Impacts of SB2009 on the Higgs Recoil Mass Measurement

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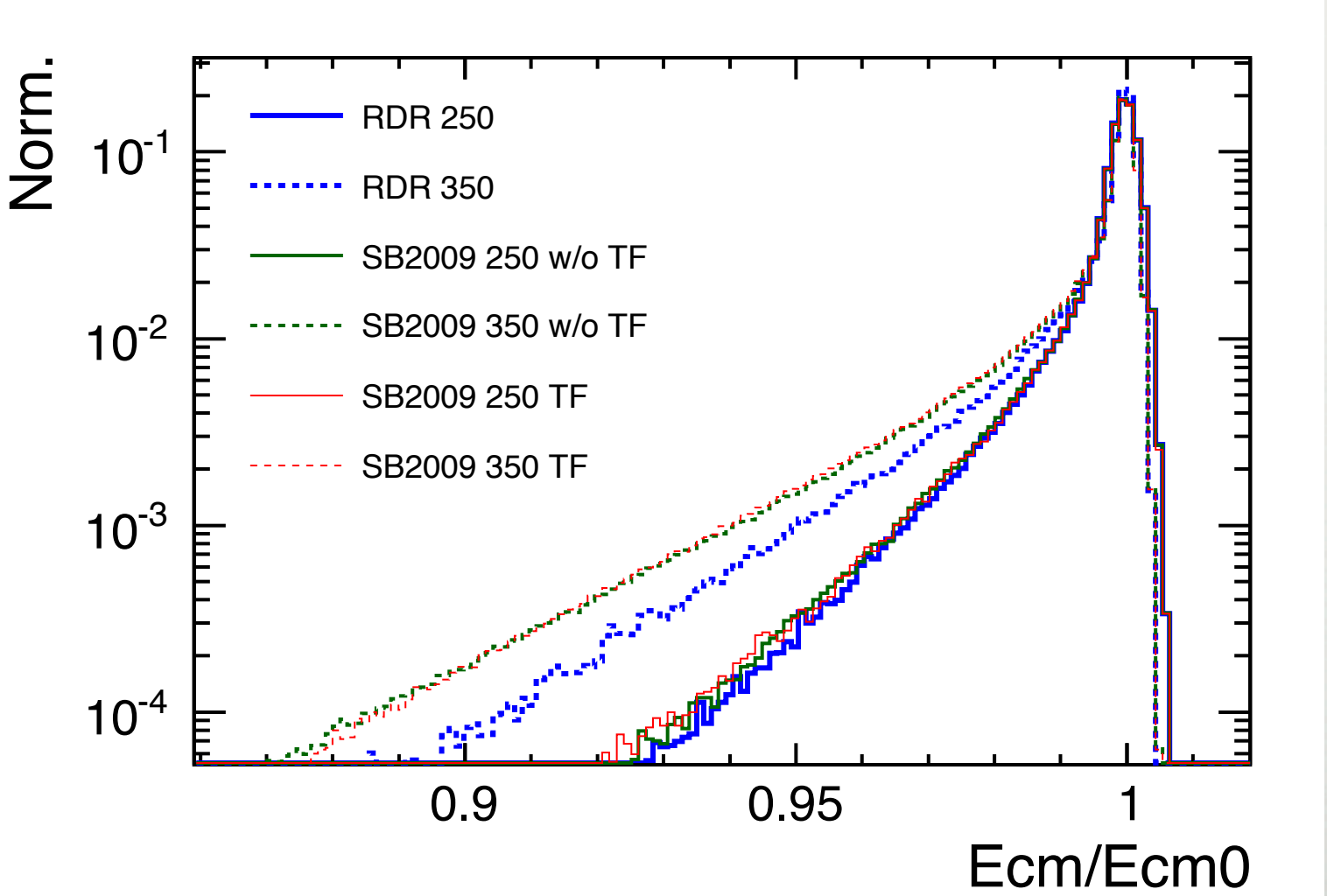
Outline

- The Object of this study:
  - get to know and to understand the impact of SB2009 on the Higgs recoil mass and cross-section measurement.
- Beam Simulation
- Estimation of the Integrated Luminosities
- Fast Simulation of the ILD detector
- Results
- Discussions -- to understand the results
- Summary

Beam Simulation

- Using GUINEA-PIG with SB2009 Beam parameters given by Brian Foster's talk on SB2009 Meeting at DESY 2009



Estimation of the Integrated Luminosity

- Estimate the Integrated Luminosity for various sets of beam parameters according to Peak Luminosities: taken RDR 500 as reference

$$\mathcal{L}_{\mathrm{int}} = \frac{\mathcal{L}_{\mathrm{peak}}}{\mathcal{L}_{\mathrm{peak,RDR500}}} \cdot \mathcal{L}_{\mathrm{int,RDR500}}$$

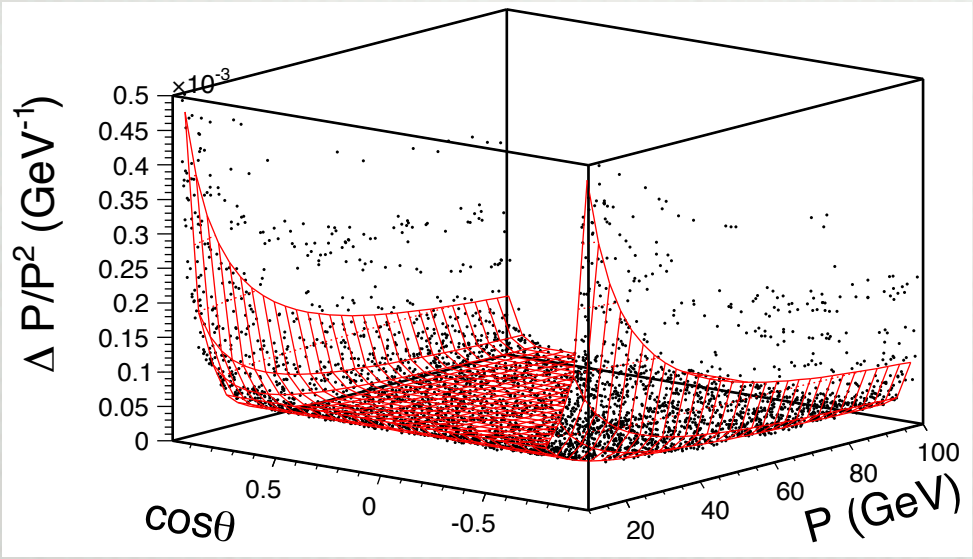
- Resulting numbers:

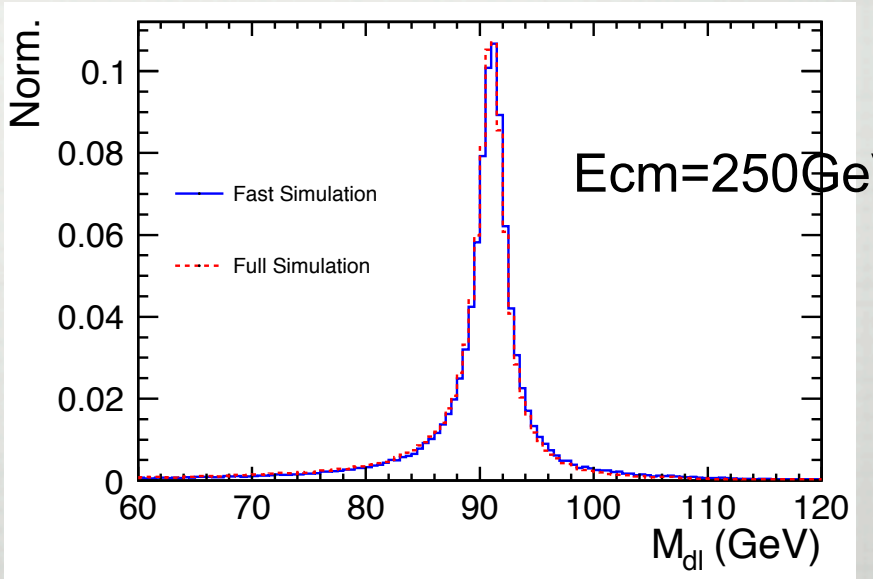
	RDR			SB2009 w/o TF				SB2009 w/ TF			
$\sqrt{s}$ (GeV)	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
Peak L ($10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.25	0.27	1.0	2.0
Integrated L (fb^{-1})	188	300	500	50	55	175	375	63	68	250	500

Fast Simulation

- A dedicated Fast Simulation Algorithm is developed for the ILD concept
- Parameterize the Momentum Resolution as a function of P and cosθ
- The MC true momentum of a given muon is smeared according to this parameterization.

$$\frac{\Delta P}{P^2} = \begin{cases} a_1 \oplus b_1/P & : \ |\cos\theta| < 0.78 \\ (a_2 \oplus b_2/P) \Big/ \sin\left(1 - |\cos\theta|\right) & : \ |\cos\theta| > 0.78 \end{cases}$$





Results

Only muon-channel, Beam Pol. (e-: -80%, e+: +30%),

- Results at Ecm=250GeV: Scaled from LOI full simulation study
- Results at Ecm=350GeV: Fast simulation, major background ZZ and WW, same analysis strategy as LOI study.

Beam Par	$\mathcal{L}_{\rm int}$ (fb^{-1})	ϵ	S/B	M_H (GeV)	σ (fb) ($\delta\sigma/\sigma$)
RDR 250	188	55%	62%	120.001 ± 0.043	11.63 ± 0.45 (3.9%)
RDR 350	300	51%	92%	120.010 ± 0.084	7.13 ± 0.28 (4.0%)
SB2009 w/o TF 250b	55	55%	62%	120.001 ± 0.079	11.63 ± 0.83 (7.2%)
SB2009 w/o TF 350	175	51%	92%	120.010 ± 0.110	7.13 ± 0.37 (5.2%)
SB2009 TF 250b	68	55%	62%	120.001 ± 0.071	11.63 ± 0.75 (6.4%)
SB2009 TF 350	250	51%	92%	120.010 ± 0.092	7.13 ± 0.31 (4.3%)

- What we can learn from the table?
  - RDR vs. SB2009:
    - Luminosity of SB2009 is smaller than RDR: worse results
  - w/ TF vs. w/o TF:
    - w/ TF has larger luminosity: better results
  - Ecm 250 vs. 350 GeV:
    - ZH cross-section is bigger at 250GeV
    - S/B is higher at 350GeV
    - δM_H is worse at 350GeV, while $\delta\sigma/\sigma$ is better at 350GeV

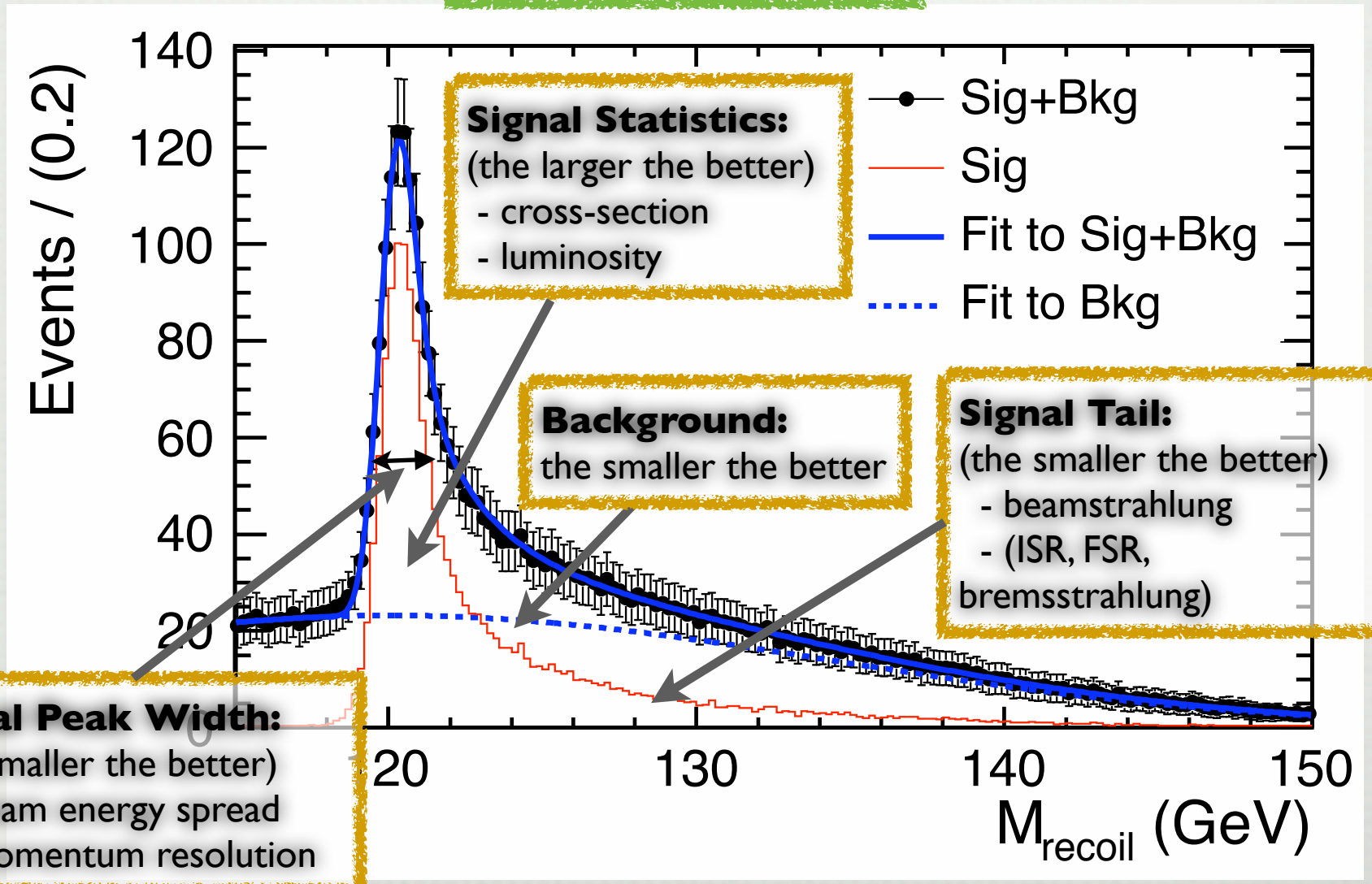
Best: RDR250

2nd Best in SB2009:

- M_H:
  SB2009 TF 250
- σ
  SB2009 TF 350

Discussions: to understand the results

Dissection Chart



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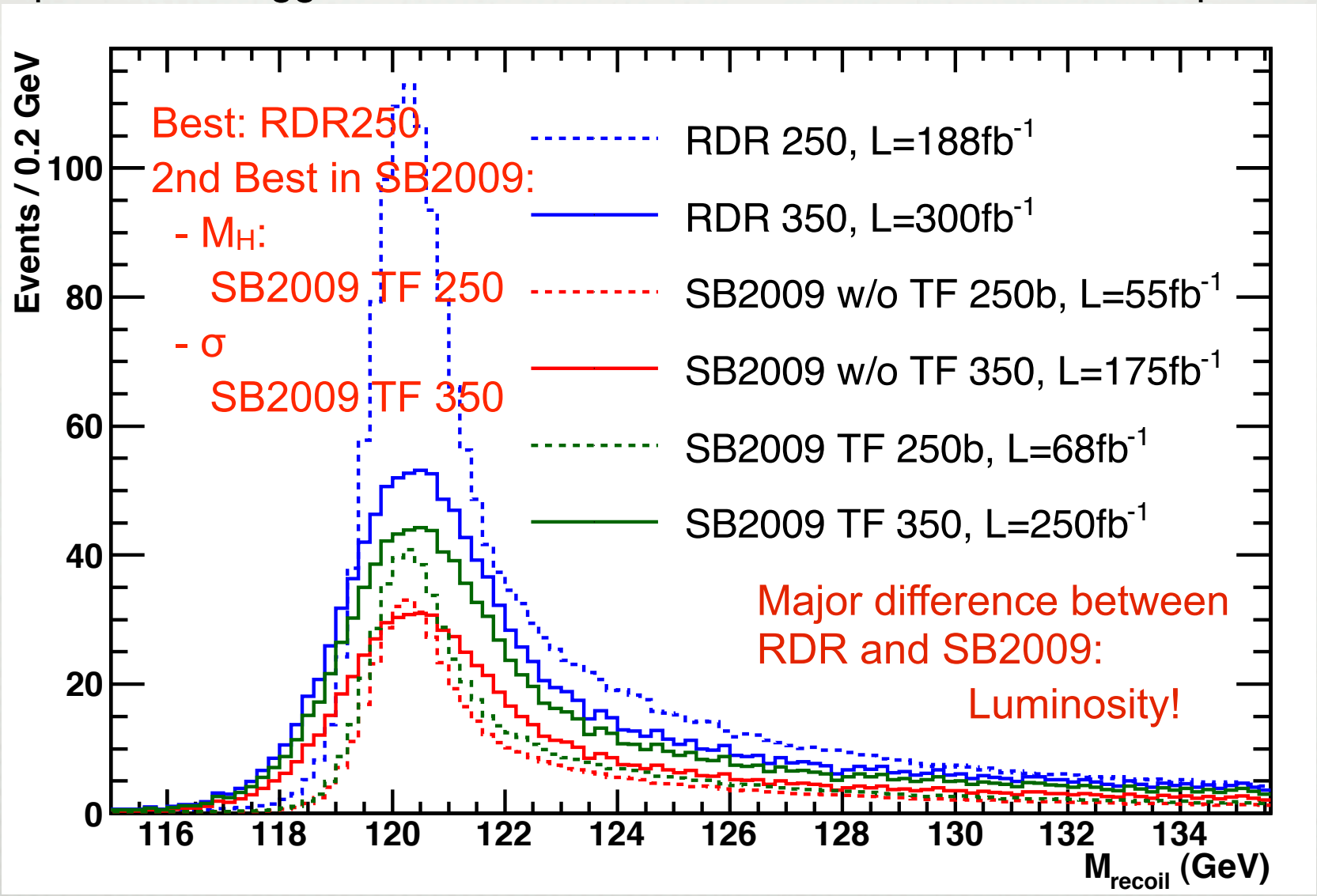
2nd Best in SB2009:

- M_H:
  SB2009 TF 250
- σ
  SB2009 TF 350

Discussions: to understand the results

Comparison of Higgs Recoil Mass distributions with different beam parameters:



Discussions: to understand the results

Comparison of Higgs Recoil Mass distributions with different beam parameters:

if we want to get the same result on M_H measurement using SB2009:

Saving the Construction Budget by 15%

<=>

Triple the running budget!!!

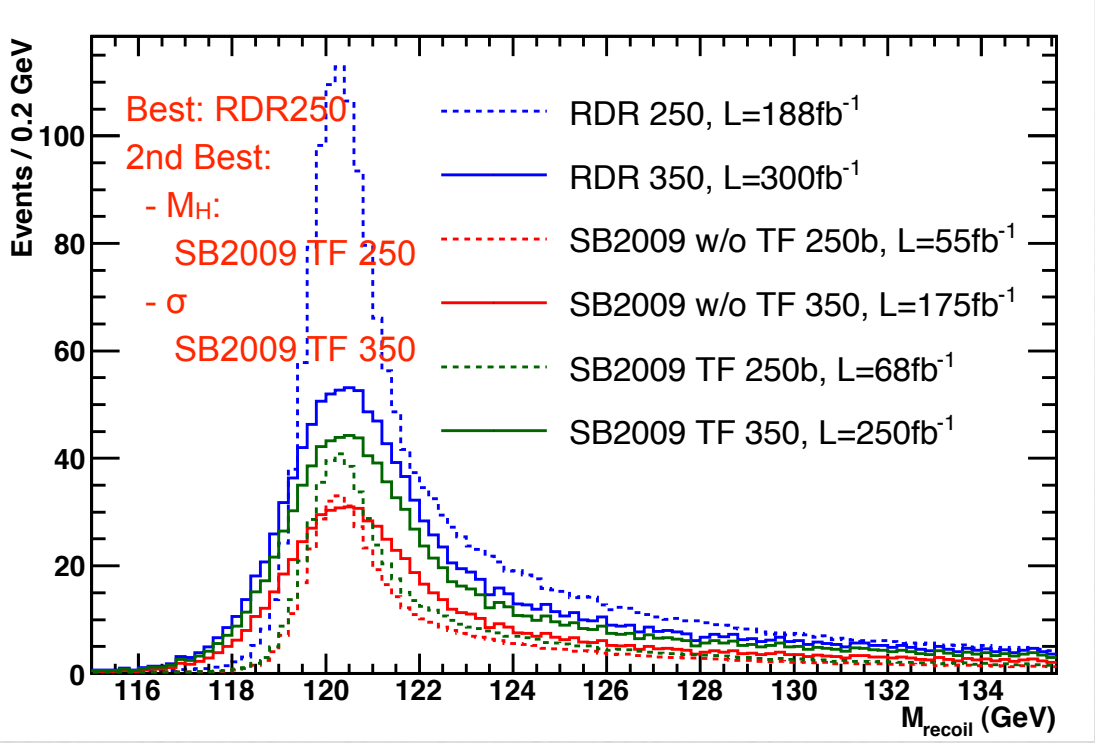
Discussions: to understand the results

Question: Why TF 250 gives better M_H result than TF 350? TF 350 has higher peak.

