

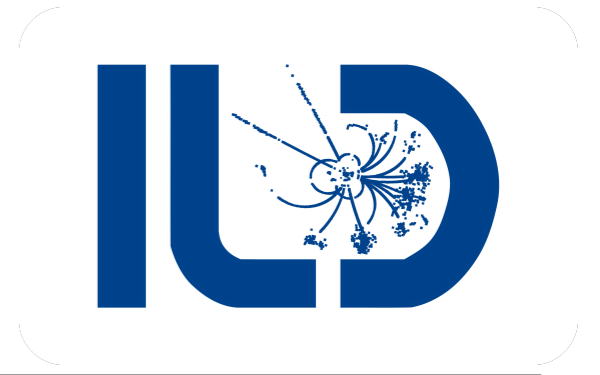
A 3D cutaway diagram of a particle detector, likely a calorimeter. The detector is shown in a perspective view, revealing its internal structure. The outer shell is light blue. Inside, there are several layers of yellow and green material, possibly absorbers or scintillators. A central cylindrical component, possibly a calorimeter core, is visible, with a series of purple, spiral-like structures around it. Two red arrows point to specific features on the central component.

# Status of ILD Benchmarking for IDR

J. List  
ILD General Meeting  
September 4, 2018

# Outline

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- Overview
- Status of the Benchmarks
- Next steps

# Overview

# Aims of the benchmarking exercise



- **quantify** the dependence of **physics performance** on various (high-level) detector performance aspects:
  - momentum resolution
  - jet energy resolution
  - flavour tag
  - particle ID
  - $V_0$ ,  $\pi^0$ , tau, charmed/beauty meson, ... reconstruction
- **quantify expected gain** from suspected improvements of the detector, e.g. ToF, new vertex geometry, ...
- **identify limiting factors** in detector design and/or reconstruction and quantify their impact
- compare large (3.5 T) vs small (4T) ILD
- write a chapter in the IDR
- get the “new” software to similar maturity as DBD as necessary preparation for a new 250 GeV physics MC production

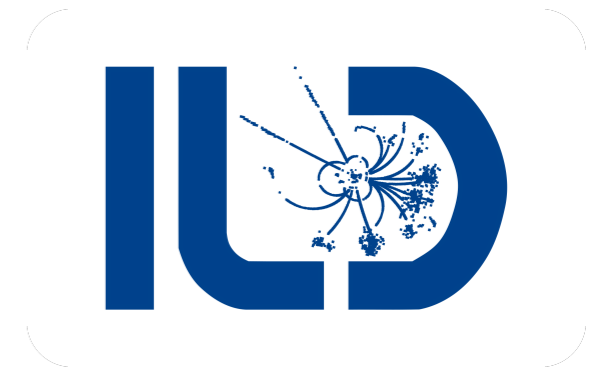


# Choice of Benchmarks

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- cover a broad range of important performance aspects
- focus on channels where dependence on detector is expected to dominate over limitations of (current) reconstruction
- 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
  - ...

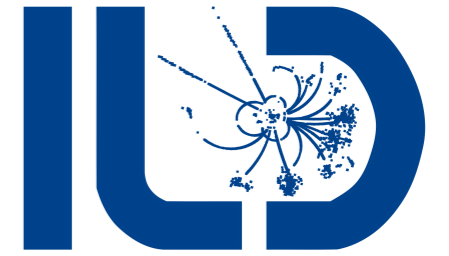
# Strategy (well, at least the plan...)



- **2-3 analysers per benchmark**, which provide
  - an overview confluence page (visible to all of ILD), linked from:  
<https://confluence.desy.de/display/ILD/Benchmarks+for+physics-driven+detector+optimisation>
  - code, scripts, macros, README on github:  
<https://github.com/ILDAnaSoft>
  - regular presentations in ILD software/analysis meetings
  - eventually an public ILD note or paper
- **1-2 reviewers**
  - follow the development of the analysis (not much time for an a posteriori review!)
  - will review the note / paper
- **Physics WG conveners (Higgs/EW, top/flavour, BSM) & Physics Coordinators:**
  - guide and monitor analyses, ensure communication
  - exchange information in weekly conveners meeting

# Status of Benchmarks - Higgs/EW

# Higgs mass from $H \rightarrow bb$ - overview



main physics observable(s):

**$M(bb)$  @ 500 GeV**

intermediate observable(s):

$M(bb)$  spectrum with and without constrained fit

performance aspect(s):

- **b-tag**
- **lepton ID**
- **JER and JES for b jets**

status summary:

- work on new samples has started

analyser(s):

Ali Ebrahimi (U Hamburg)  
Junping Tian (U Tokyo)

reviewer(s):

Frank Simon (MPI Munich)

last presentation:

July 11



# BR(H-> $\mu\mu$ ) - overview



main physics observable(s):

**BR(H-> $\mu\mu$ ) from nunuH @ 500 GeV**

analyser(s):

Shin-ichi Kawada

intermediate observable(s):

**M( $\mu\mu$ )**

reviewer(s):

Ivanka Bozovic,  
Filip Zarnecki

performance aspect(s):

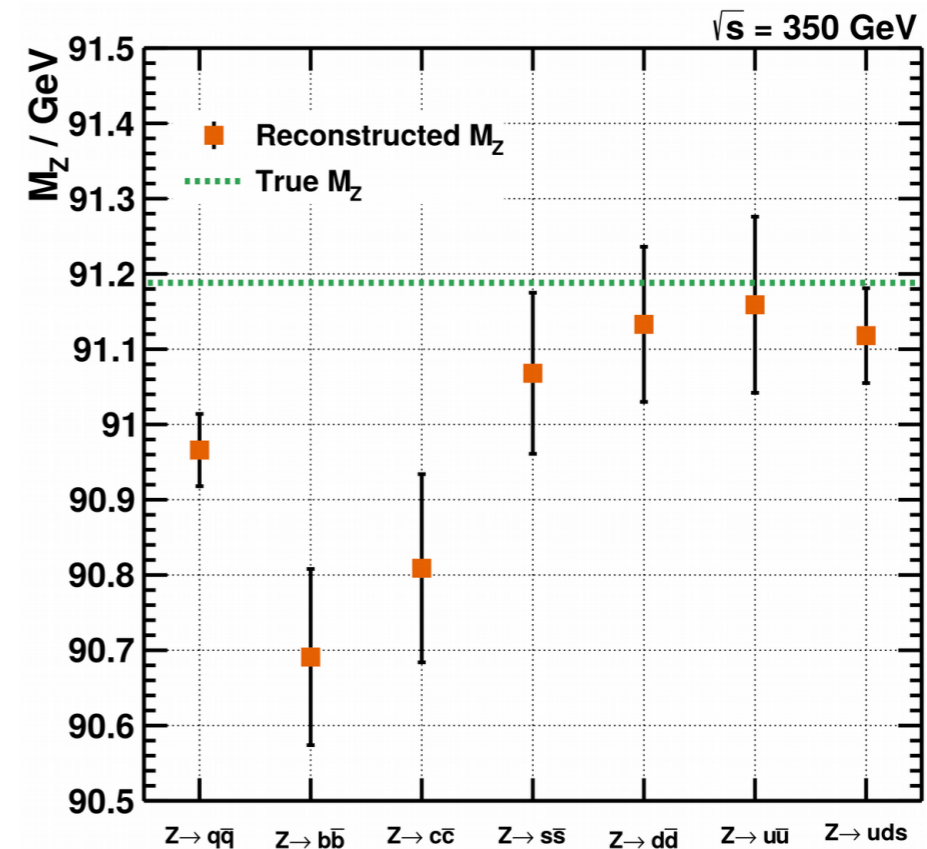
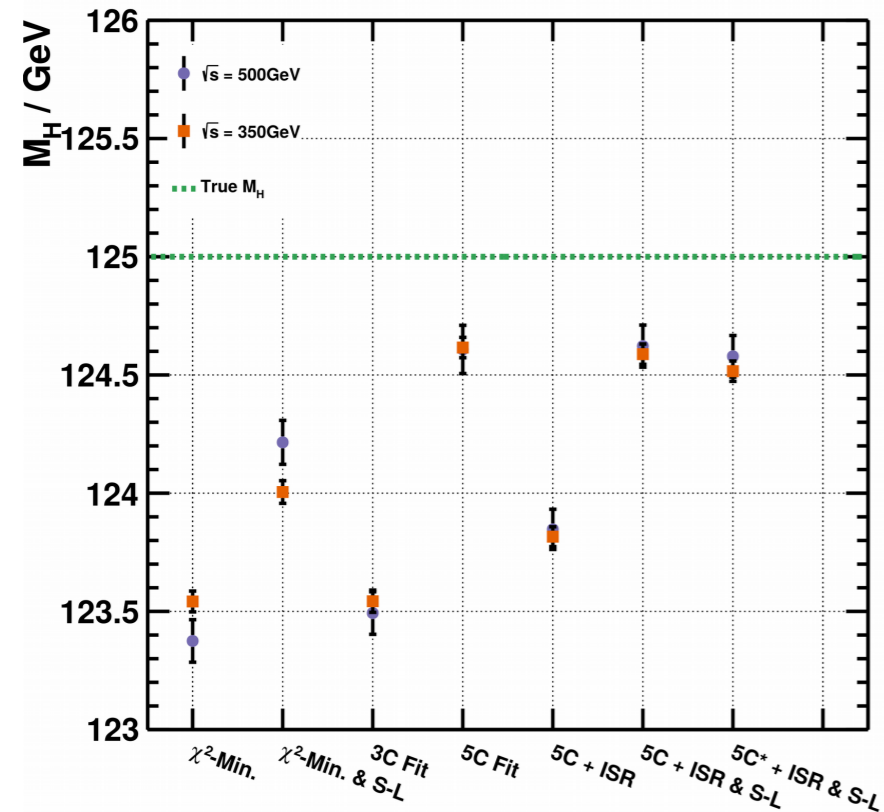
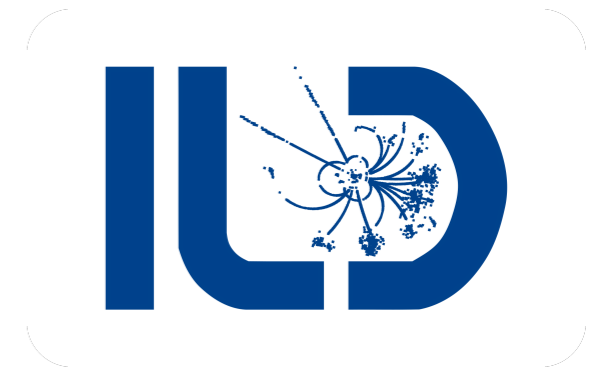
- high momentum **pt resolution**
- **muon ID** efficiency/purity

last presentation:  
Aug 22

status summary:

