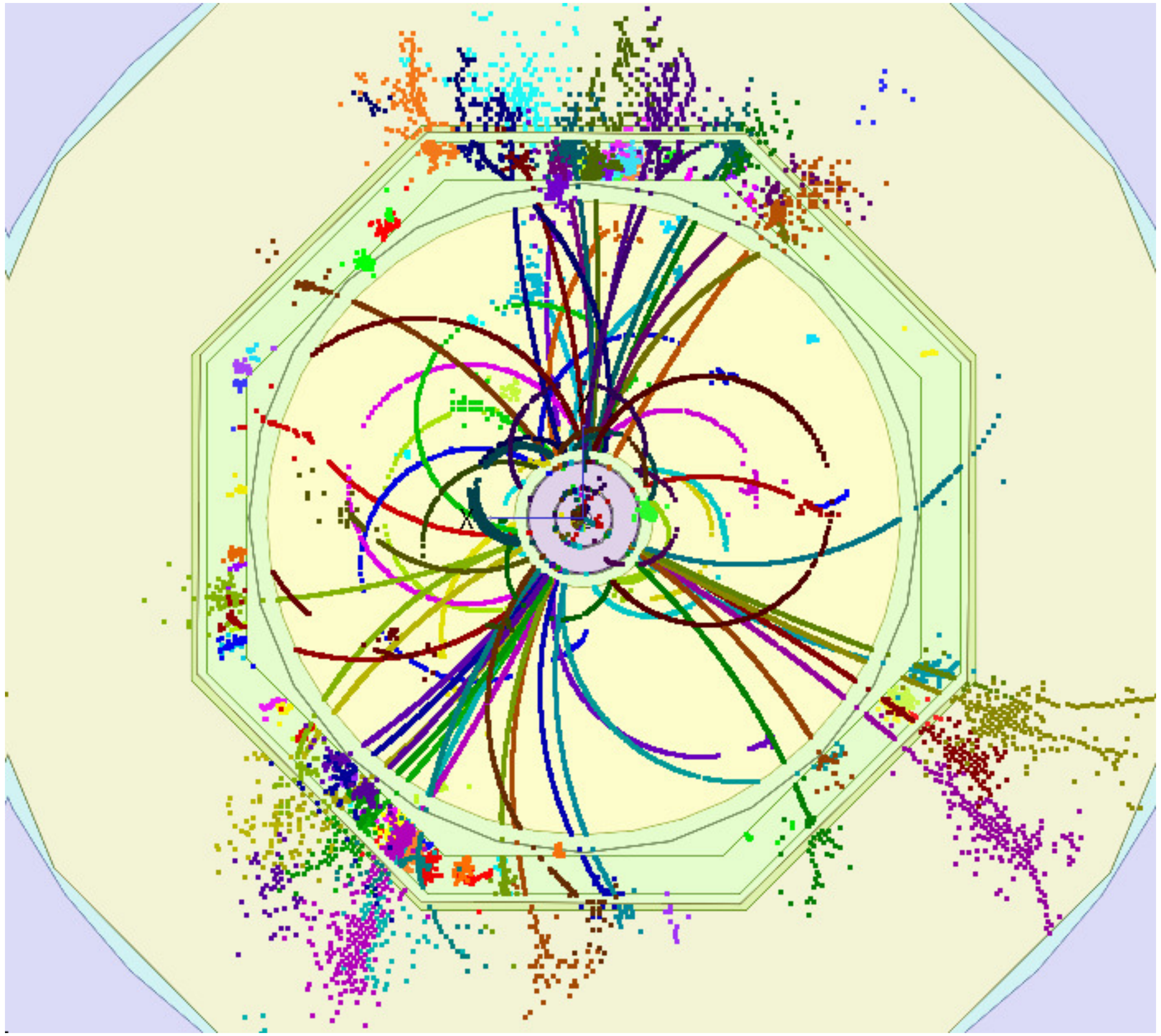
Simulation Concept for Snowmass

J. List
June 9, 2020



Introduction

- e^+e^- physics will be a major topic this Snowmass
- studies for Snowmass are an excellent opportunity to involve new people
- provide simple to use but qualitatively convincing tools!
- HOW ?

Concept overview - what will we offer

Generator-level events

- stdhep format
- E_{CM} = 250GeV*, 350GeV, 500GeV, 1TeV
- "full SM" + selected signals
- L ~= E_{CM} * fb^{-1} / GeV :-)
- Whizard 1.95
- beam energy spectra
- full treatment of spin / polarisation
  (beams -> tau decays)
- OPAL hadronisation tune
- head-on

* 250 GeV superseeded soon by Whizard 2.8.x, 10 ab-1, LCIO format => stdhep on request

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Delphes card for "generic (I)LC detector"

- describing a particle flow detector in Delphes is a challenge
- **but widely used in pp community**
- simple Delphes card from SiD (C.Potter)
  => performance factors 2… 10 away from full simulation!
- very involved CLICdp setup (P.Roloff et al)
- **ILD is working on a reasonable description**

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Simulation a grande vitesse (SGV)

- as fast as Delphes
- **very, very close to full simulation!**
- battle-proven in many, many ILC studies
- **not known in pp community**

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full, Geant4-based simulation & reconstruction

- the full level of detail
- profiting directly from 20 years of development and experience
- **requires "joining" ILD / SiD**

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miniDST

- brand-new initiave within ILD
- define a **reduced, high-level data format** (isolated leptons & photons, jets, particle flow objects, MCtruth)
- **readable in root** (loading one shared library), no Marlin etc required
- filled from **1) SGV, 2) full simulation**, and, possibly 3) Delphes

Generator-level event samples

- **DBD-samples (Whizard 1.95):**
  - readily available in stdhep format on the grid (ilc-vo)
  - ***=> copy to some Snowmass space for access without ilc-vo membership?***
- **new 250 GeV samples (Whizard 2.8.x), new beam spectrum:**
  - upcoming, but by default lcio format only
  - ***=> upon request: write also sthep, but then disk space needs to be provided!***
- **LCC Generator Group is available for advice and support for generating additional samples (eg BSM signals).**

Delphes

- will provide a Delphes card describing “a generic ILC detector”
- avoid Delphes-based “SiD vs ILD” comparisons
- existing SiD card 2…10x worse than ILD full simulation

=>

- **no central processing of events with Delphes planned on our side**

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DELPHES task force

Goal:
- prepare the updated ILC detector model for Snowmass studies.

Key developments planned:

- Include forward detector description
  - LumiCal and LHCAL included in particle flow reconstruction
  - Increase of the angular coverage for exotic studies…
- Verify/improve description of calorimeter segmentation
- Verify/improve “granularity” of response description
  - Better modeling of single-particle reconstruction
- Improve description of b- and c- tagging
  - Also taking into account angular and energy dependence
- More options for jet clustering
  - Choice between inclusive and exclusive clustering with different number of jets

Dedicated repository created: https://github.com/ILDAnaSoft/ILDDelphes

SGV

- **the** battle-proven ILC fast simulation tool
- **ready to be used at anytime by anybody:**

```
svn export https://svnsrv.desy.de/public/sgv/tags/SGV-3.0rc1/
SGV-3.0rc1/

Then

bash install
```

  - producing either LCIO-DST or direct analysis / root tree writing
  - see also: **https://agenda.linearcollider.org/event/8525/contributions/45543/attachments/35501/55052/berggren-ildphone-12may20.pdf**
- **plan for Snowmass: provide miniDST filled from SGV**
  => storage outside of ilc-vo to be provided by Snowmass

Full Simulation

- the ultimate level of realism
- requires getting in contact with SiD / ILD
  - both Detector Concepts welcome newcomers!
  - ILD offers a “guest membership” - costs nothing, apart from following ILD publication rules
- **plan for Snowmass: provide miniDST filled from ILD full simulation & reconstruction - somewhat later than SGV-miniDST, though.**
  => analyses can start with SGV-miniDST, option to move to ILD-miniDST if deeper interest
  => again storage outside of ilc-vo to be clarified / provided by Snowmass?
  => SiD version ?

Summary

- available already:
  - DATA: generator-level event samples 250 GeV, 350 GeV, 500 GeV, 1 TeV
  - TOOL: SGV fast simulation
- in preparation, hopefully in place by ~mid July:
  - DATA: SGV-miniDST of the above generator-level samples
  - TOOL: Delphes card for a “generic ILC detector”
- in preparation, coming during ~fall:
  - DATA: ILD-miniDST of new 250 GeV samples, other energies tbd
  - TOOL: miniDST output for Delphes ?
- data with “ILD” in the name will require at least “guest membership”

Backup

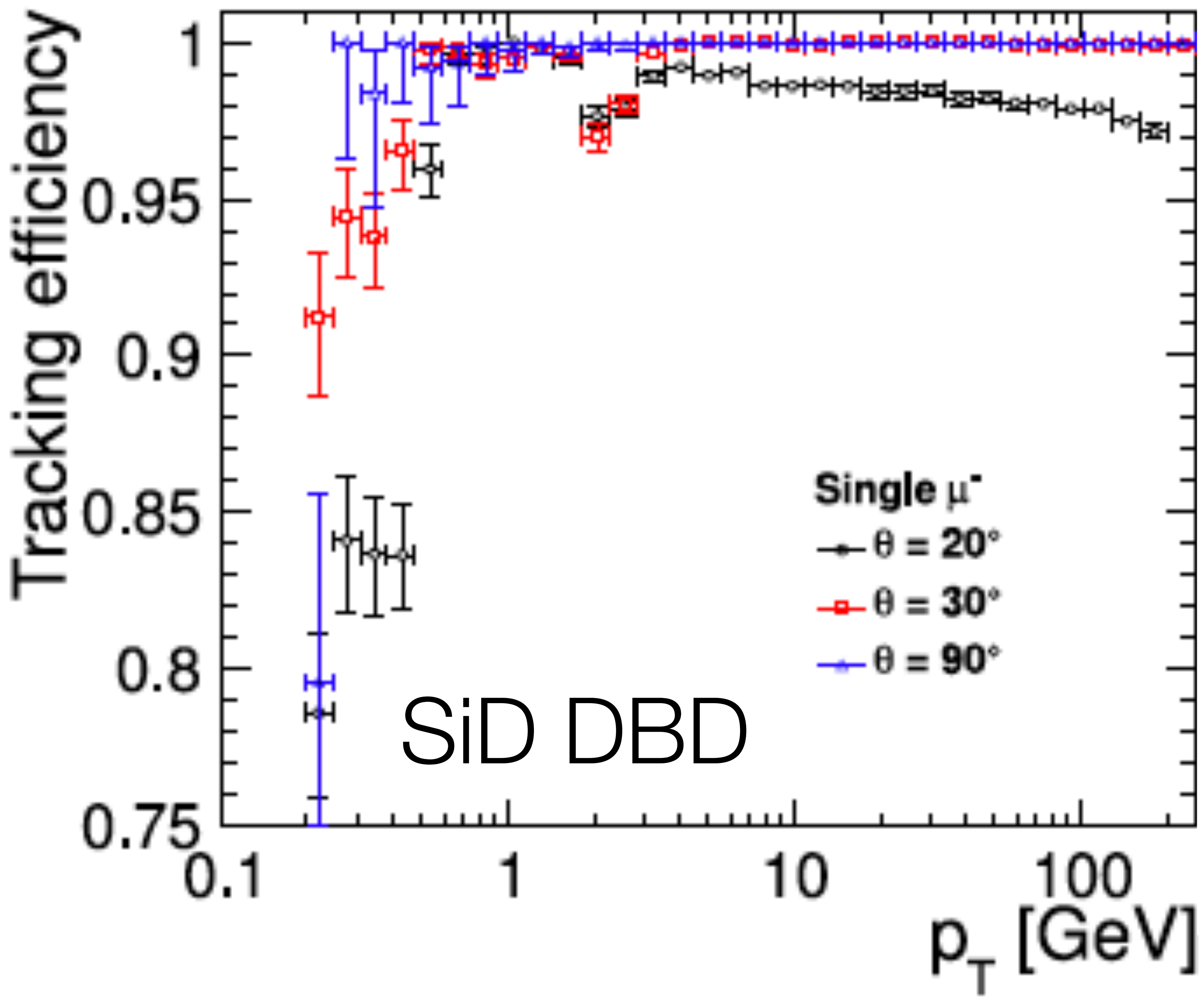
- arXiv:1602.07748 (SiD Delphes card by Chris Potter)
- compared to full simulation performance as in
  - SiD DBD
  - ILD IDR

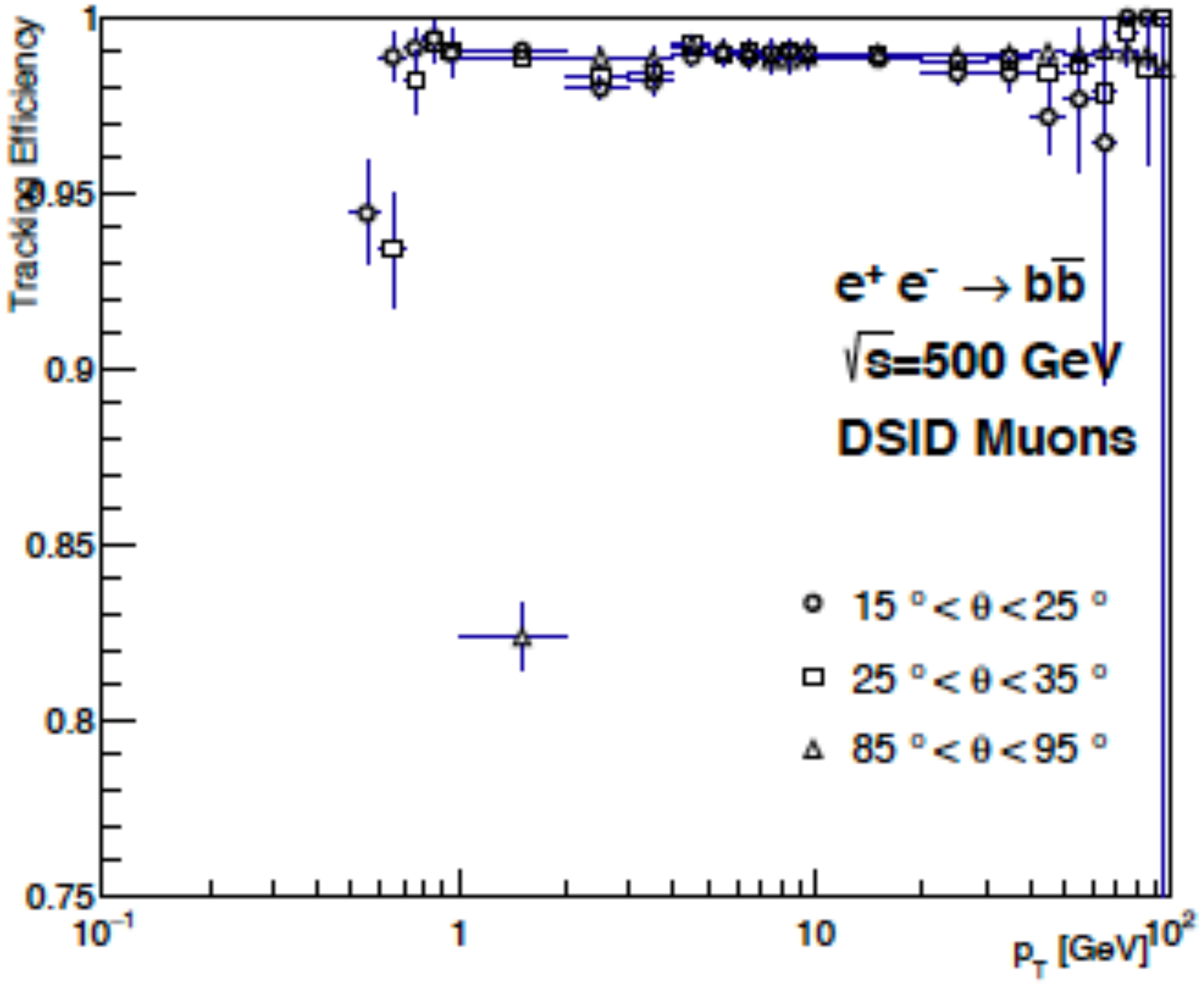
Parameter	Value
ParticlePropagator	
Radius HalfLength Bz	2.493m 3.018m 5.0 T
TrackingEfficiency	
ChargedHadronTrackingEfficiency ElectronTrackingEfficiency MuonTrackingEfficiency	see DBD Figure 3.5 see DBD Figure 3.5 see DBD Figure 3.5
MomentumSmearing	
ChargedHadronMomentumSmearing MuonMomentumSmearing ElectronEnergySmearing	see DBD Figure 3.9 see DBD Figure 3.9 see DBD Figure 3.9
ECal,HCal	
ECal ResolutionFormula HCal ResolutionFormula	$\sigma_E/E = 0.010 \oplus 0.170/\sqrt{E}$ $\sigma_E/E = 0.094 \oplus 0.559/\sqrt{E}$
Photon,Electron,Muon Efficiency	
PhotonEfficiency ElectronEfficiency MuonEfficiency	see DBD Figure 10.6 see DBD Figure 10.7 see DBD Figure 10.8
FastJetFinder	
JetAlgorithm ParameterR InputArray	6 [antik_t] 1.0 EFlowMerger/eflow
BTagging	
EfficiencyFormula 0 EfficiencyFormula 4 EfficiencyFormula 5	0.007 0.03 0.7
TauTagging	
EfficiencyFormula 0 EfficiencyFormula 15	0.001 0.4

