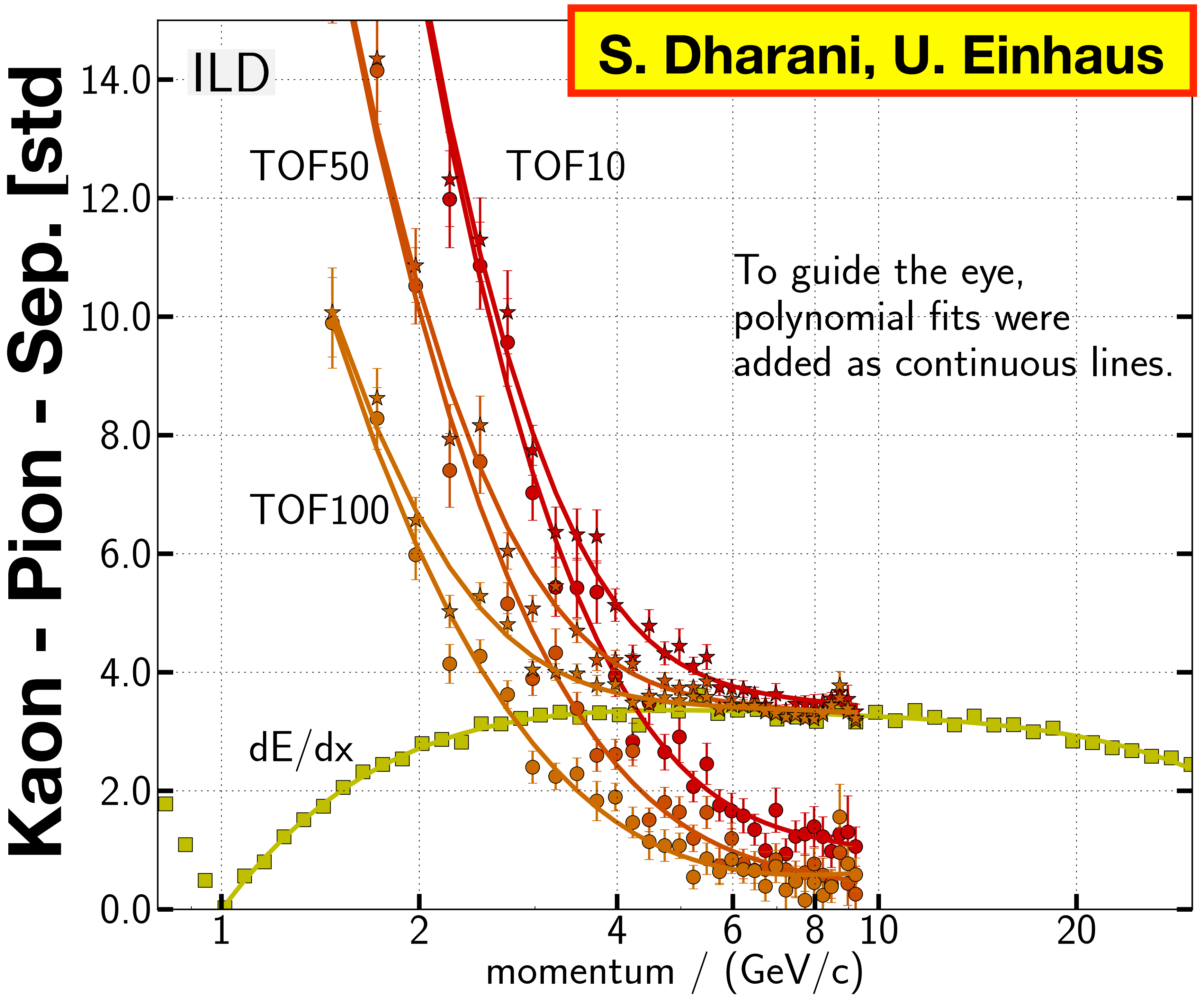
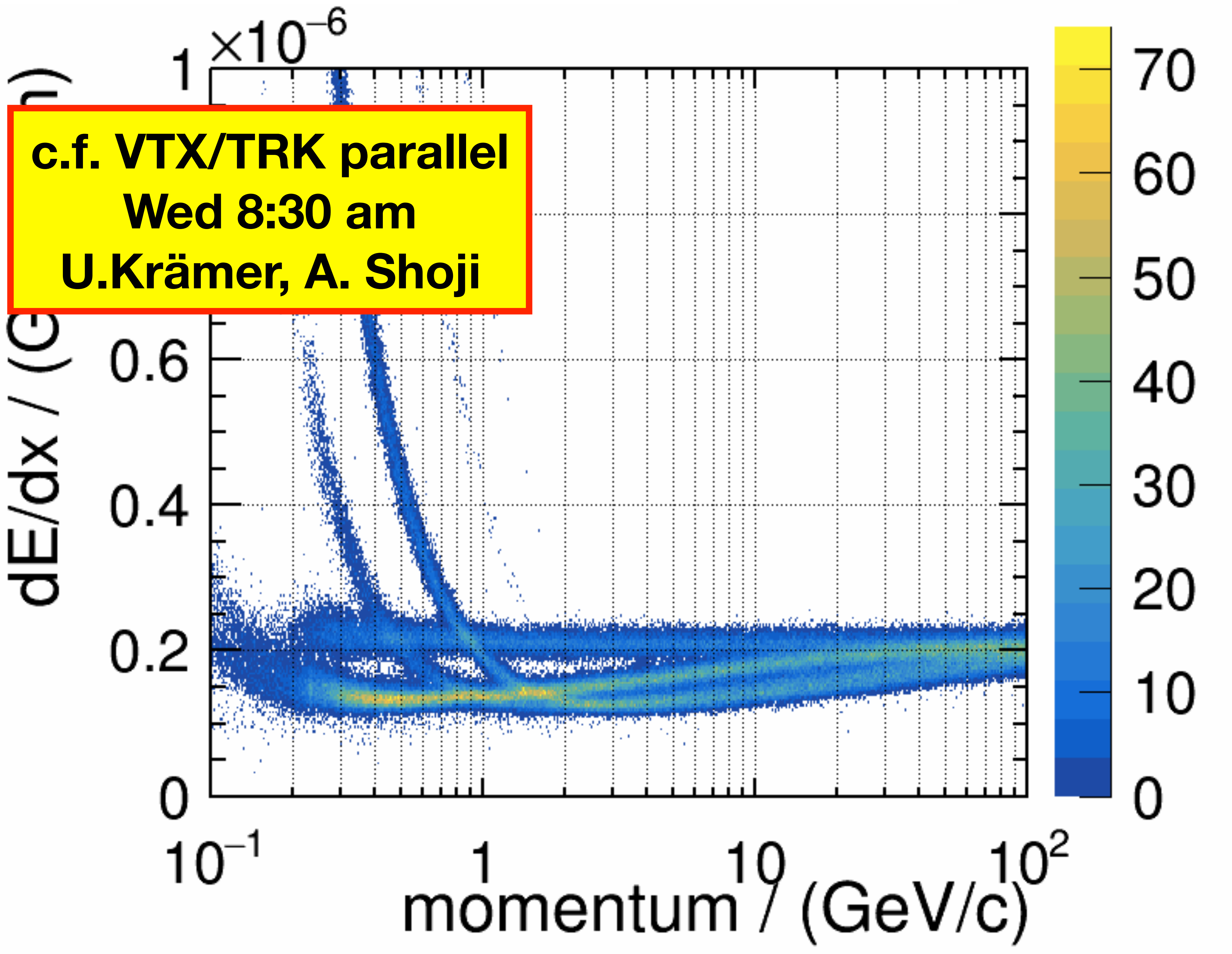


c.f. VTX/TRK parallel
Wed 8:30 am
U.Krämer, A. Shoji



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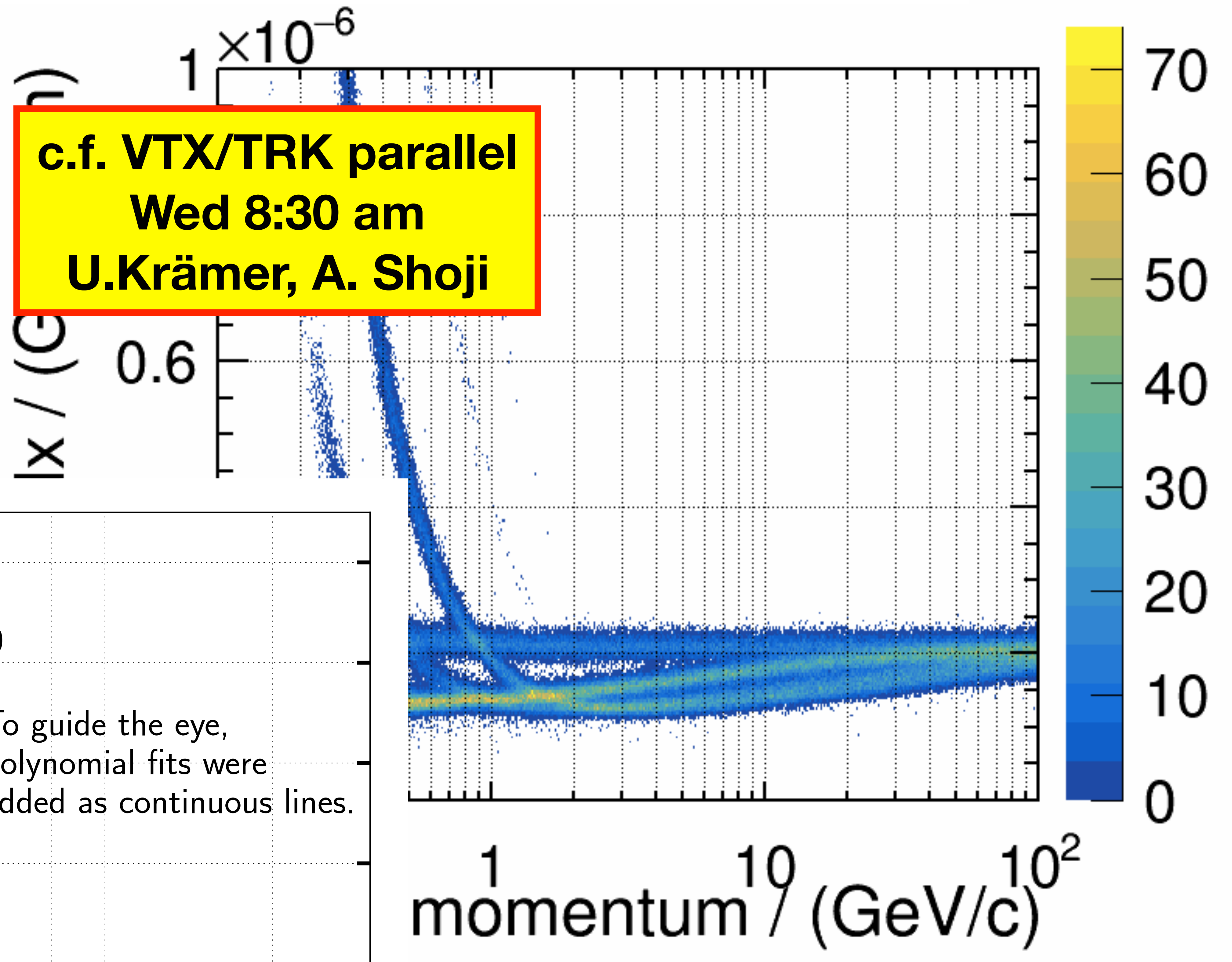

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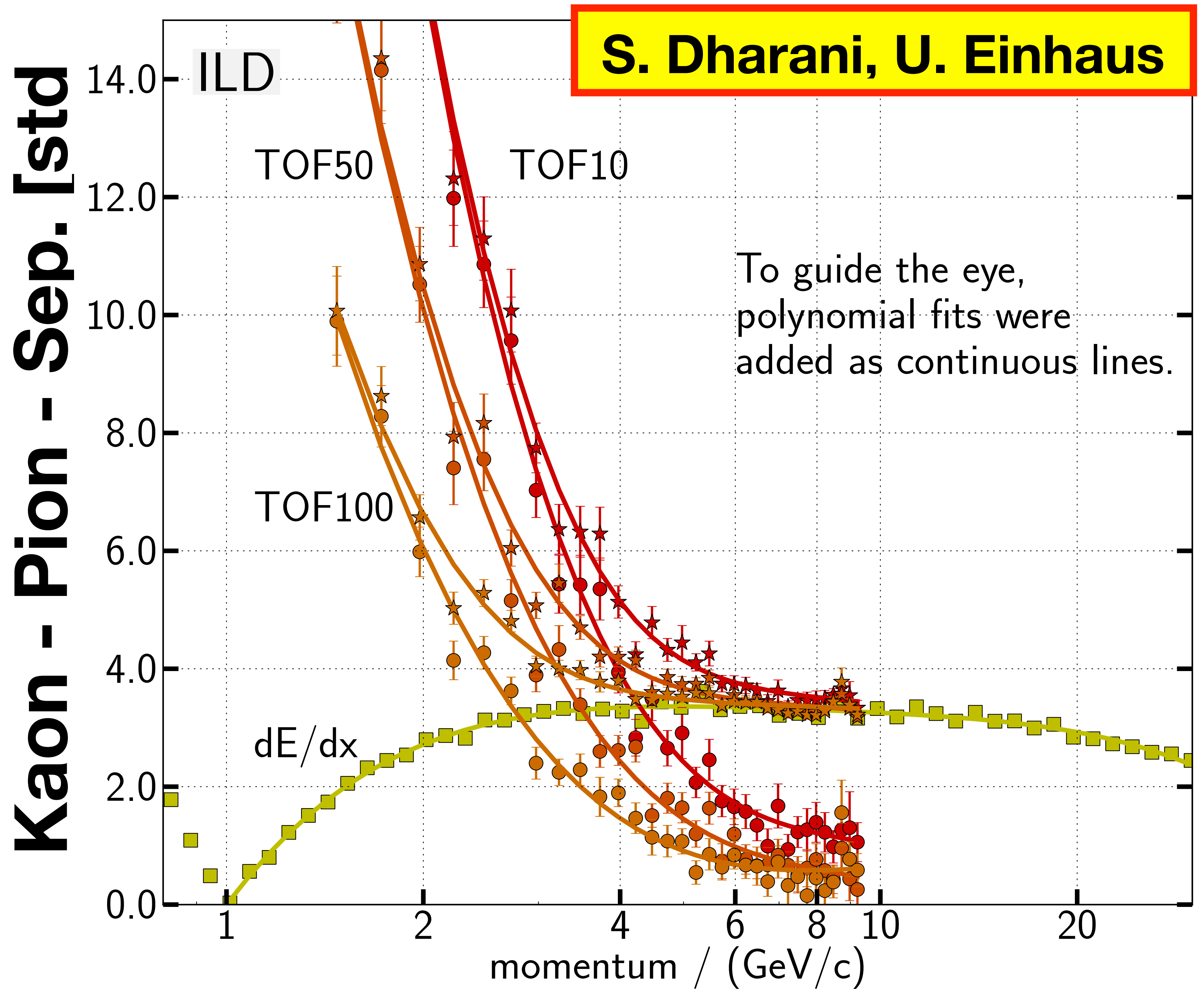