- DBD analysis completed
- advanced paper draft (DBD)
- analysis of new samples started

# M(H->bb) - results



DBD analysis of  $1 \text{ ab}^{-1}$  at CoM energies of 350 and 500 GeV

- Full simulation
- Jet-specific energy resolution
- Mass reconstruction with/out kinematic fitting
- Statistical uncertainty comparable with the recoil technique

## IDR analysis

- Study effect of heavy quarks
- Investigate other sources of systematic uncertainties
- Intermediate observables: JER, Jet direction resolution, lepton momentum resolution
- Work in progress

# H- $\rightarrow\mu\mu$ - results

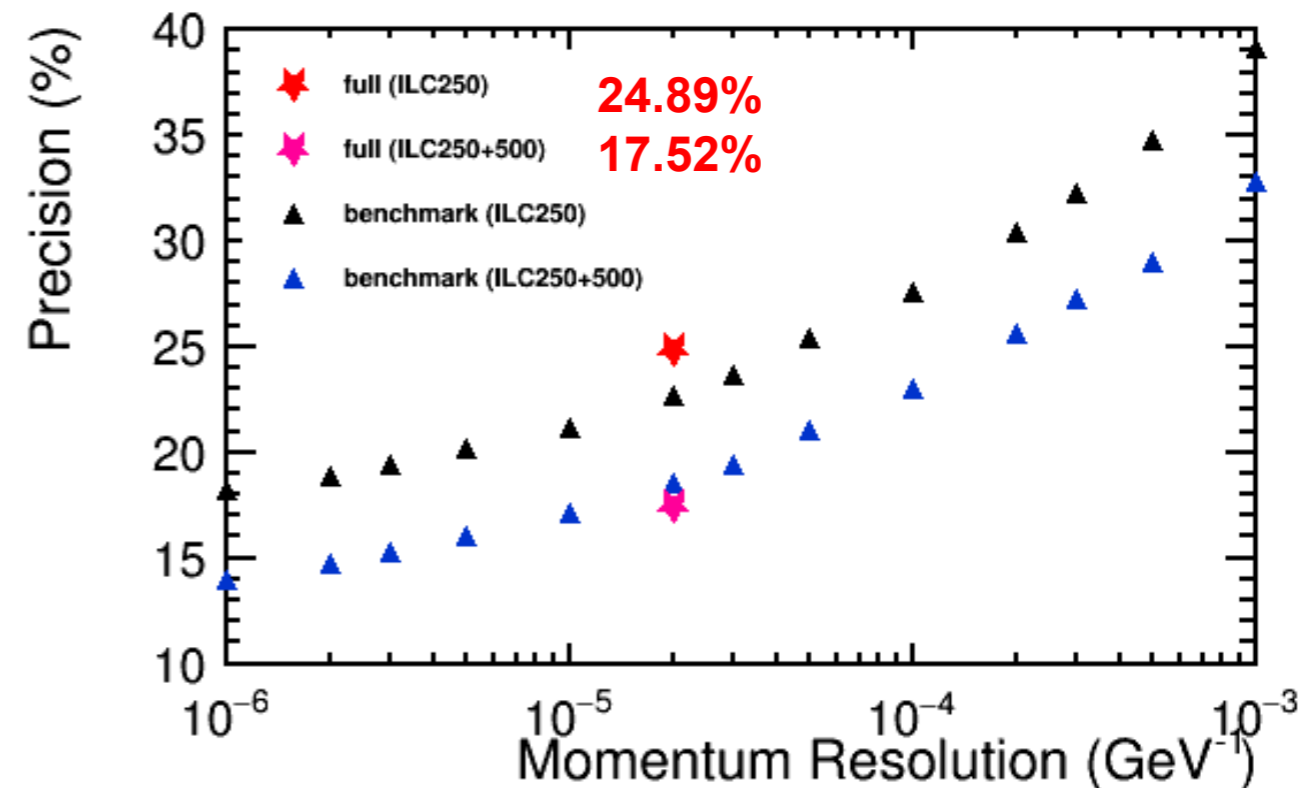


DBD analysis for  $\nu\nu H + qqH$ ,  $2 \text{ ab}^{-1}$  250 GeV +  $4 \text{ ab}^{-1}$  500 GeV, canonical pol. sharing

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

IDR analysis for  $\nu\nu$   $4 \text{ ab}^{-1}$  500 GeV, canonical pol. sharing

- perfect momentum resolution ( $2 \cdot 10^{-6}$ ): x%
- perfect muon ID: y%
- “theoretical limit” (100% eff, 0 bkg): z%



IDR full sim:

- muon ID suffers from various features (missing TPC hits, too hard track cuts in Pandora, ...) => few percent worse
- work in progress...



# H->invisible — overview

main physics observable(s):

**95% CL upper limit on BR(H->invisible) from qqH @ 500 GeV**

analyser(s):

Yu Kato

intermediate observable(s):

**M(jj), Recoil Mass**

reviewer(s):

Marcel Vos

performance aspect(s):

- jet energy resolution
- recoil mass resolution

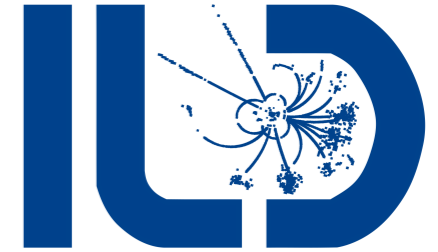
last presentation:

Sep 5, 2018 (plan)

status summary:

- DBD analysis @ 250 GeV completed
- analysis of new samples started
- JER evaluation of new samples completed

# H->invisible - results



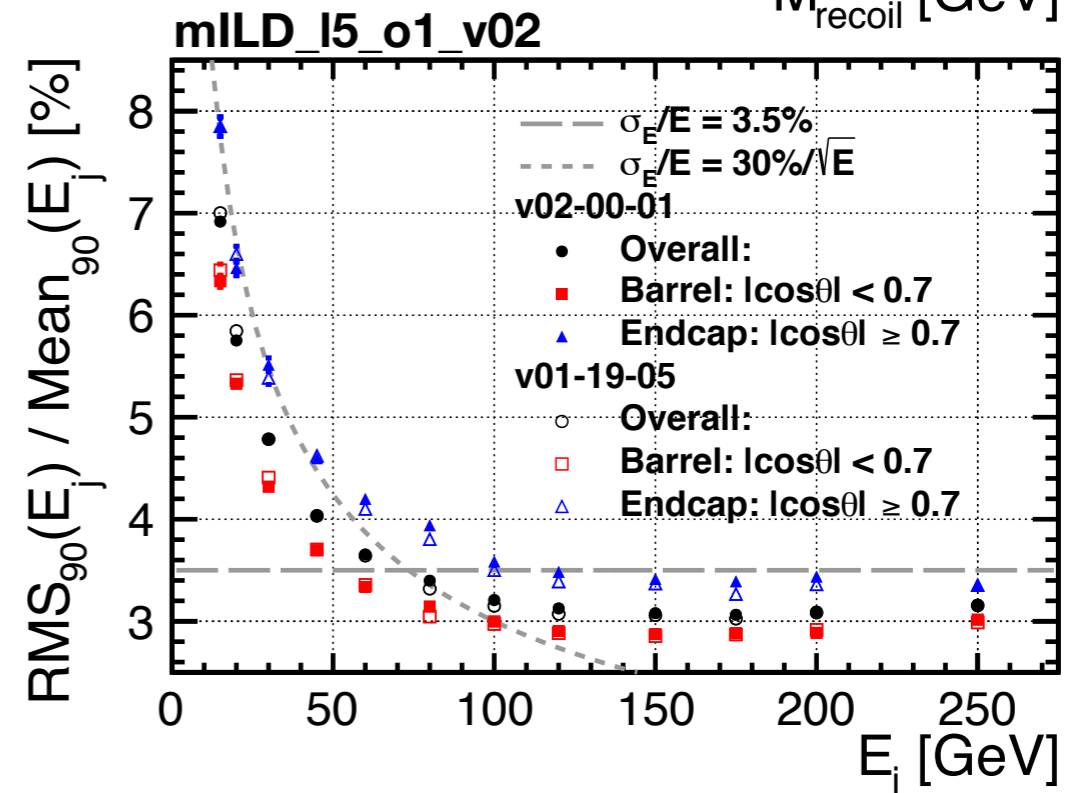
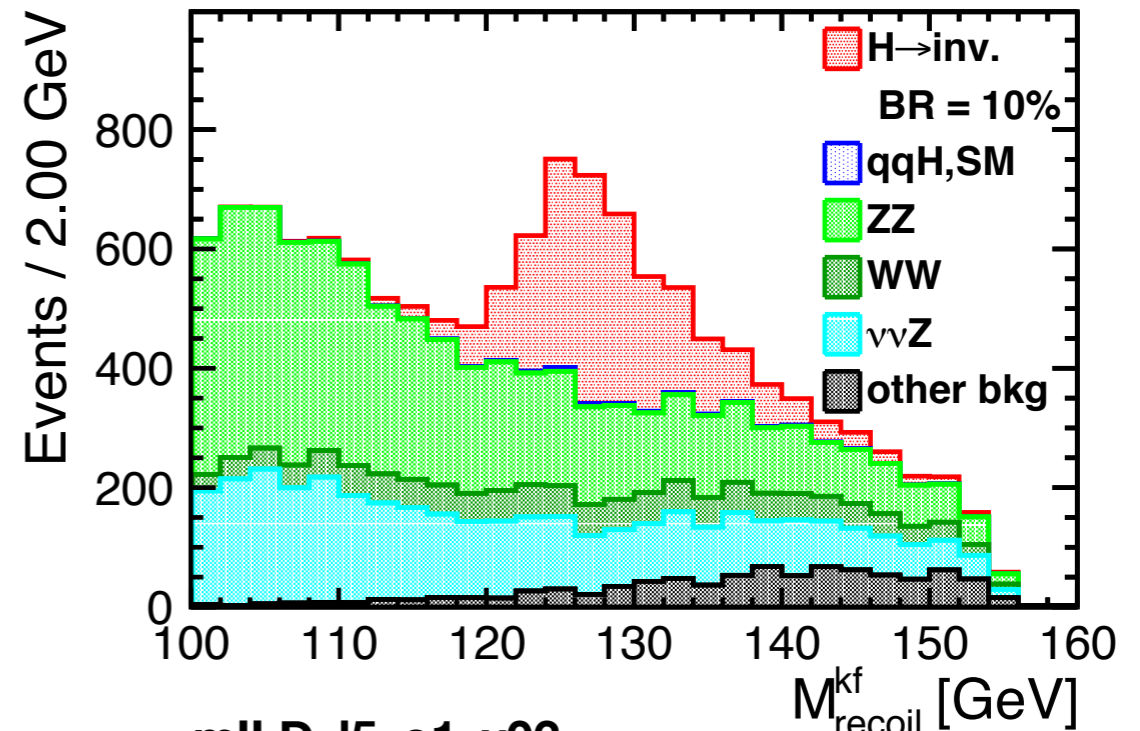
DBD analysis for qqH, 2 ab<sup>-1</sup> 250 GeV, canonical pol. sharing