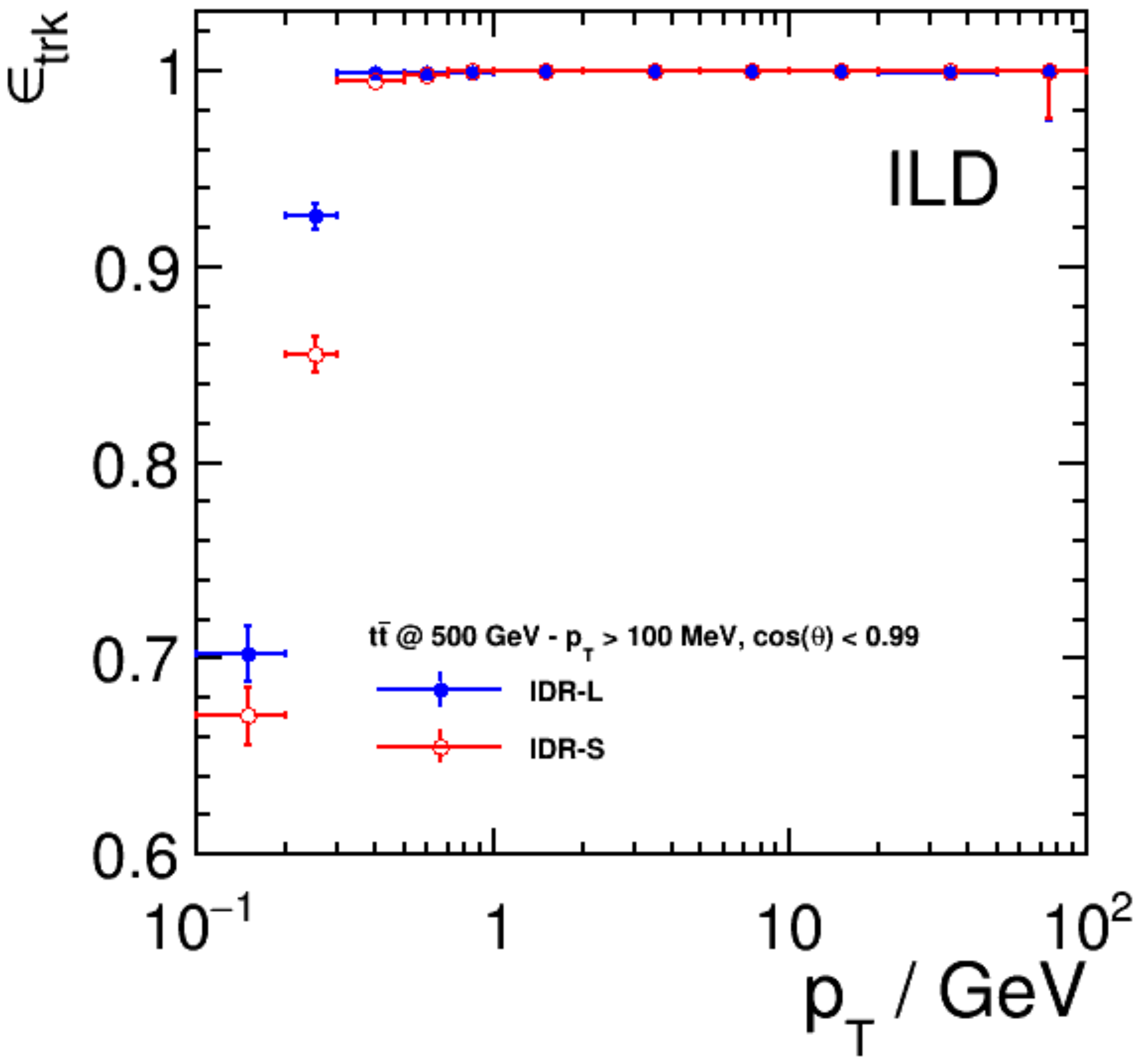
ILD IDR

$$\sigma(E)/E \sim 17\%/\sqrt{(E/\mathrm{GeV})}$$
$$\sigma(E)/E \sim 50\%/\sqrt{(E/\mathrm{GeV})}$$

Tracking efficiency







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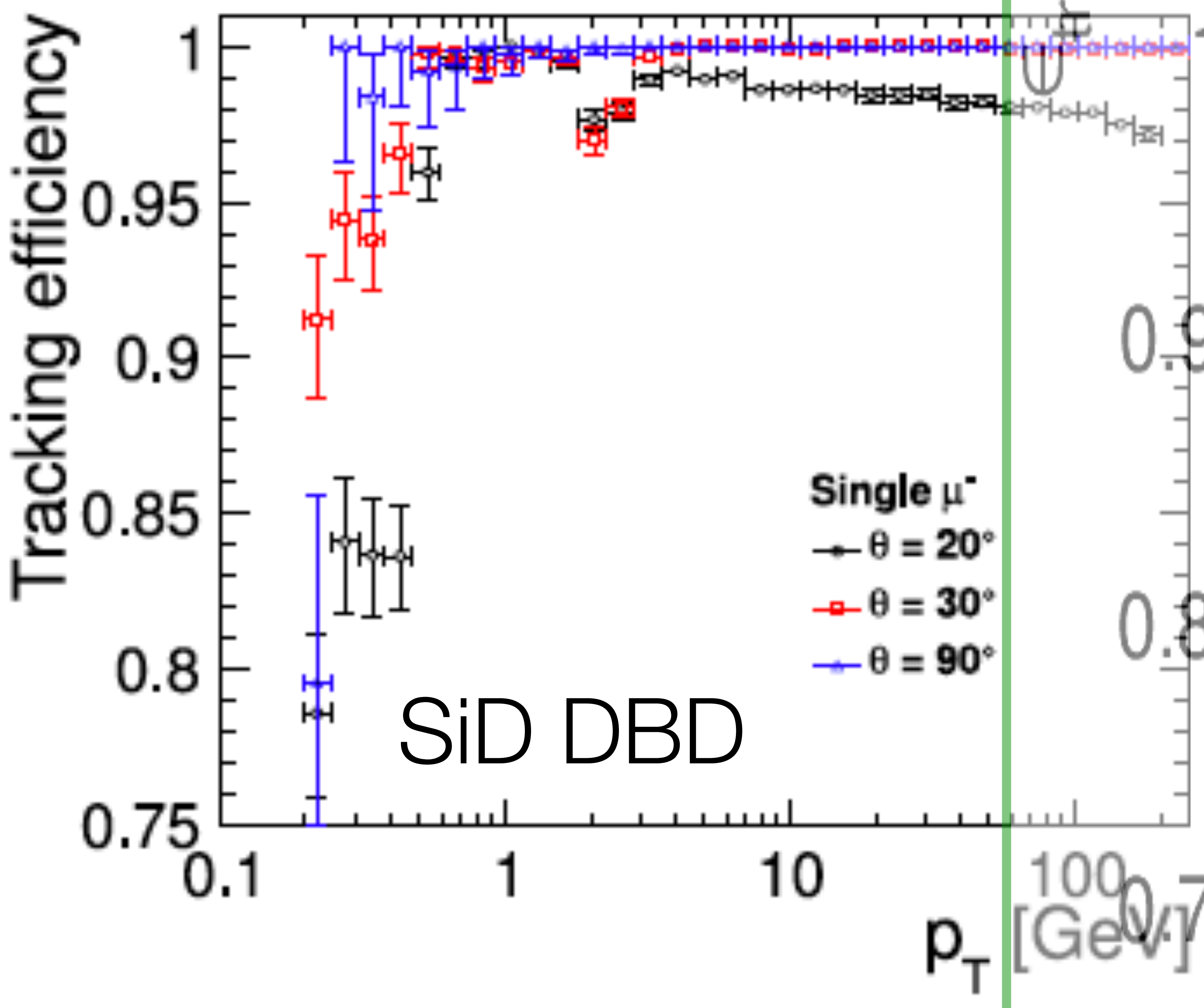