- Answer: although TF 350 higher peak, it also has much larger width!

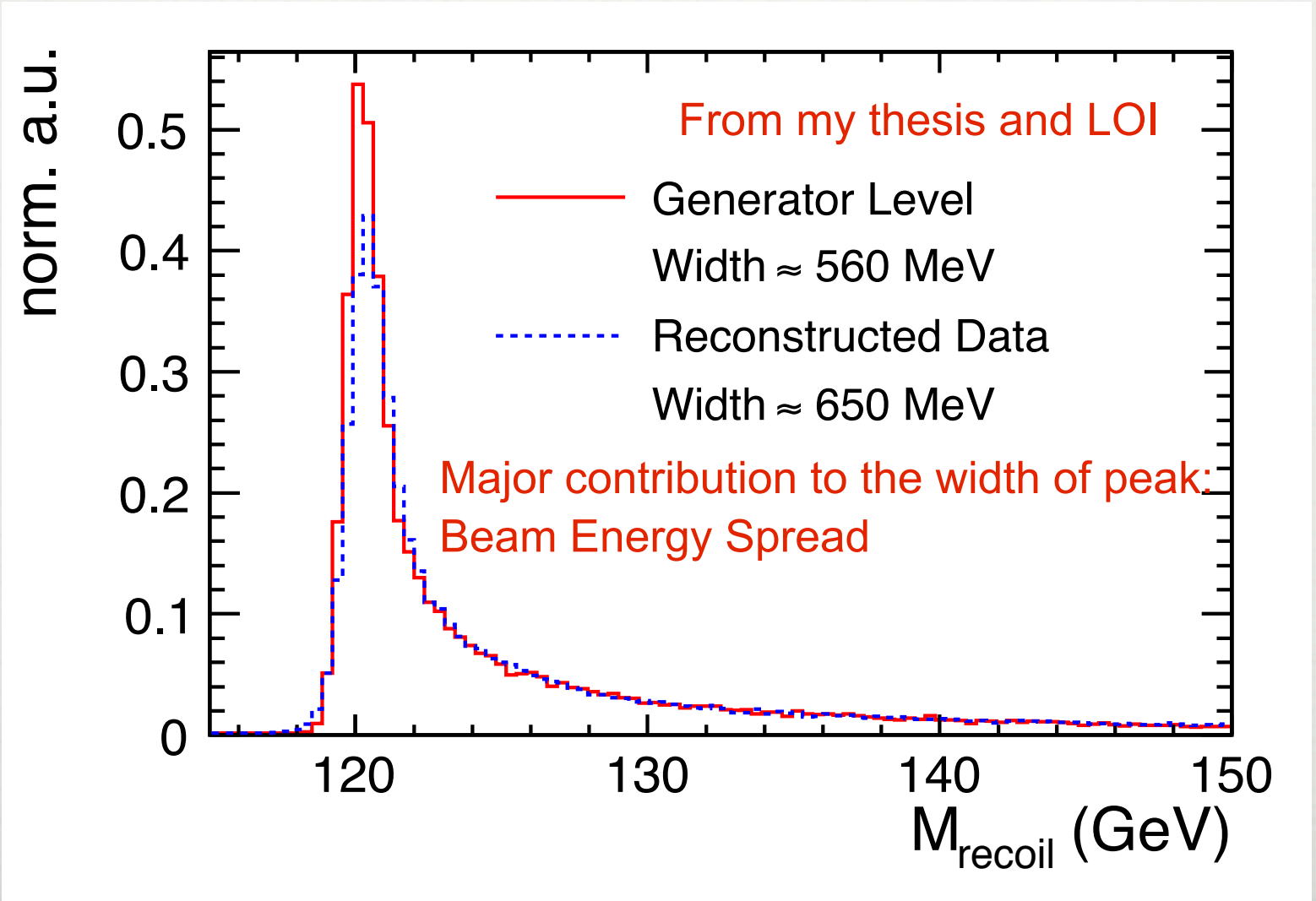
Question: Why it has larger width?

- Answer: its momentum resolution is bad. next slide.



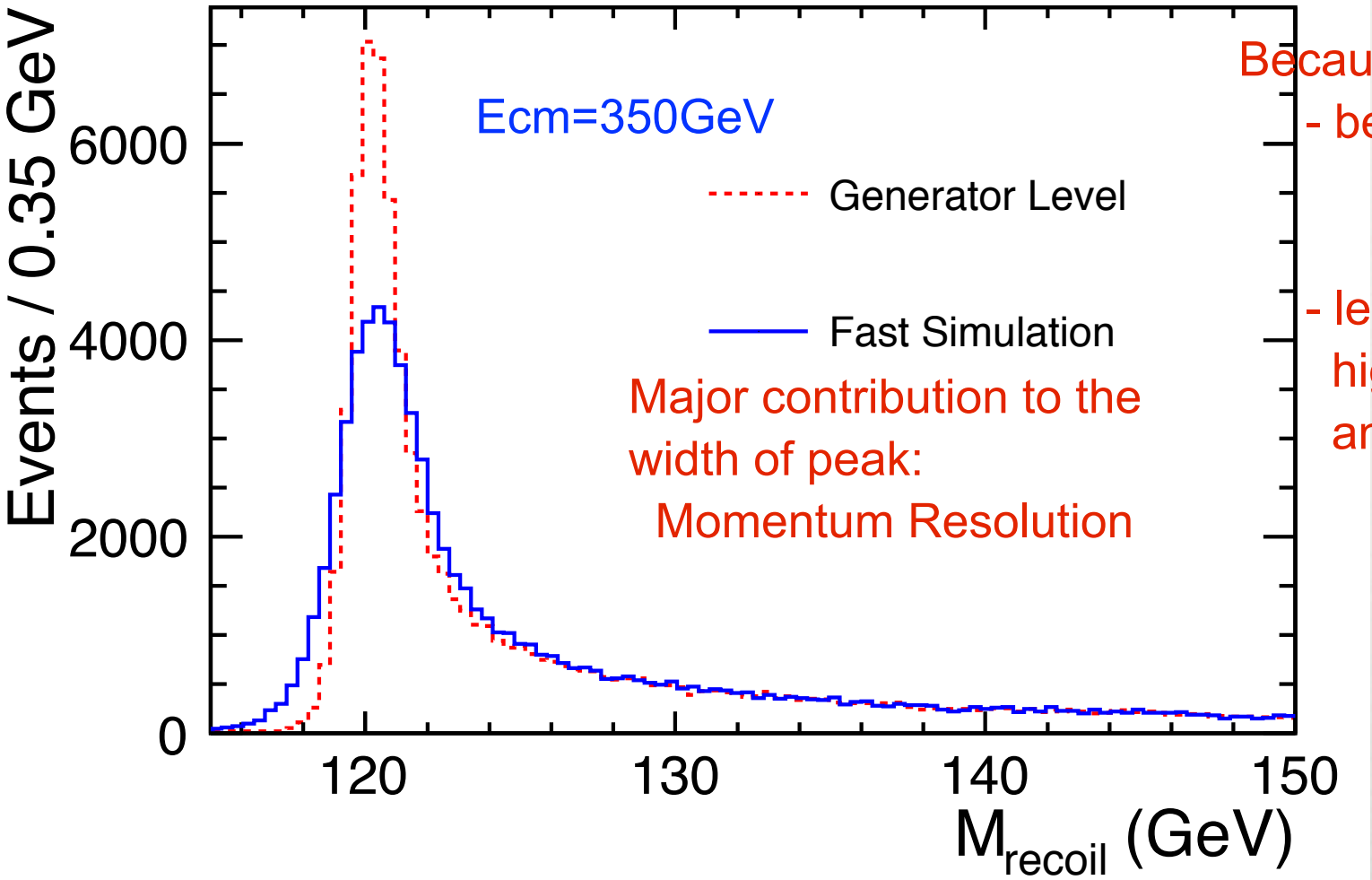
Discussions: to understand the results

- Comparison Before and After Detector Simulation: ZH at 250 GeV



Discussions: to understand the results

- For a given luminosity, Comparison Before and After Detector Simulation.

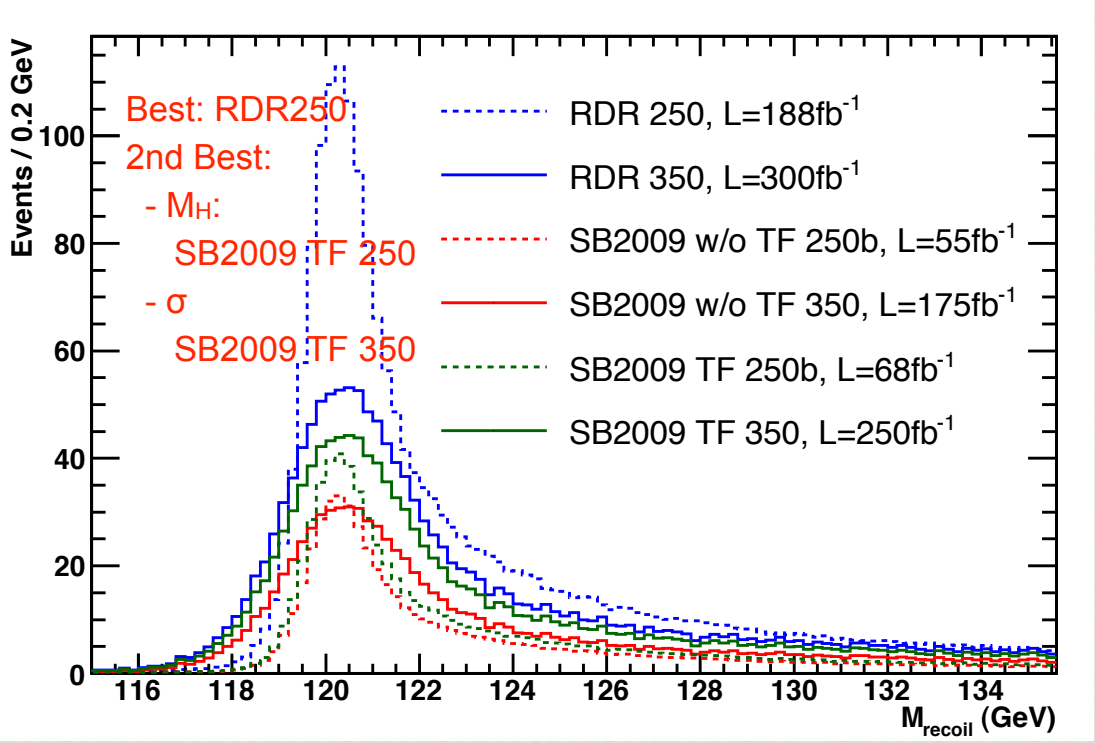


Because:
- beam energy spread : same at 250 and 350 GeV
- lepton momentum is higher at 350GeV, and $\Delta P \sim P^2$

Discussions: to understand the results

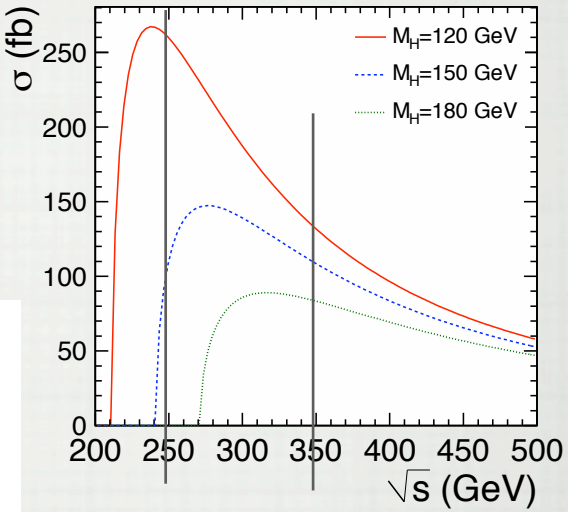
Now, we can also understand why δM_H is worse at 350GeV, while $\delta\sigma/\sigma$ is better at 350GeV ?

Because: the $\delta\sigma/\sigma$ is more sensitive to statistics than the width of the mass peak!



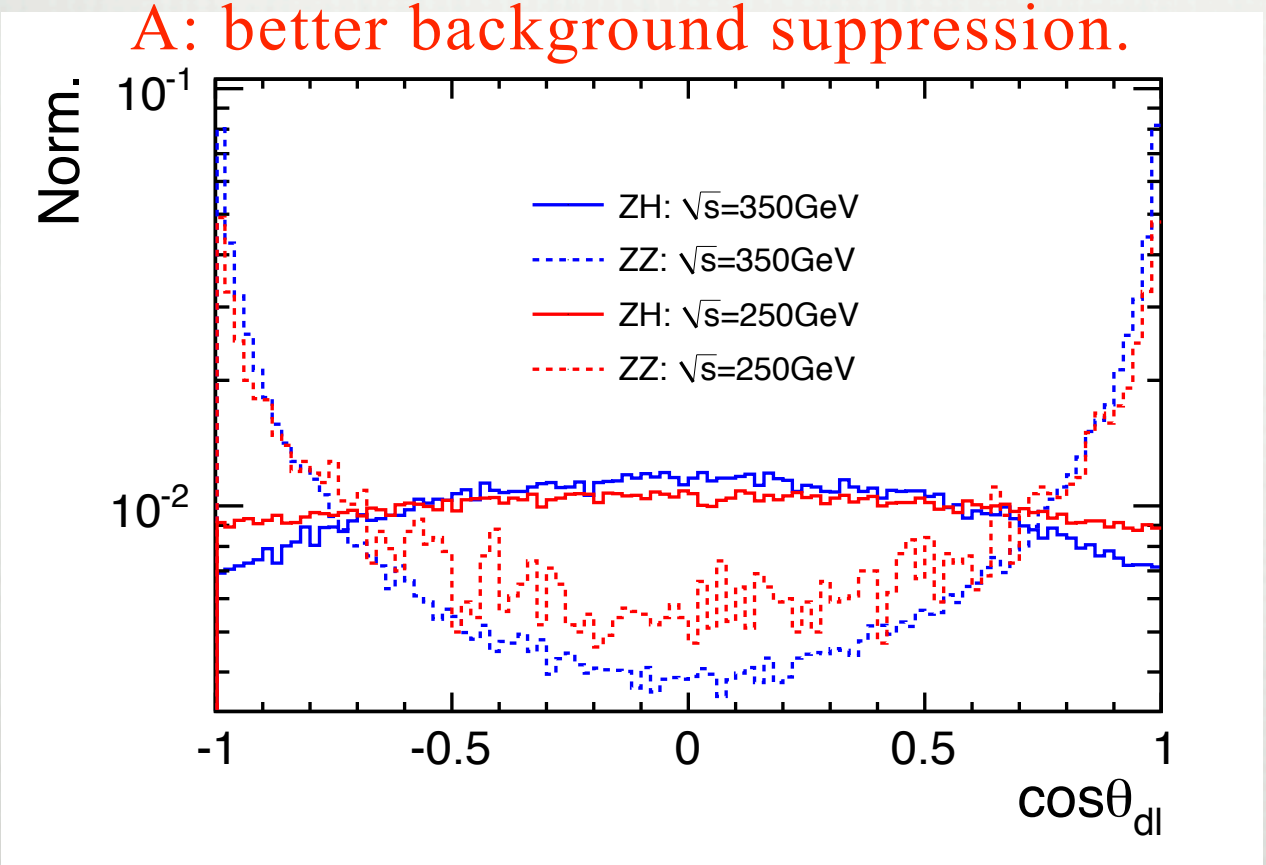
Discussions: to understand the results

Q: Why 250GeV has larger cross-section?



Q: Why S/B is larger at 350GeV?

A: better background suppression.



Summary

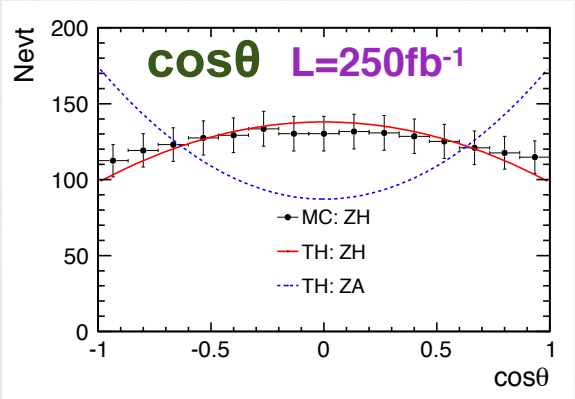
- Worse results from SB2009 due to smaller luminosity
  - RDR250: δM_H=43MeV $\delta\sigma/\sigma$=3.9%
  - SB2009 TF 250: δM_H=71MeV
  - SB2009 TF 350: $\delta\sigma/\sigma$=4.3%
- **saving 15% construction cost <=> triple running cost : for a same δM_H**
- TF gives better results than w/o TF
- at Ecm=350GeV, background suppression can be more efficient
- at Ecm=350GeV, given the luminosity, detector effect is dominant

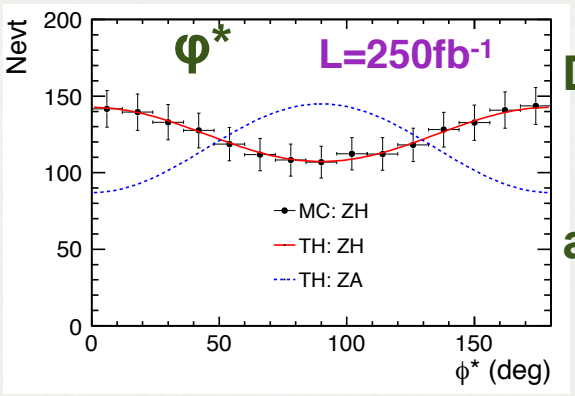
backups

Higgs Spin Parity: Angular Analysis

We can determine the Higgs Spin Parity from angular analysis:

H: $J^{PC}=0^{++}$
A: $J^{PC}=0^{+-}$

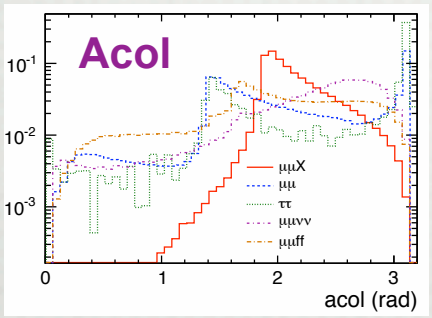




Definition:
θ : ZH production angle
φ*: Z decay azimuthal angle in the Z rest frame

But, in the background suppression we employed many angular cuts!

e.g.



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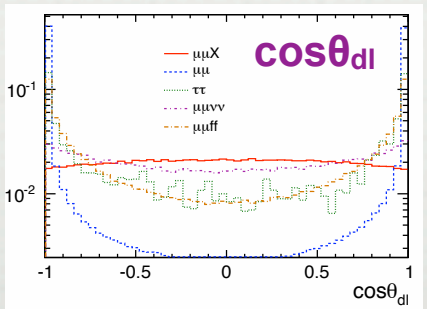

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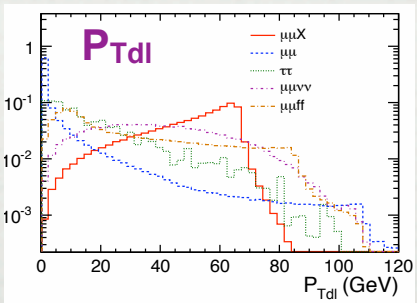

, etc....

This means we have to re-design our background suppression in order to perform this analysis: working in progress...

Discussions: to understand the results

- The Object of this study:
  - get to know and to understand the impact of SB2009 on the Higgs recoil mass and cross-section measurement.
- What issues may impact this measurement, in general?

(1) Physics:

(a) cross-section of ZH signal

(b) background

(2) Accelerator Effects:

(a) Integrated Luminosity

(b) Beam Energy Spread

(c) Beamstrahlung

(3) Detector Effects: momentum resolution of tracking

Event Generation

- Event generation using PYTHIA:
  - Beam Pol. (e-: -80%, e+: +30%) at Ecm=350GeV

Reaction	Cross-Section
$\boldsymbol{ZH \to \mu\mu X}$	**7.1 fb**
WW	346 fb
ZZ	165 fb

- Estimate the Integrated Luminosity for various sets of beam parameters according to Peak Luminosities: taken RDR 500 as reference

$$\mathcal{L}_{\mathrm{int}} = \frac{\mathcal{L}_{\mathrm{peak}}}{\mathcal{L}_{\mathrm{peak,RDR500}}} \cdot \mathcal{L}_{\mathrm{int,RDR500}}$$

- Resulting numbers:

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Integrated L (fb^{-1})	188	300	500	50	55	175	375	63	68	250	500

Analysis

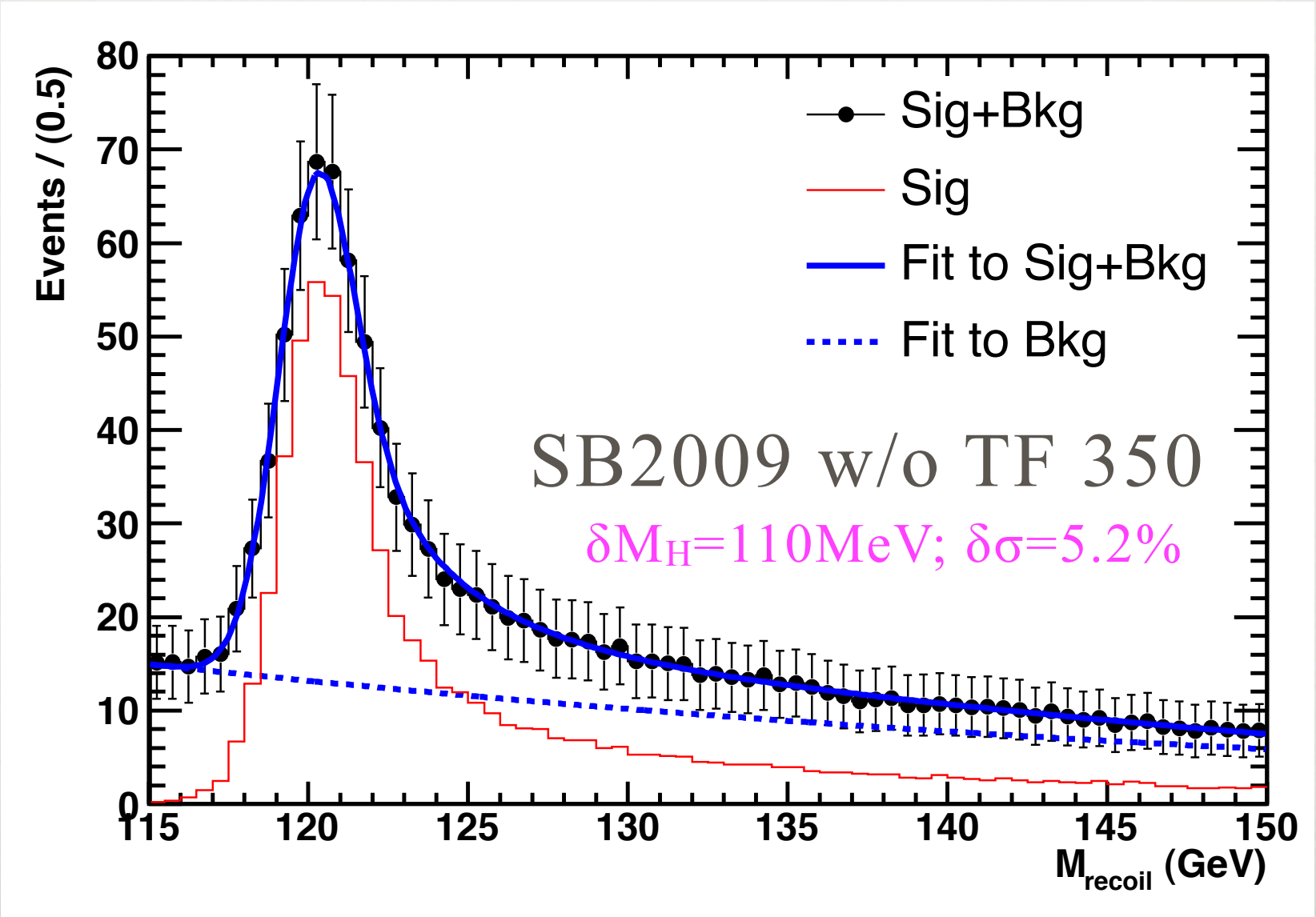
- Same analysis procedure as for the LOI:

Cut-Chain
(1) $\lvert\cos\theta_{\mu}\rvert < 0.99$
(2) $P_{Tdl} > 20$ GeV
(3) $M_{dl} \in (80,\ 100)$ GeV
(4) $acop \in (0.2,\ 3.0)$
(8) $M_{recoil} \in (115,\ 150)$ GeV
(9) Likelihood Further Rejection (using variables P_{Tdl}, $\cos\theta_{dl}$, M_{dl} and $acol$)