- left pol.: 0.44% (900 fb<sup>-1</sup>)
- right pol.: 0.31% (900 fb<sup>-1</sup>)
- using kinematic fit with JER

IDR analysis for qqH 4ab<sup>-1</sup> 500 GeV, canonical pol. sharing

- evaluate JER with new samples
- left pol.: x% (1800 fb<sup>-1</sup>)
- right pol.: y% (1800 fb<sup>-1</sup>)
- work in progress...

$\sqrt{s} = 250 \text{ GeV}$ ,  $(P_{e^-}, P_{e^+}) = (+0.8, -0.3)$ ,  $\int L dt = 250 \text{ fb}^{-1}$ , Cut: No.1~No.9 **w/ kinematic fit**





# $ee \rightarrow \tau\tau$ - Overview

main physics observable(s):

**A\_FB, A\_LR, tau pol @ 500 GeV**

intermediate observable(s):

- **$\tau$  decay mode identification matrix**
- **$\tau$  momentum reconstruction**

performance aspect(s):

- **$\tau$  reconstruction eff / pur**
- **$\pi^0$  reconstruction, energy resolution**

status summary:

- MC level studies to estimate above
- now working on full reco
- for polarisation, concentrating on  $\tau^+ \rightarrow \pi^+ \nu$  and  $\tau^+ \rightarrow \pi^+ \pi^0 \nu$  decay channels [large BR, strong sensitivity to polarisation]

analyser(s):

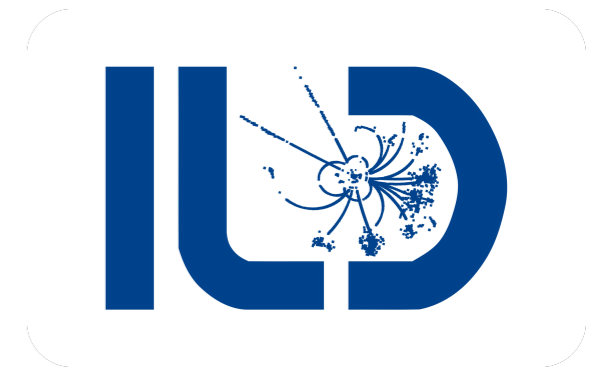
Keita Yumino (KEK)  
Daniel Jeans (KEK)

reviewer(s):

Mikael Berggren  
(DESY)

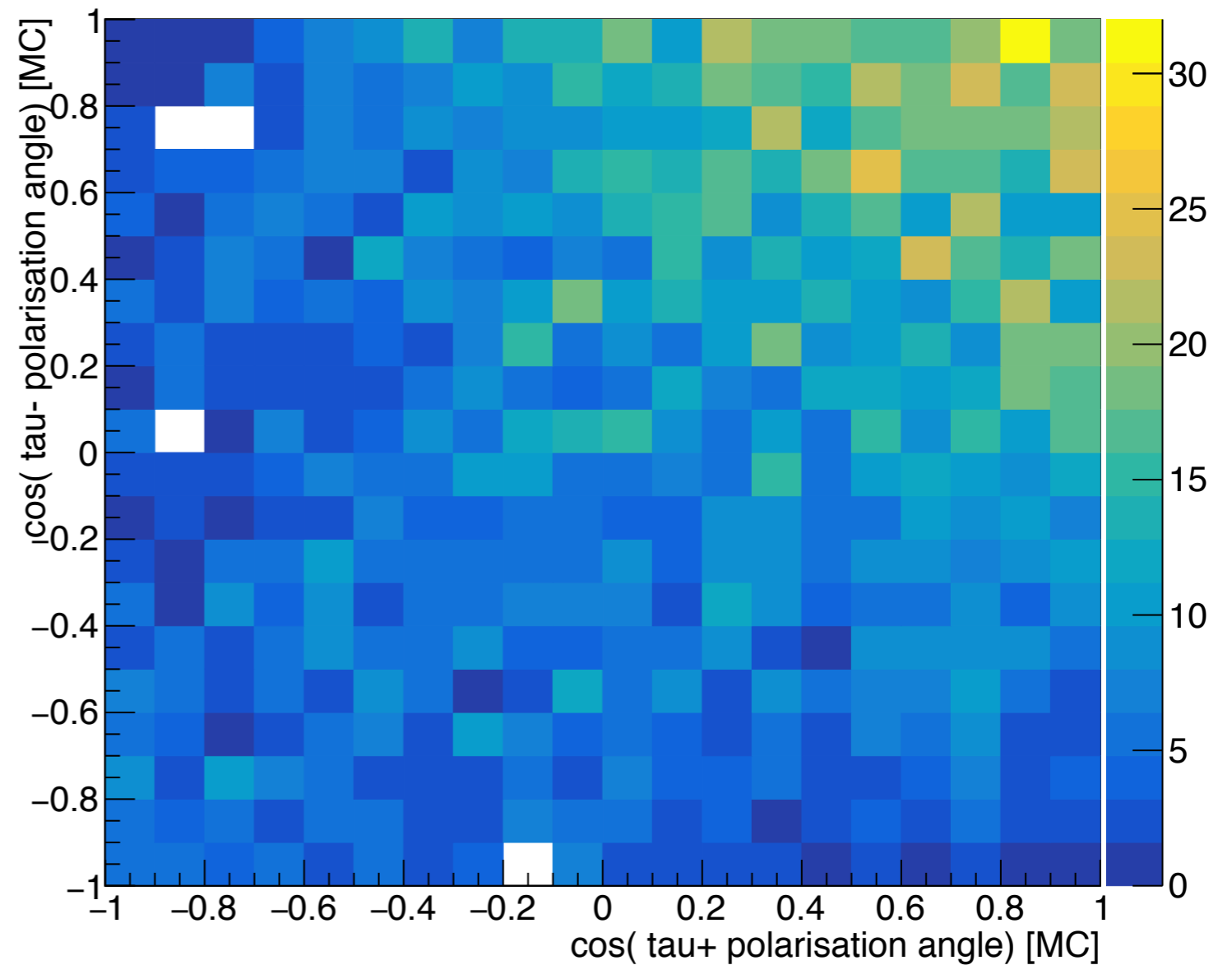
last presentation:  
Sept 5 (tomorrow)

# $ee \rightarrow \tau\tau$ - results



proof of principle  
plot:  
 $\tau^-$  vs  $\tau^+$  polarisation  
angle  
for  $\tau \rightarrow \pi \pi^0 \nu$   
decay  
 $\Rightarrow$  on a good way...

$ee \rightarrow \tau\tau$ , high inv. mass, ( $\rho, \rho$ )  $\tau$  decays





# WW $\rightarrow$ qq $\nu$ — overview

main physics observable(s):

**$M_W$ ,  $aTGCs$ , polarisation @ 500 GeV**

intermediate observable(s):

**W production and decay angles**

performance aspect(s):

- **JES / JER**
- **lepton ID and resolutions**

status summary:

- Justin working on constrained fit incl. vertex information
- Elisabetta getting started
- Mila working, status ?

analyser(s):

Mila Pandurovic (Belgrade)  
Justin Anguiano (Kansas)  
Elisabetta Gallo (DESY)

reviewer(s):

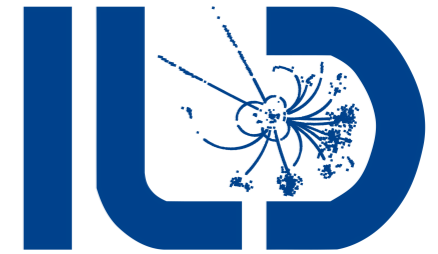
Klaus Desch (Bonn)

last presentation:

none yet, possibly Sep 5?