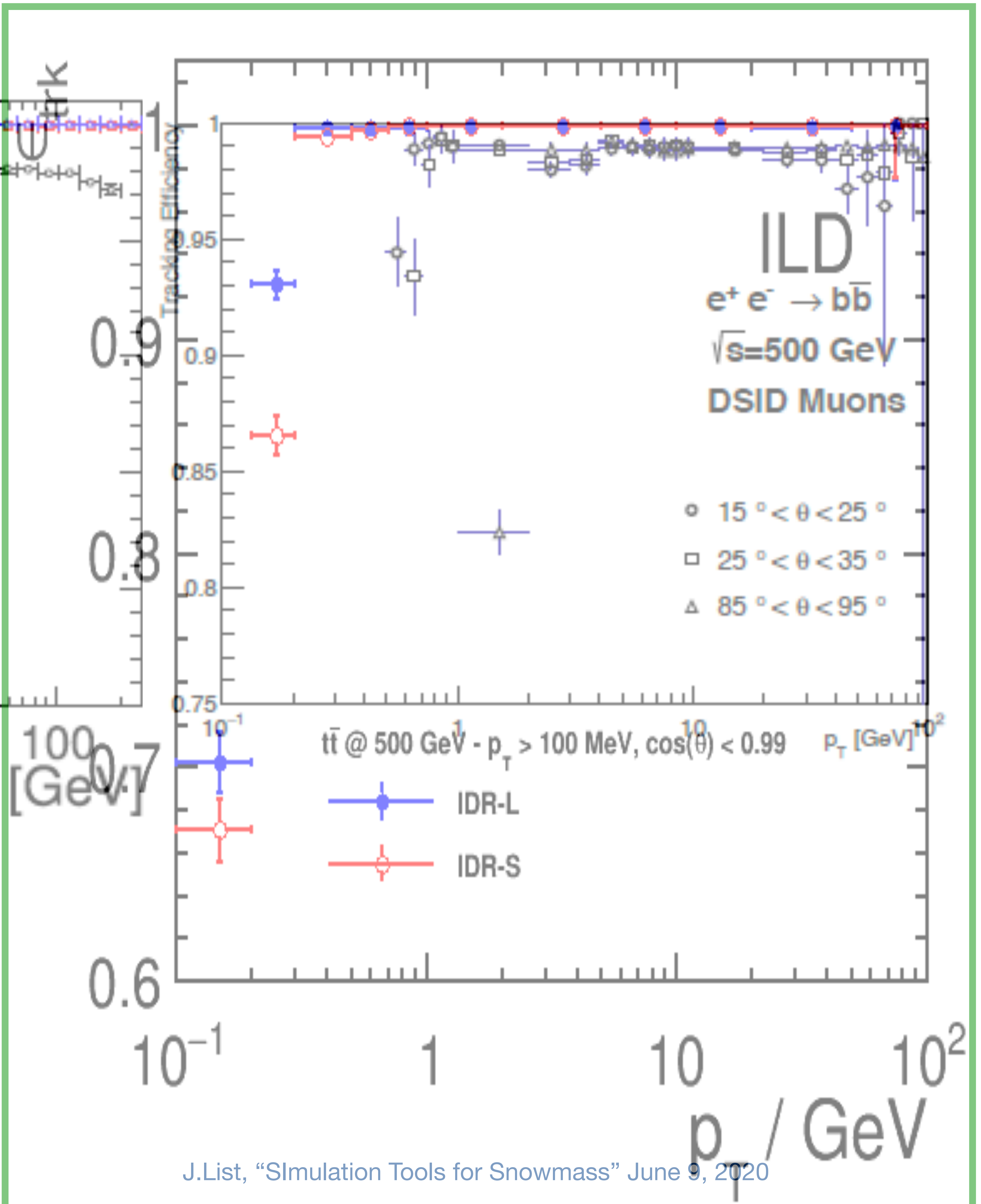

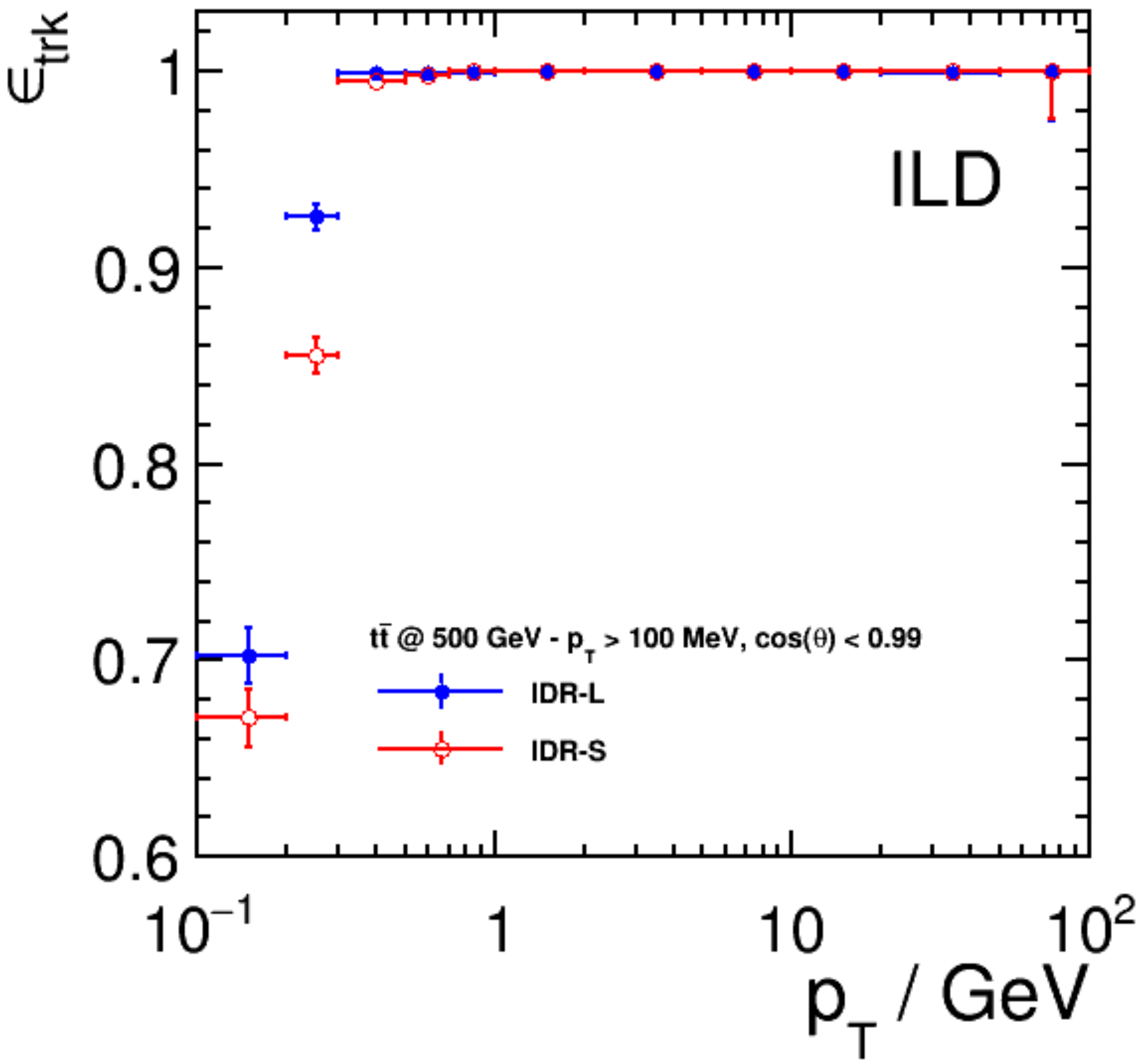

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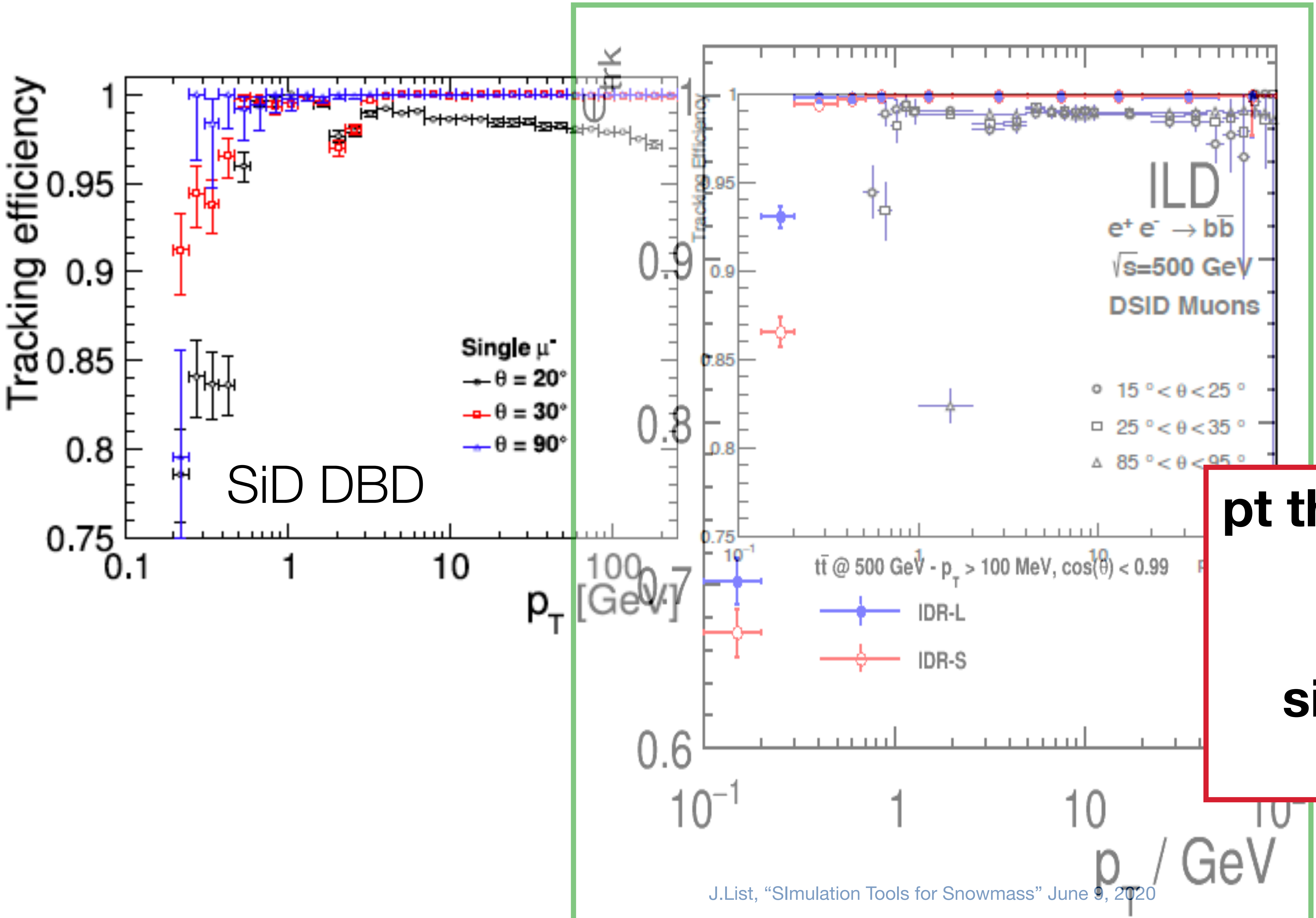
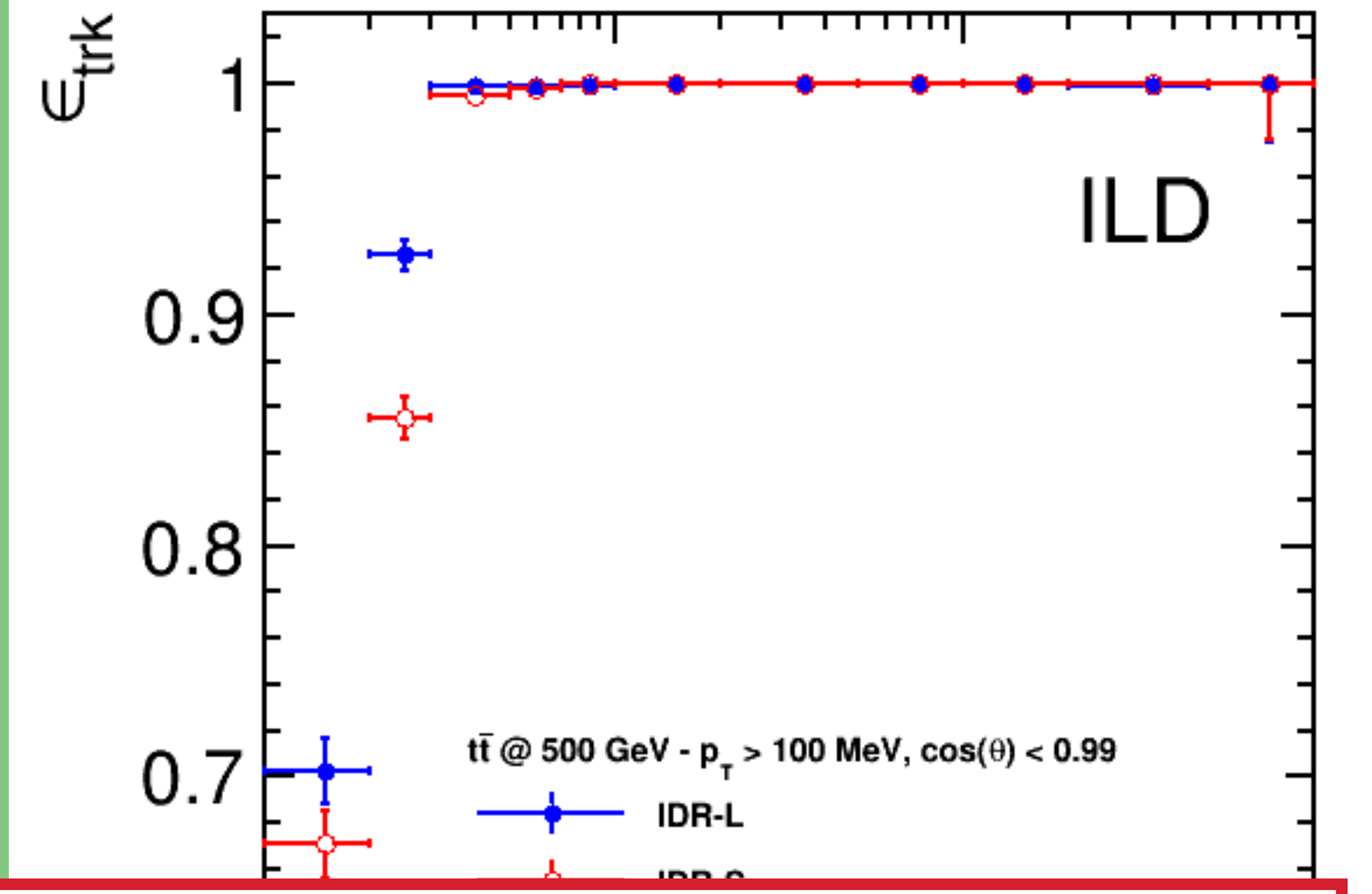
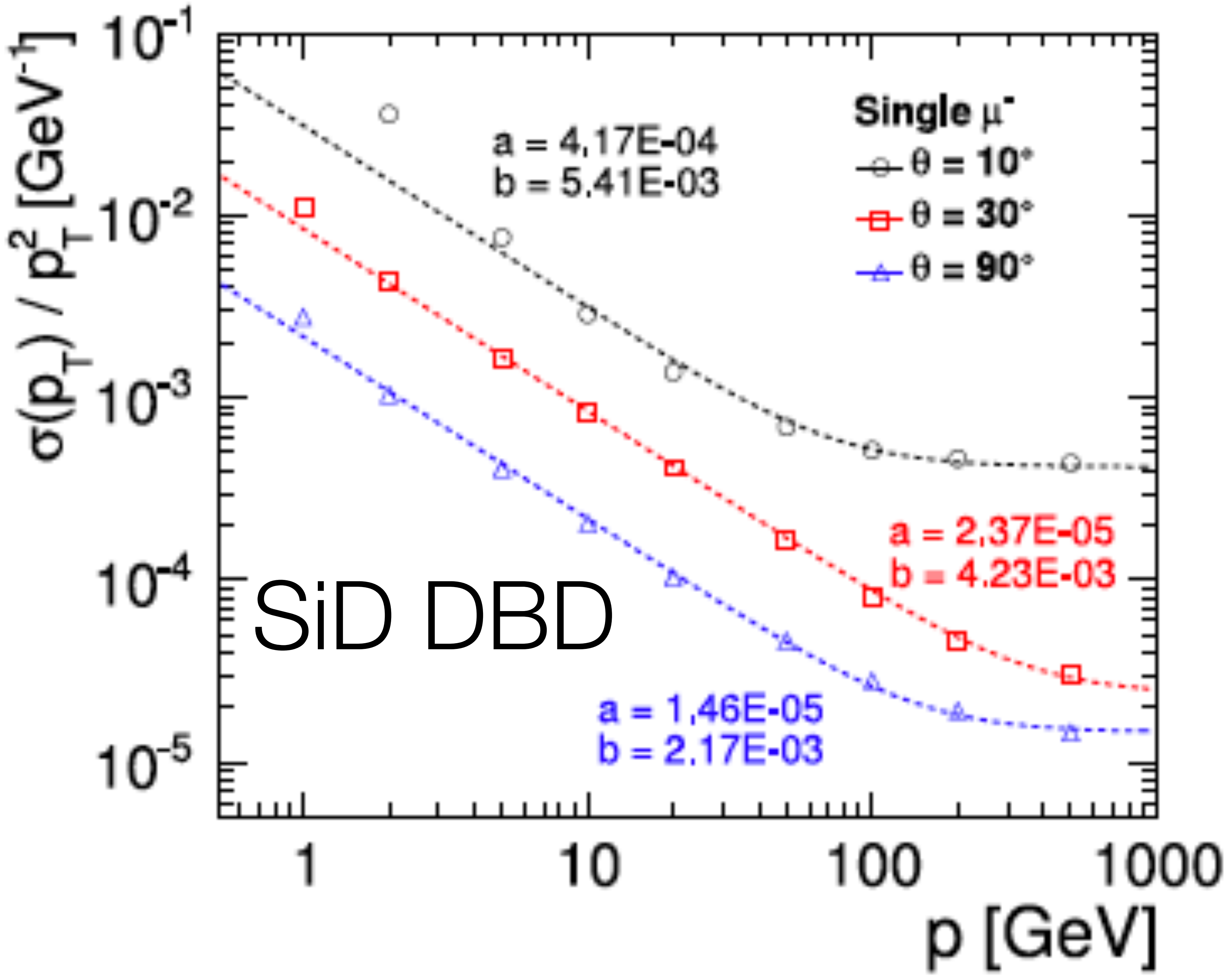
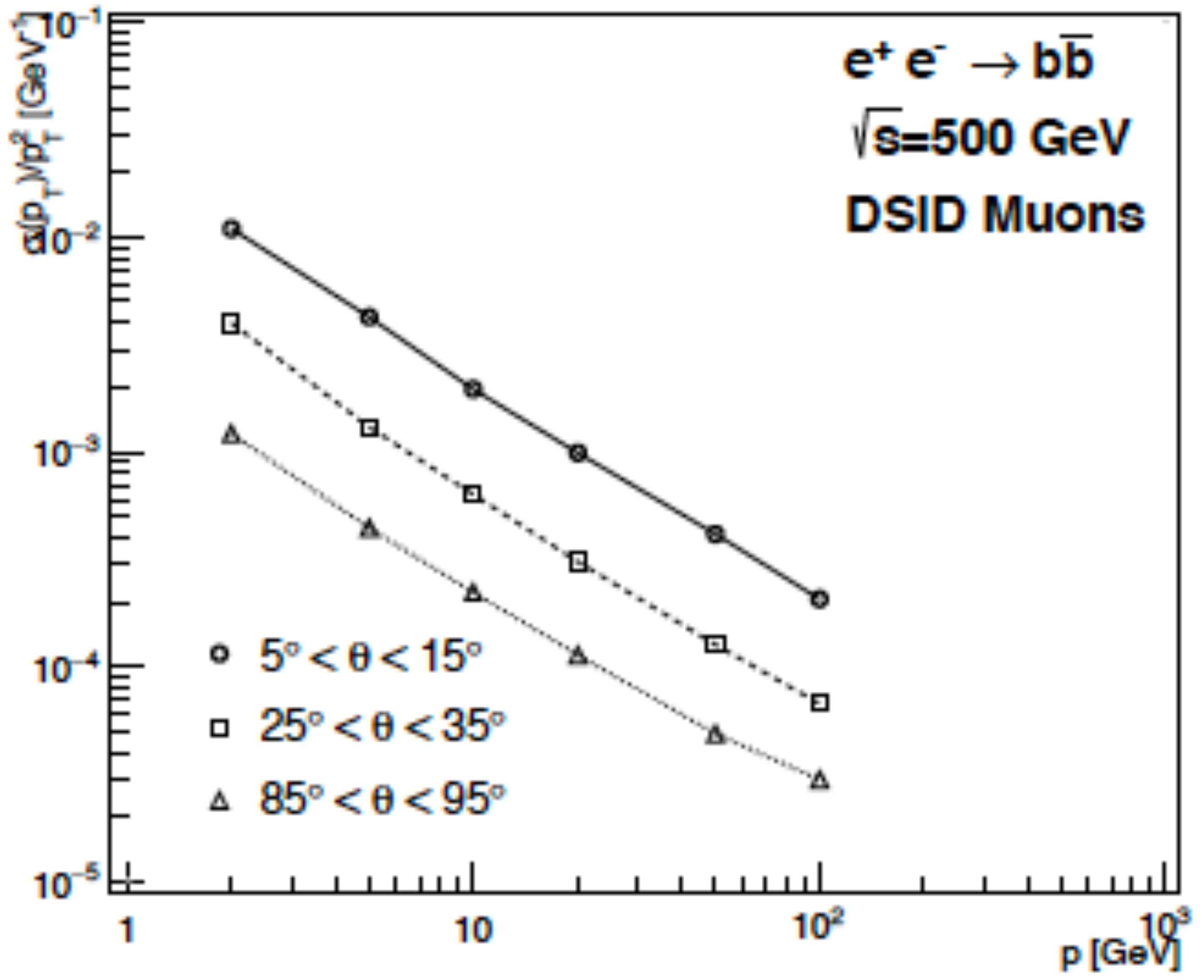


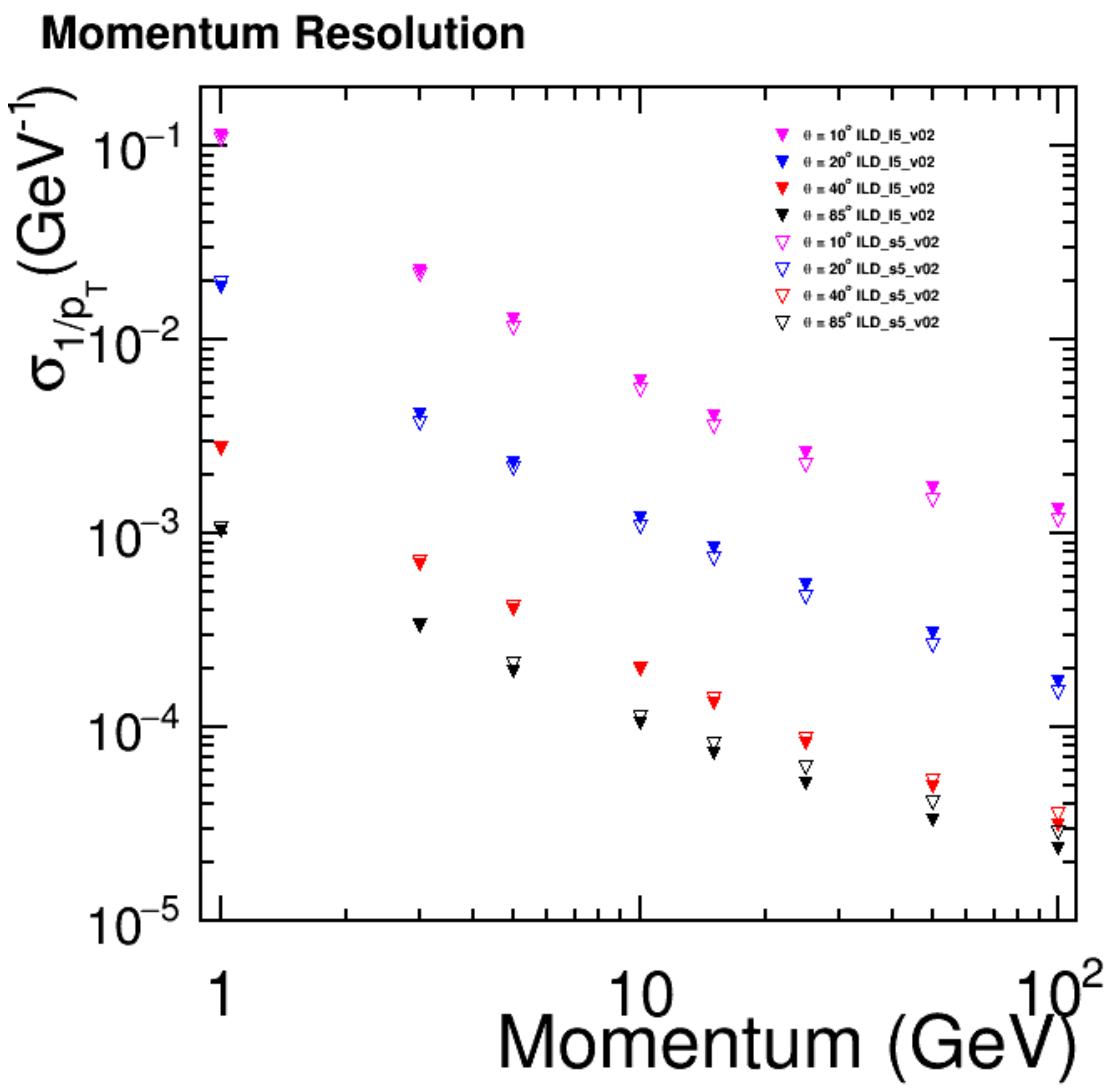


pt threshold in SiD Delphes ~5x higher than ILD full simulation, significant inefficiency even at high pt

1/pt resolution vs p







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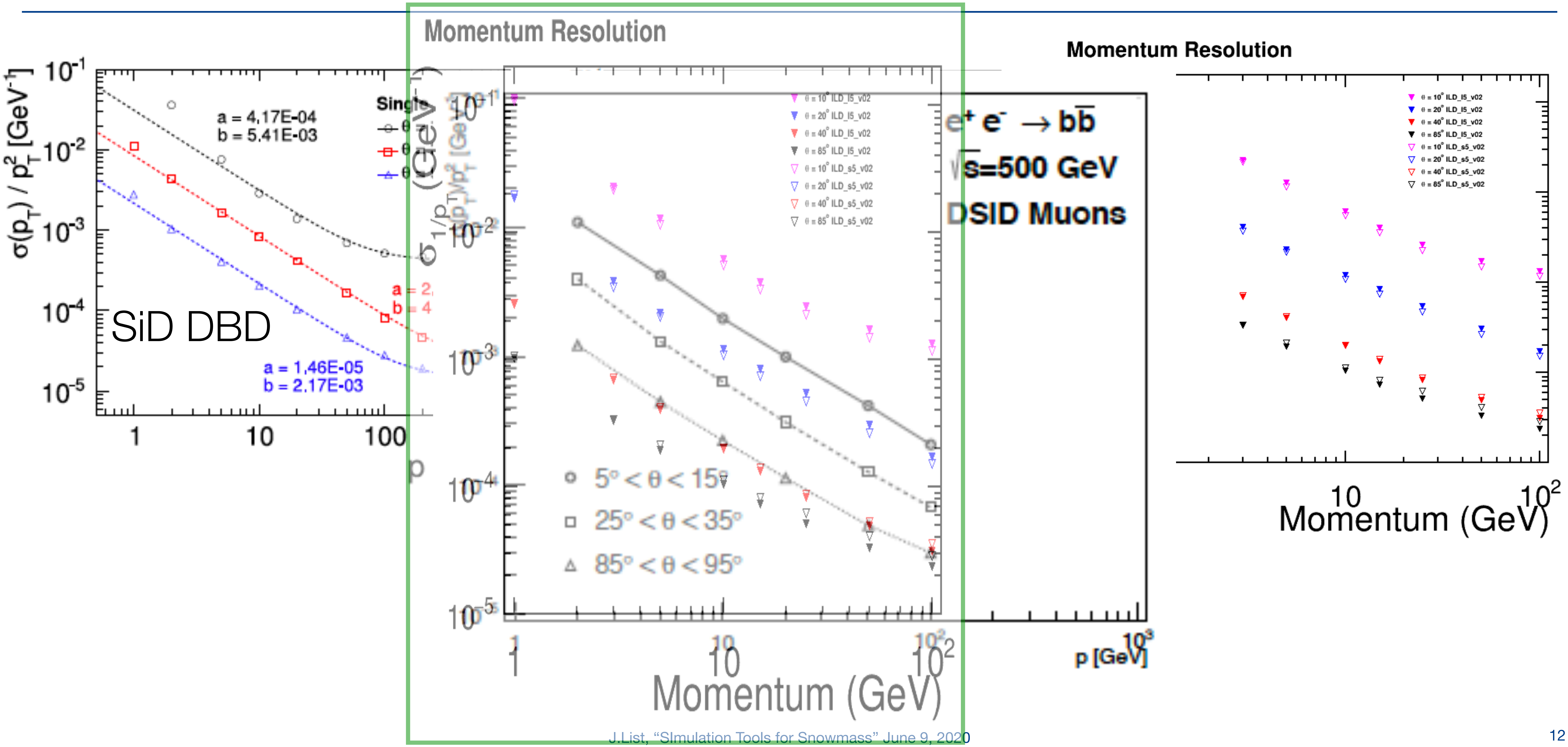