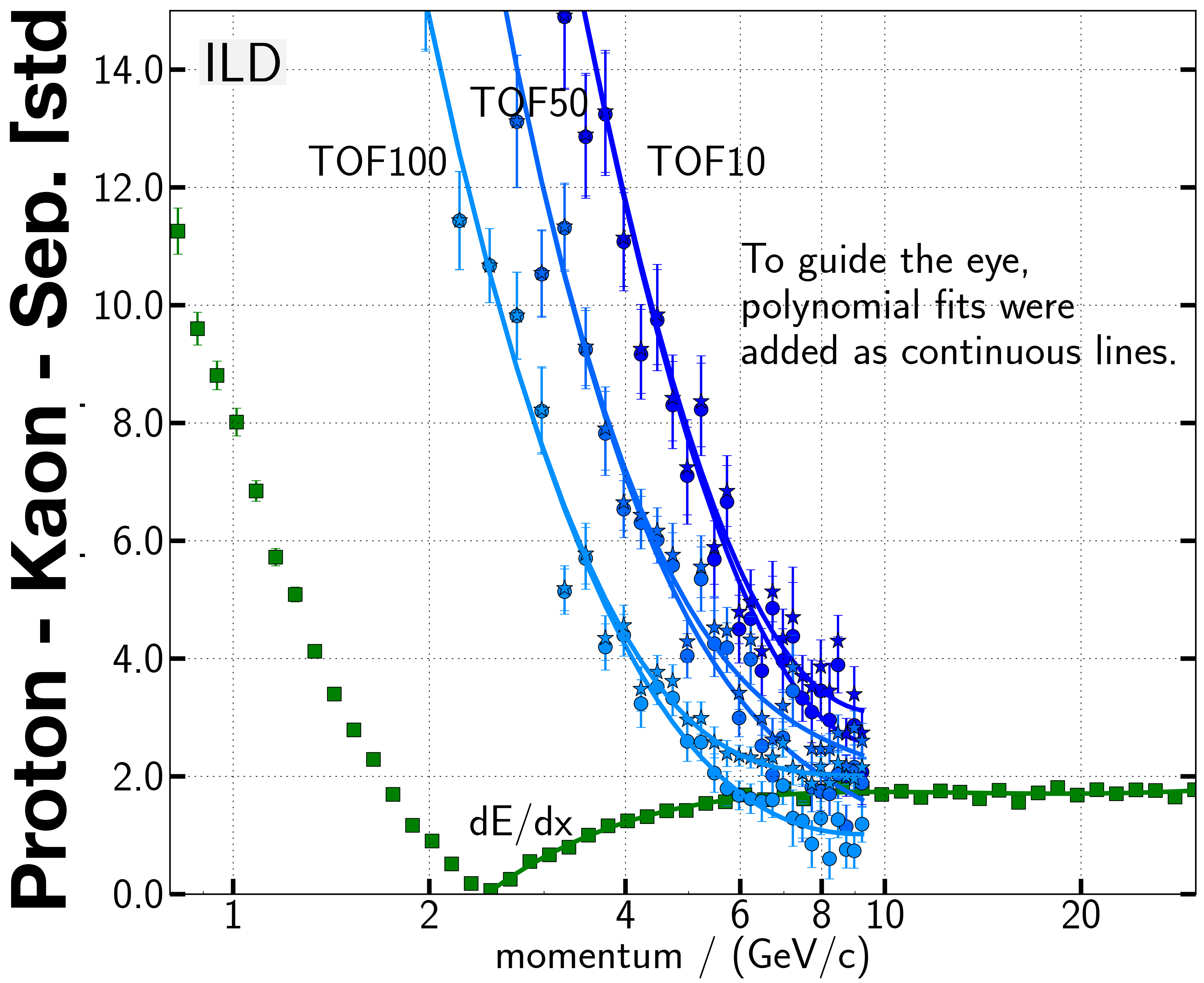

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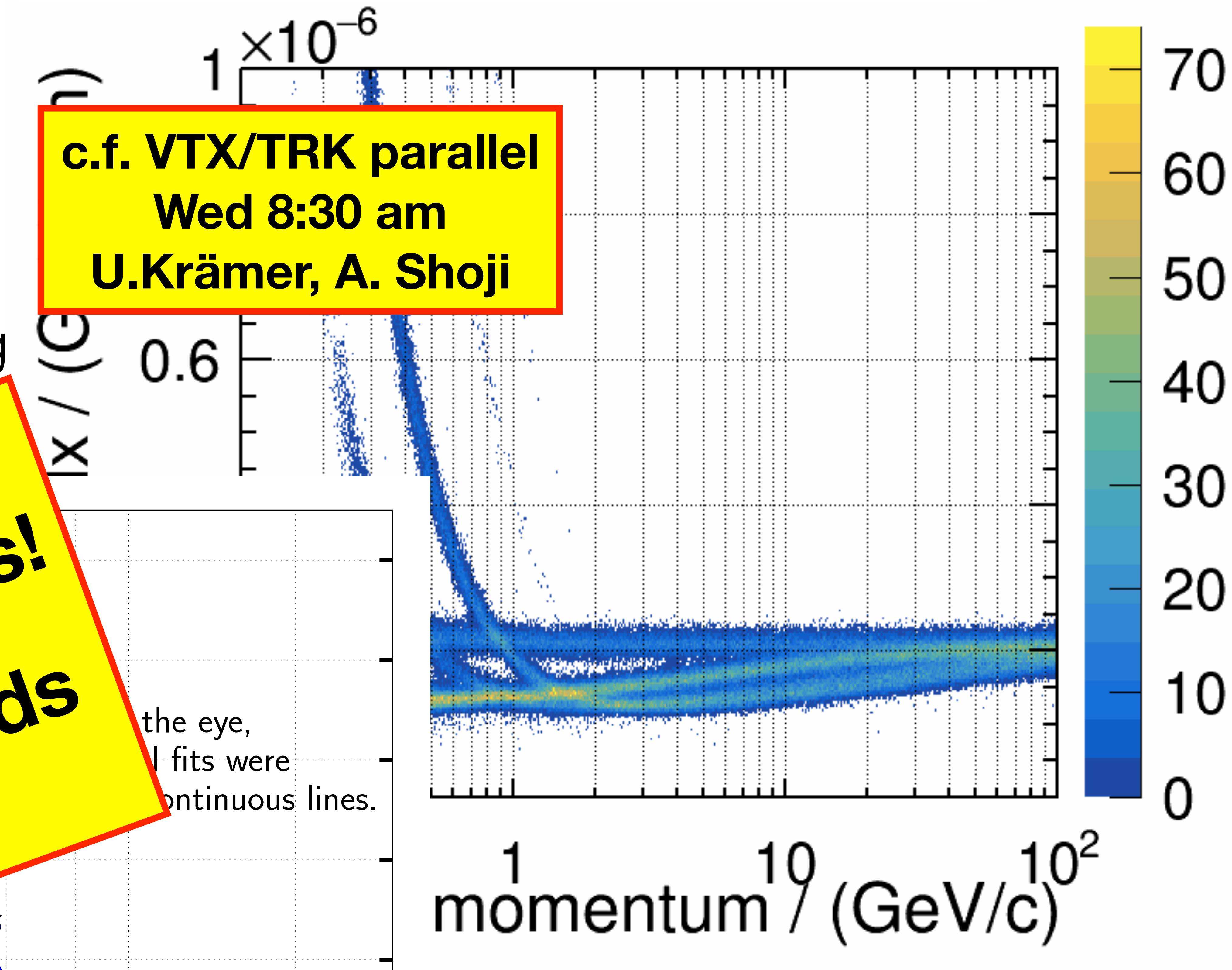

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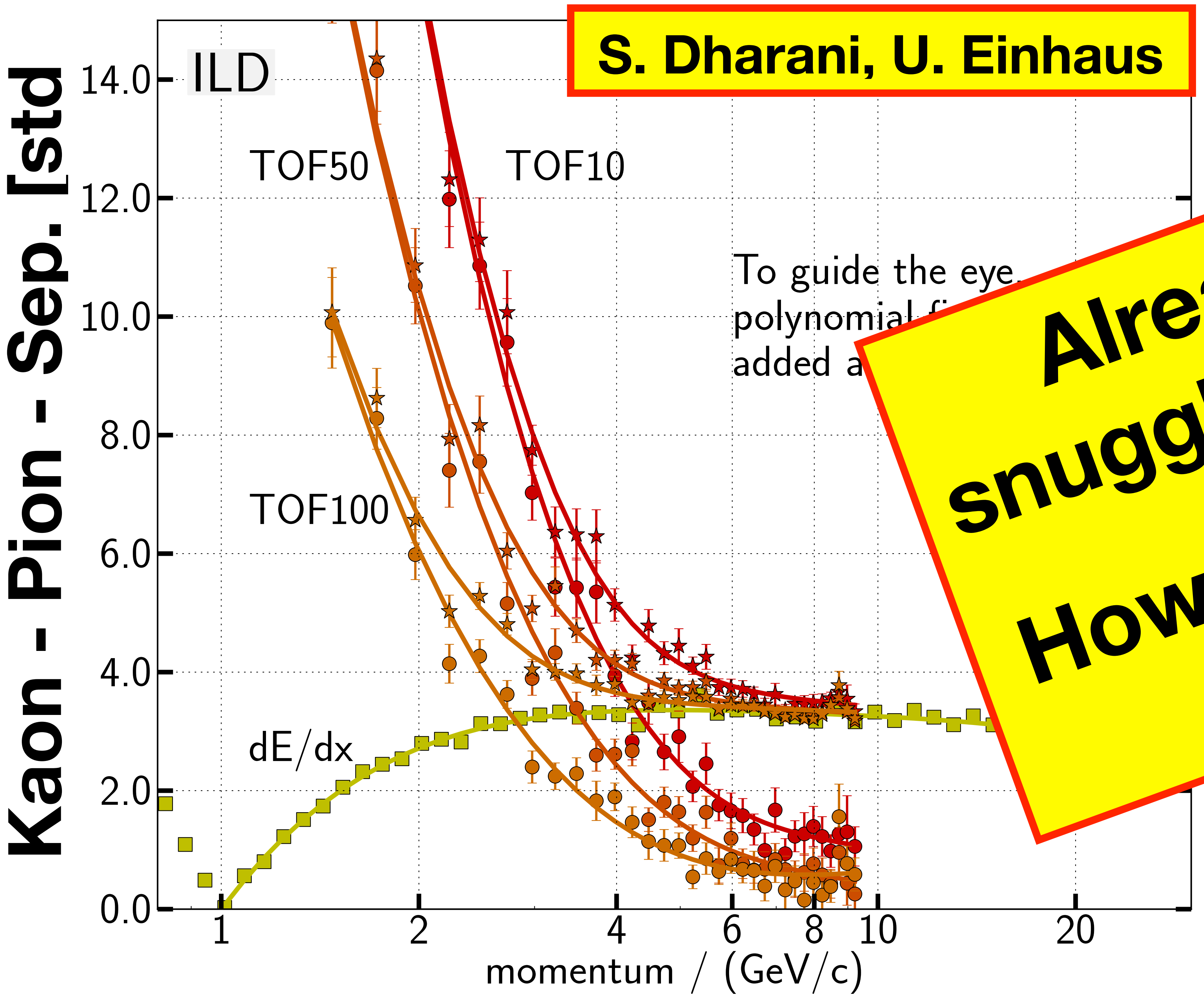

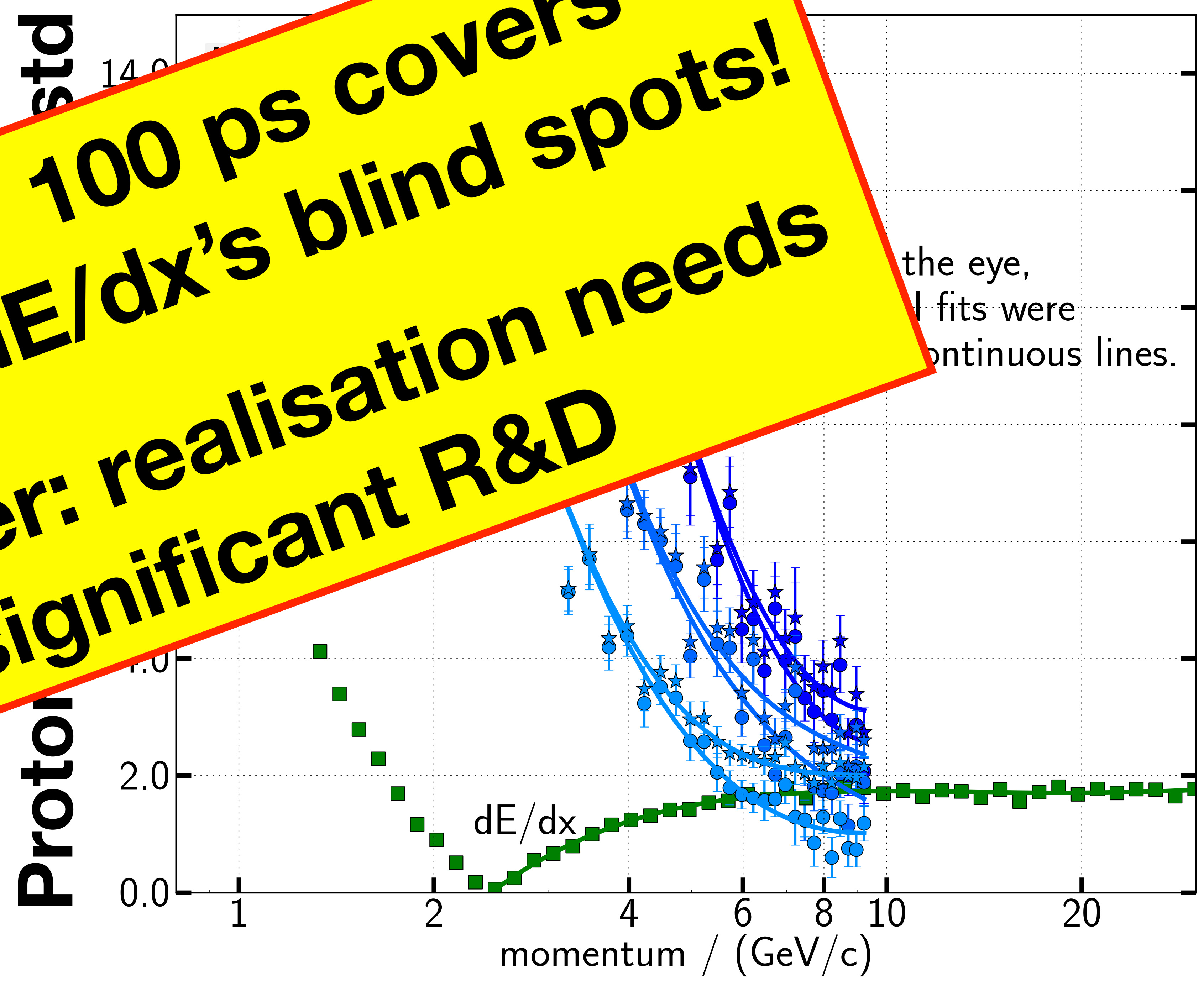

Already 100 ps covers snuggly dE/dx's blind spots!