# Quartic Gauge Couplings - overview



main physics observable(s):  
**limits on aQGC @ 500 GeV**

analyser(s):  
Jakob Beyer (Dresden)

intermediate observable(s):  
**Mjj vs Mjj from nunuqqqq**

reviewer(s):  
Taikan Suehara  
(Kyushu)

performance aspect(s):

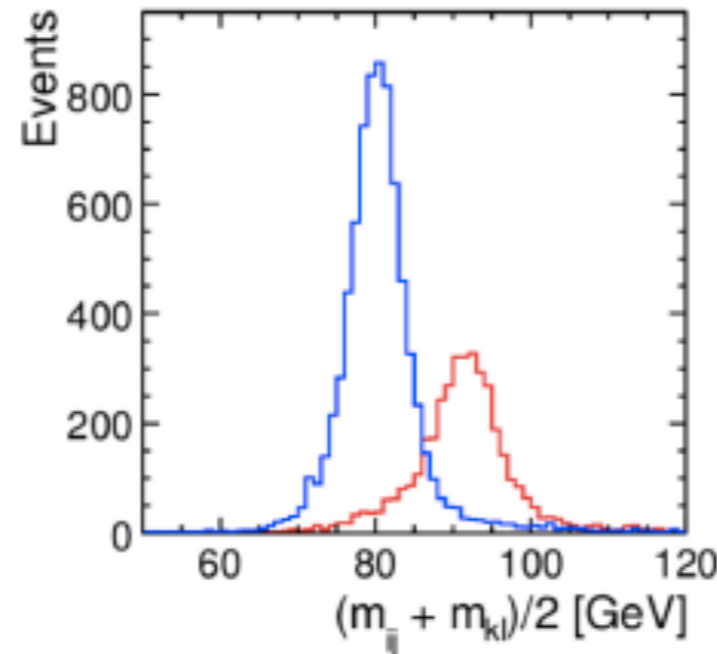
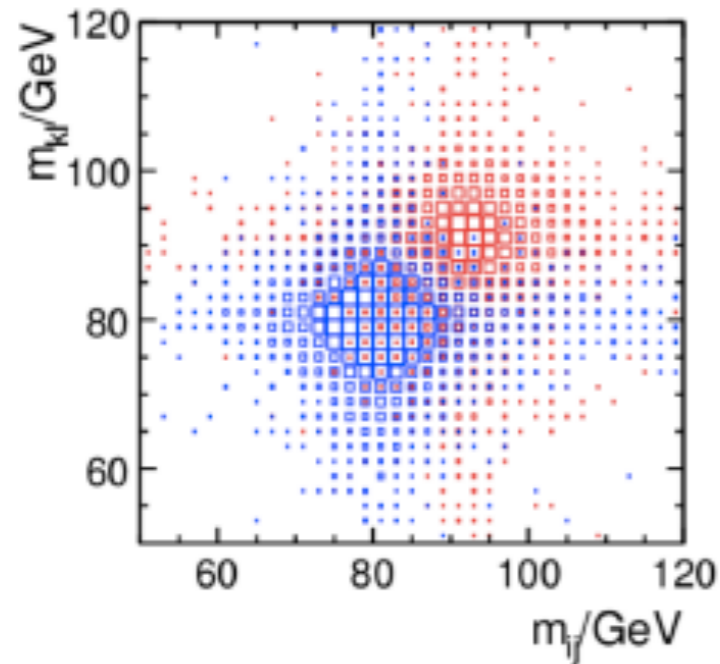
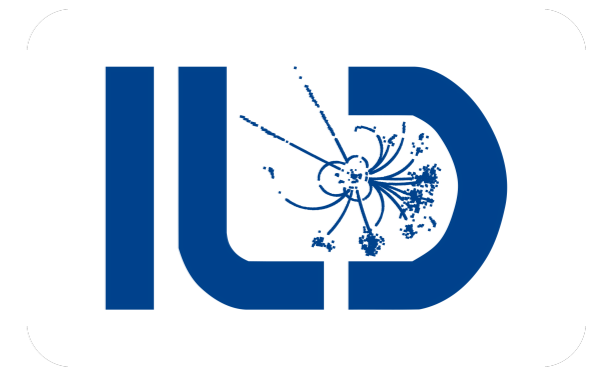
- **JER & JES (udscb)**
- **jet angle resolution**
- **leptons in jets**

last presentation:  
Jun 13

status summary:

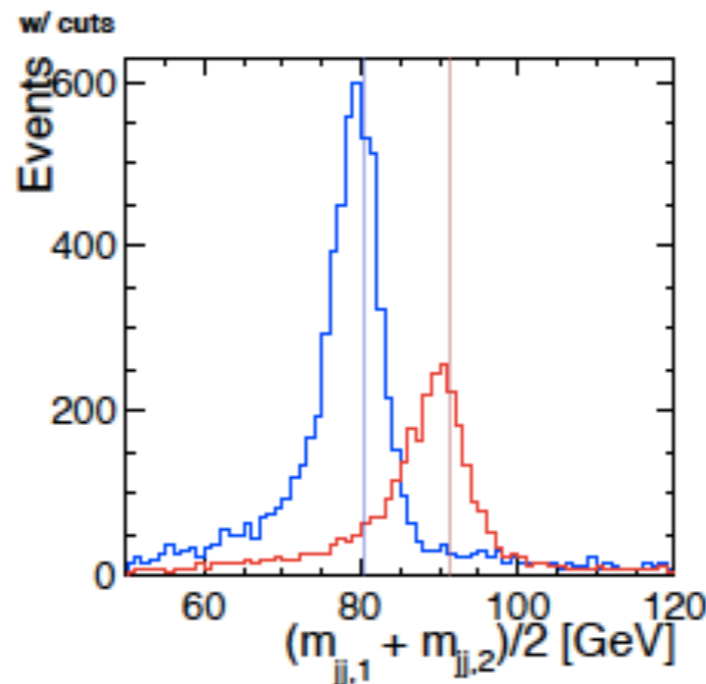
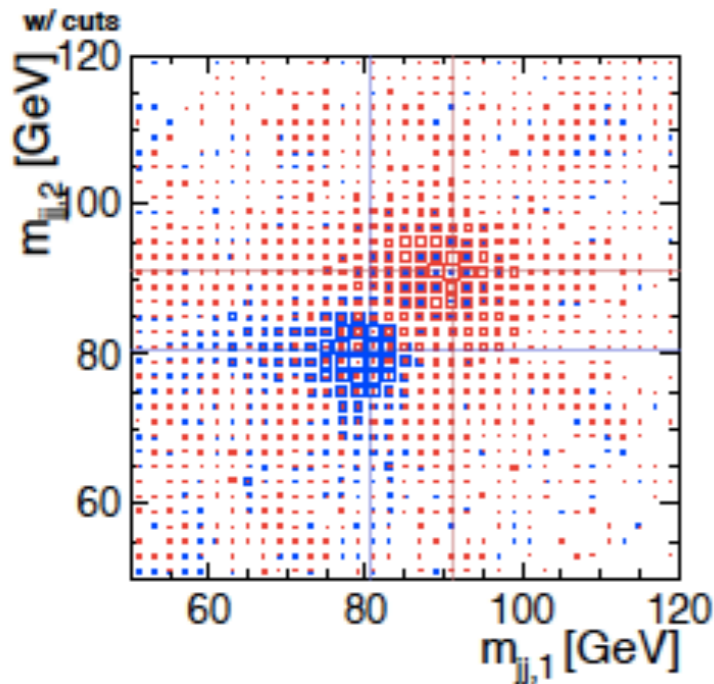
- new software chain just became fully ready for 1 TeV
- well prepared on preliminary samples, waiting for production...
- problems with Whizard2 for anomalous coupling part