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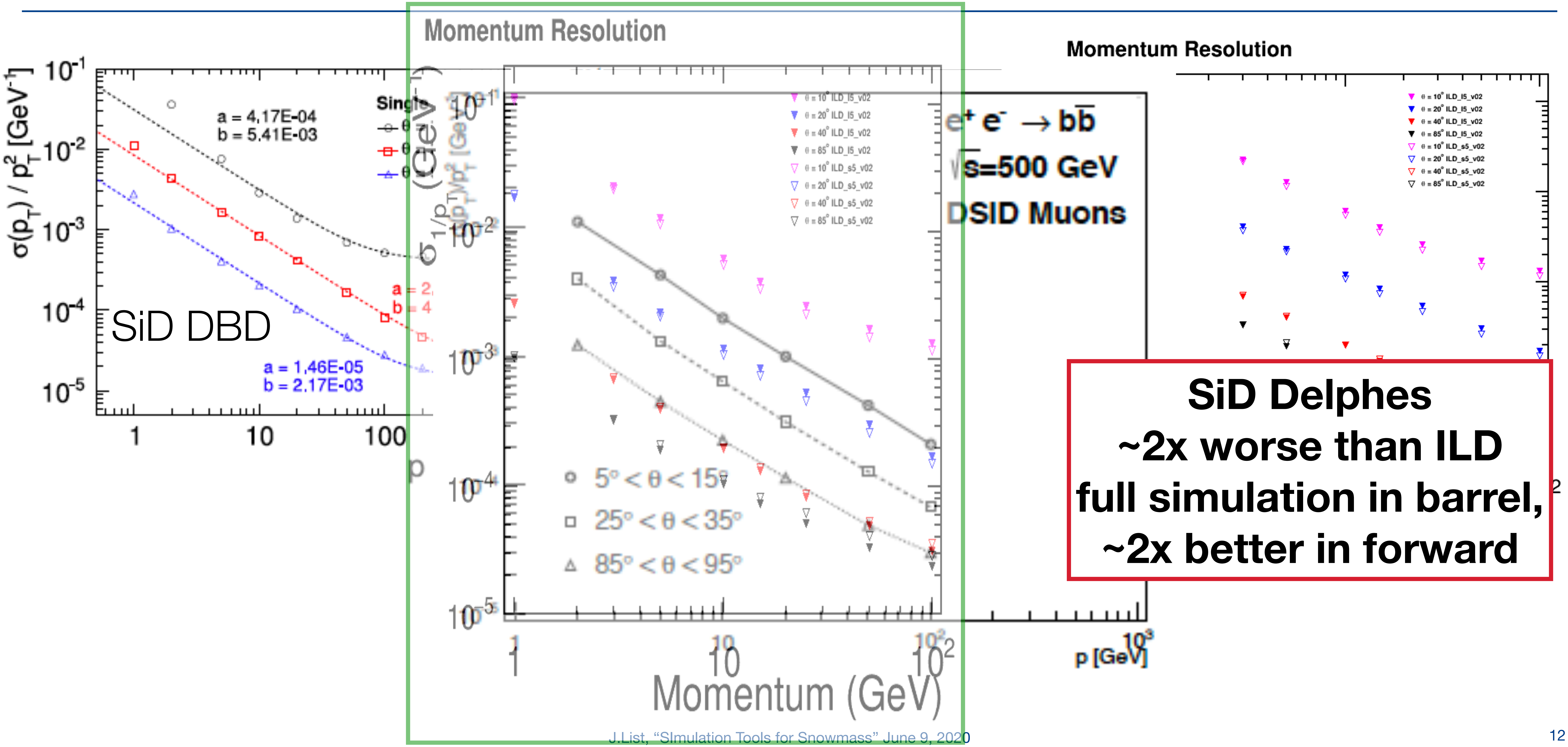
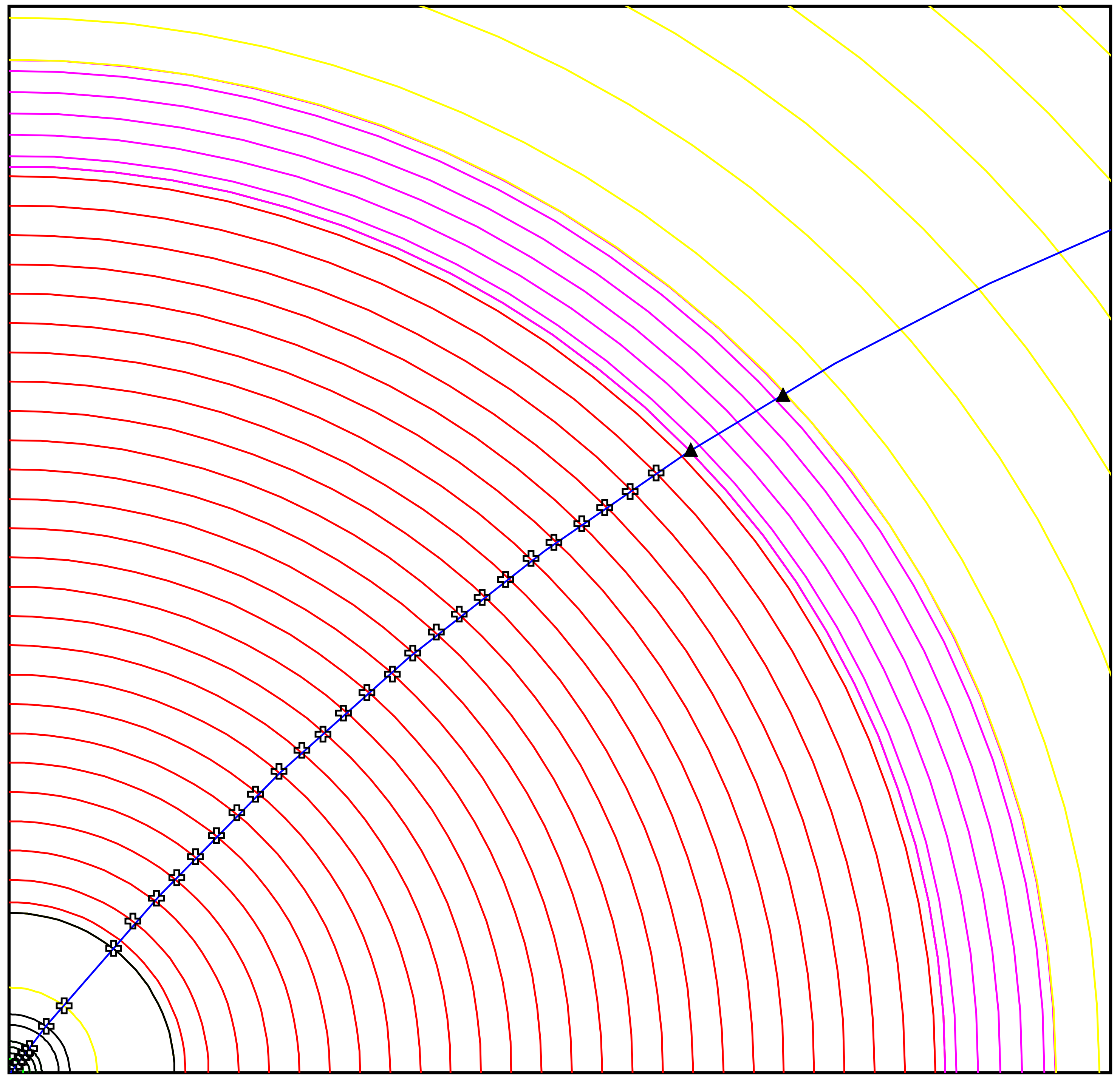


SiD Delphes
~2x worse than ILD full simulation in barrel,
~2x better in forward

SGV: How tracking works

SGV is a machine to calculate covariance matrices

Tracking: Follow track-helix through the detector.



- Calculate cov. mat. at perigee, including material, measurement errors and extrapolation. NB: this is exactly what Your Kalman filter does!
- Smear perigee parameters (Choleski decomposition: takes all correlations into account)
- Helix *parameters* exactly calculated, *errors* with one approximation: helix moved to (0,0,0) for this.

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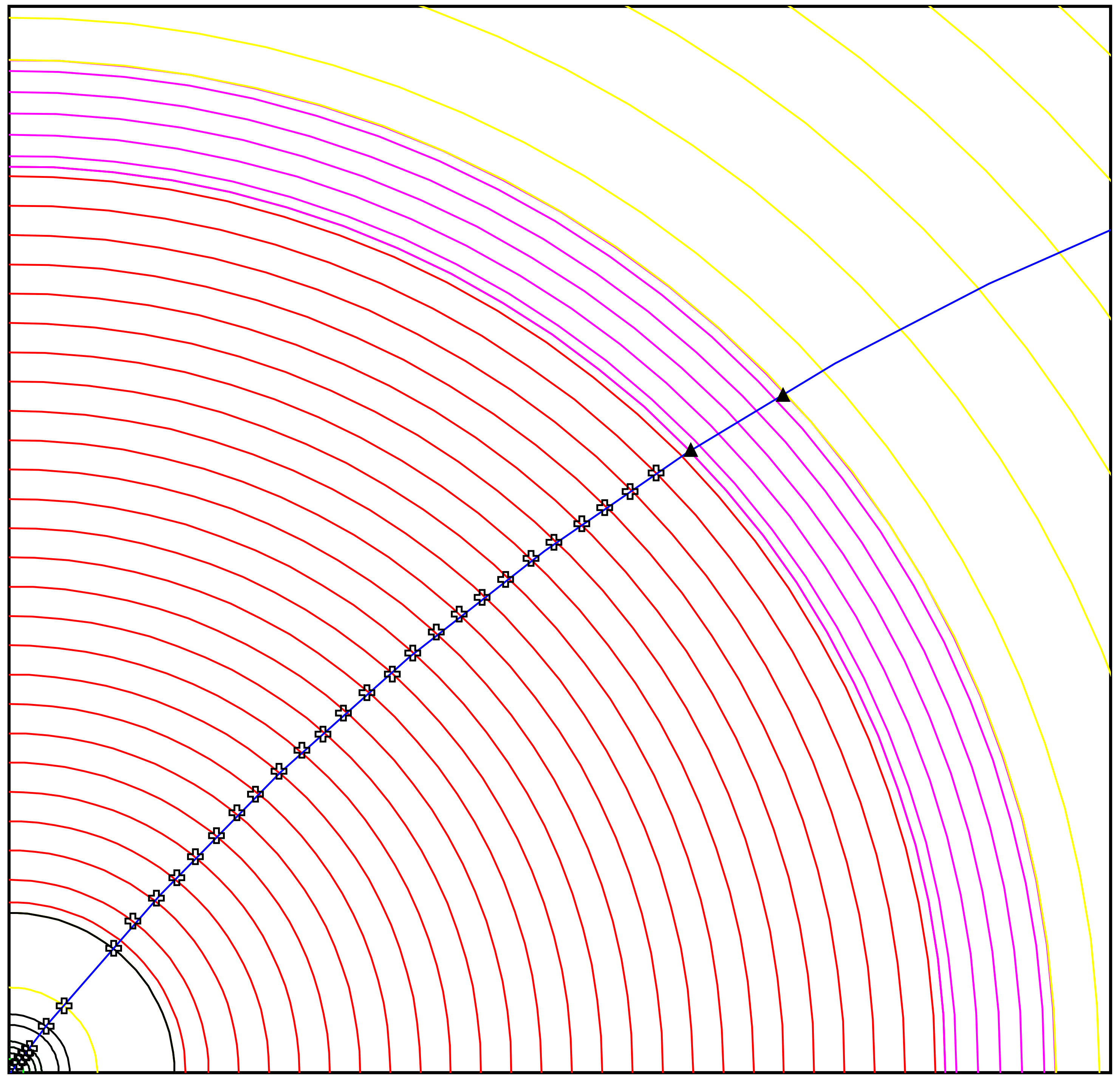