However: realisation needs significant R&D

Physics Performance

Choice of Physics Benchmarks

- cover a broad range of important performance aspects
- focus on channels where detector is expected to dominate over limitations of reconstruction / analysis
- **ECM = 500 GeV** (in one case 1 TeV) since **more challenging** for detector than 250 GeV:
  - higher momenta
  - more collimated jets
  - more forward topologies
  - higher backgrounds
  - …

Benchmark	b/c JER/JES	uds JER/JES	pt res	mu ID	e ID	γ E / θ	ISR tag	Beam Cal	b-/c-tag	PID,vertex charge	tau ID
M(H->bb)	■		■	■					■	■	
BR(H->mumu)			■	■			■				
H->invisible	■	■									
ee->tautau						■					■
ee->WW->qqlnu		■	■	■	■					■	■
ee->nunuqqqq	■	■					■				
ee->gammaZ			■	■	■	■					
tt->bb qqlnu									■	■	
BR(H->bb/cc/gg)	■	■							■	■	
low DM Higgsinos				■	■	■		■			
mono-photon WIMPs							■	■			
extra H bosons			■	■			■				

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[illegible]			■	■	■	■					
[illegible]									■	■	
[illegible]	■	■							■	■	
[illegible]				■	■	■		■			
mono-photon WIMPs							■	■			
extra H bosons			■	■			■				

A few examples….

… all work in progress!

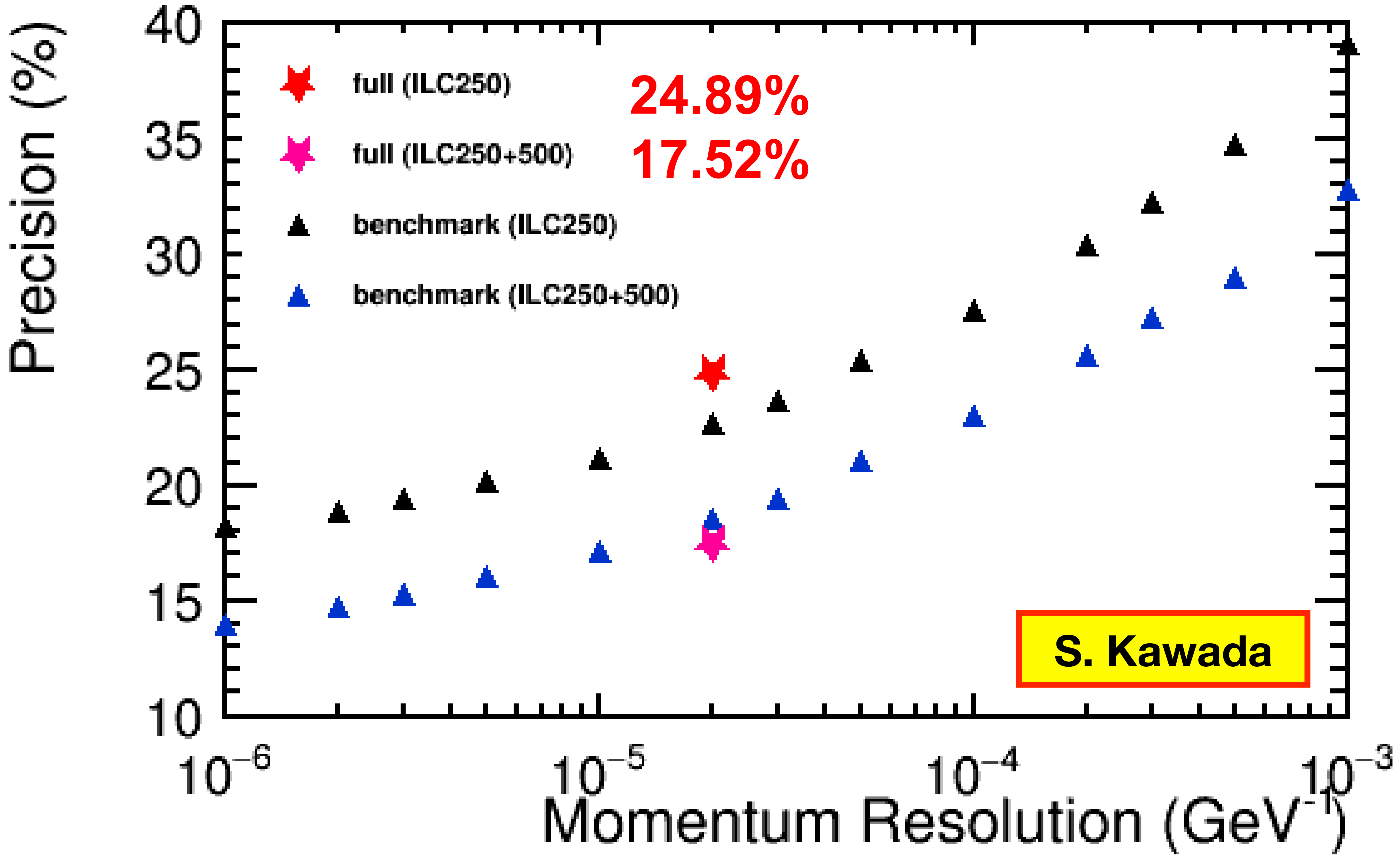
H->$\mu\mu$ and momentum resolution

main physics observable:
$\sigma(\nu\nu$**H**) x **BR(H->$\mu\mu$) @ 500 GeV**
=> analysis on new samples w.i.p.

main performance aspect:
p_t resolution for high-momentum tracks

DBD analysis for $\nu\nu$H + qqH, 2 ab^{-1} 250 GeV + 4ab^{-1} 500 GeV, canonical pol. sharing

- **full sim: 18%**
- **"perfect" momentum resolution ($2*10^{-6}$): 14%**
- **"theoretical limit" (100% eff, 0 bkg): 7%**



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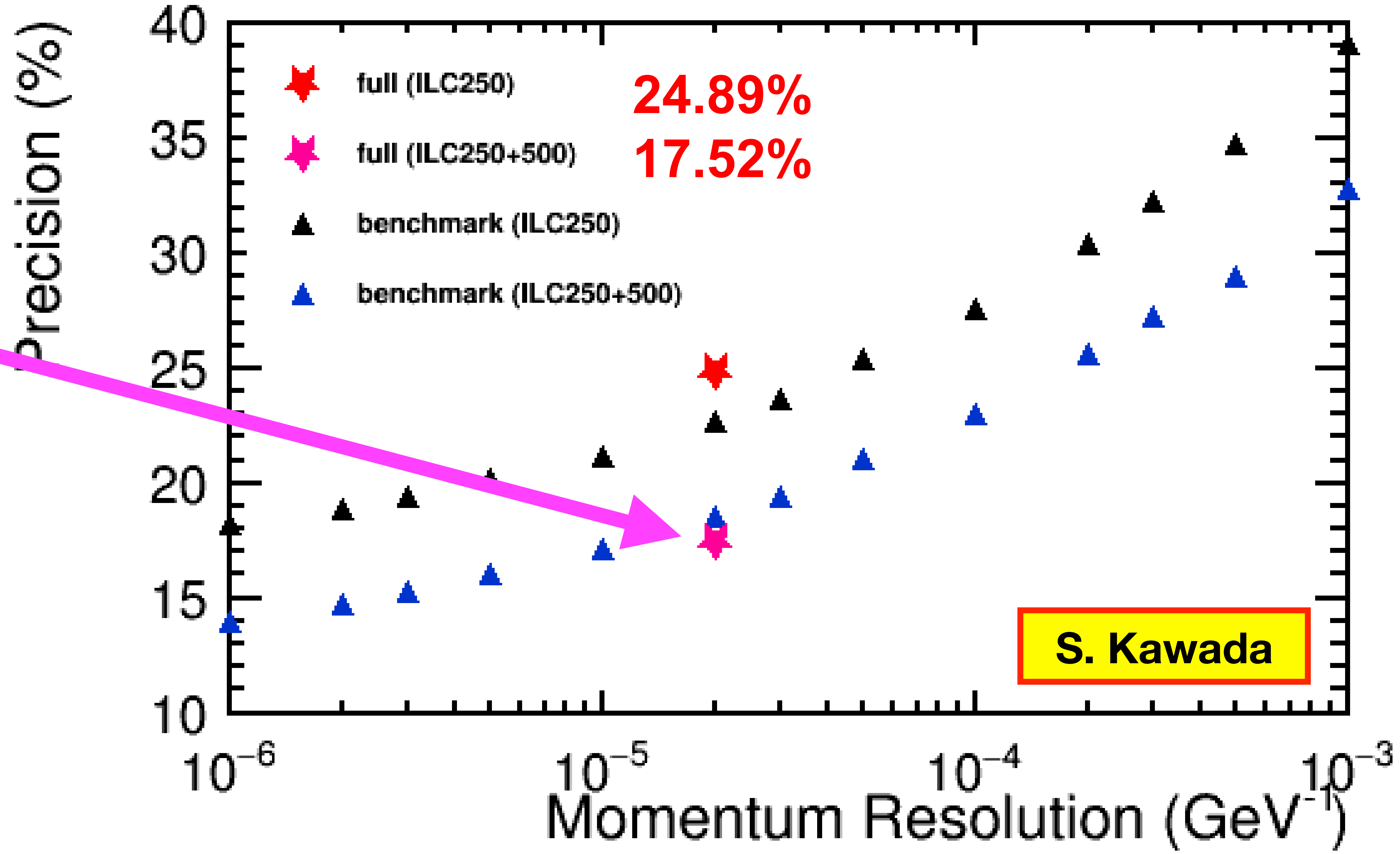

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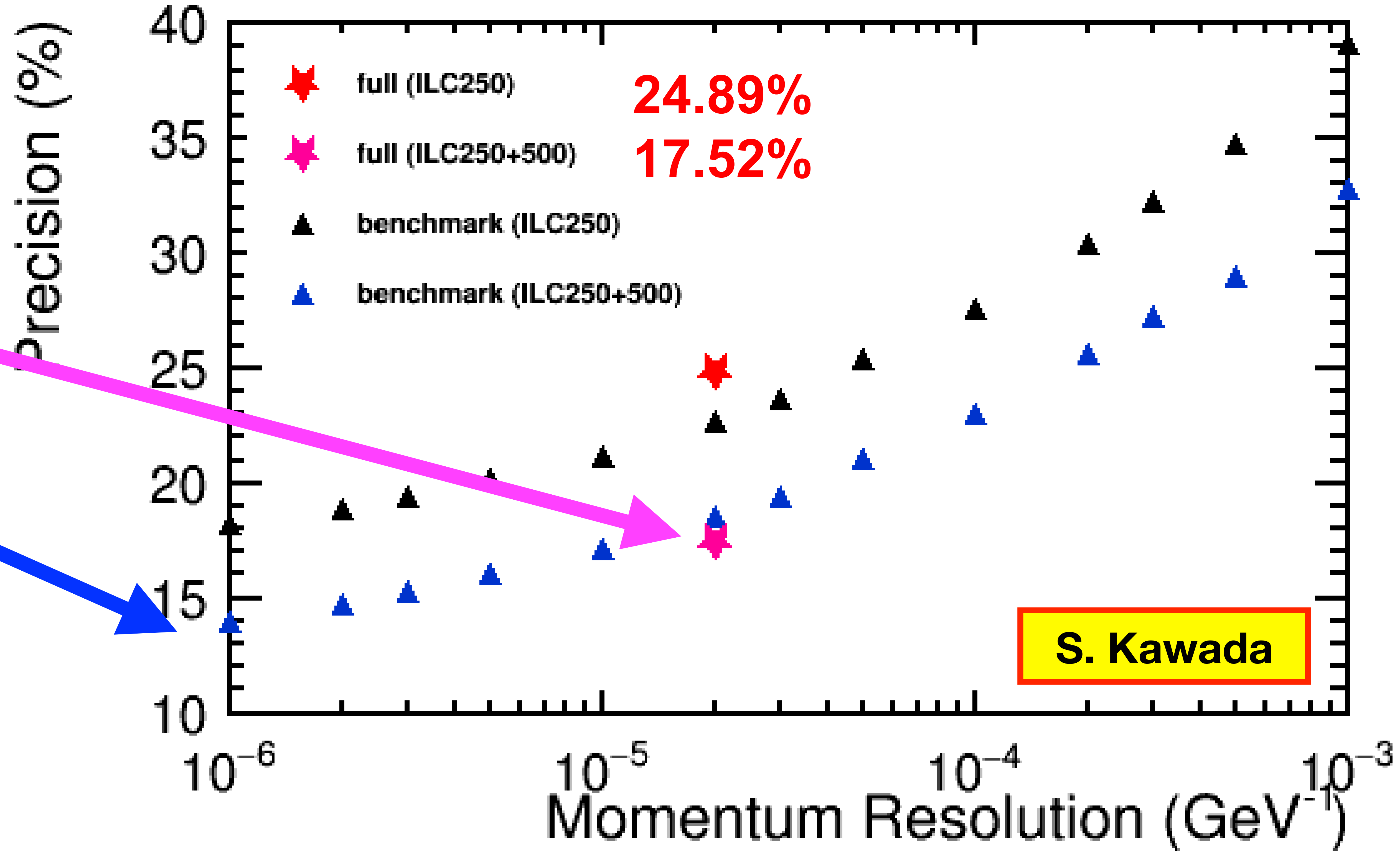

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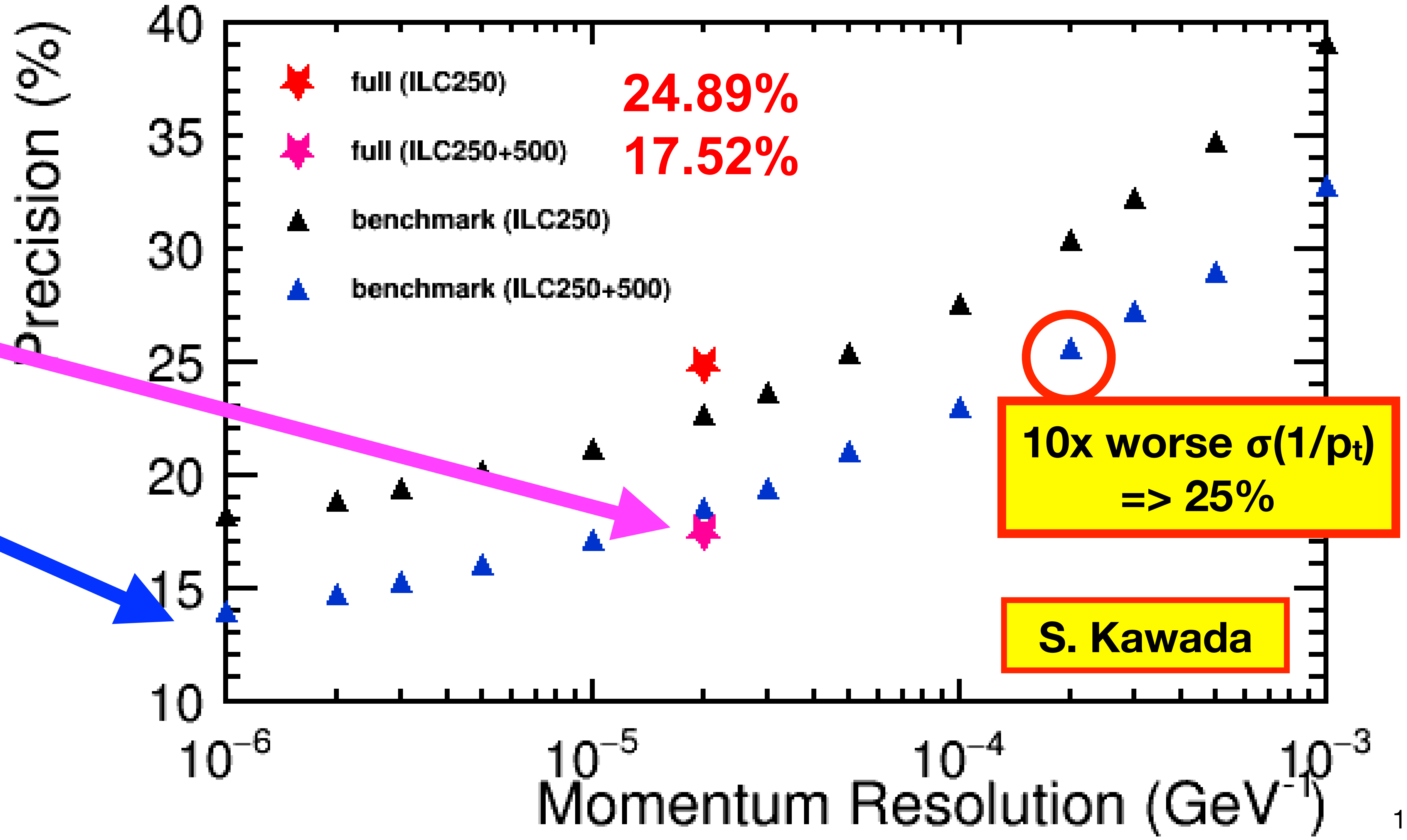

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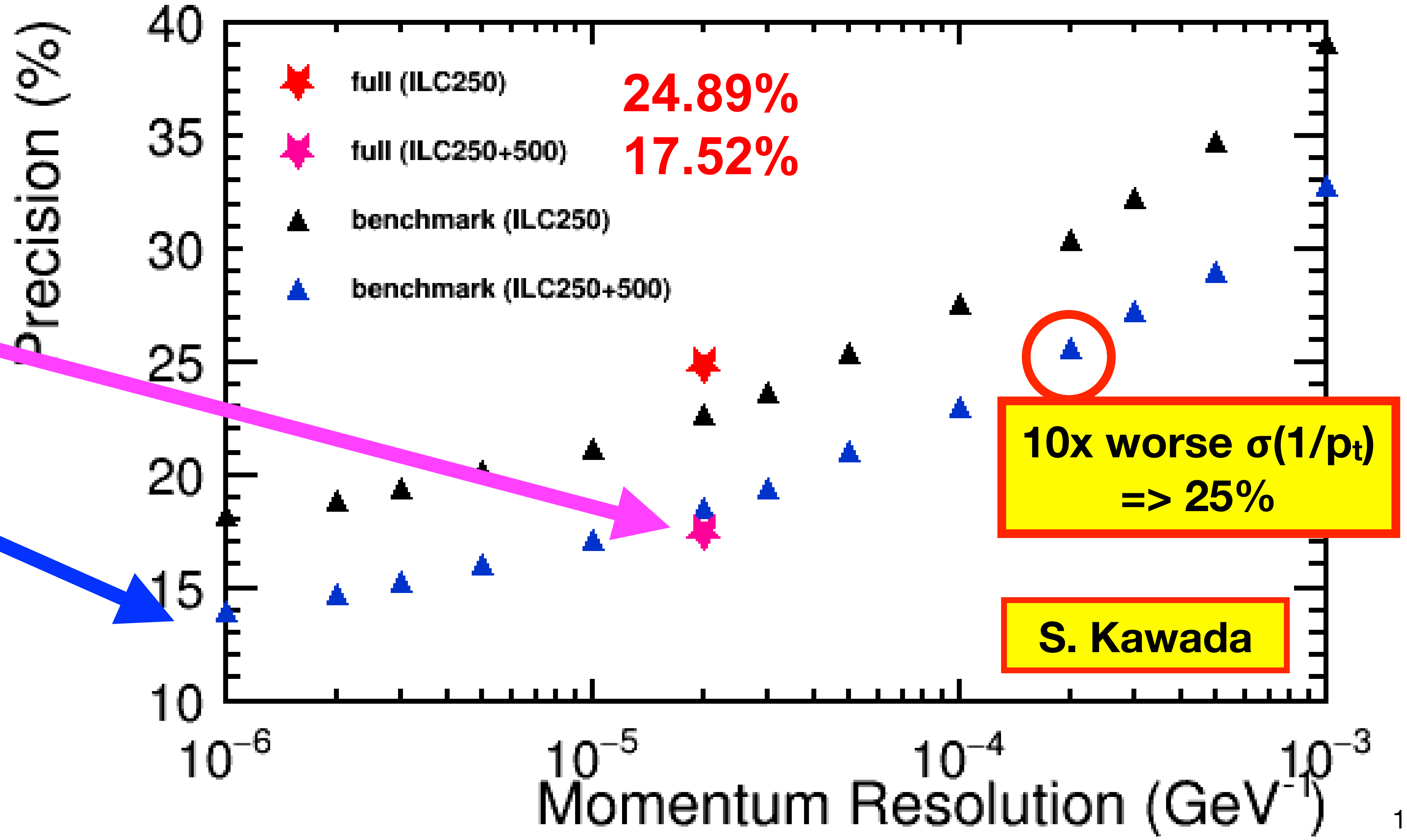


c.f. Higgs parallel
Thu 8:30 am
S.Kawada

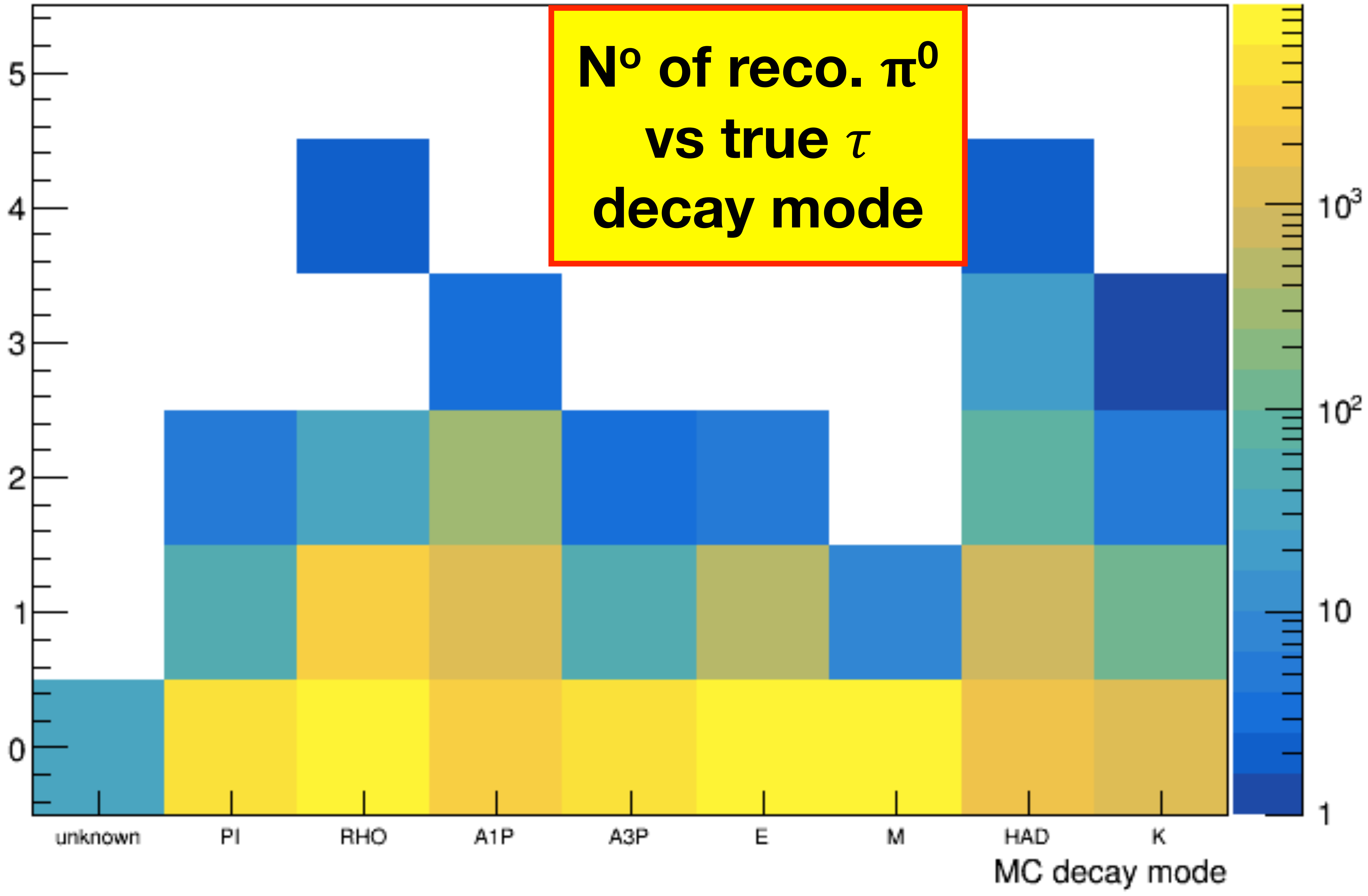
$e^+e^- \rightarrow \tau^+\tau^-$ @ 500 GeV