# Quartic Gauge Couplings - results



## Letter of Intent

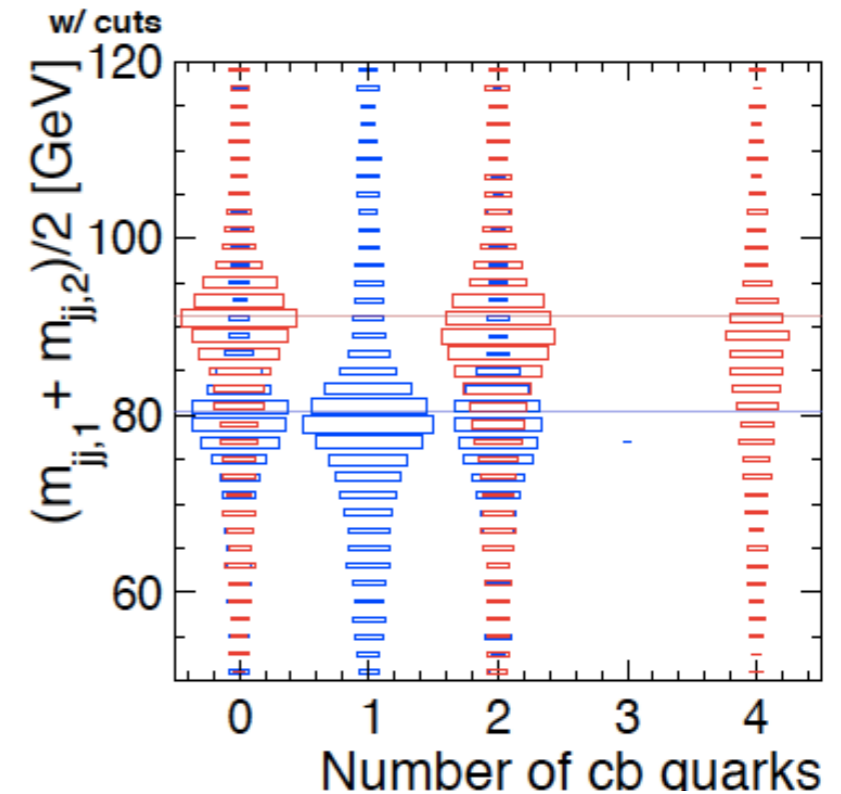
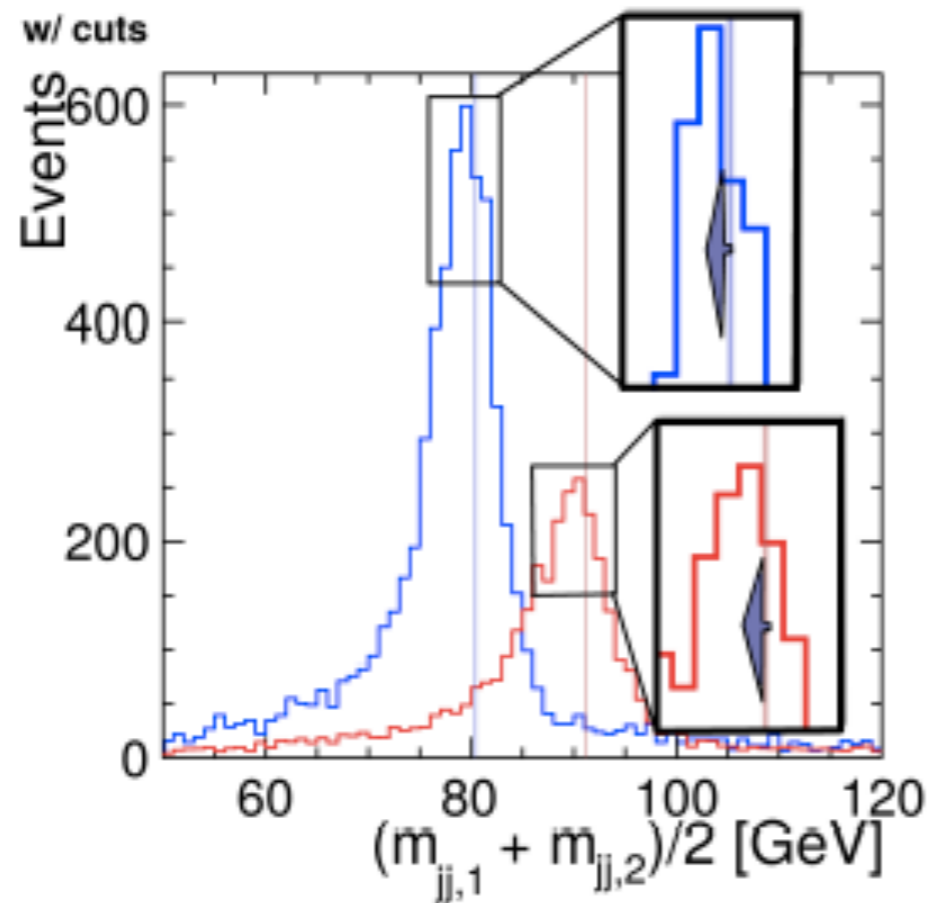
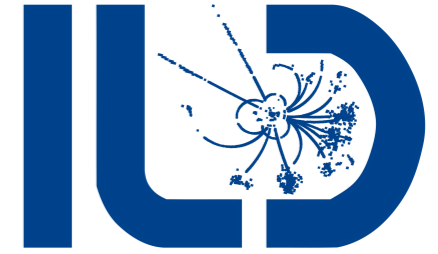
- ▶ Well-separated and resolved  $WW$  and  $ZZ$  peaks



## Own analysis

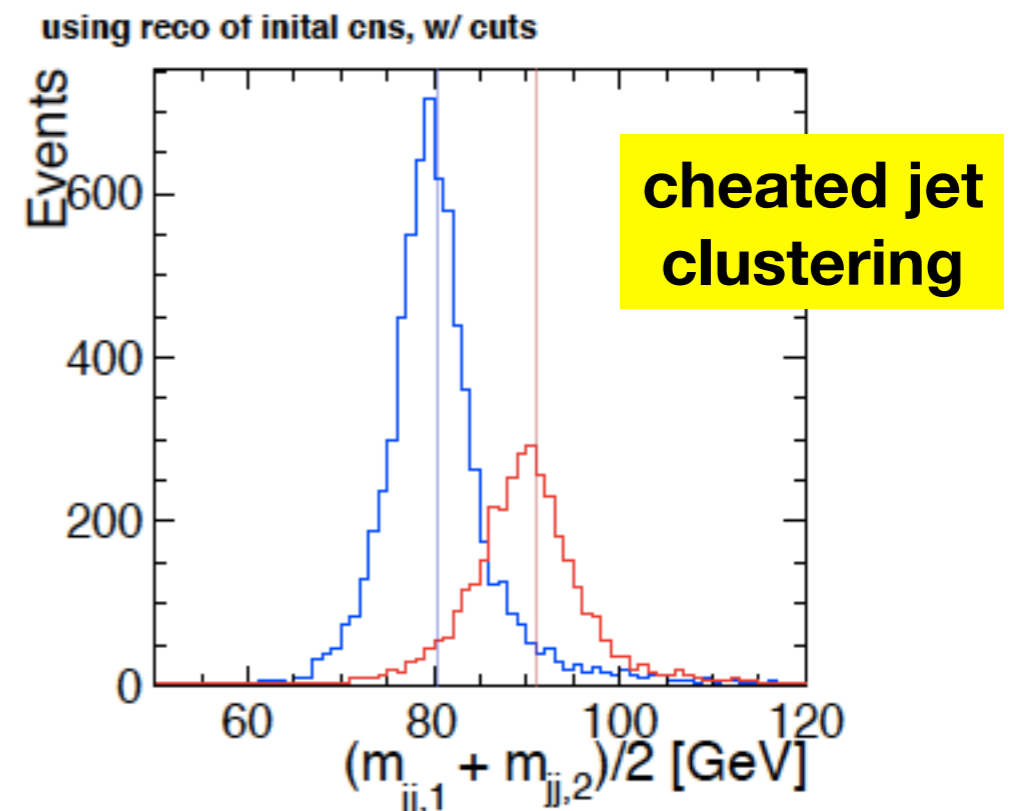
- ▶ Distribution tails (not observed in Lol)
- ▶ Mass peaks shifted wrt. boson masses

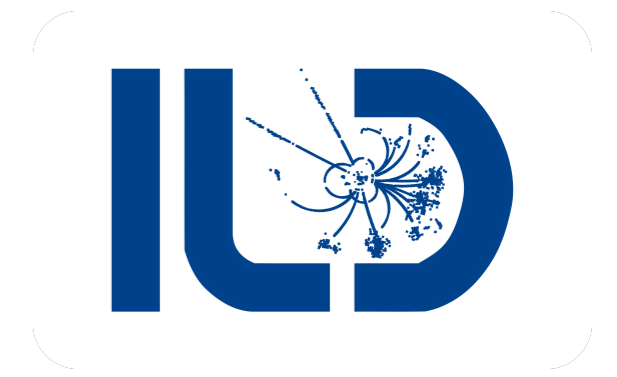
# Quartic Gauge Couplings - results



identified two “culprits”

- energy scale for heavy quark jets
- jet clustering...
- Lol: only “uddu” and cheated jets???





# $e^+e^- \rightarrow \text{gamma Z}$ - overview

main physics observable(s):

**A\_LR for cross section of  $e^+e^- \rightarrow \text{gamma Z}$  @ 500 GeV**

analyser(s):

Takahiro Mizuno,  
Junping Tian

intermediate observable(s):

**$\cos\theta_z, M(ff)$**

reviewer(s):

Matthew Wing

performance aspect(s):

**lepton/photon reconstruction efficiencies,  
momentum/energy resolution/scale, JER/JES**

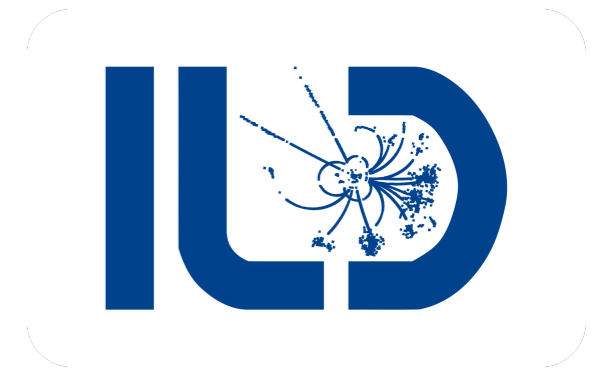
last presentation:

Aug 22, 2018

status summary:

- DBD analysis started
- Analysis of new samples will be started on Sep 13

# $e+e- \rightarrow \text{gamma } Z$ - results



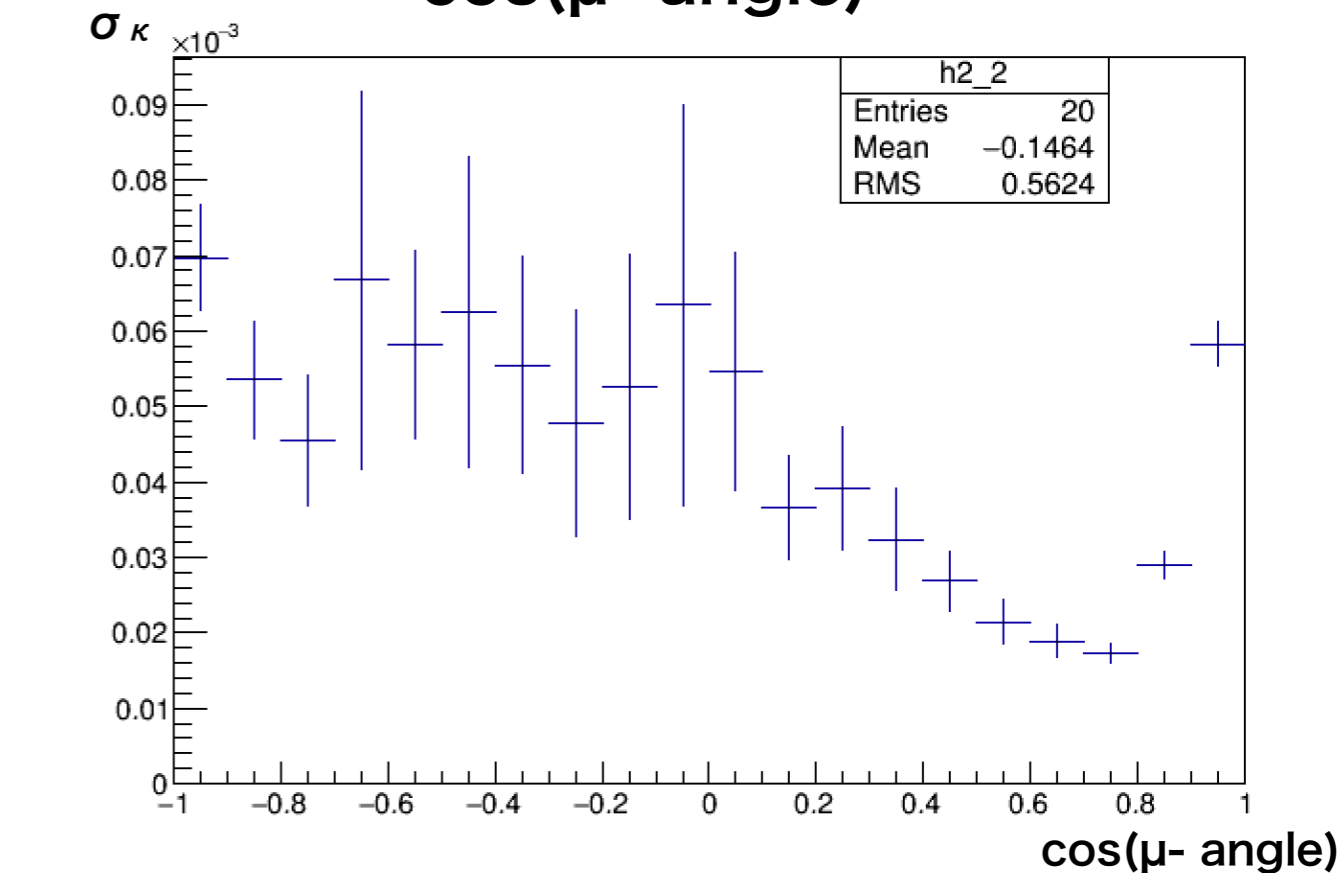
DBD analysis for  $e_R + e_L \rightarrow \text{gamma } Z$ , collection efficiency is studied.

- In the  $M(\mu \mu) > 400$  GeV case, it is close to 100% at any angle.
- In the  $|M(\mu \mu) - 91.2| < 10$  GeV case, it becomes low ( $\sim 0.5$ ) when one of the other muon tends to go in the beam pipe direction.
- In the  $M(\mu \mu) < 20$  GeV case, it is very low because two muons are collimated and hence are rejected by isolation requirement.

DBD analysis for  $e_R + e_L \rightarrow \text{gamma } Z$ , muon energy resolution and  $\sigma_\kappa$  are studied.

- Standard deviation (STDV) of  $\sigma_\kappa$  is  $< 10^{-4}$ .
- STDV of  $\sigma_\kappa$  is higher (but  $< 10^{-4}$ ) when muon energy is low. This is because there are more multiple scatterings.
- STDV of  $\sigma_\kappa$  of TPC is theoretically  $2 \cdot 10^{-5}$ .

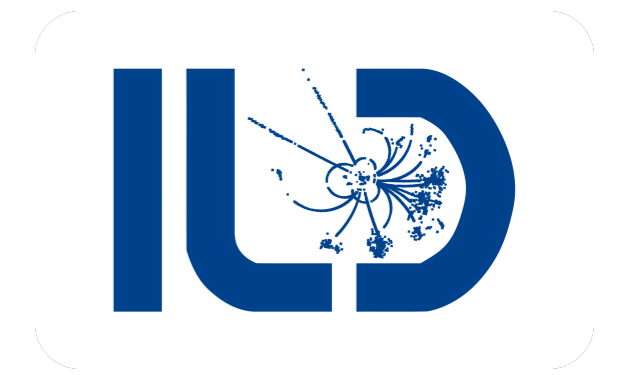
## STDV of $\sigma_\kappa$ as a function of $\cos(\mu\text{-angle})$



Future plan:

- Look at the new samples for large and small ILD model
- Do full analysis including background
- Study electron channel, and jet channel

Status of Benchmarks - Top/ Flavour tag



# $tt \rightarrow bbqqqq$ - overview

main physics observable(s):

**A\_LR and A\_FB @ 500 GeV**

intermediate observable(s):

- **polar angle distributions of t- / b-quark**
- **M<sub>top</sub> and M<sub>W</sub>**

performance aspect(s):

- **vertex charge,**
- **Kaon ID**
- **flavour tag**

status summary:

- **tt -> fully hadronic on new samples too challenging til IDR**

analyser(s):

**Sohail Amjad,  
Adrian Irlles,  
Yuichi Okugawa**

reviewer(s):

Marcel Vos (IFIC)

last presentation:

Aug 22



# tt->bbqqqq - overview

main physics observable(s):  
**A\_LR and A\_FB @ 500 GeV**

analyser(s):  
**Sob...**

intermediate observable(s):  
• **polar angle distributions of**  
• **M<sub>top</sub> and M<sub>w</sub>**

perform

Armel Vos (IFIC)

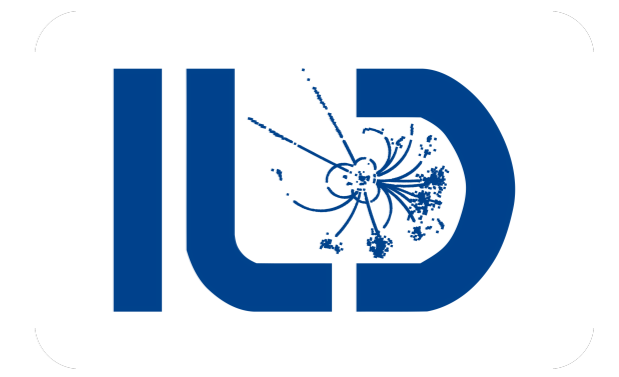
last presentation:  
Aug 22

summary:

• **tt -> fully hadronic on new samples  
too challenging til IDR**

**Currently redefining benchmark,  
e.g. cover performance aspects based on  
ee->bb and tt->bbqqlnu,  
where code and reference performance exists from DBD**





# H->bb/cc/gg - overview

main physics observable(s):

**BR (H->bb/cc/gg) from  $\nu\nu H$  @ 500 GeV**

intermediate observable(s):

**$M_H$  (bb/cc/gg)**

performance aspect(s):

- **b-tag / c-tag**
- **JER / JES for heavy flavours**

status summary:

- understanding code from DBD analysis
- debugging / de-featuring LCFIPlus on new samples and interplay with z-vertex smearing

analyser(s):

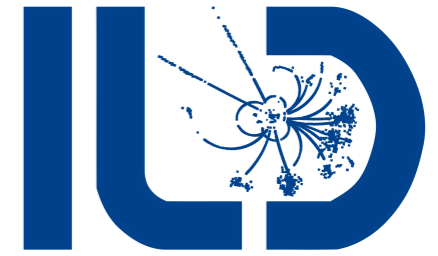
Masakazu Kurata (KEK)  
Ryo Yonamine (Tohoku)

reviewer(s):

Hiroaki Ono (NDU Niigata)  
Frank Simon (MPI Munich)

last presentation:

July 11 (mostly LCFIPlus)



# H->bb/cc/gg - overview

main physics observable(s):

**BR (H->bb/cc/gg) from  $\nu\nu H$  @ 500 GeV**

analyser(s):

Masakazu Kurata (KEK)  
Ryo Yonamine (Tohoku)

intermediate observable(s):

**$M_H$  (bb/cc/gg)**

reviewer(s):

Hiroaki Ono (NDU Niigata)  
Frank Simon (MPI Munich)

performance aspect(s):

- **b-tag / c-tag**
- **JER / JES for heavy flavours**

last pres  
July 2018 (LCFIPlus)

status summary:

- understanding code from DBD analysis
- debugging / de-featuring LCFIPlus on new samples and interplay with z-vertex smearing

**Urgently needs  
more person power**

# Status of Benchmarks - BSM



# Light Higgsinos - overview

main physics observable(s):

**M, pol.  $\sigma$ 's @ 500 GeV**

analyser(s):

Swathi Sasikumar (DESY)

intermediate observable(s):

- **purity of z-vertex groups**
- **sqrt(s') from ISR recoil,  $E_{\pi^*}$  vs sqrt(s')**

reviewer(s):

Akimasa Ishikawa  
(Tohoku)

performance aspect(s):

- **low pt tracking eff/pur & PID**
- **ISR reconstruction**
- **BeamCal veto**

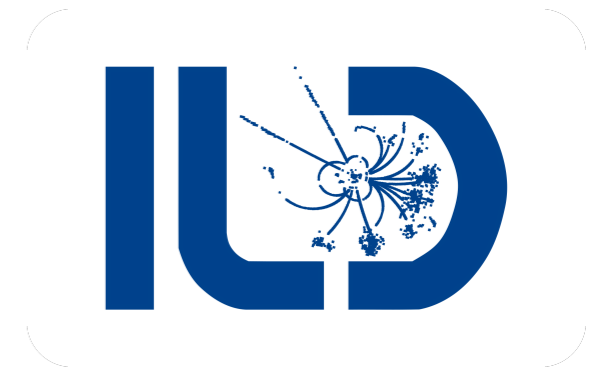
last presentation:

Aug 22

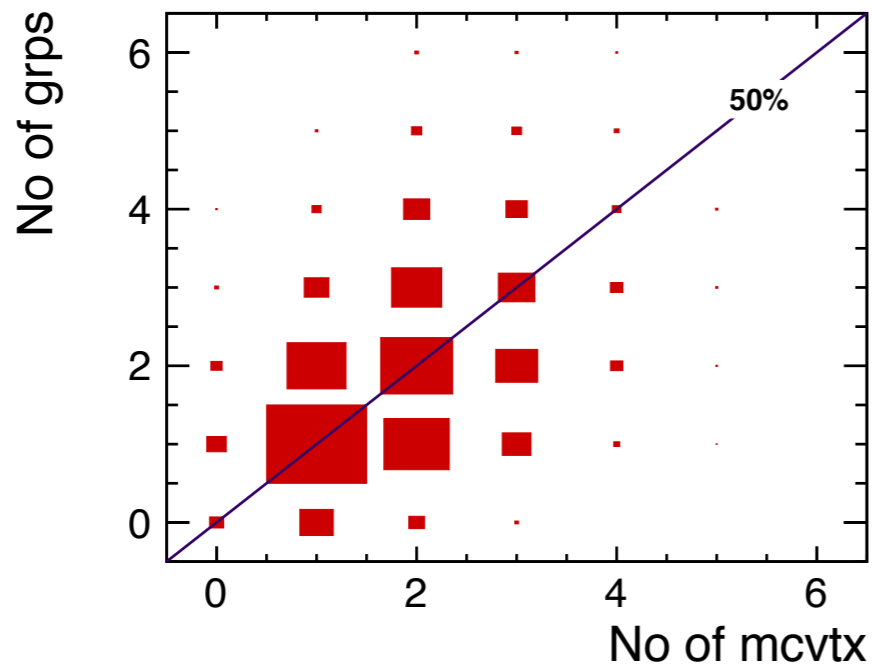
status summary:

- **low-pt tracking efficiency and track-based z-vertex finder on new samples as expected**

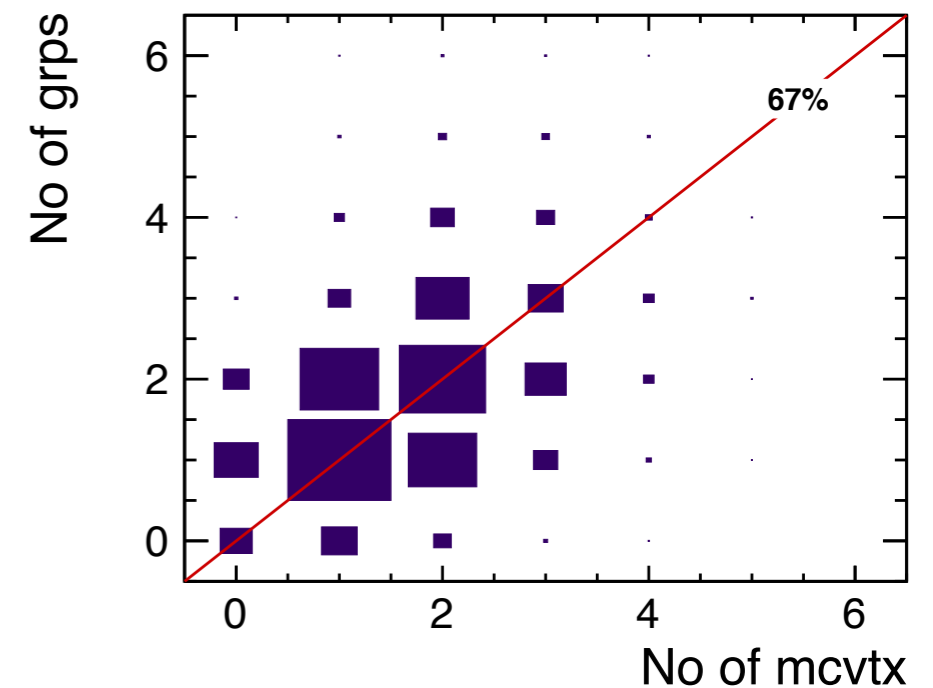
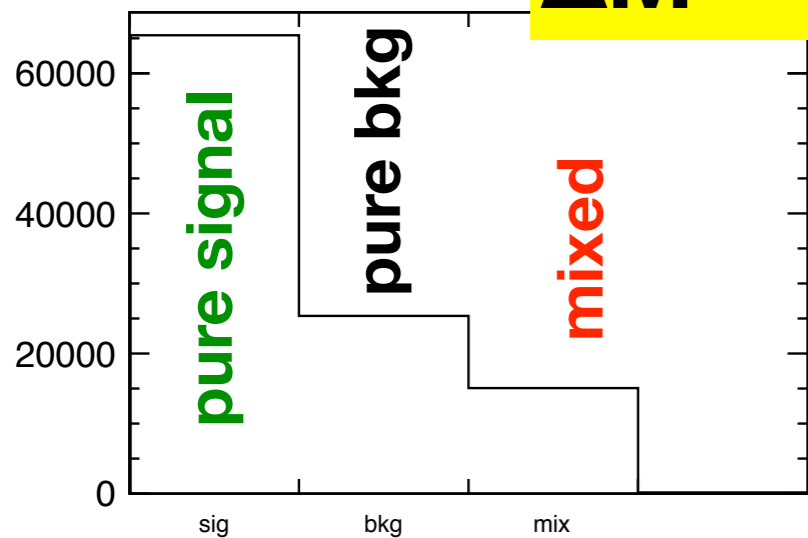
# Light Higgsinos - results (ILD 15)



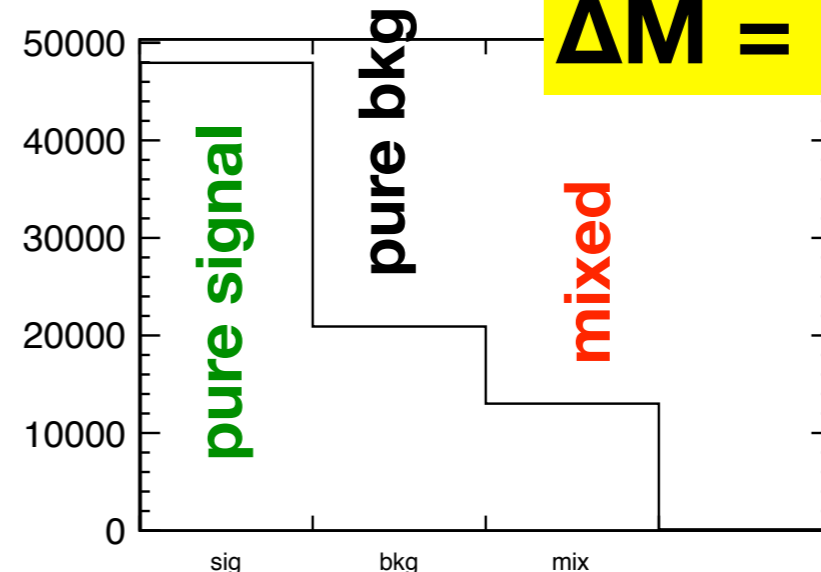
group tracks based on  $z_0$ , identify signal vs  $\gamma\gamma \rightarrow$  low pt hadrons



**$\Delta M = 770 \text{ MeV}$**



**$\Delta M = 1.6 \text{ GeV}$**





# Monophoton WIMPs - overview

main physics observable(s):

- **95% CL limit on  $\Lambda$  vs  $M$  @ 500 GeV for V (A)**
- **$\delta M$  vs  $M$  for Vector (Axialvector),**
- **$\chi^2$  (Vector vs Axialvector) vs  $M$**

intermediate observable(s):

**photon energy spectrum**

performance aspect(s):

- **photon:** eff./pur., E and angular resolutions
- Bhabha veto efficiency in **BeamCal**
- veto **tracks from  $\gamma\gamma$  / pair backgrounds**

status summary:

- very first look into new samples
- progress slowed by exams & illness
- hope to resume now

analyser(s):

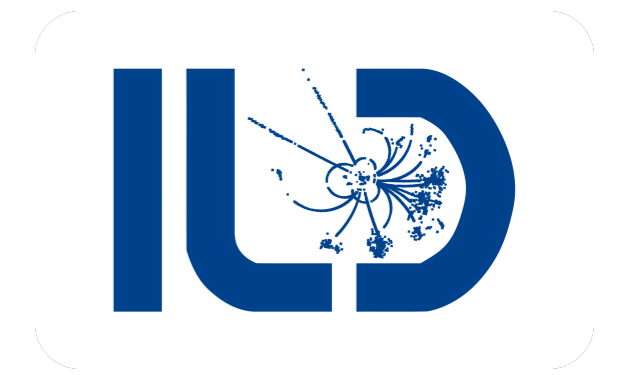
Ahmed Mustahid (Tohoku)

reviewer(s):

Filip Zarnecki (Warsaw)

last presentation:

July 25 (DBD samples)



# Monophoton WIMPs - overview

main physics observable(s):

- **95% CL limit on  $\Lambda$  vs M @ 500 GeV for V (A)**
- **$\delta M$  vs M for Vector (Axialvector),**
- **$\chi^2$  (Vector vs Axialvector) vs M**

intermediate observable(s):

**photon energy spectrum**

performance aspect(s):

- **photon:** eff./pur., E and angular resolutions
- Bhabha veto efficiency in **BeamCal**
- veto **tracks from  $\gamma\gamma$  / pair backgrounds**

status summary:

- very first look into new samples
- progress slowed by exams & illness
- hope to resume now

analyser(s):

Ahmed Mustahid (Tohoku)

reviewer(s):

Filip Zarnecki (Warsaw)

last presentation:

July 25 (500 samples)

**Urgently needs  
more person power**



# Extra Higgs bosons - overview

main physics observable(s):  
**95% CL limit on  $g(\text{Zhh})$  vs  $M_h$  @ 500 GeV**

analyser(s):  
Yan Wang (DESY)

intermediate observable(s):  
**recoil mass spectrum ( $\mu\mu$ )**

reviewer(s):  
Kiyotomo Kawagoe (Kyushu)  
Junping Tian (Tokyo)

performance aspect(s):

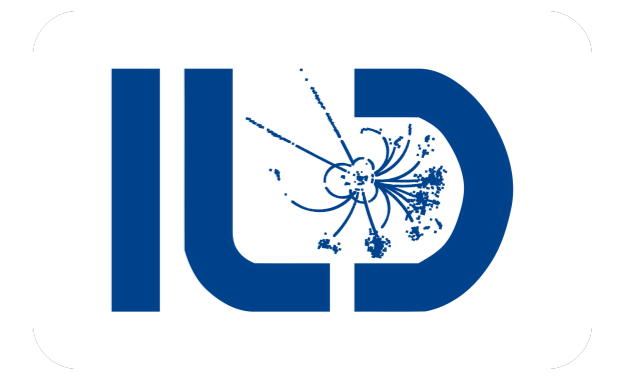
- **muon ID efficiency / purity**
- **momentum resolution** (not only high-pt)
- **ISR reconstruction**

last presentation:  
Aug 22

status summary:

- analysis ~completed on DBD samples at 250 GeV
- **importance of performance aspects quantified**
- working on new samples



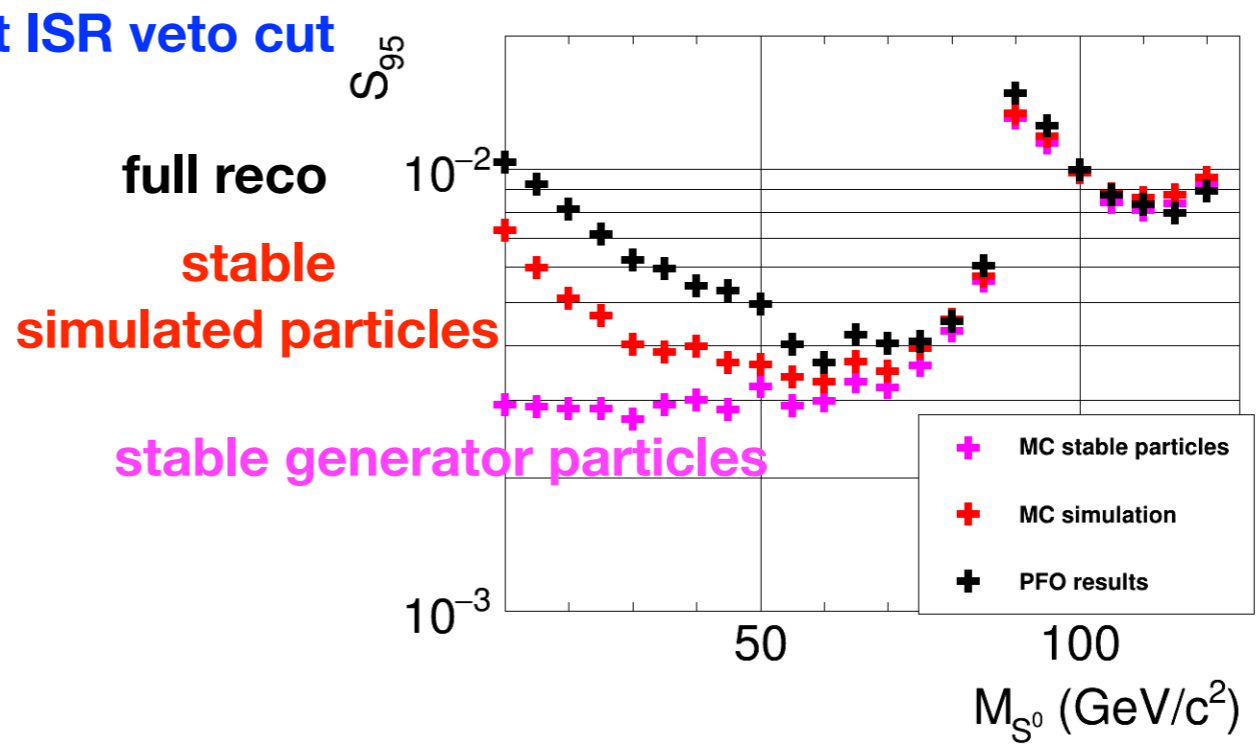
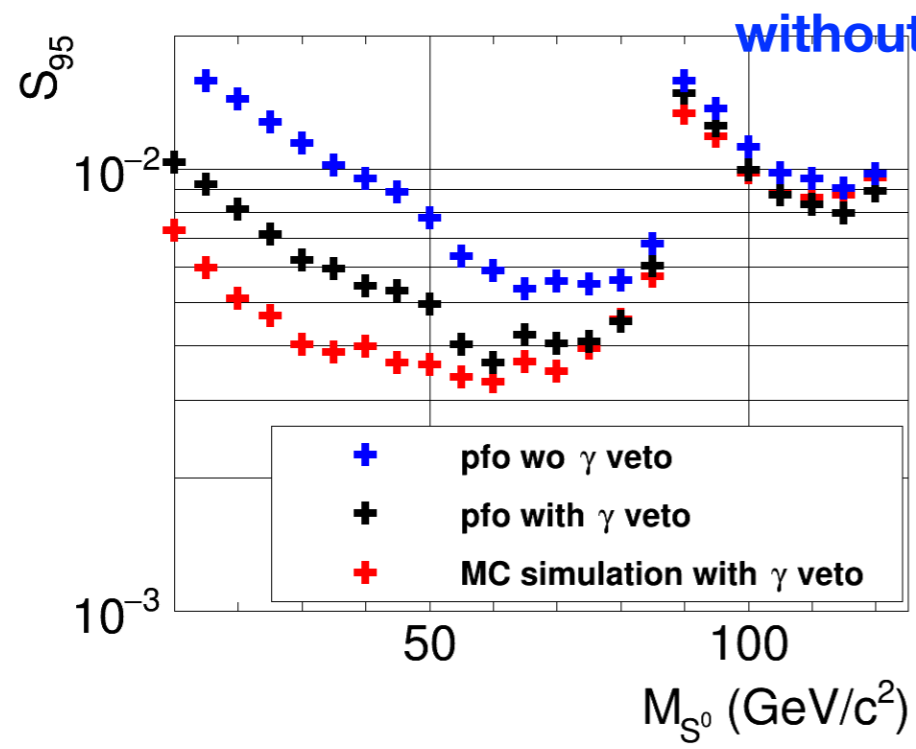


# Extra Higgs bosons - results

**DBD analysis** for  $\mu\mu H$ ,  $2 \text{ ab}^{-1}$  250 GeV,  
 canonical pol. sharing  
 $S_{95} := \sigma_{95}(Z H(M_H=X)) / \sigma_{SM}(Z H(M_H=X))$

**conclusions for detector optimisation (@ 250 GeV!)**

- full sim  $\sim$  generator level for  $M_H > 70 \text{ GeV}$
- low masses: ISR veto crucial
- understand **magenta** vs **red**:  $\gamma$  conversions?



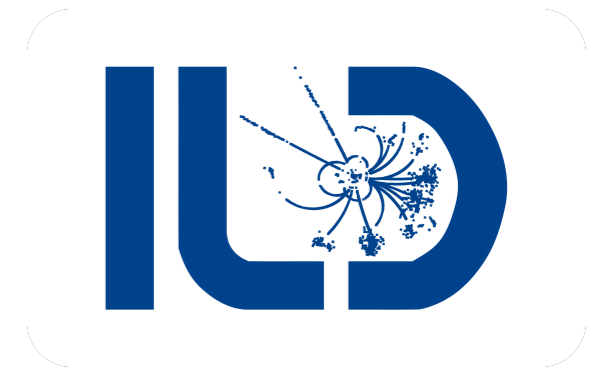
**IDR full sim:**

- signal samples processed
- first look into backgrounds at 500 GeV - WiP (plot shown on Aug 22 buggy)

Next Steps & Conclusions

# Next Steps

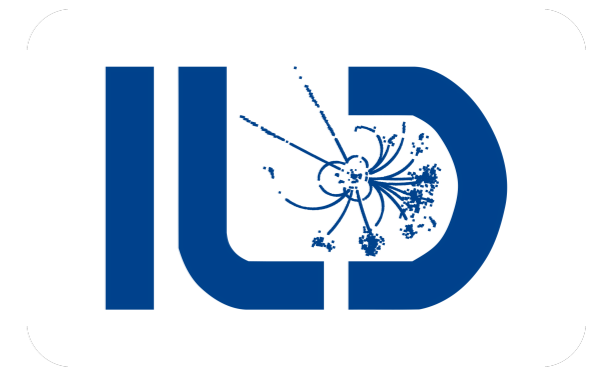
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- presentation of the last so far not yet presented analyses in software & analysis phone meeting
- Oct 19-21: **ILD Benchmarking Days**
  - as pre-meeting to LCWS
  - hands-on working meeting of all analysers, reviewers & physics/software conveners
  - any analysis which should go into the IDR needs to be ~ complete by then and have a skeleton in the IDR
  - ... and have note / paper draft soon thereafter

# Conclusions

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- all of this is on a very critical path
- many people can work only a small amount of their time on the analyses and/or are not very experienced
- any help is welcome!!!
- I personally hope that now after summer we see a real push in **all** of the analyses...