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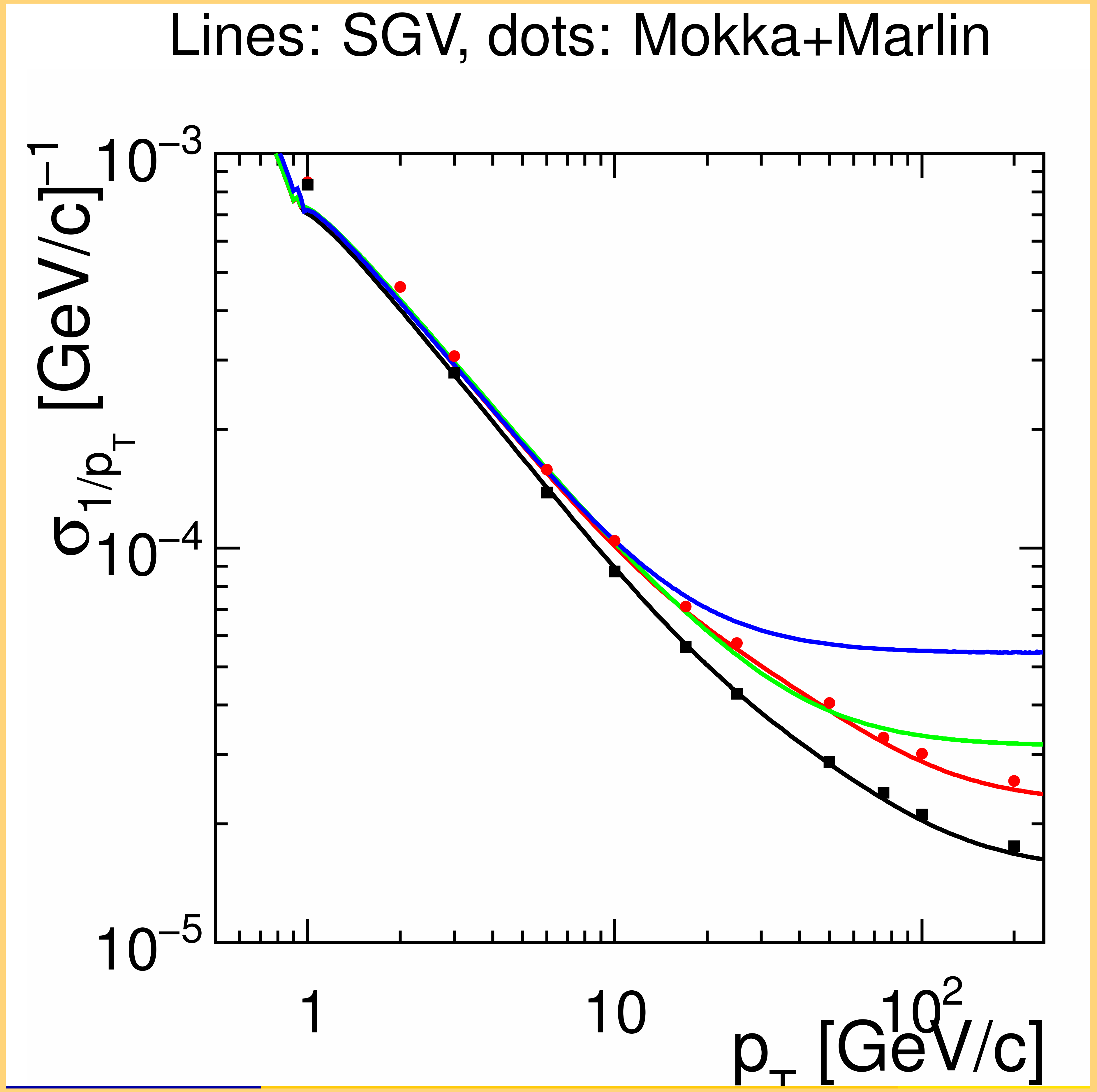
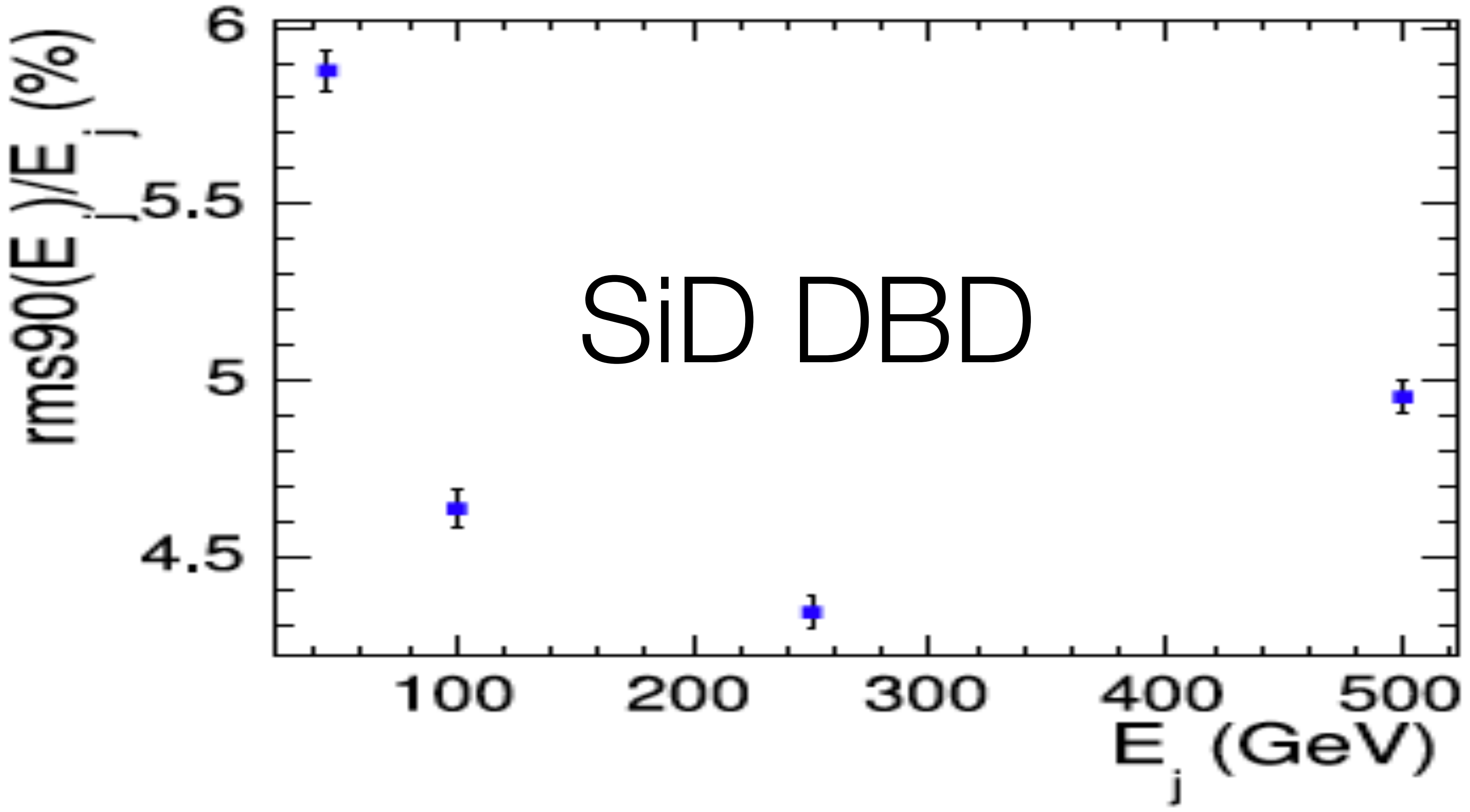
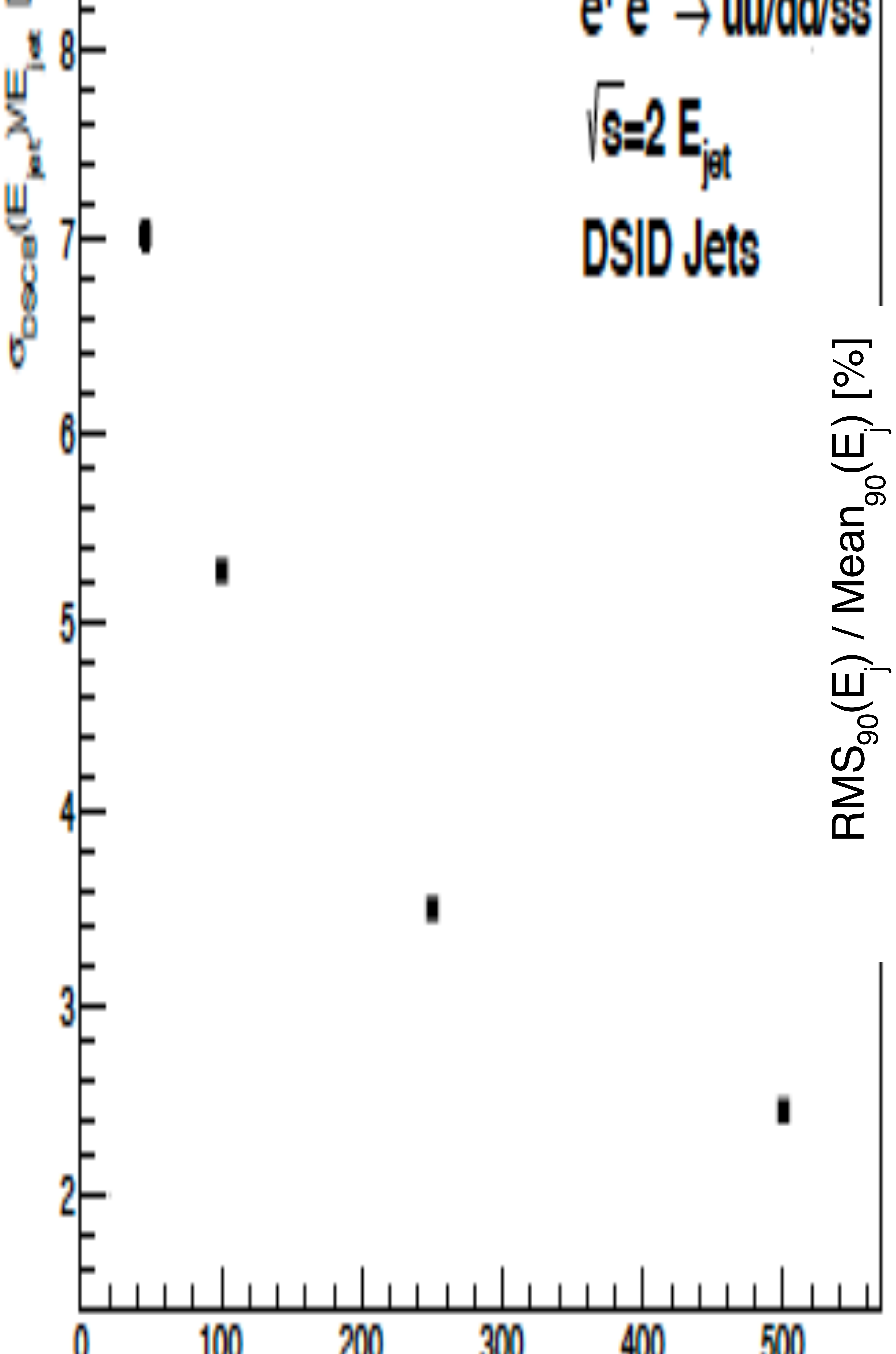
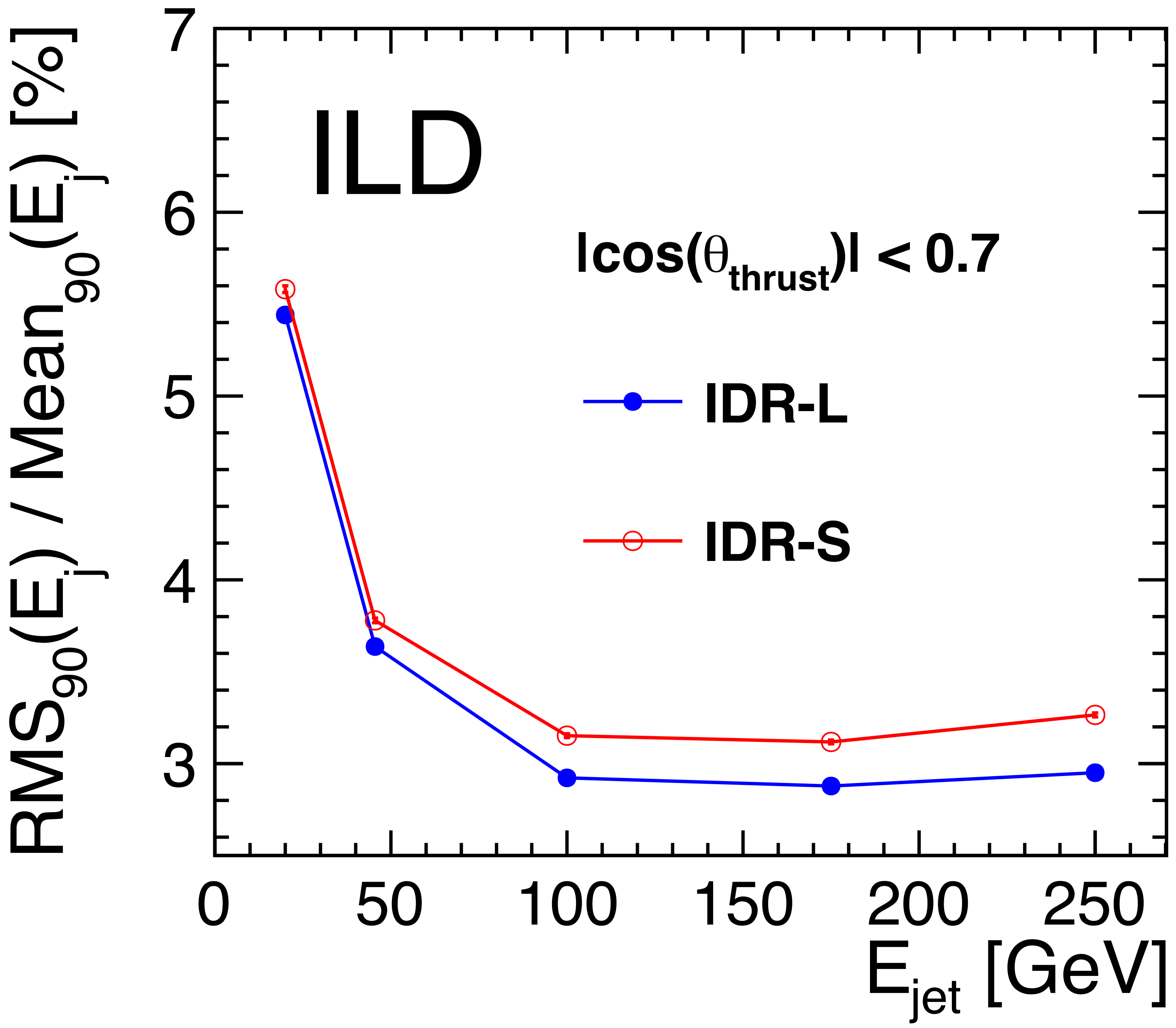


Jet Energy Re







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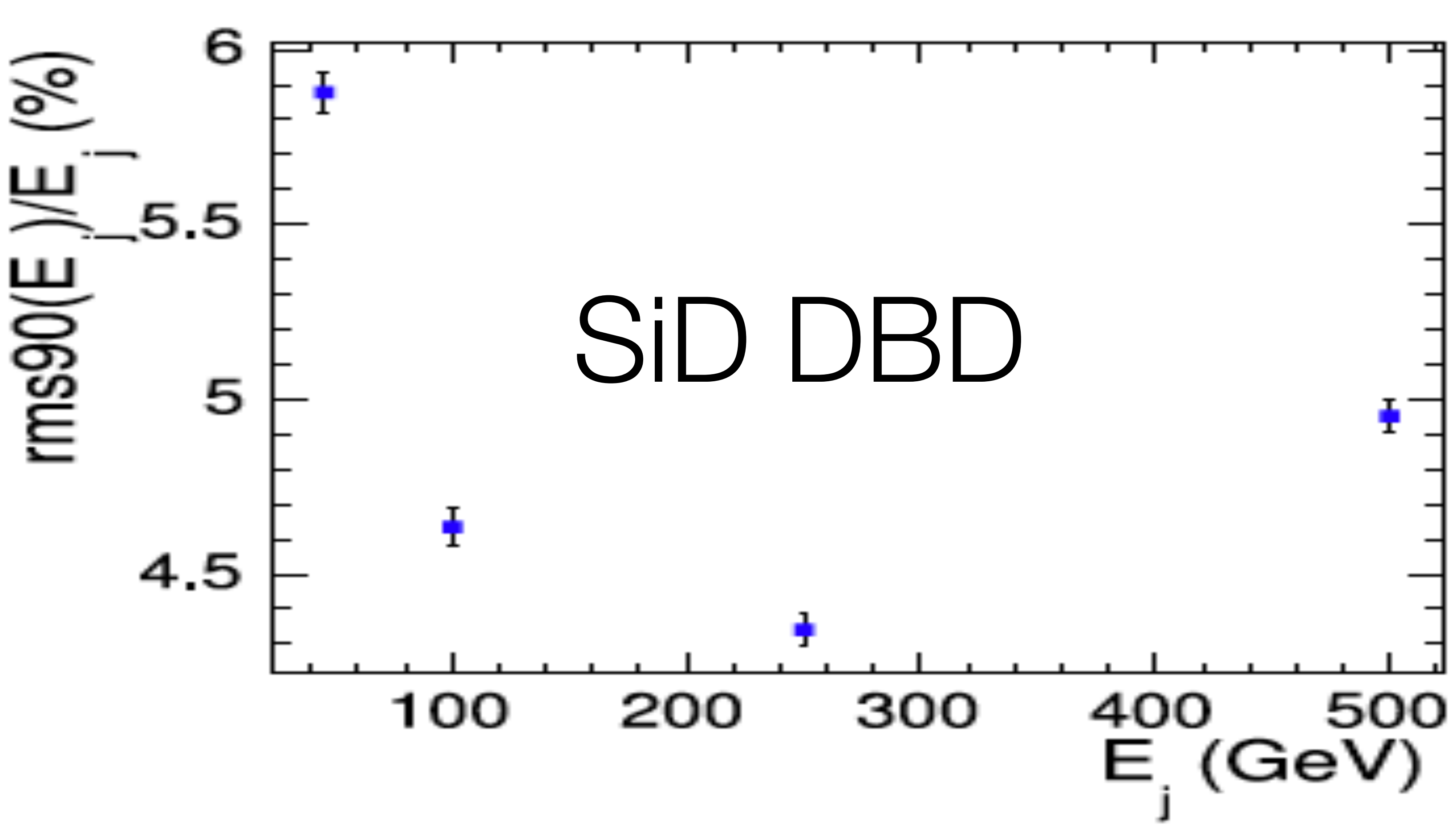