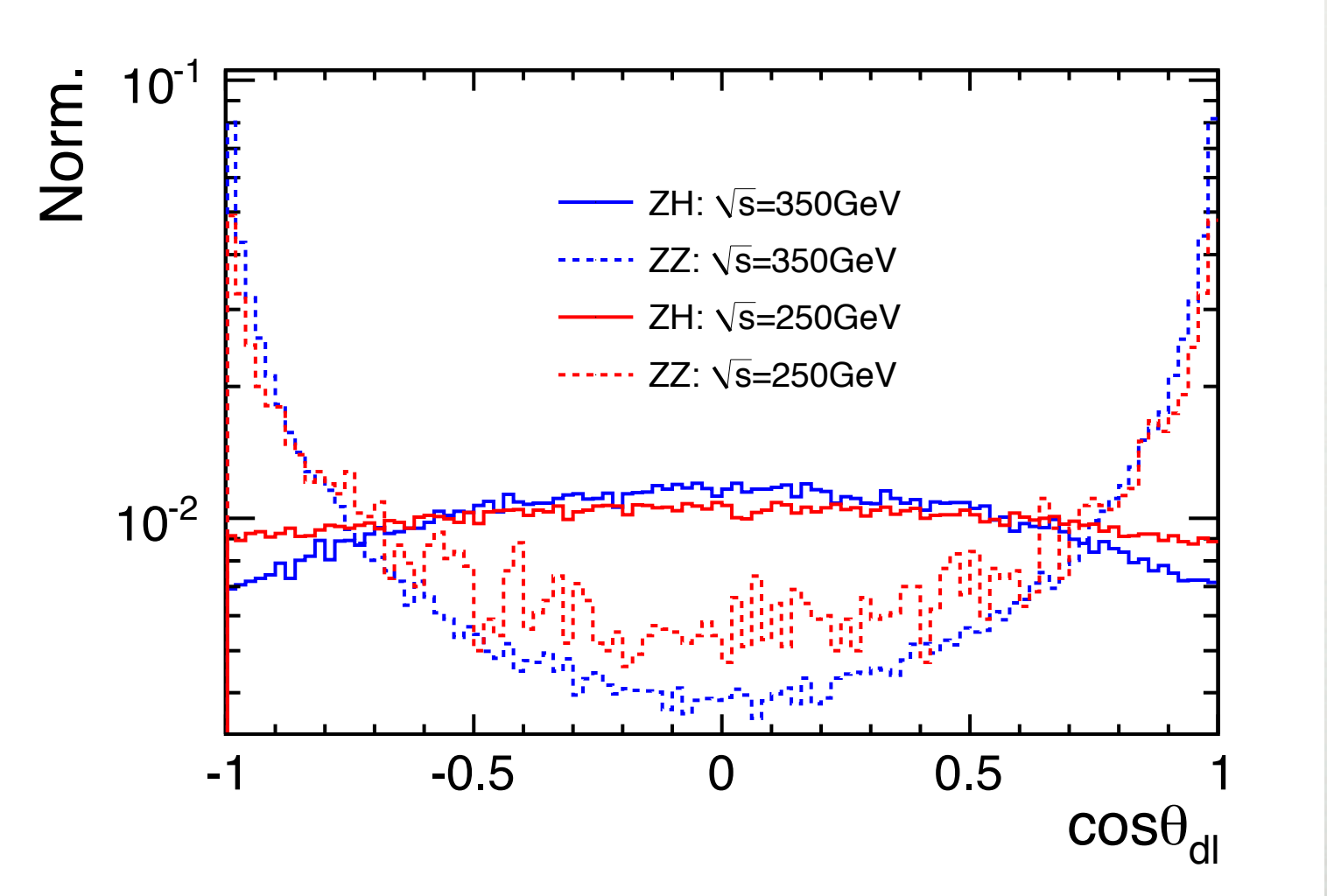
- Numbers of signal and bkgs: Ecm=350GeV

Reactions	$ZH \to \mu\mu X$	ZZ	WW
$N_{initial}$	1248	29k	61k
$N_{selected}$	633	658	30

Analysis


Events / (0.5)
80
70
60
50
40
30
20
10
0
115
120
125
130
135
140
145
150
M_{recoil} (GeV)
Sig+Bkg
Sig
Fit to Sig+Bkg
Fit to Bkg
SB2009 w/o TF 350
δM_H=110MeV; $\delta\sigma$=5.2%

BKG suppression



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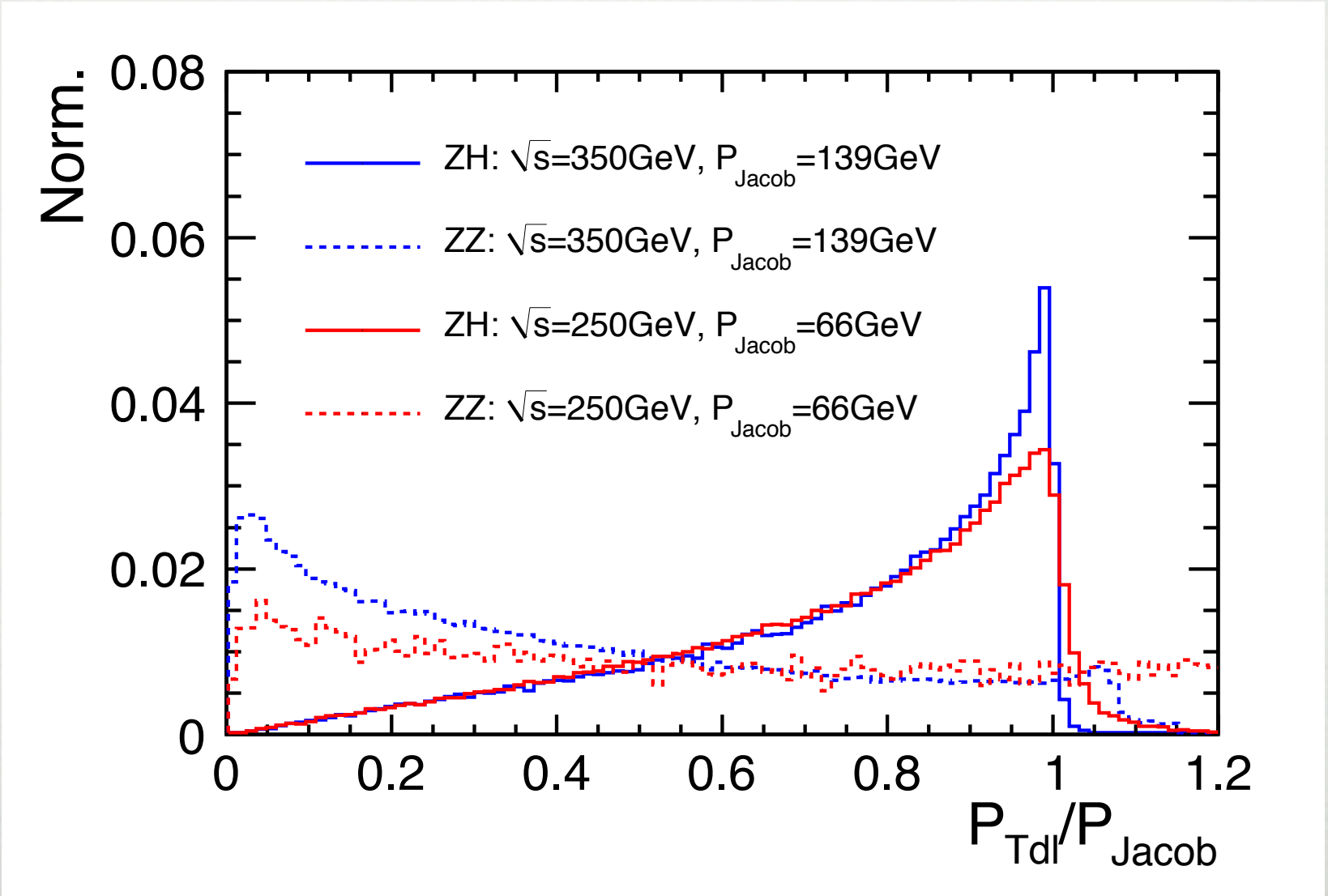

Higgs Recoil Mass 250 vs 350