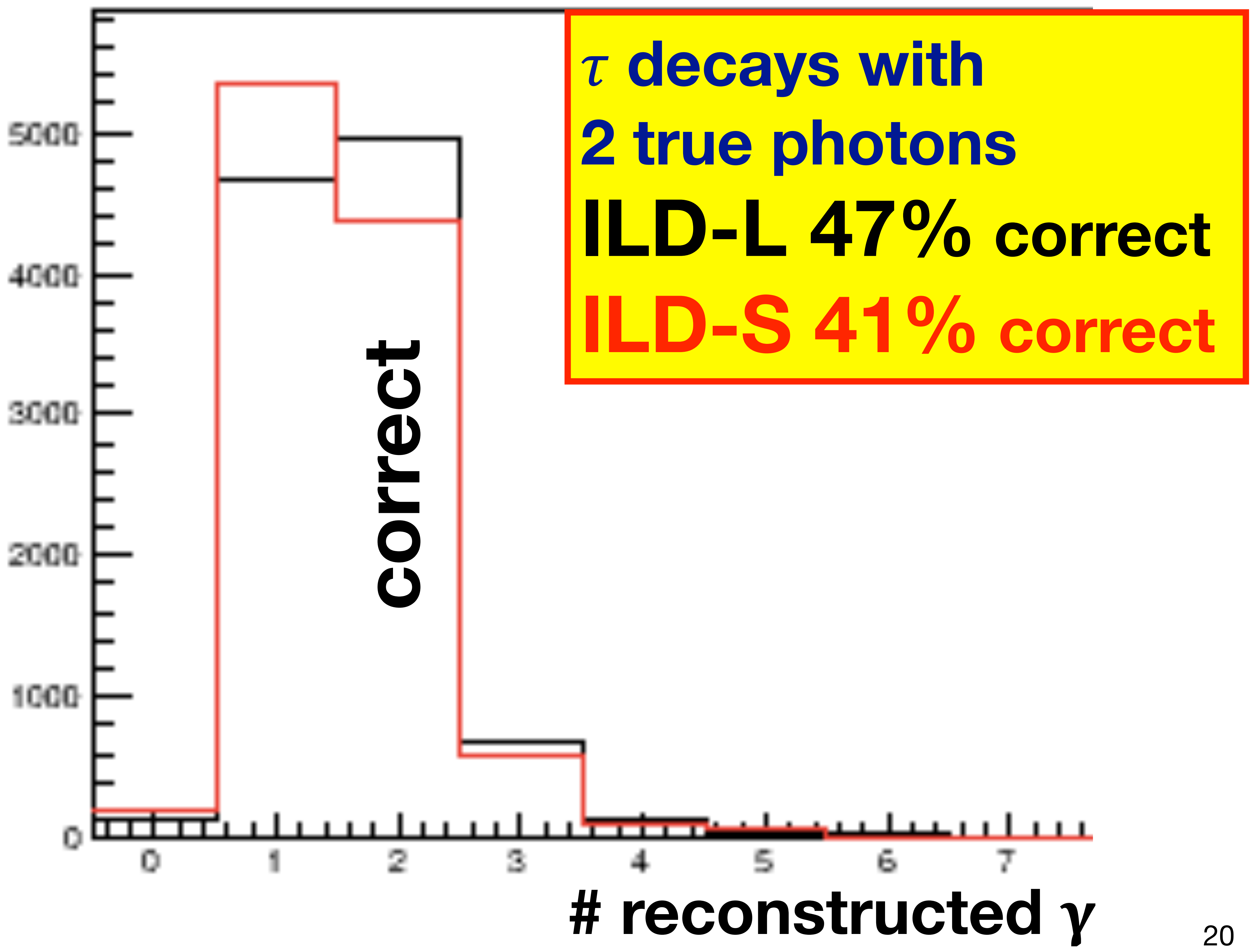
K. Yumino & D. Jeans

main physics observables:
A_{FB}, tau polarisation

intermediate observables:
tau decay mode separation

main performance aspect:
$\pi^0 \rightarrow \gamma\gamma$ reconstruction





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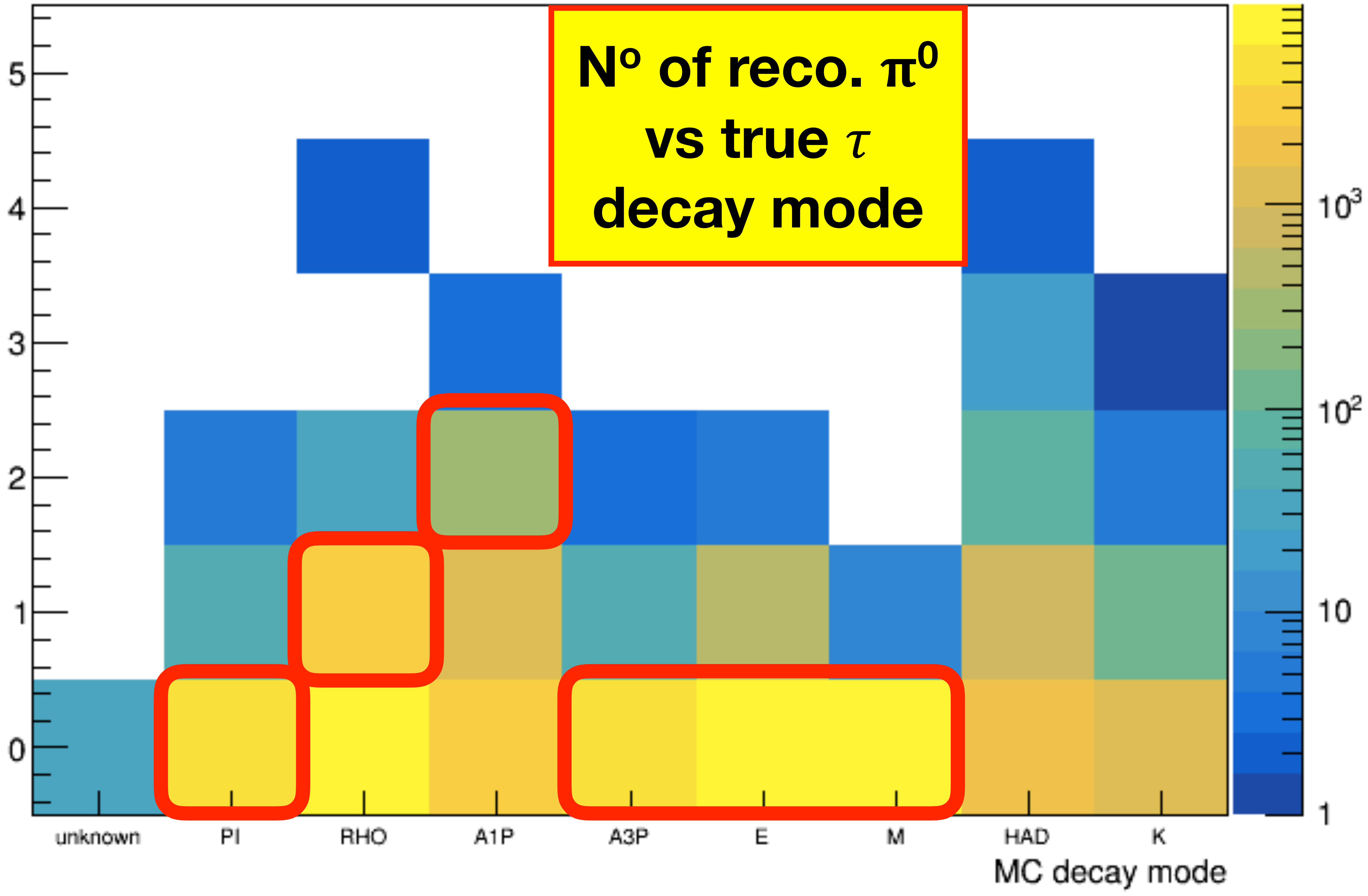

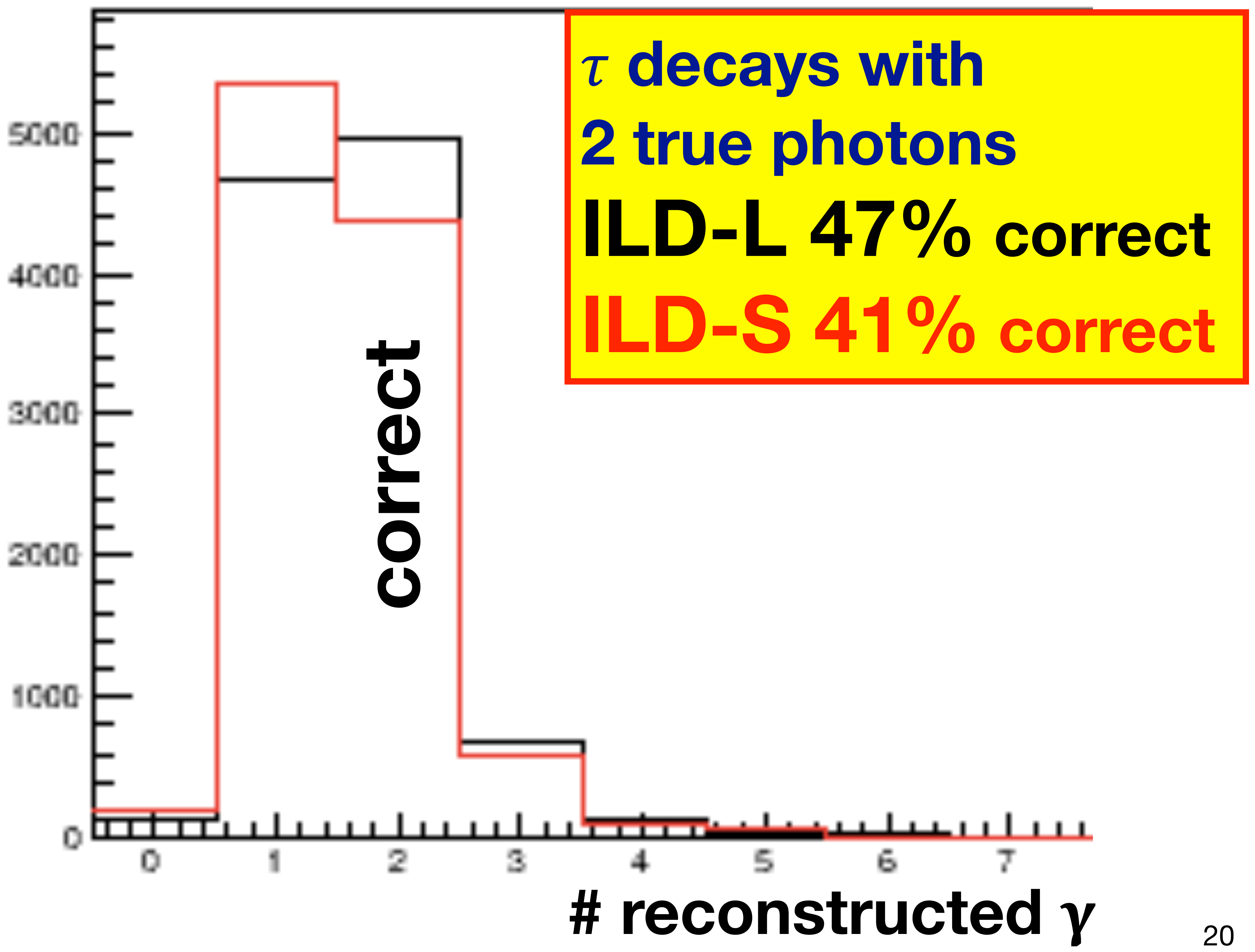

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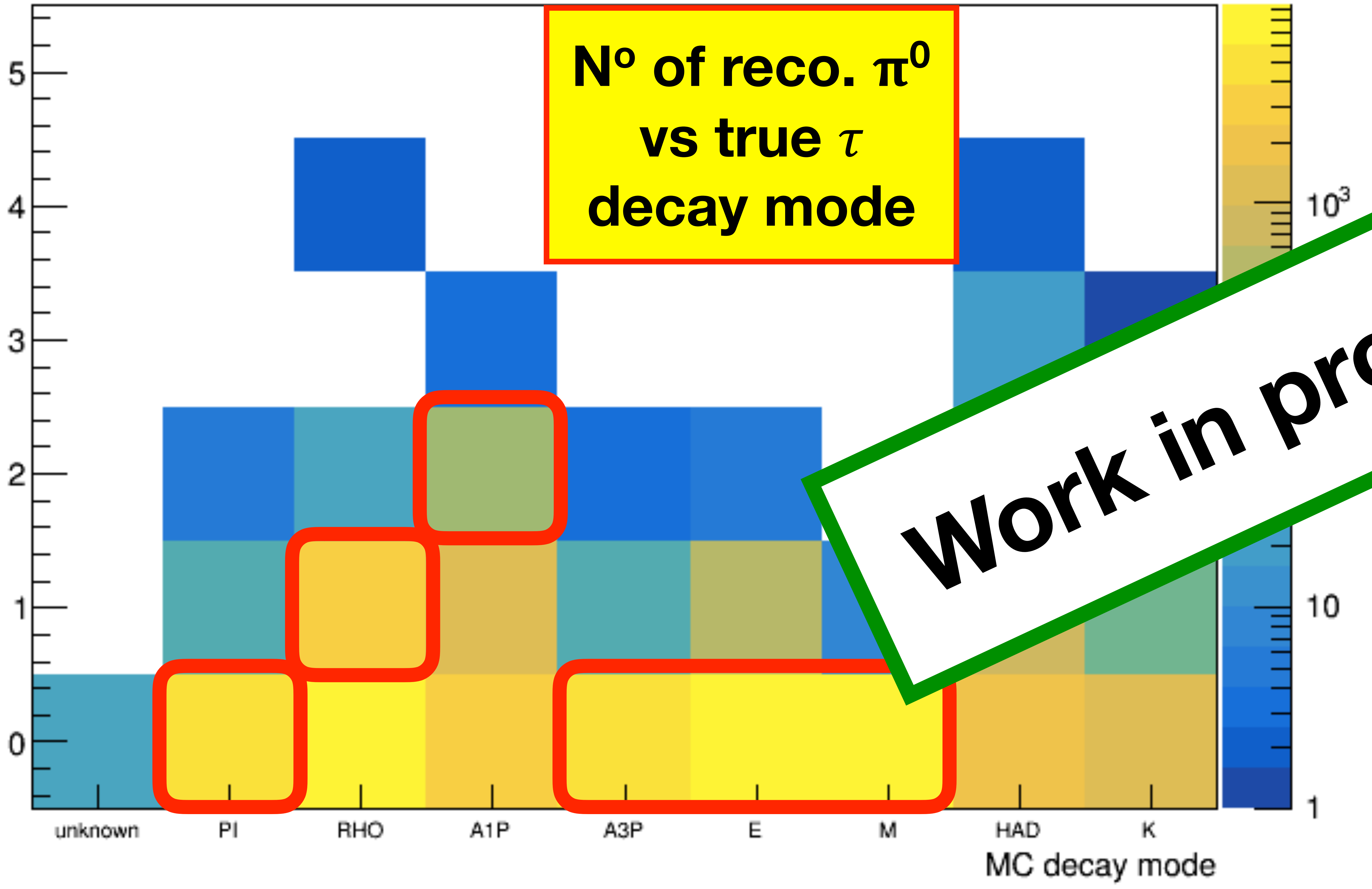

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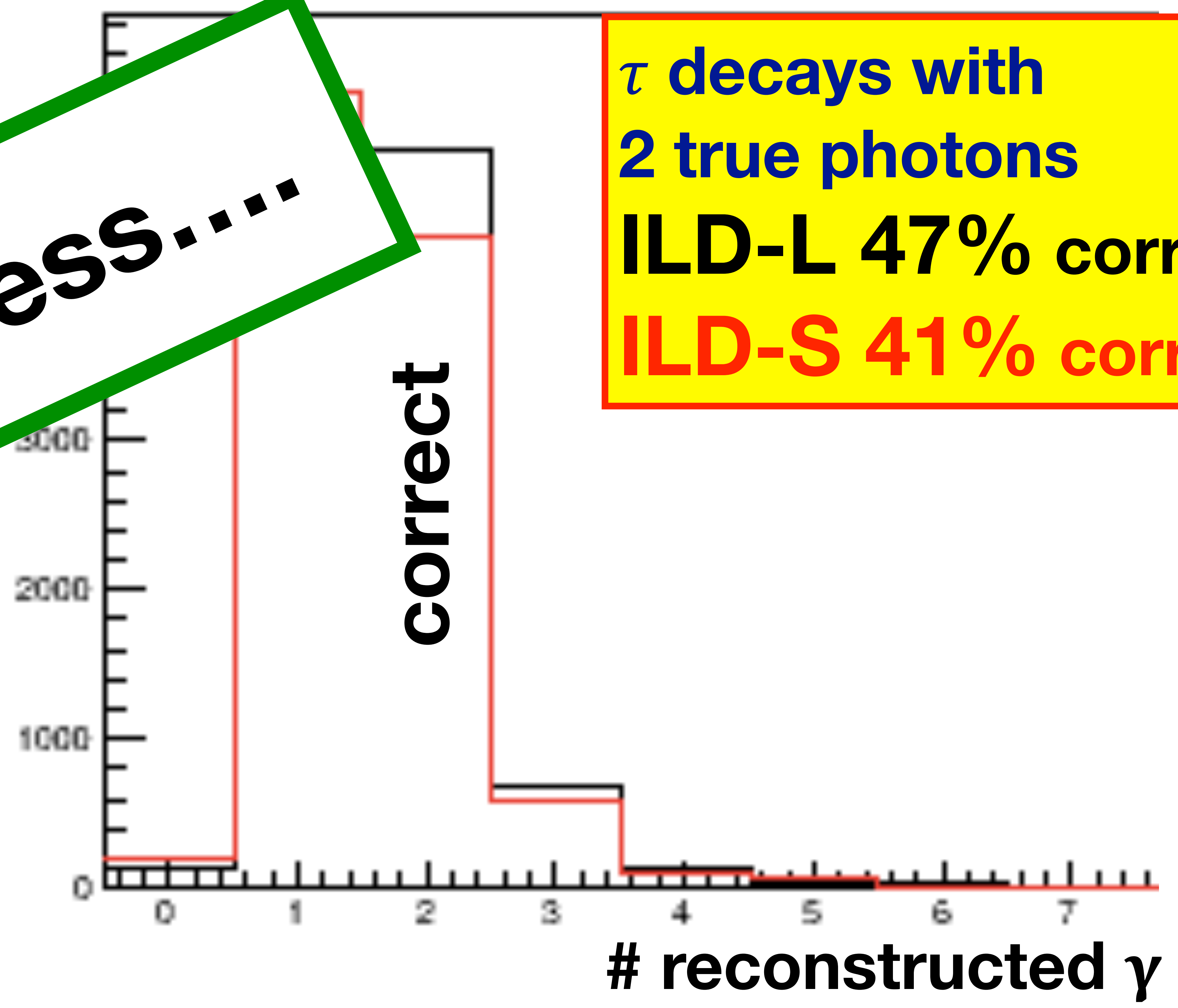

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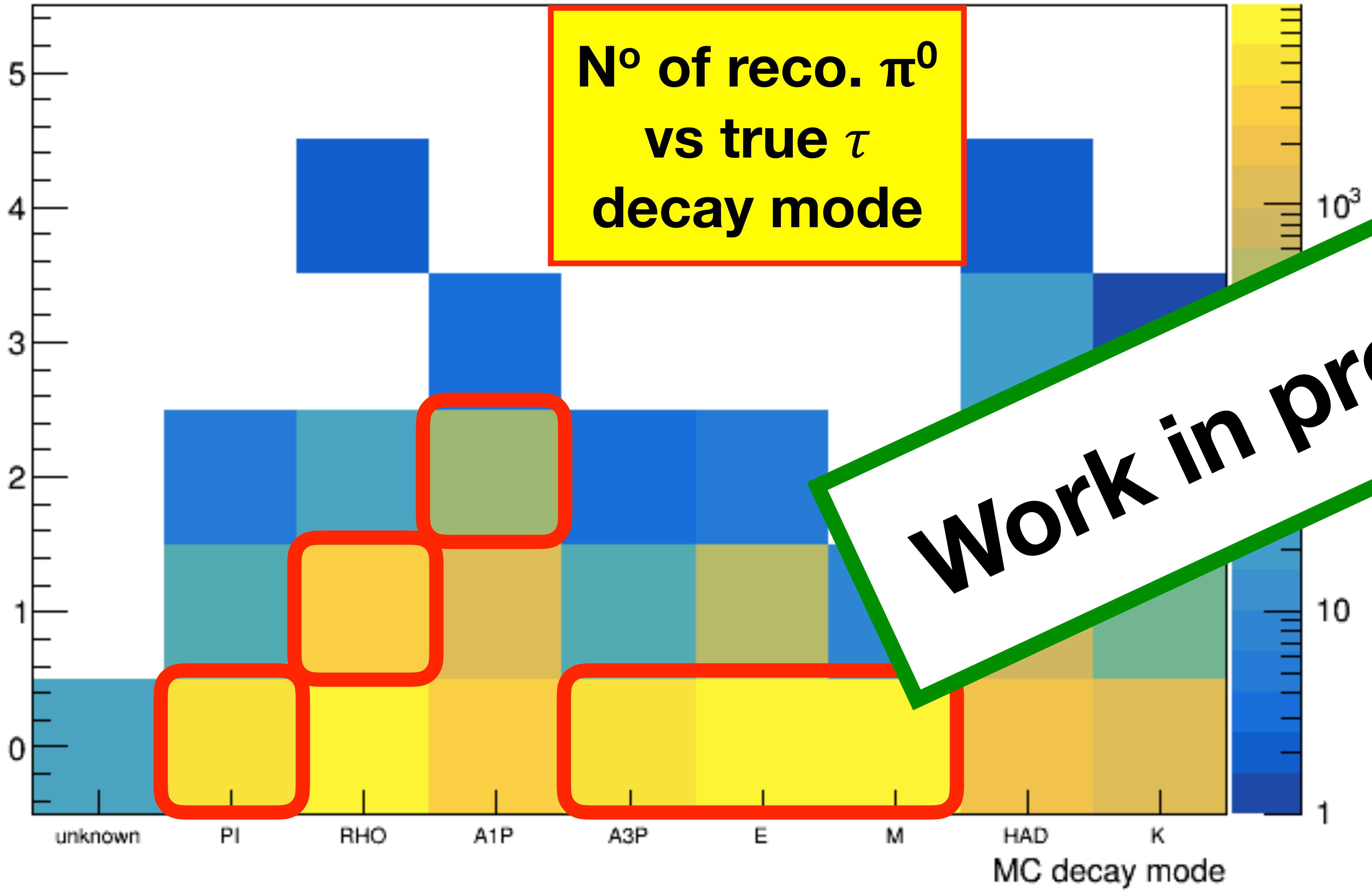

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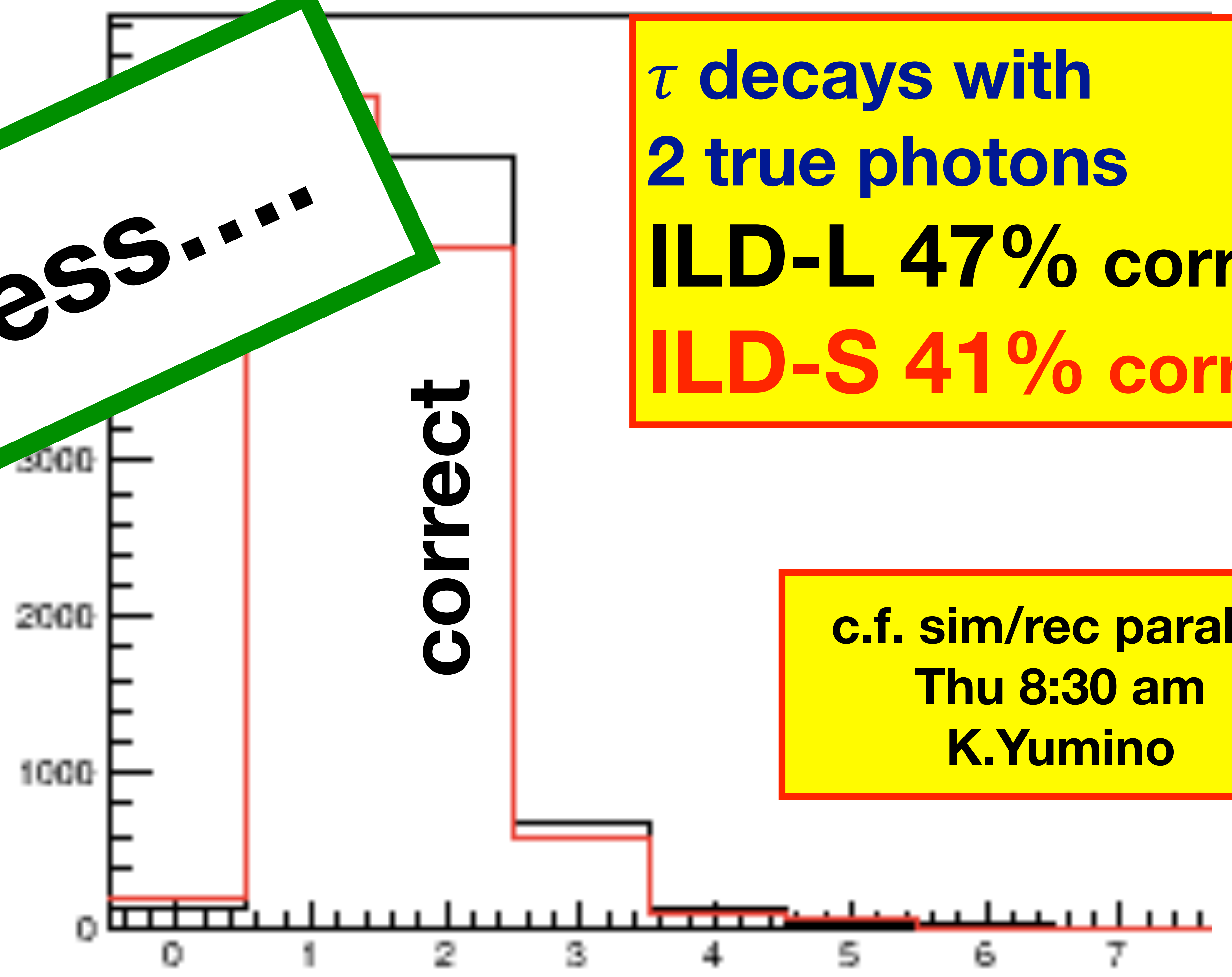

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c.f. sim/rec parallel
Thu 8:30 am
K.Yumino

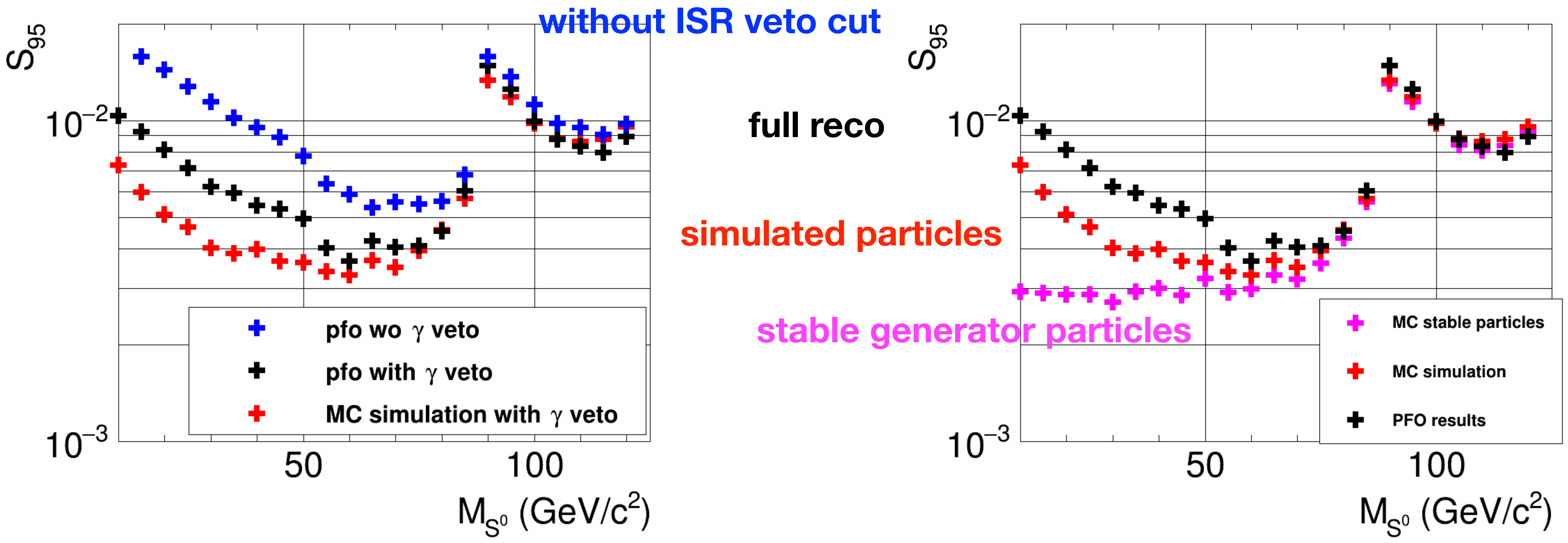
Exotic Higgs bosons via recoil method

Y. Wang

main physics observable: **95% CL limit on S_{95} vs M_H from $\mu\mu$H recoil**
$S_{95} := \sigma_{95}(ZH(M_H=X)) / \sigma_{SM}(ZH(M_H=X))$

performance aspect(s):

- **muon ID & p resolution**
- **ISR reconstruction**



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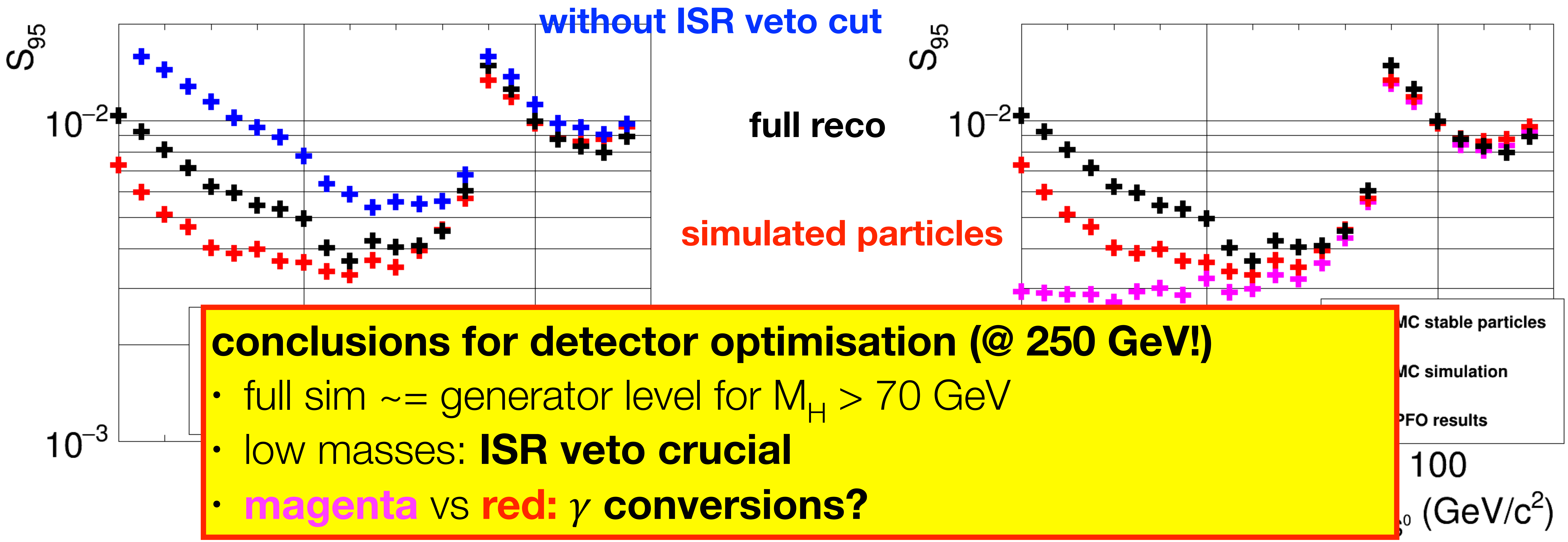

conclusions for detector optimisation (@ 250 GeV!)
- full sim ~= generator level for M_H > 70 GeV
- low masses: **ISR veto crucial**
- **magenta** vs **red:** γ **conversions?**

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c.f. BSM parallel Thu 2 pm Y.Wang

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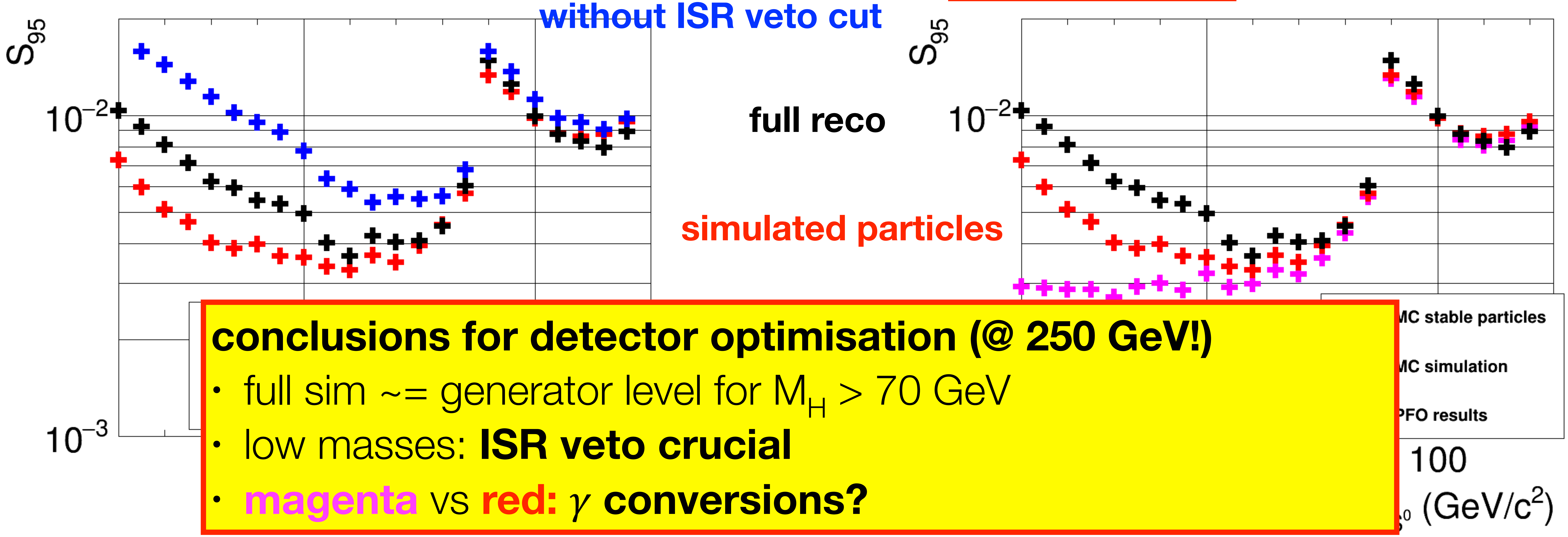

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Conclusions

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- **ILD is well alive despite difficult funding/person power situation**
- **ILD members are very active in**
  - R&D collaborations (testbeams…)
  - preparing input for the European Strategy Update, for ILD *and* ILC
- **ILD completed first large scale MC production with new simulation & reconstruction chain based on DD4HEP**
- **ILD is re-optimizing its detector design:**
  - benchmarking **“large” and “small” ILD** with selected physics channels
  - investigating possible **improvements** to the detector concept: e.g. **forward tracking & time-of-flight**
- **All developments since DBD will be summarised in the ILD Design Report “IDR”**

Backup

Quartic Gauge Couplings

J. Beyer

main physics observable:
limits on aQGC @ 1 TeV

intermediate observable:
M_{ij} vs M_{lk} from ννqqqq

main performance aspect:
JER & JES (udscb)

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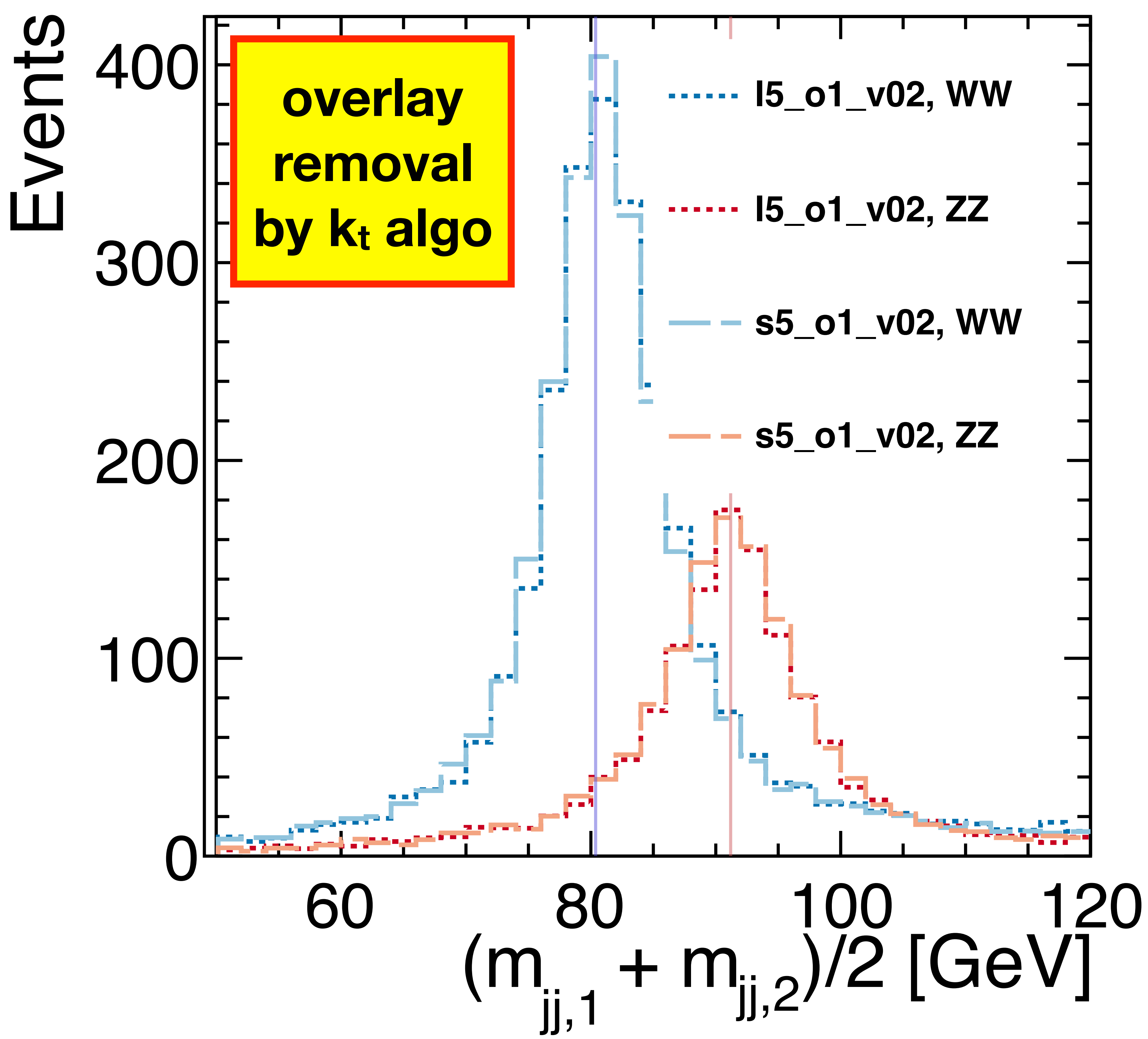

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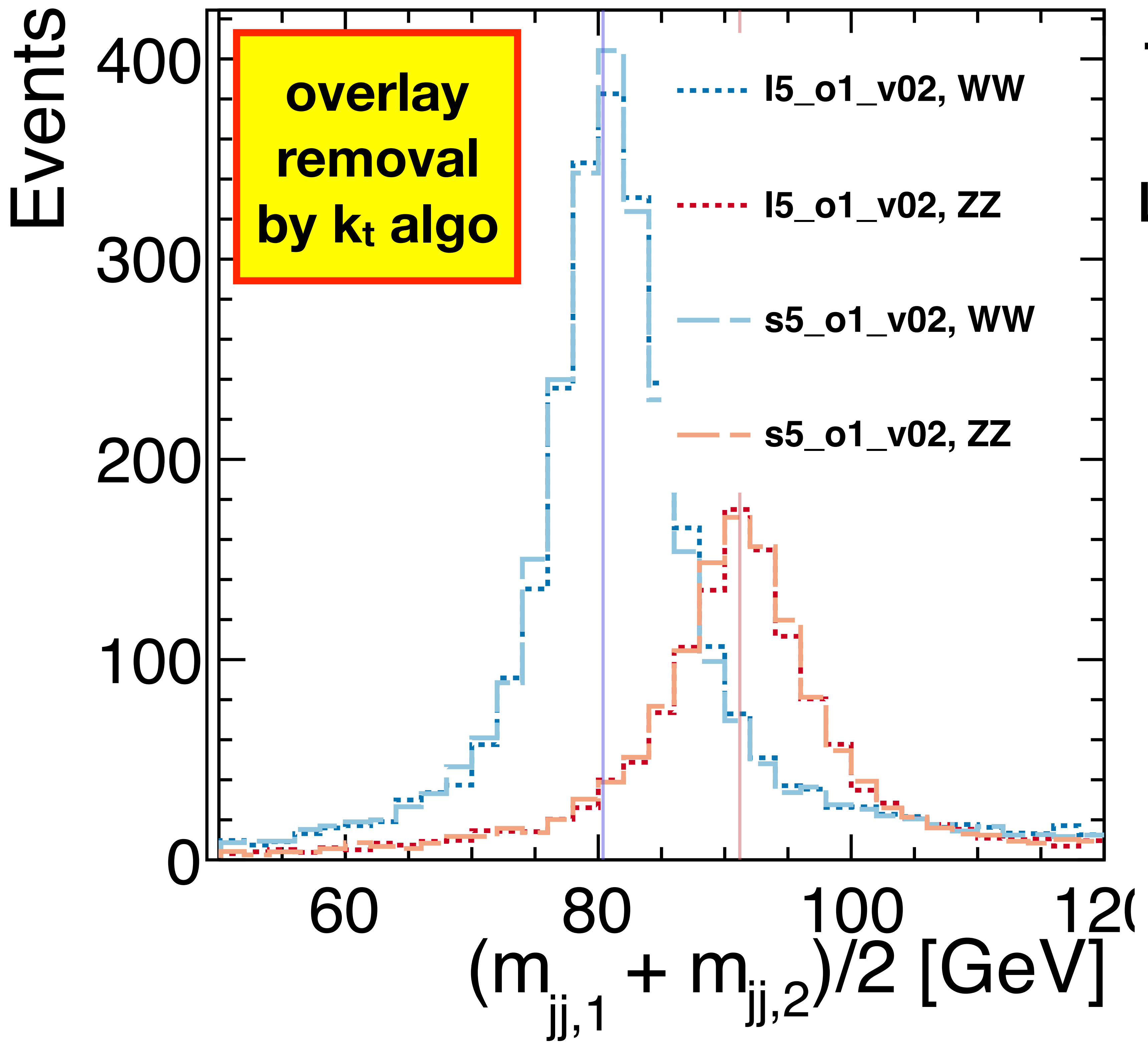

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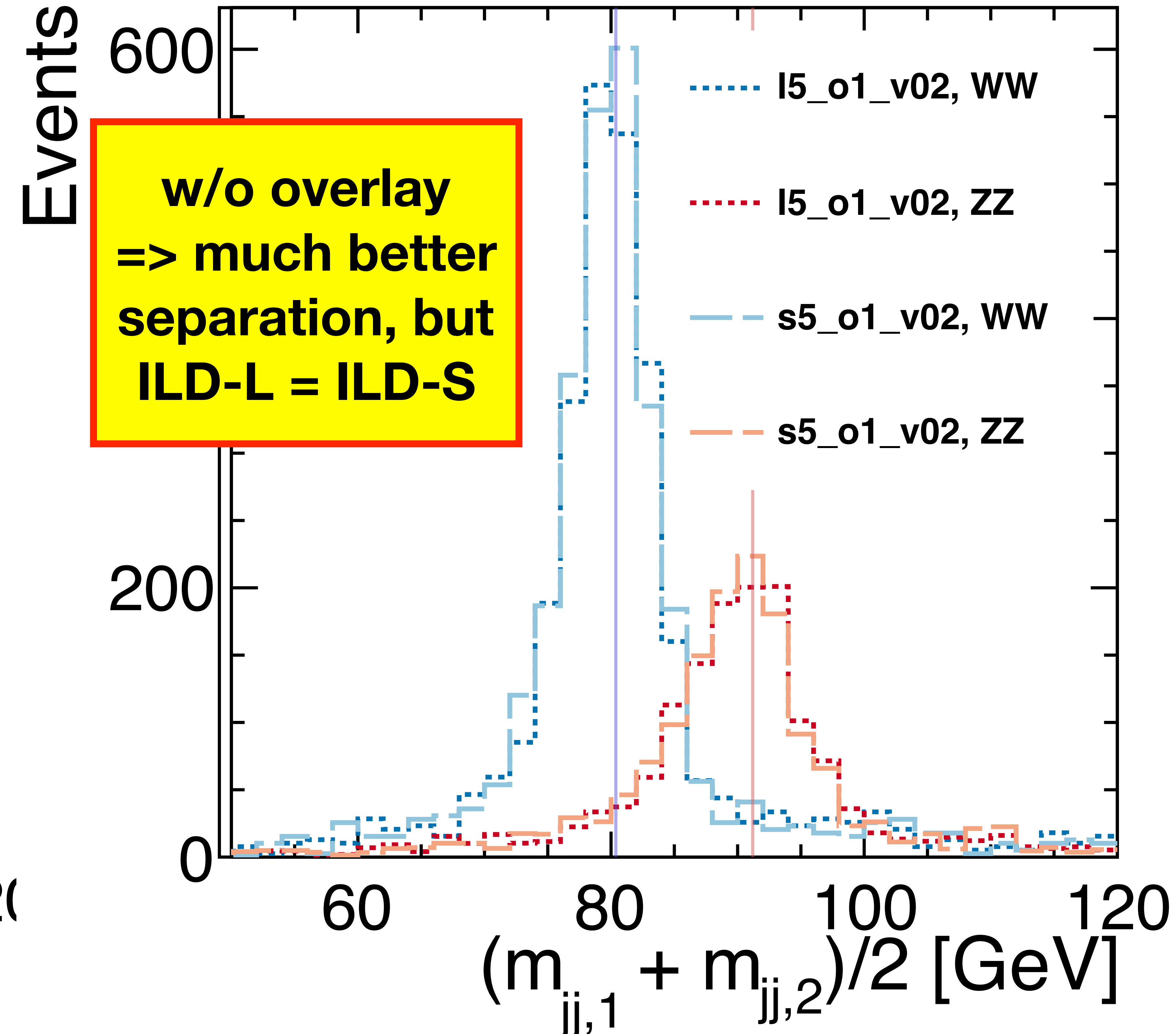

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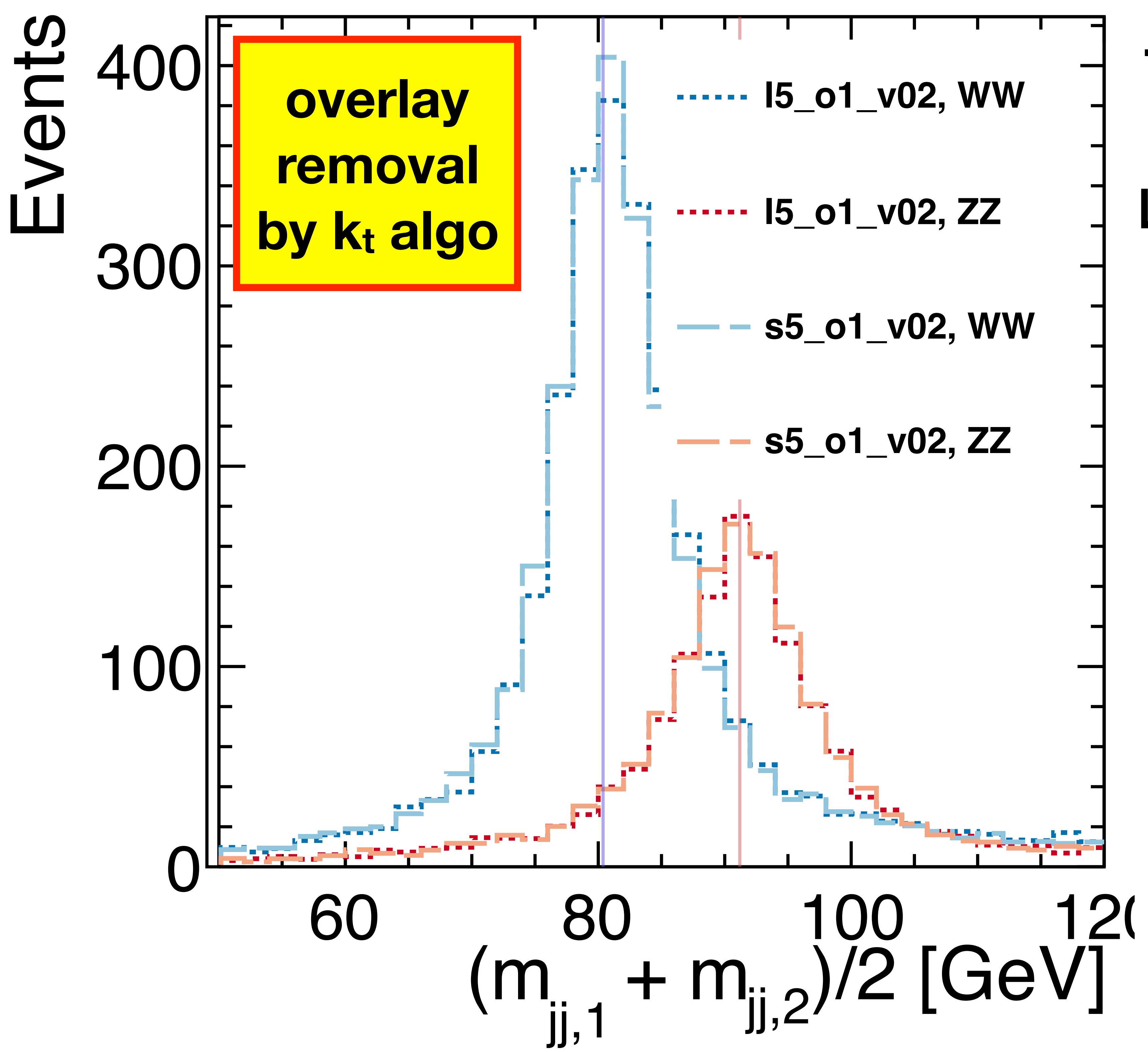

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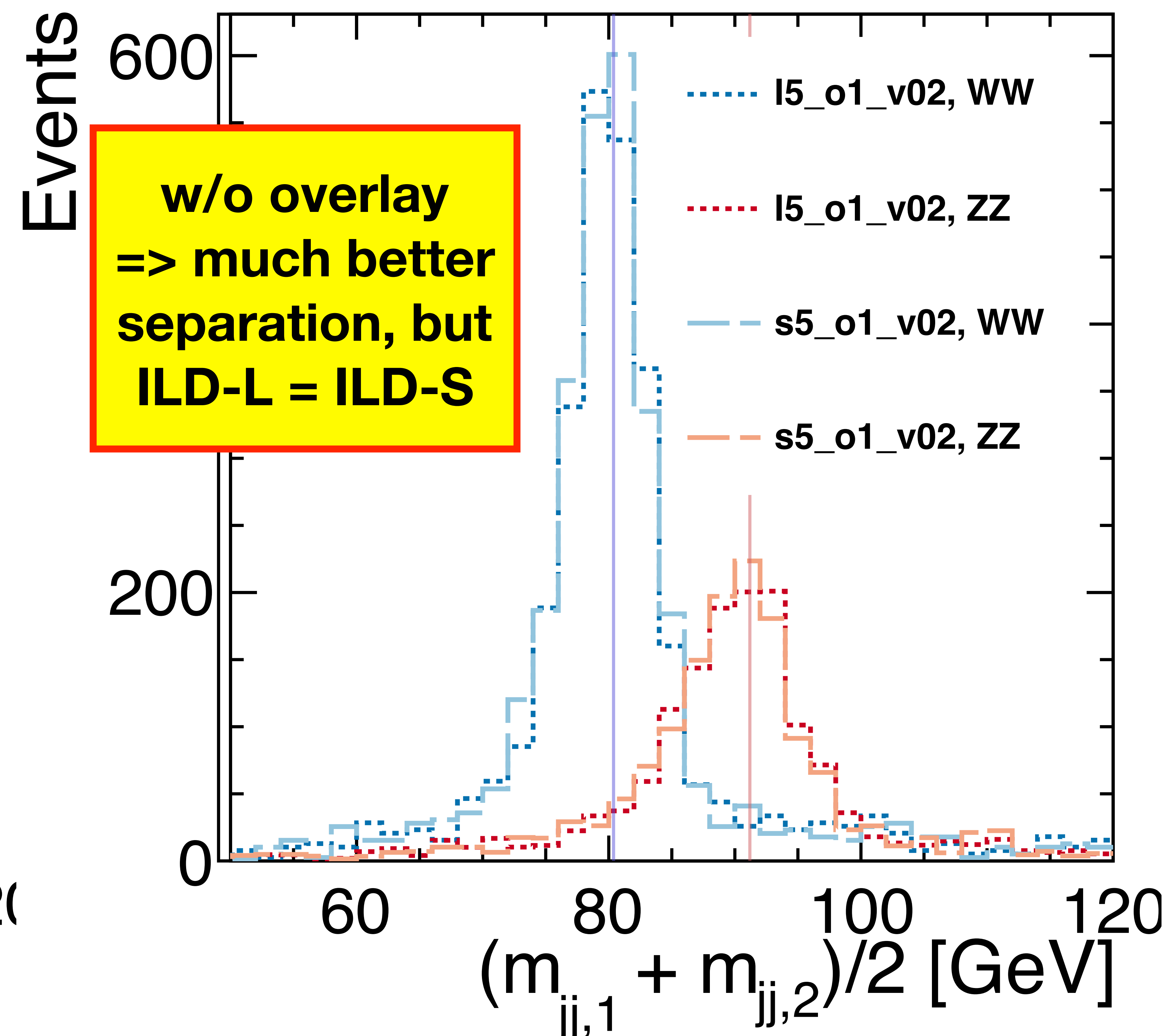
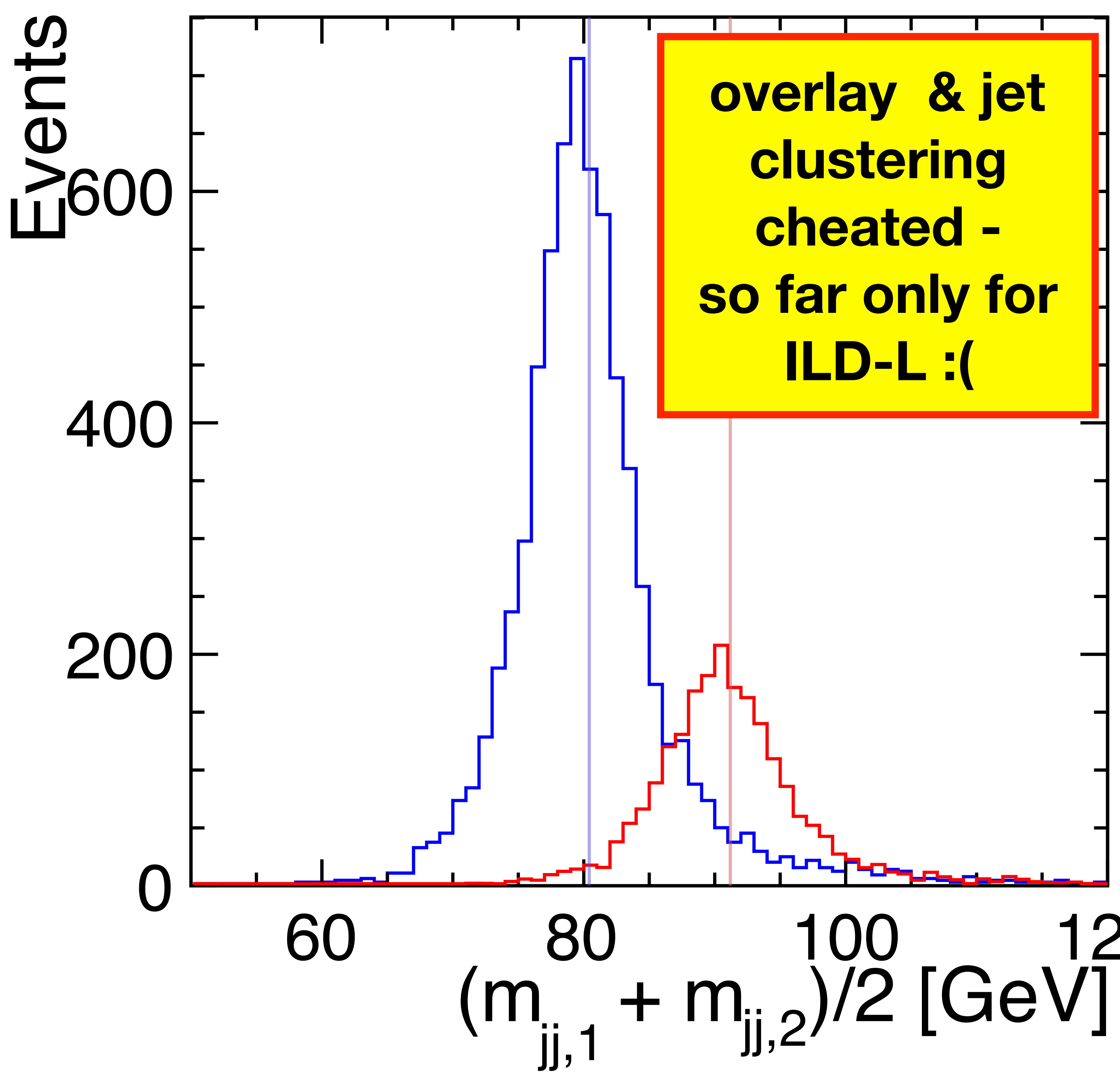


using reco of inital cns, w/ cuts, only udsc



Higgsinos

Higgsinos

Physics example: low ΔM new particles!
eg Higgsinos ΔM=770 MeV