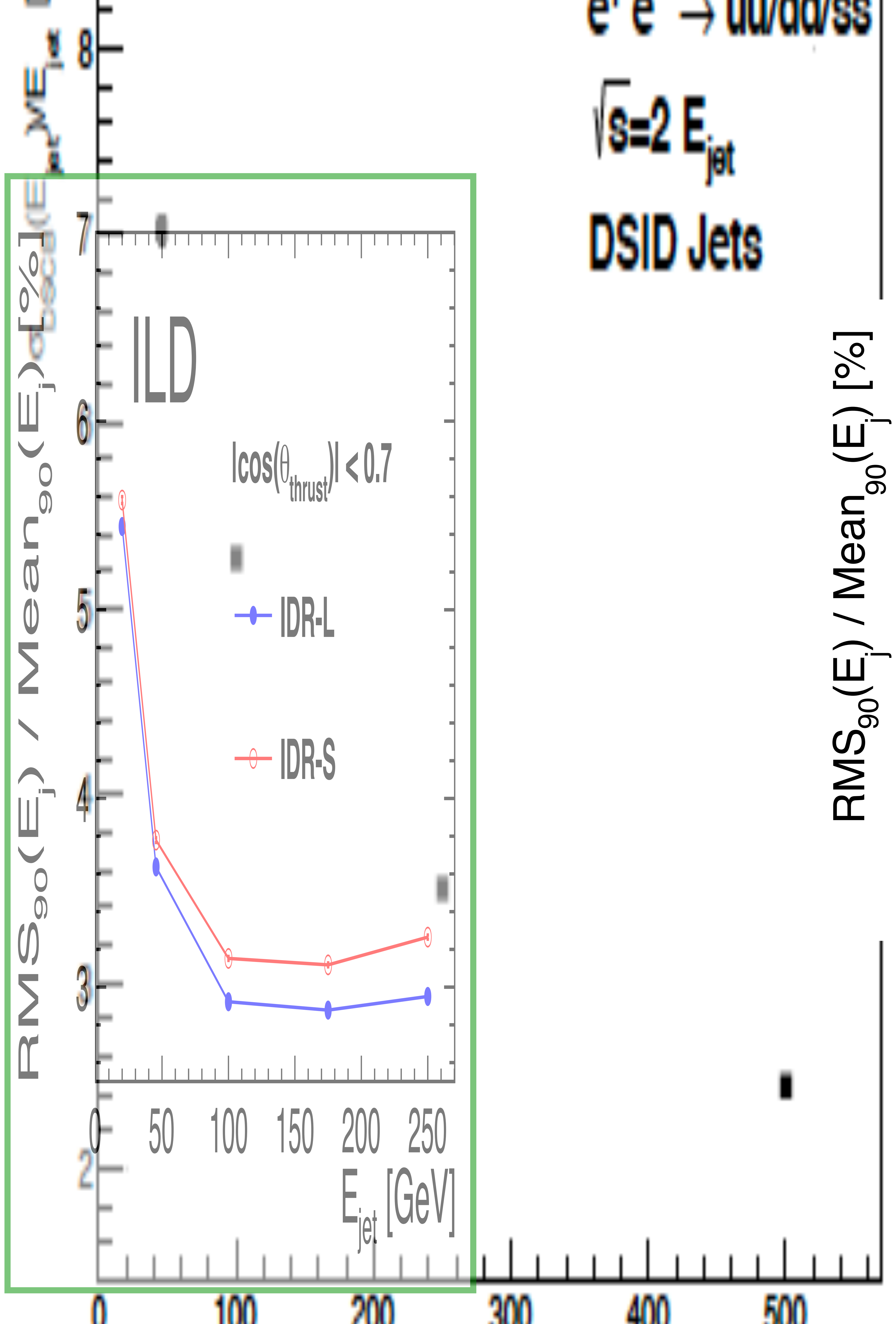

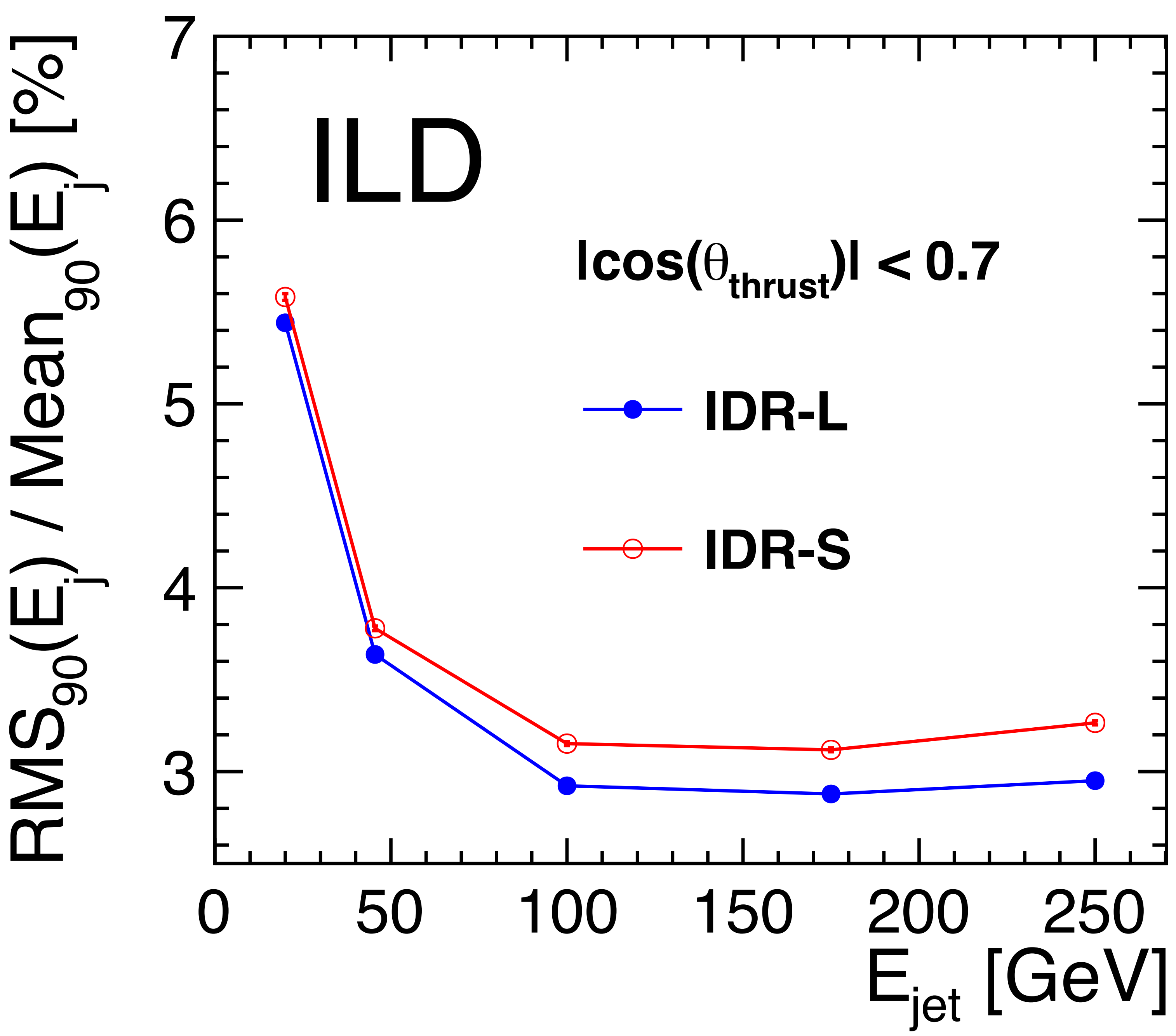

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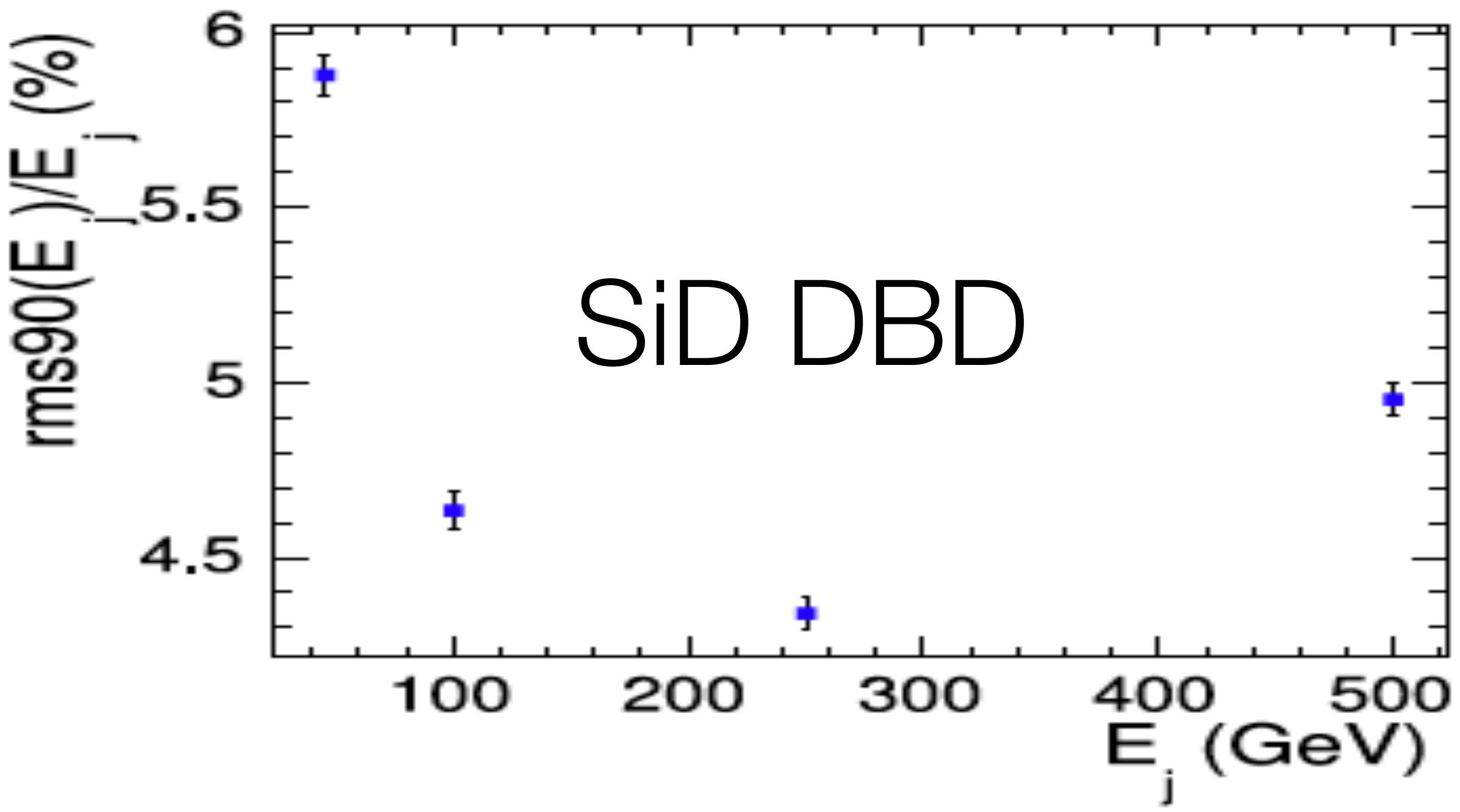
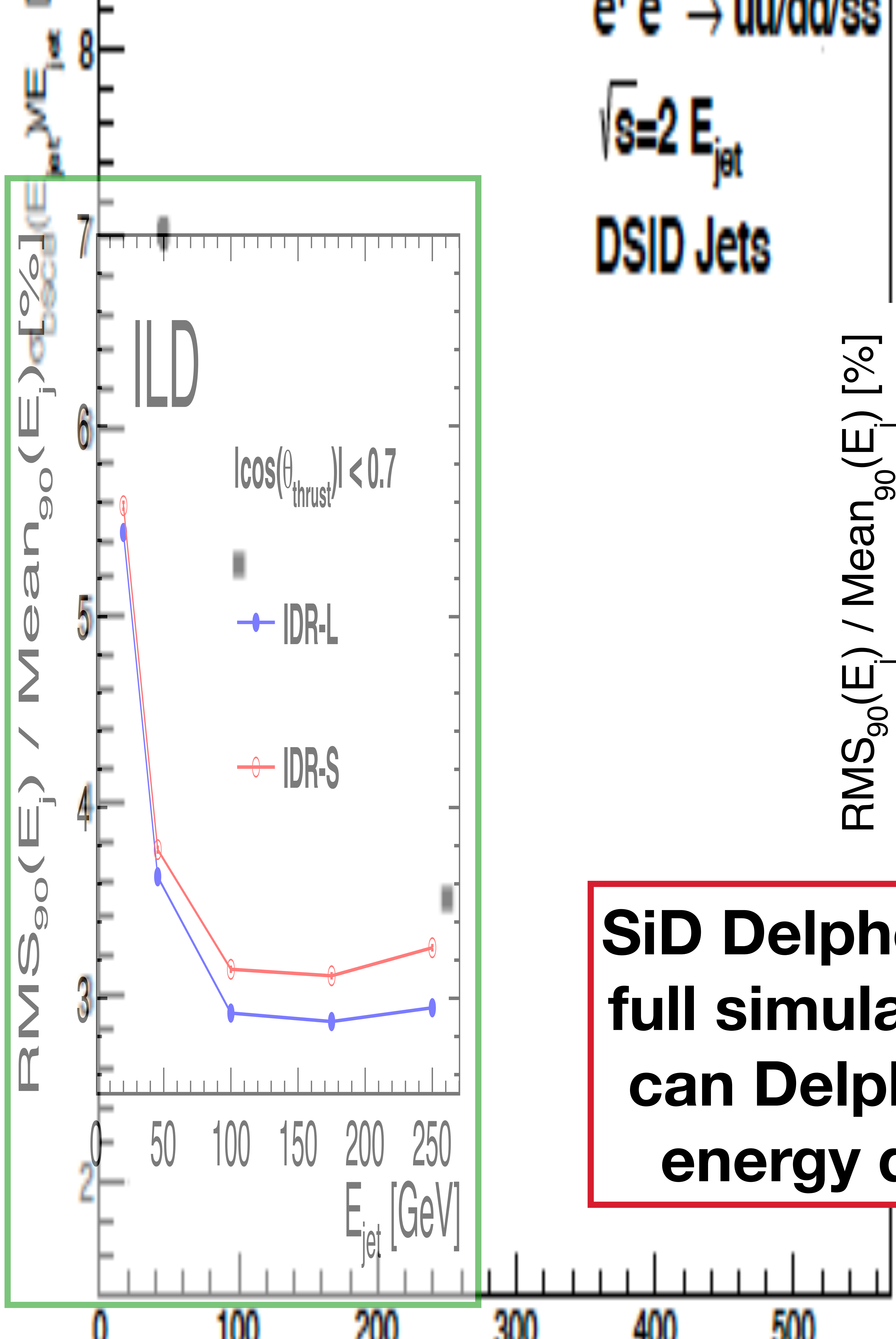
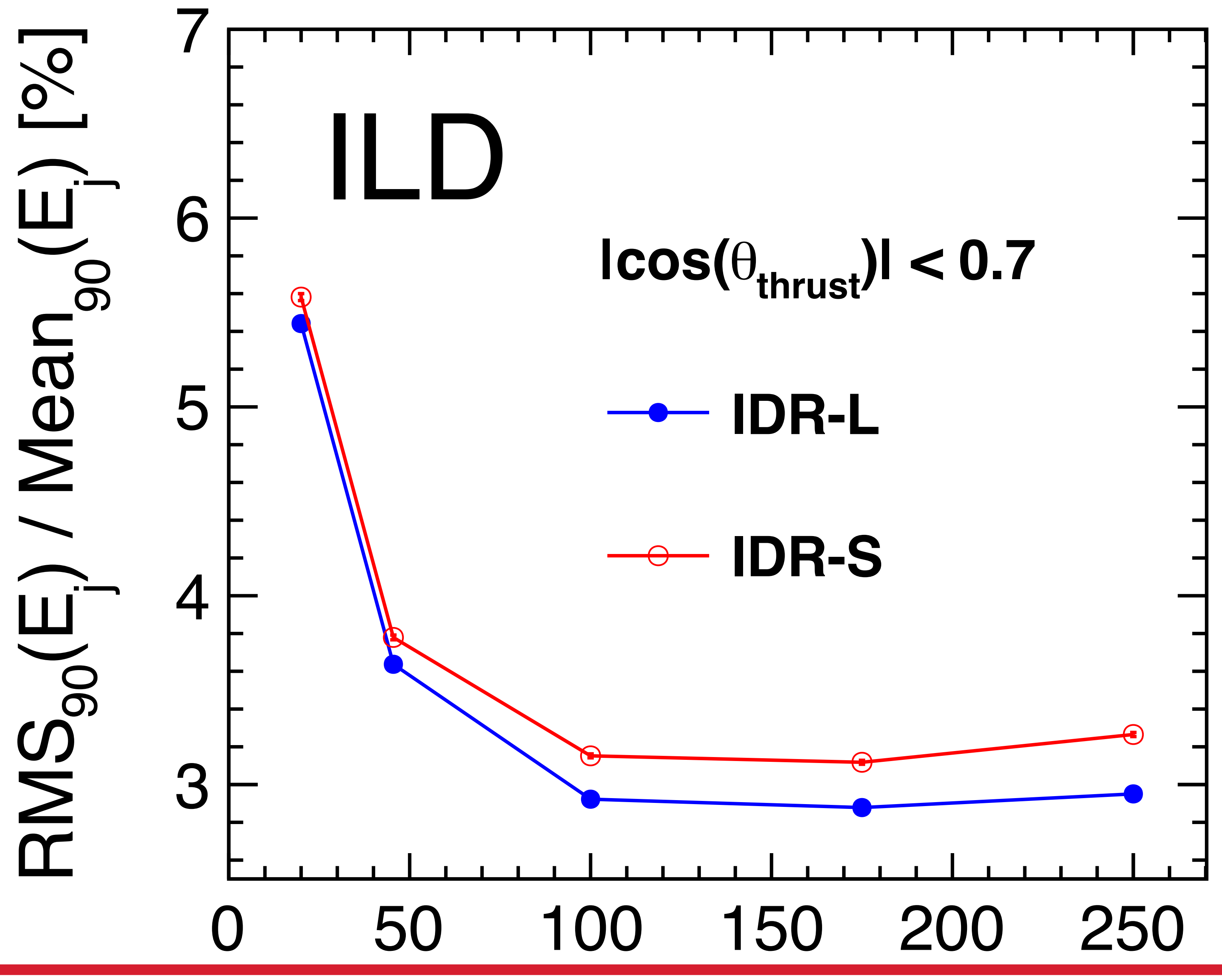
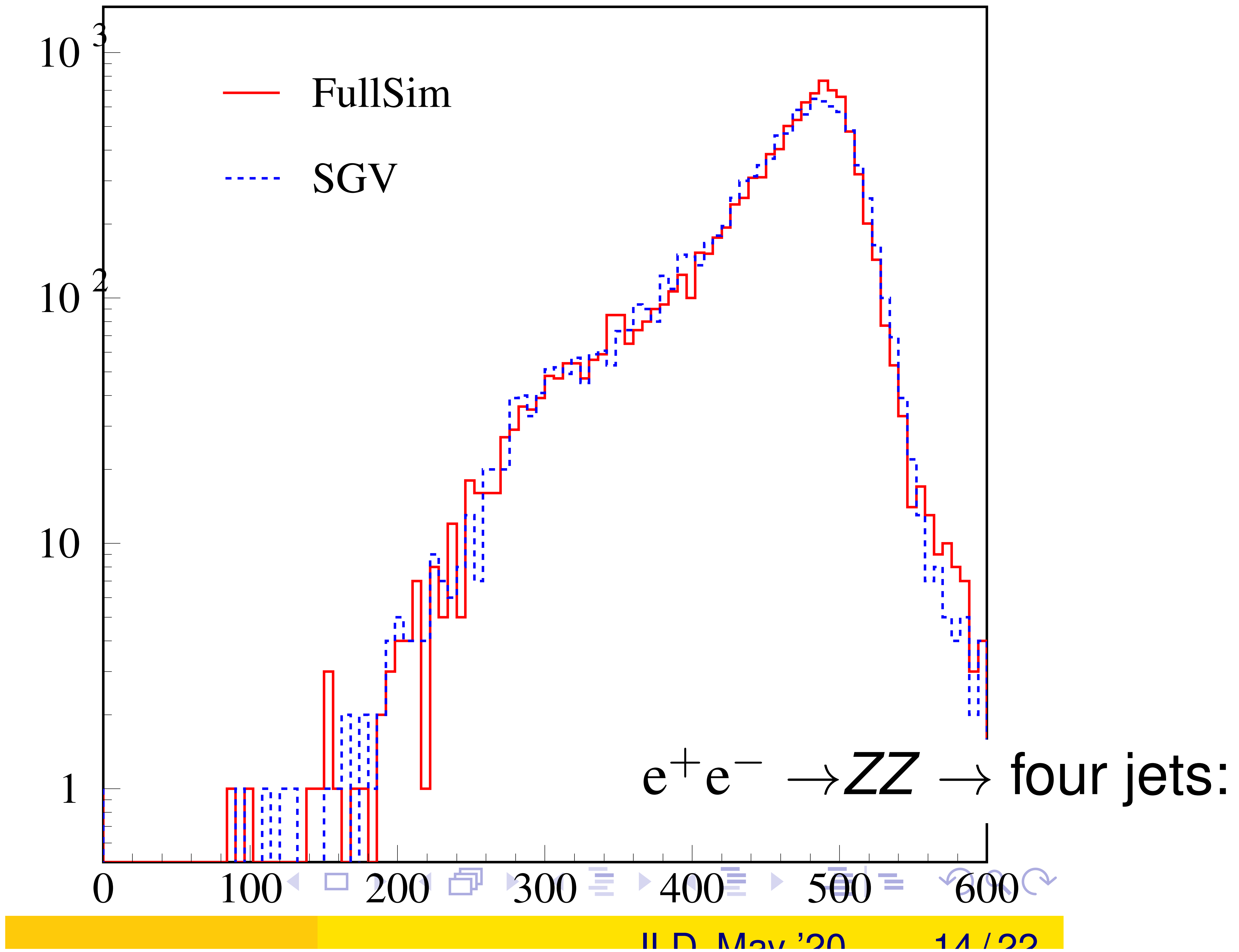


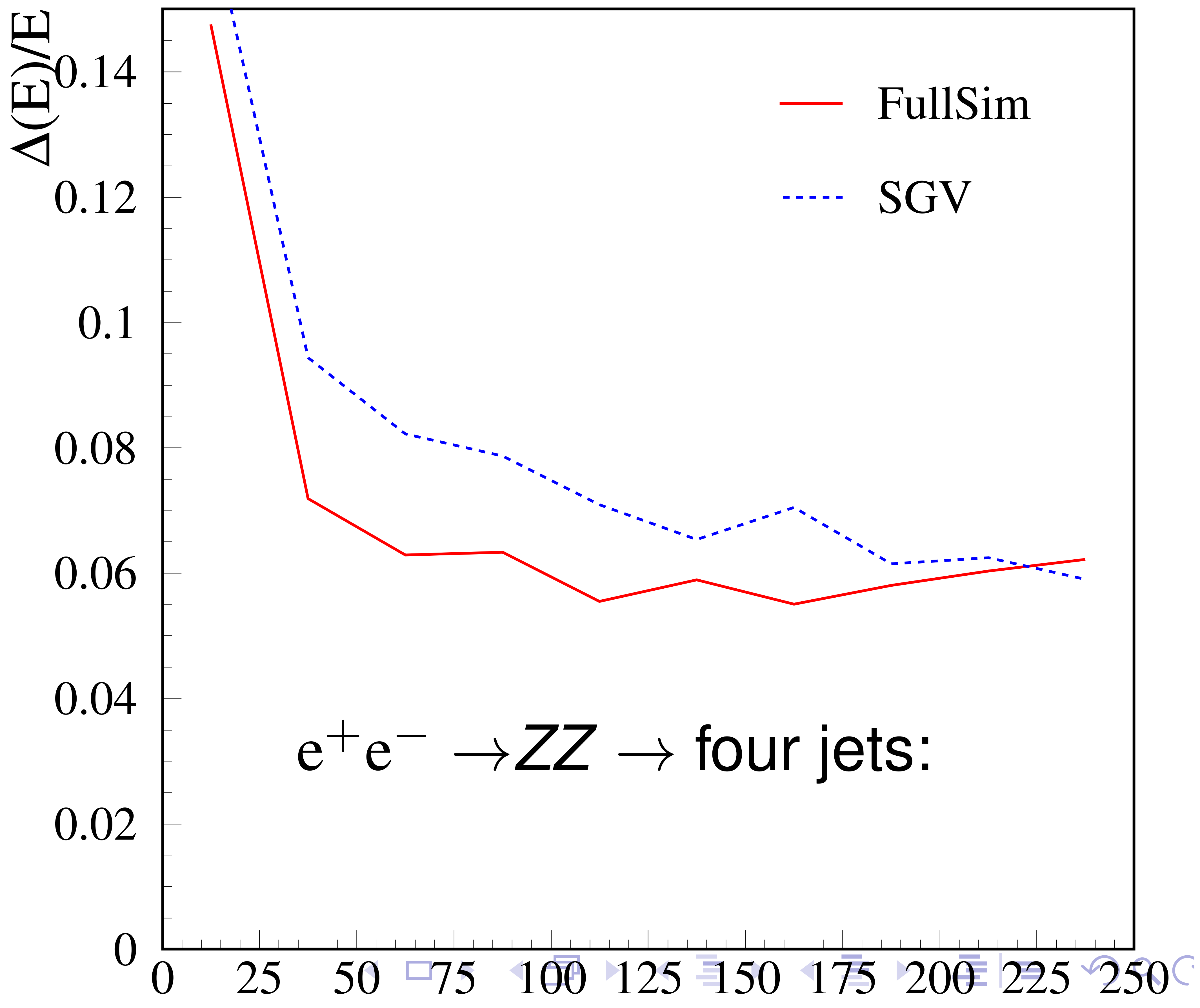




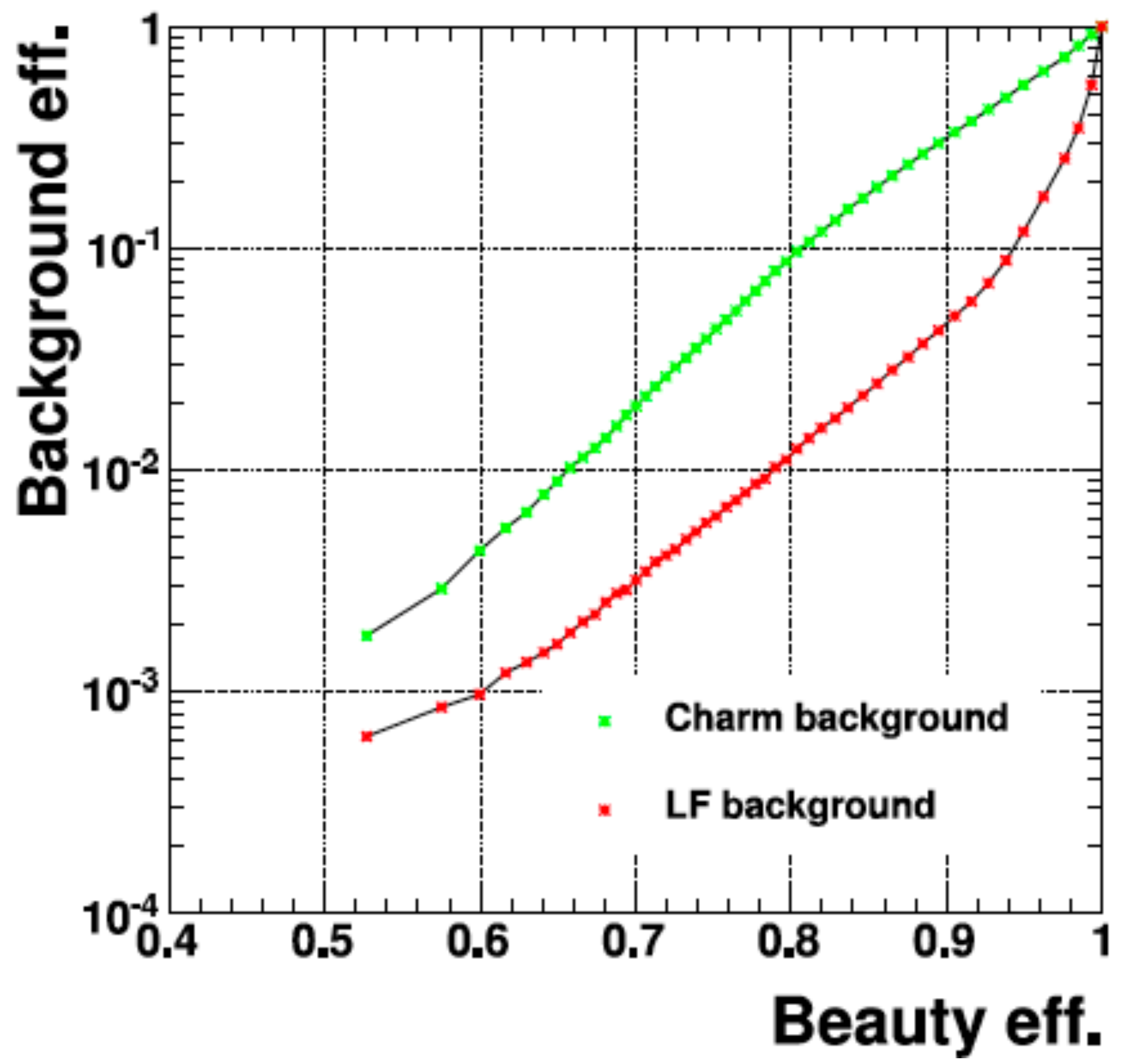
SiD Delphes ~2x worse than ILD full simulation for E_{jet} < 100 GeV can Delphes model PFlow-like energy dependence of JER?

SGV - Total Energy and JER



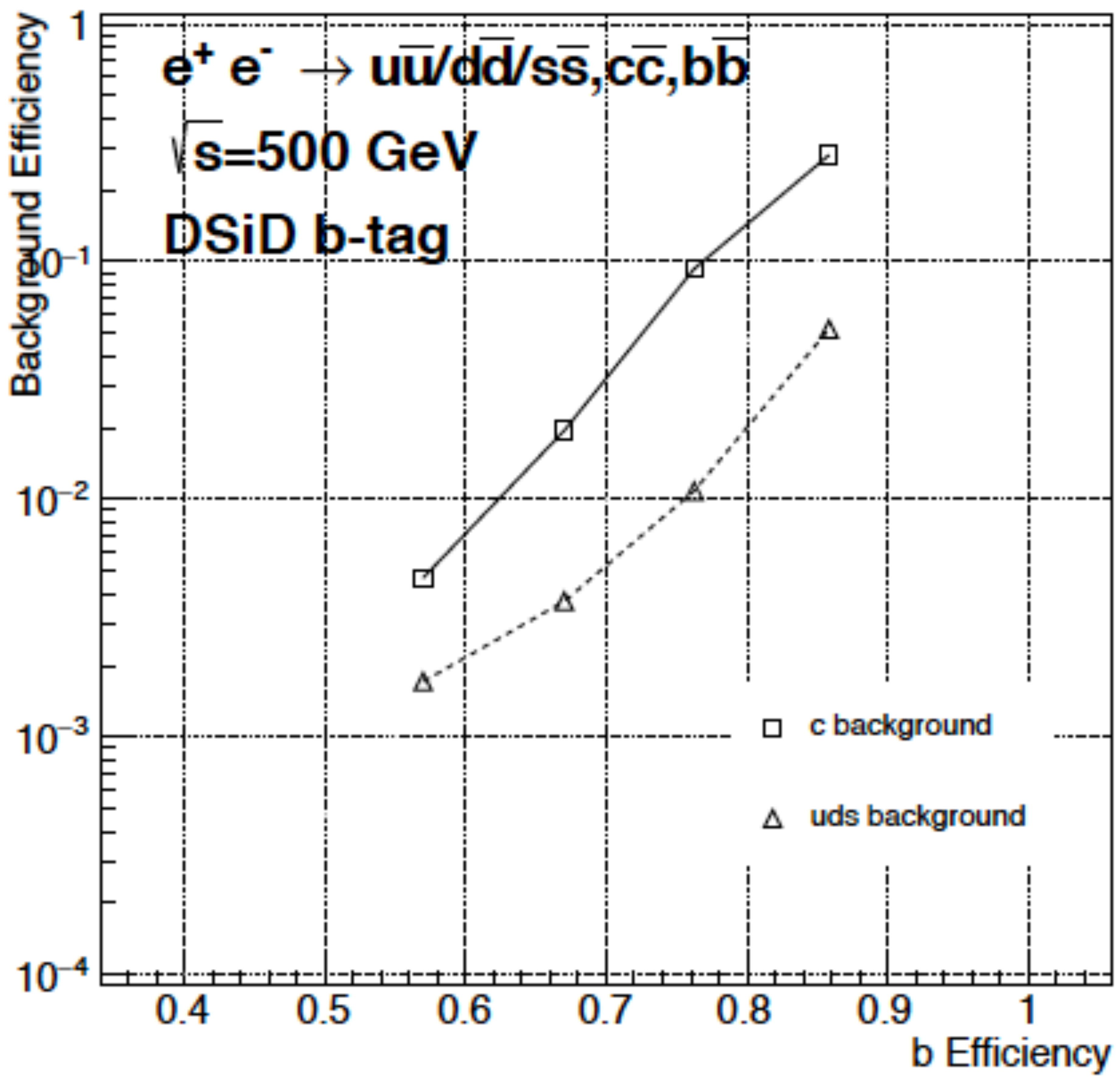


b-tag

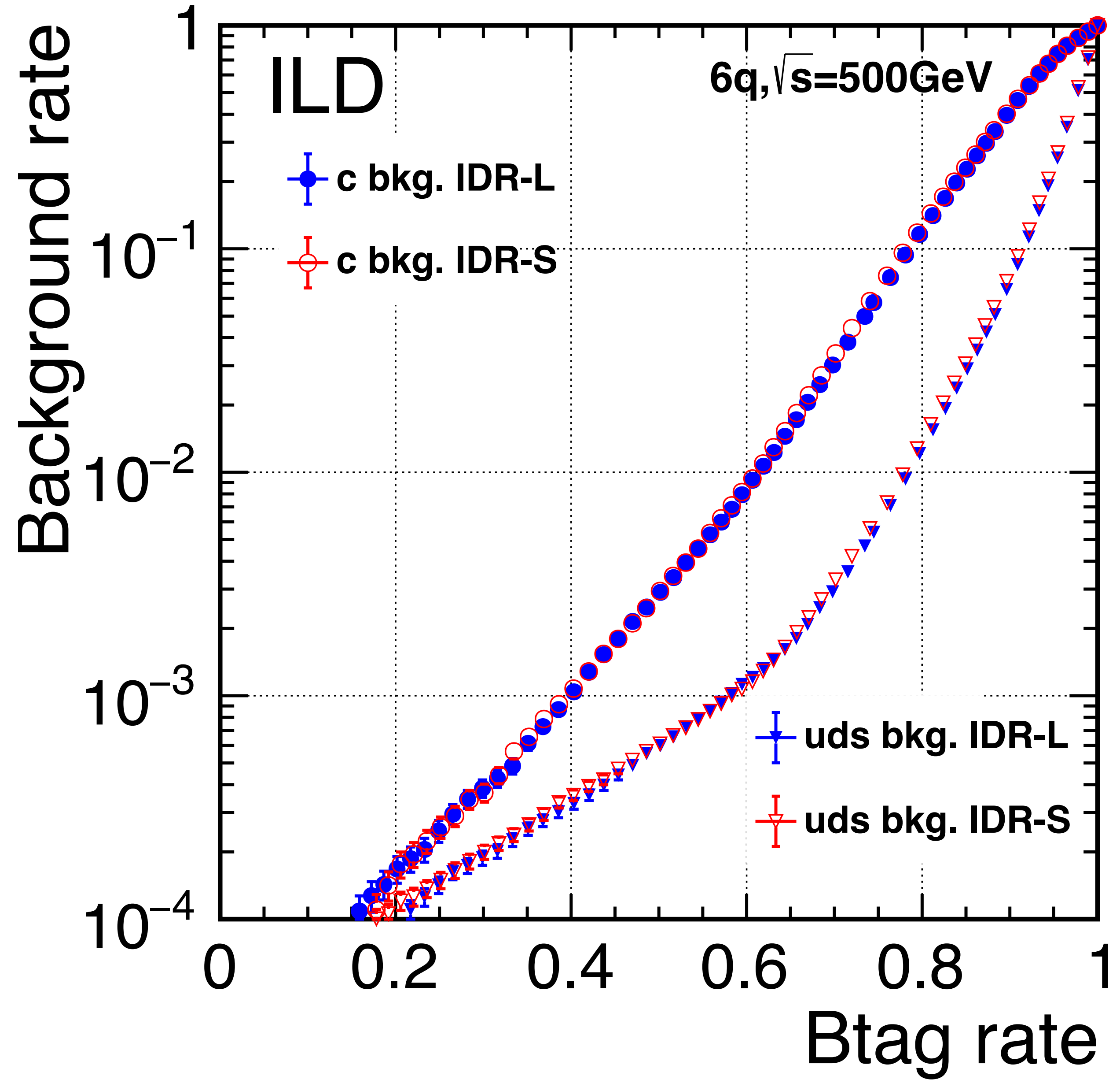


Background eff.
Charm background
LF background
Beauty eff.

SiD DBD

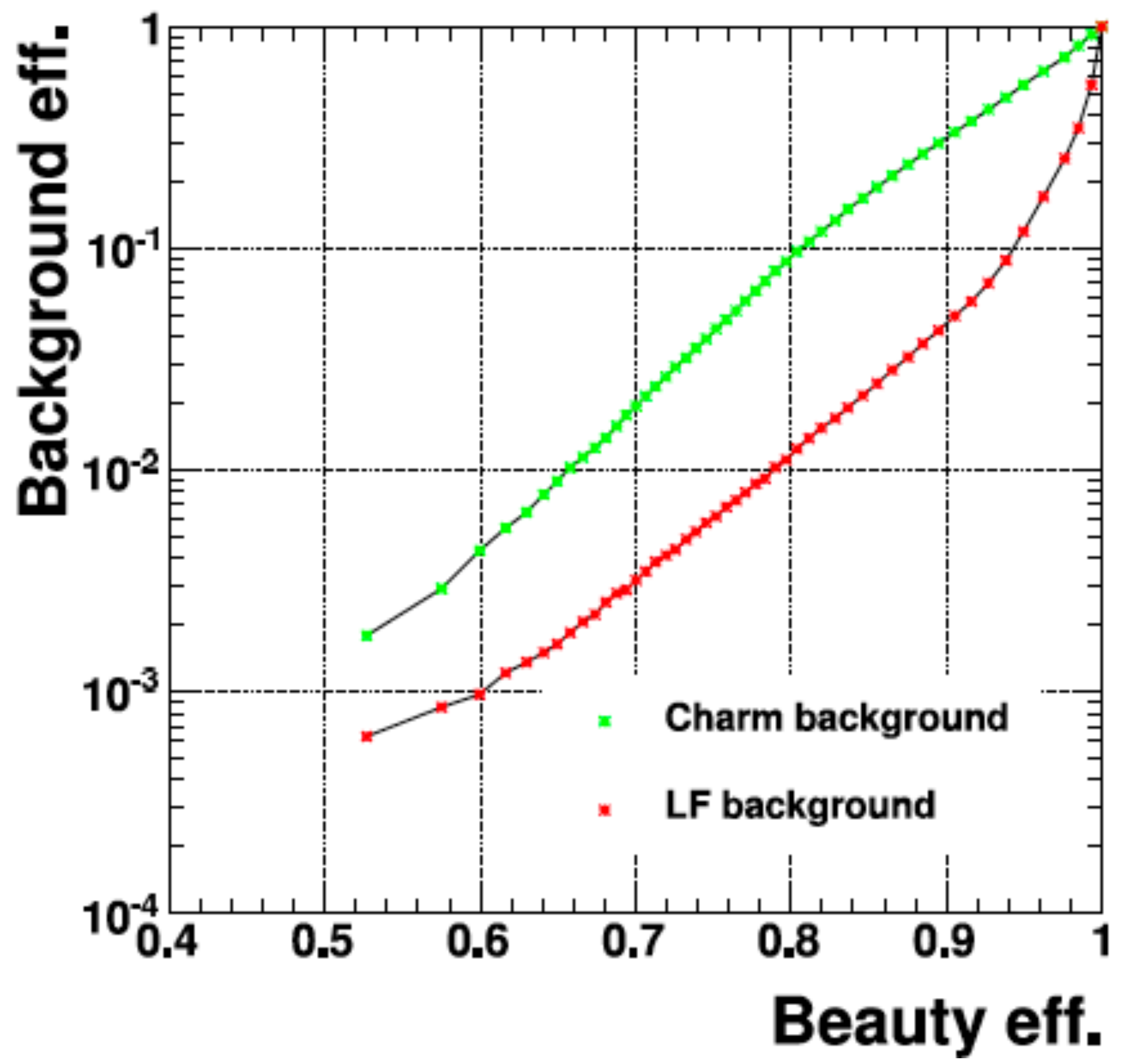


e+ e- → uū/dd̄/ss̄,cc̄,bb̄
√s=500 GeV
DSiD b-tag
Background Efficiency
c background
uds background
b Efficiency



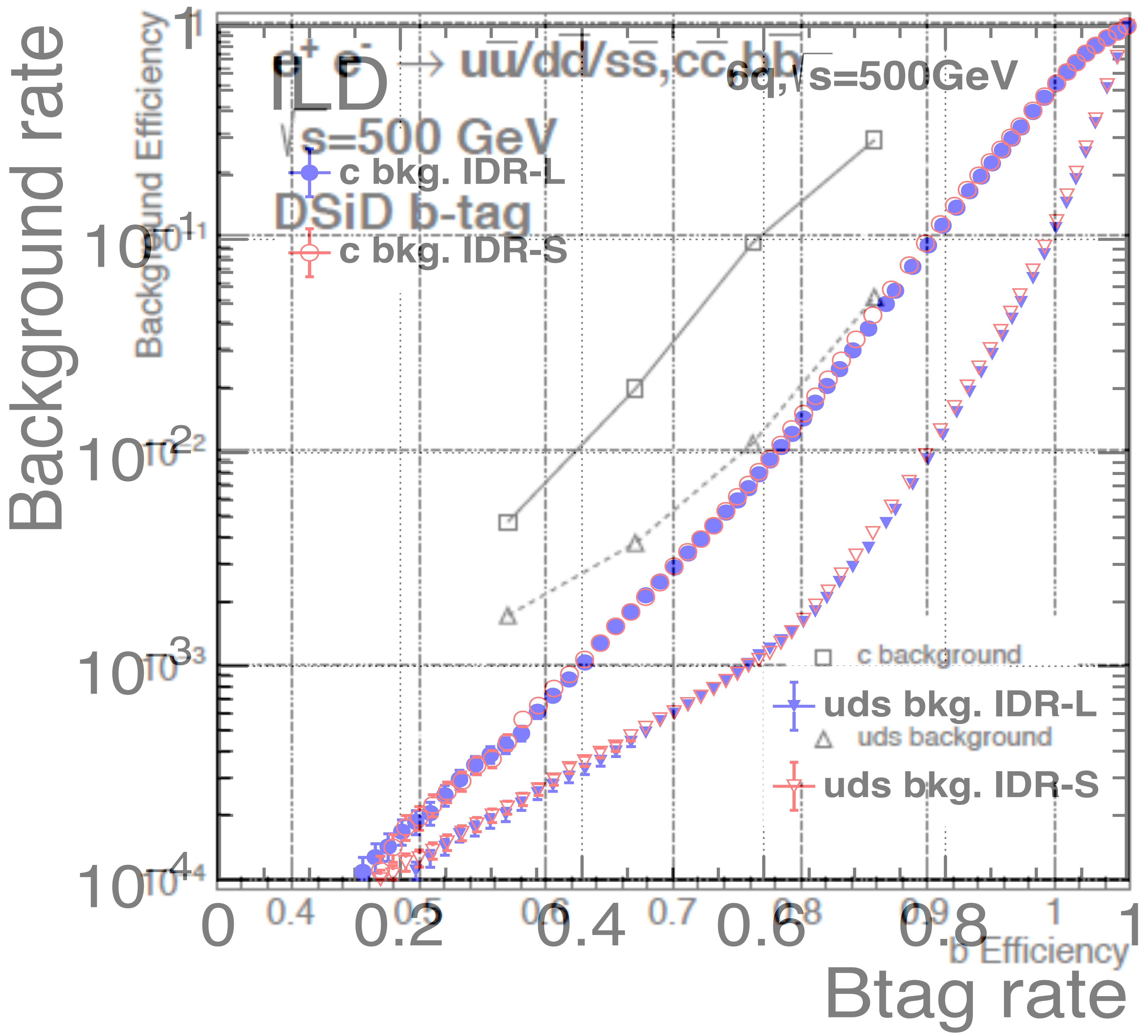
ILD
6q,√s=500GeV
c bkg. IDR-L
c bkg. IDR-S
uds bkg. IDR-L
uds bkg. IDR-S
Background rate
Btag rate

b-tag

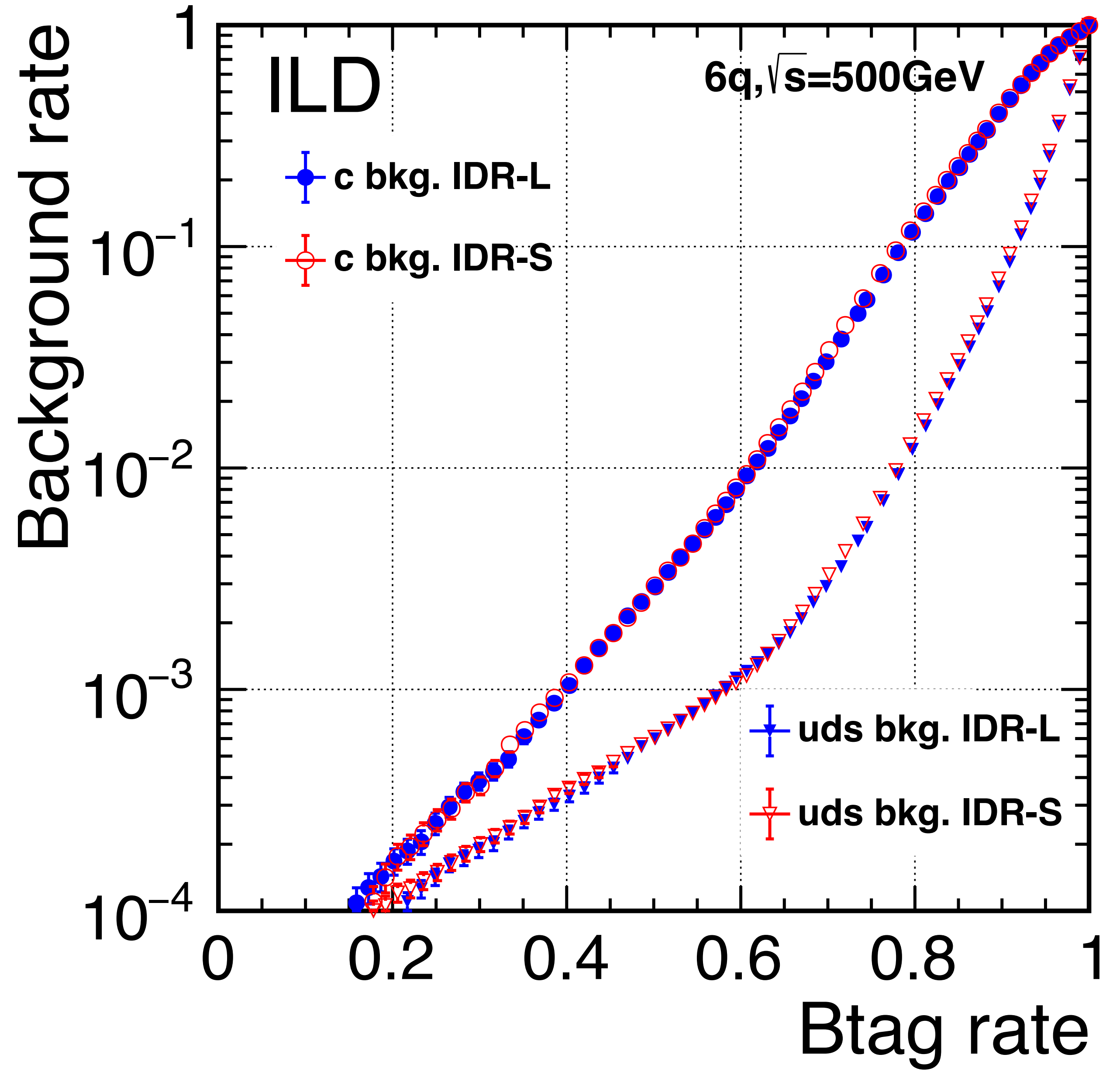


Background eff.
Beauty eff.
Charm background
LF background

SiD DBD

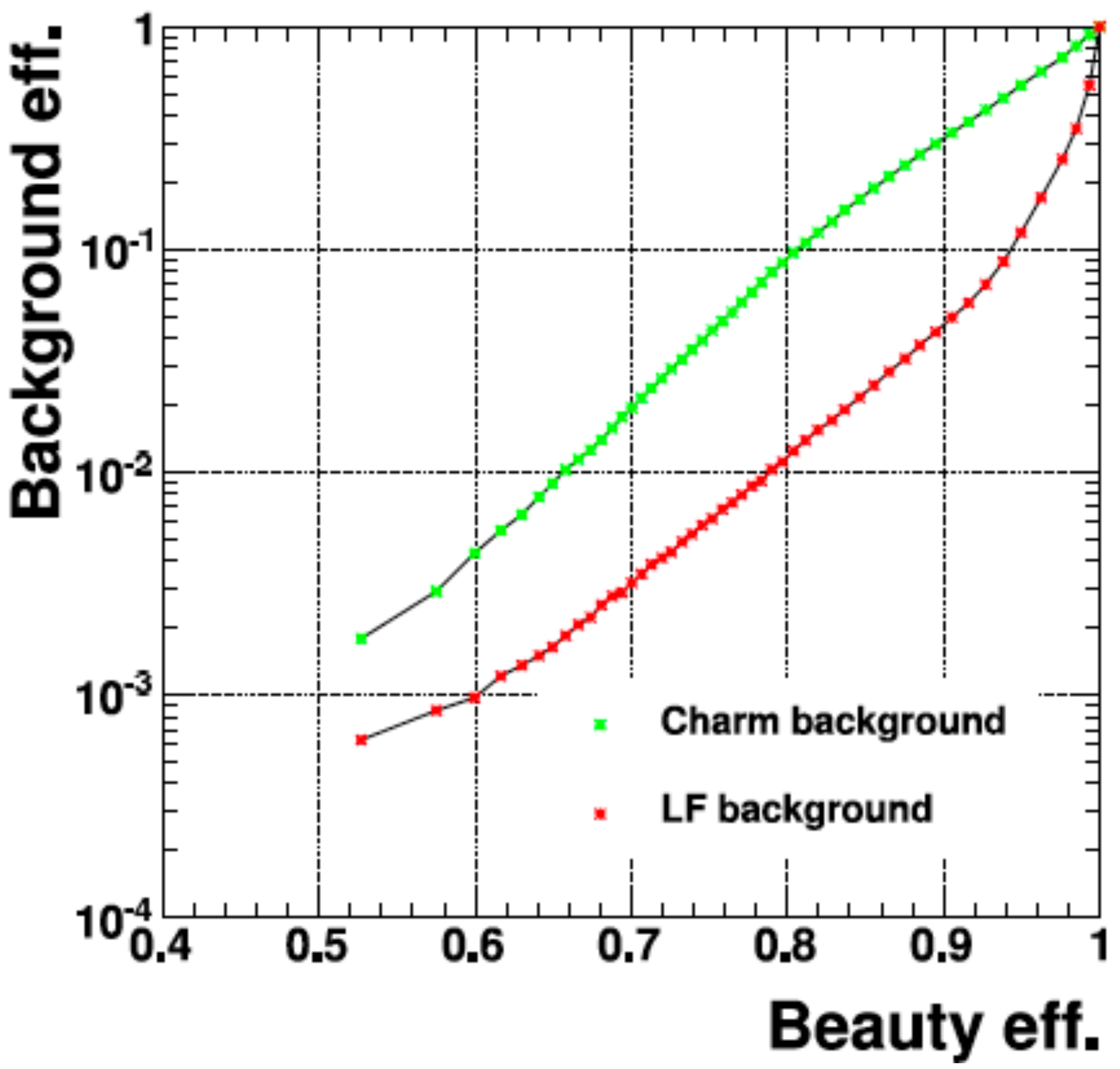


Background rate
Btag rate
c bkg. IDR-L
c bkg. IDR-S
uds bkg. IDR-L
uds bkg. IDR-S
c background
uds background
DSiD b-tag
b Efficiency

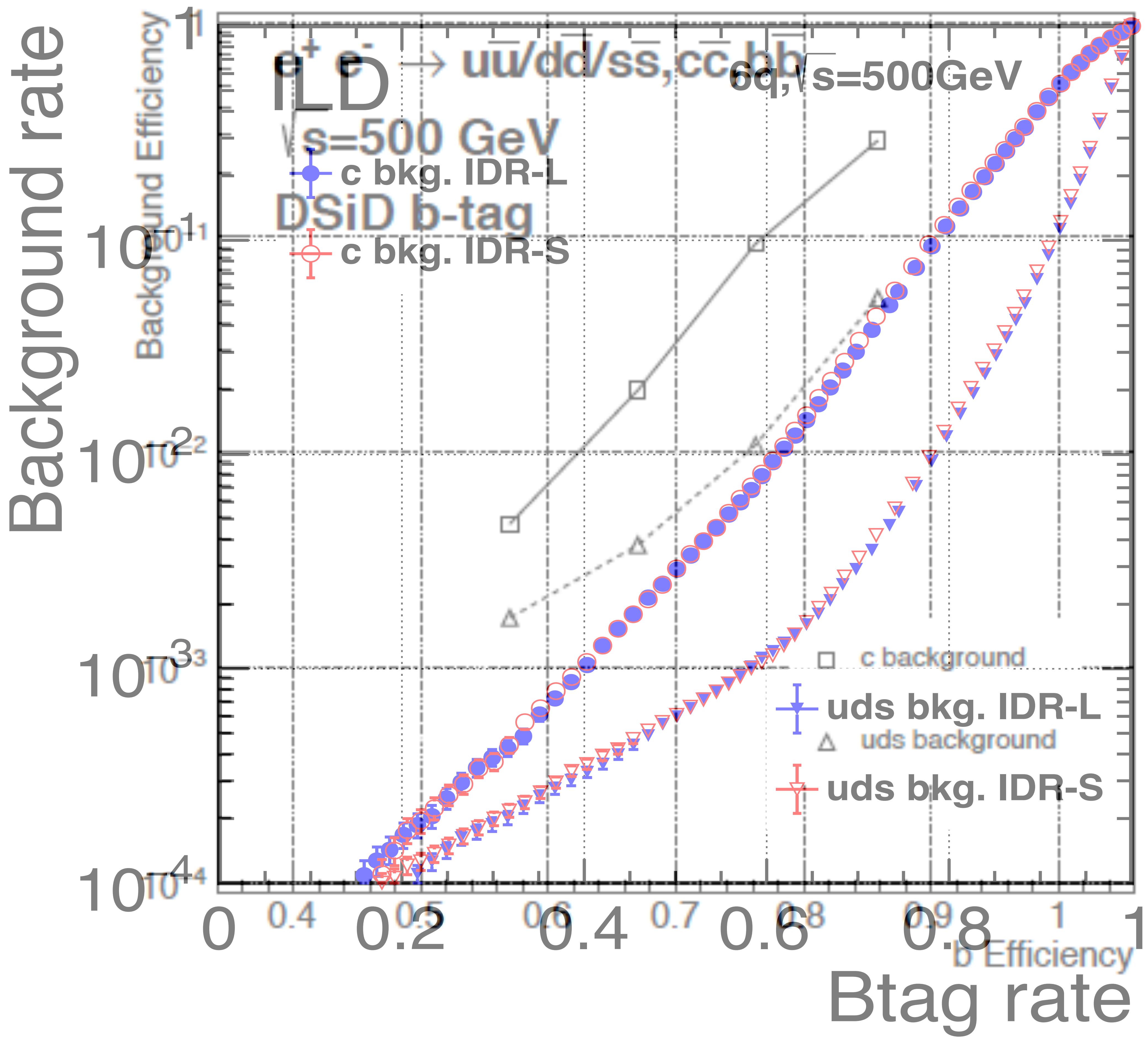


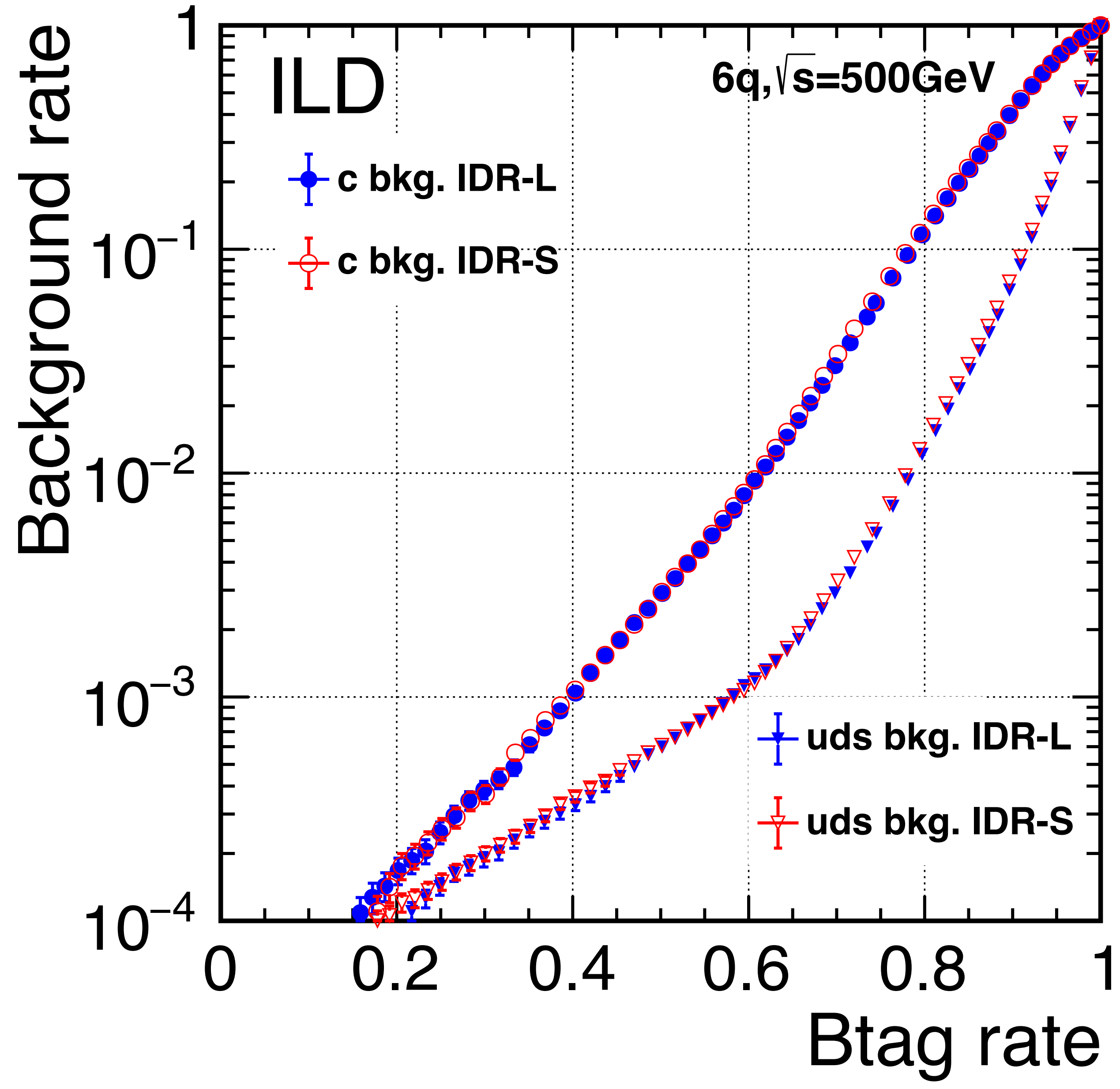
ILD
6q,√s=500GeV
c bkg. IDR-L
c bkg. IDR-S
uds bkg. IDR-L
uds bkg. IDR-S
Background rate
Btag rate

b-tag



SiD DBD





SiD Delphes ~10x worse than ILD full simulation

SGV - Flavour Tag. (!)

Zhh at 1 TeV: