National University
The Graduate University
for Advanced Studies [SOKENDAI]

Optimization Study

Impact on the Radius of TPC

LCTPC-Japan
T.Ogawa 2014.

Motivation

1. Small ILD.

— ECAL group wants to reduce the radius of calorimeter to 1600 mm or 1400 mm.

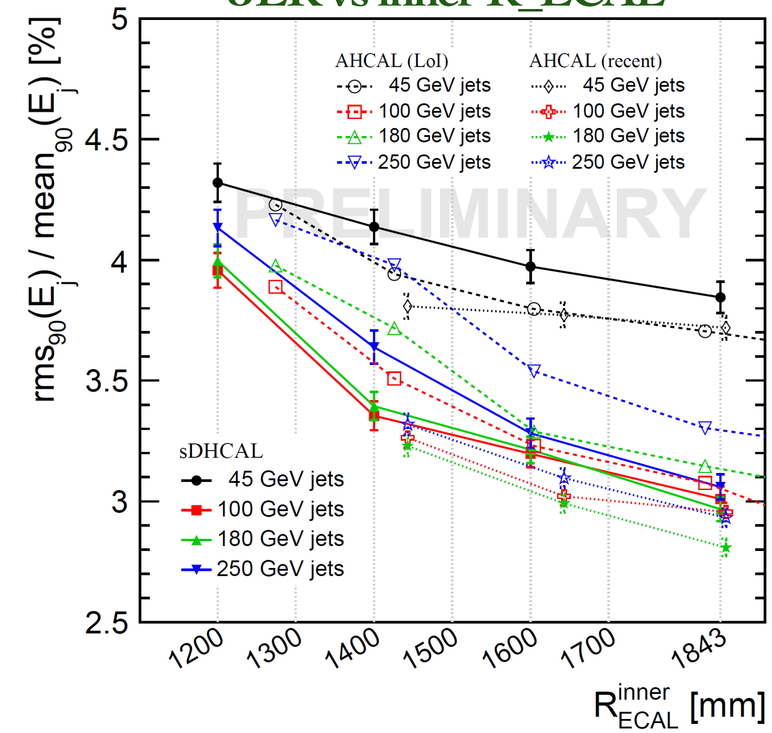
to reduce the high cost of SiECAL

— In that case,

TPC also has to reduce the radius to about 1600 mm or 1400 mm.

Trong Hieu TRAN (LLR) @ LCWS13

JER vs inner R_ECAL



2. Our main purpose.

— ILC project exists, firstly, for high precision measurement of higgs.

— Precise measurement of **σzh** and **Mh** using recoil mass technique with l-channel

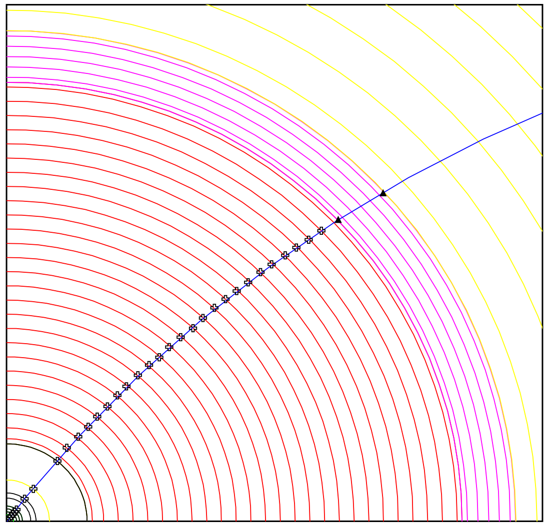
is one of the KEY measurement to study higgs.

— For precise measurement, the radius is important in terms of momentum resolution (1/L^2.5)

— With smaller radius, we will not be able to achieve the precision which we want to.

Simulation - Geometry

From Mikael(DESY) slides



1. Using SGV fast simulation, I checked detector performance or its tendency.

2. Concerning geometry.

— **Geometry of TPC is made by iteration of sensitive object.**

ILD_00
Mikael Default setting

```
LAYER       : TPC
REPEAT      : TIMES=26, DELTA_R=5.448
GEOMETRY :  R=39.5  , ZMIN=0.0, ZMAX=230.25

LAYER         : TPC-OWALL
GEOMETRY   : R=181.8 , ZMIN=0.0, ZMAX=240.25
MATERIAL     : X0=.0200082718,  A=6
MEASUREMENT : CODE=0
```

— **I changed "TIMES" to make small TPC, like 26, 24, 22, 20, ….**

DELTA_R=5.448
DELTA_Z=230.25/26~8.85

mm	Full(DBD)	Geom1	Geom2	Geom3	Geom4	Geom5	Geom6
TPC_Outer Wall R	1808	1818	1709	1600	1491	1382	1273
TPC_Outer Wall Z	2350	2403	2225	2048	1871	1694	1517

— **Same time, make geometries be small, proportionally,**
keeping thickness of geometries and empty part in default thickness.

Simulation - Condition

1. Signal and all Bkg are reconstructed using each TPC radiuses.

    — 9 processes. (Sig & SM bkg)

2. Condition.

    — √s is 250GeV (L=250fb^-1) and 350GeV (L=350fb^-1).

    — Beam polarization is (-0.8, +0.3)

3. Particle identification.

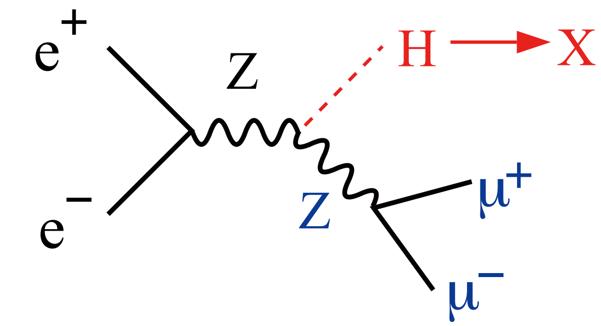
— In case of full simulation, we can apply particle identification.

⇨ Efficiency and purity of μ-ID is more than 99%.

— In case of SGV simulation, we can not apply particle identification, (apply only momentum cut).

⇨ Look MC-truth-link, take it if particle type is μ.

— Reconstruct Z (with best μ-pair) and apply γ recovering (cosθ > 0.9992).



Only Signal

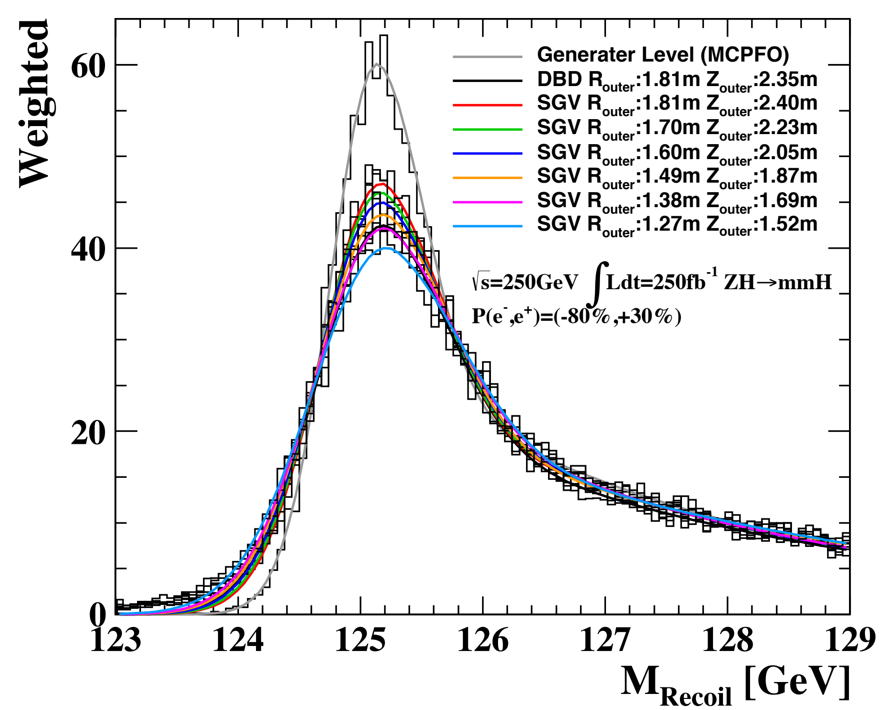
σ_{reso} from contribution of beam and detector .

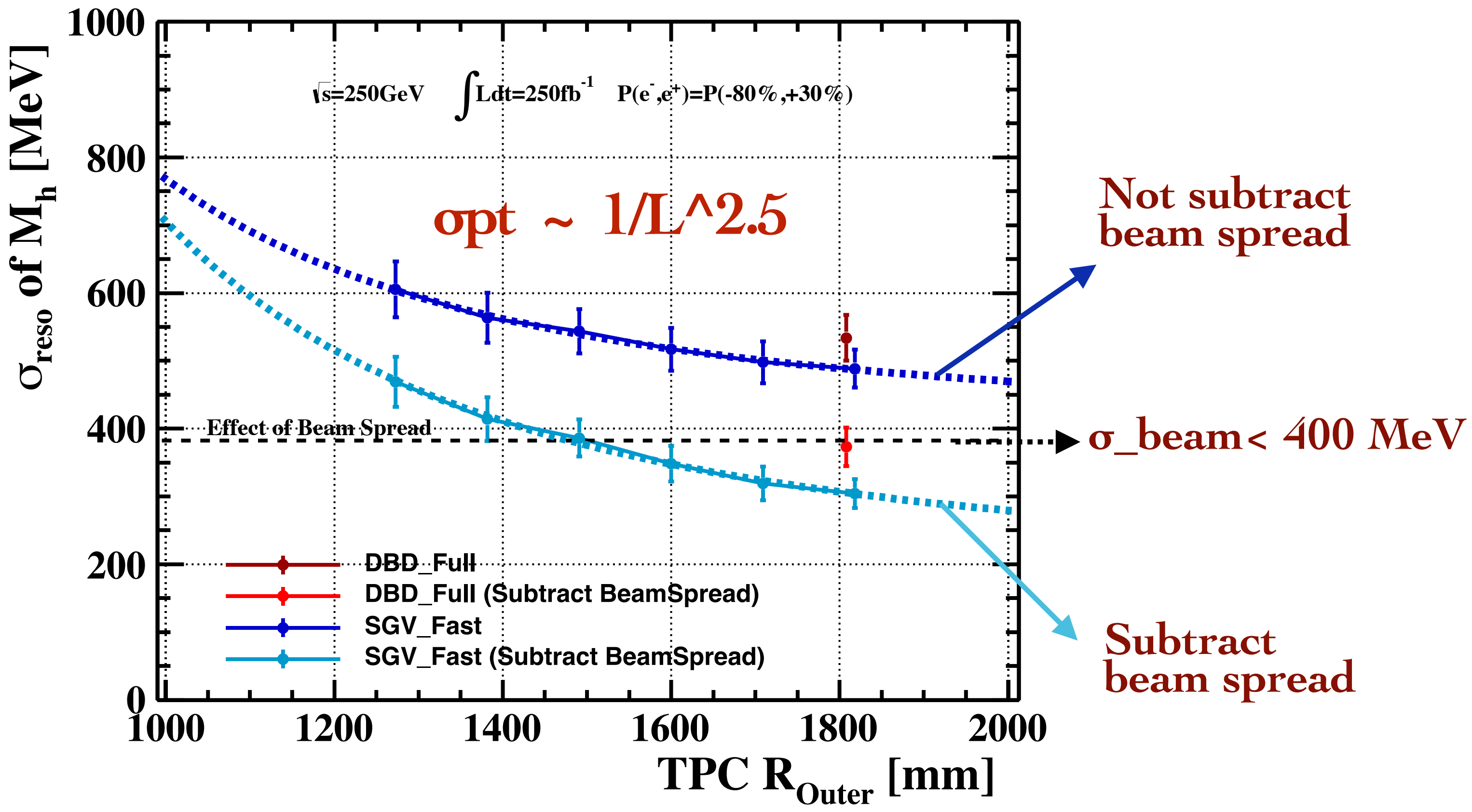
Detector Resolution √s=250GeV

1. **Contributions from the beam spread and the uncertainty of detector response.**

   ➪ **σ_reso^2 = σ_beam^2 + σ_detector^2**

Fit only sharper region withGPET





— σ_detector (detector contribution) is 300 MeV (at TPC outer R 1.8 m).
400 MeV (at TPC outer R 1.4 m).

➪ Resolution degrades ~ 33 % (R: 1.8 m ⇒ 1.4 m).

— Include beam spread.

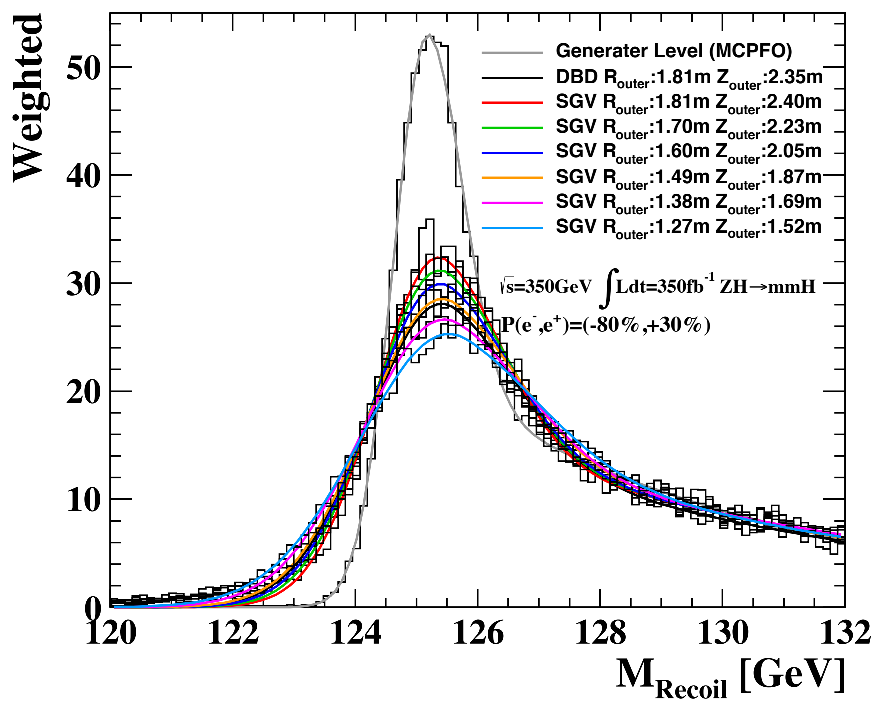
➪ **Resolution degrades ~ 10 % (R: 1.8 m ⇒ 1.4 m).**

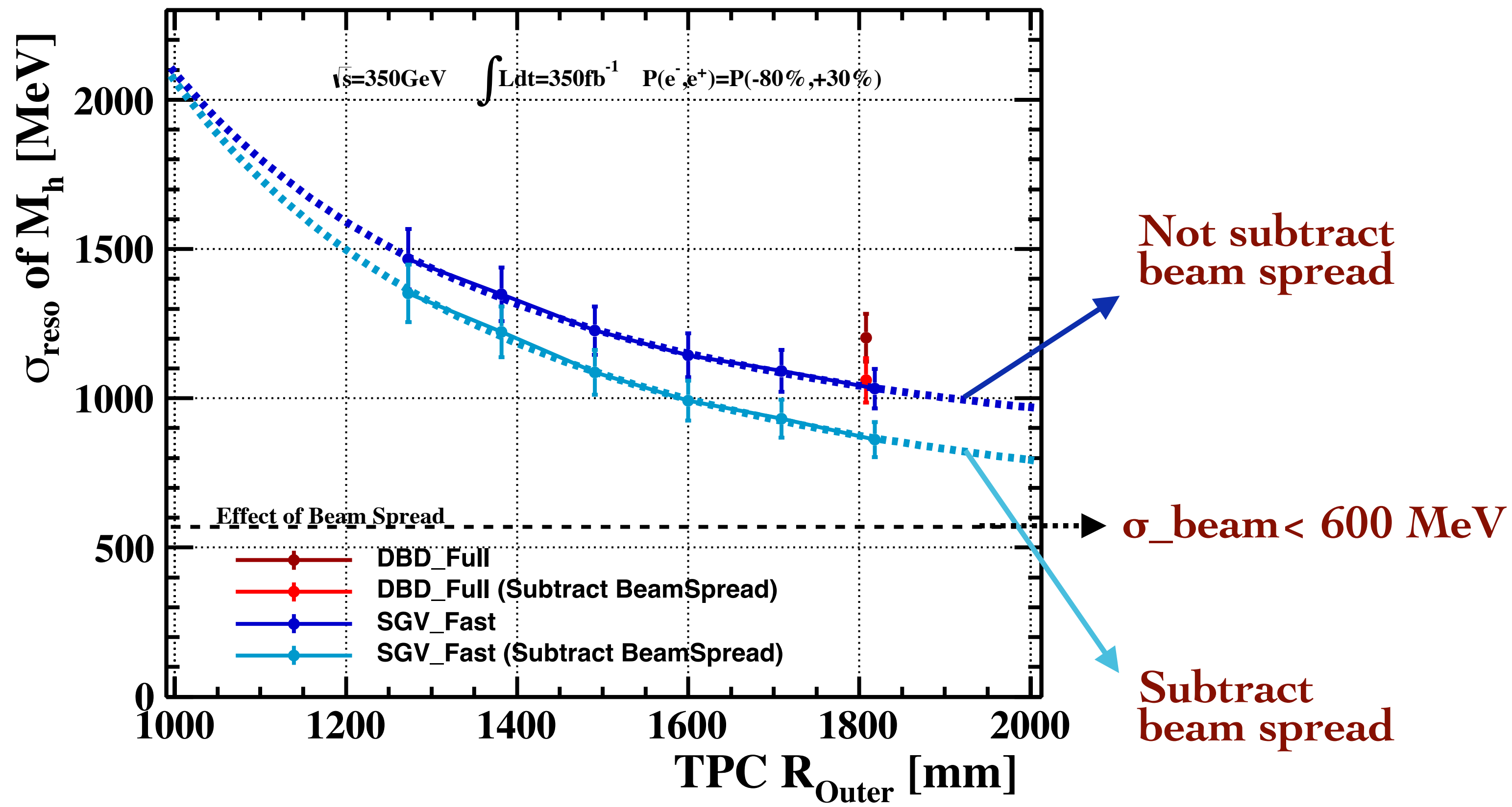
Detector Resolution √s=350GeV

1. Contributions from the beam spread and the uncertainty of detector response.

   ➪ σ_reso^2 = σ_beam^2 + σ_detector^2

Fit only sharper region withGPET





— σ_detector (detector contribution) is 850 MeV (at TPC outer R 1.8 m).
1200 MeV (at TPC outer R 1.4 m).

➪ Resolution degrades ~ 41 % (R: 1.8 m ⇒ 1.4 m).

— Include beam spread.

➪ **Resolution degrades ~ 25 % (R: 1.8 m ⇒ 1.4 m).**

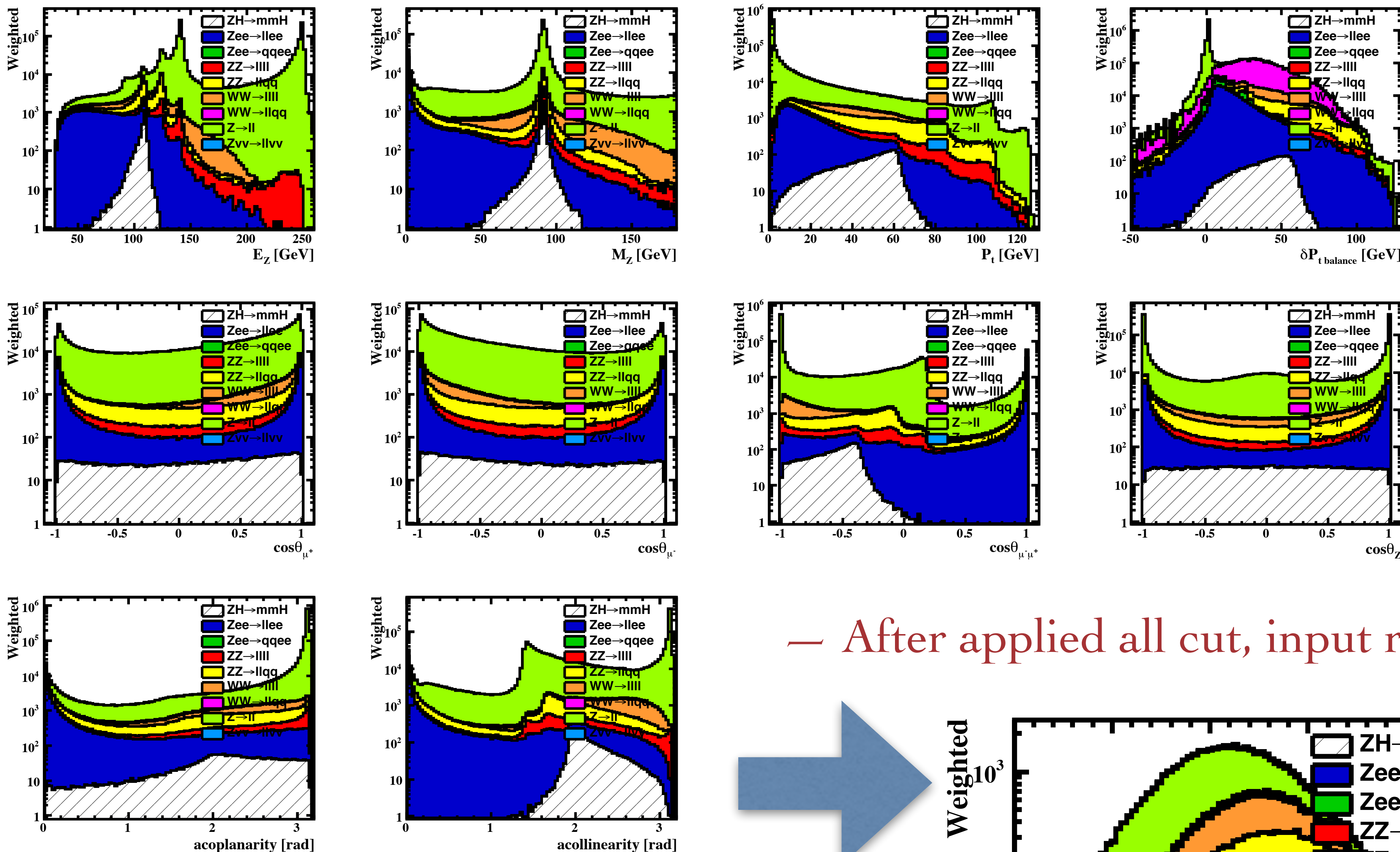
※ **Detector contribution is more dominant, compared with 250GeV.**

Together with BG

Precision of σzh and Mh.

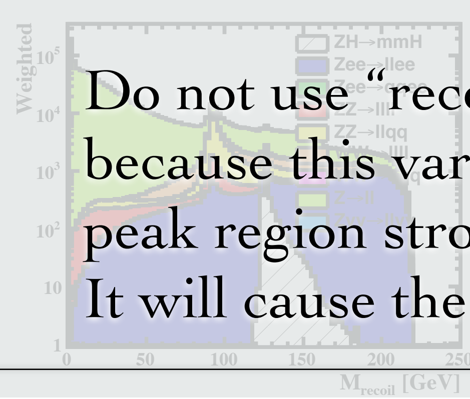
Variables to Suppress BG

1. Same cut values are applied for each detector model.



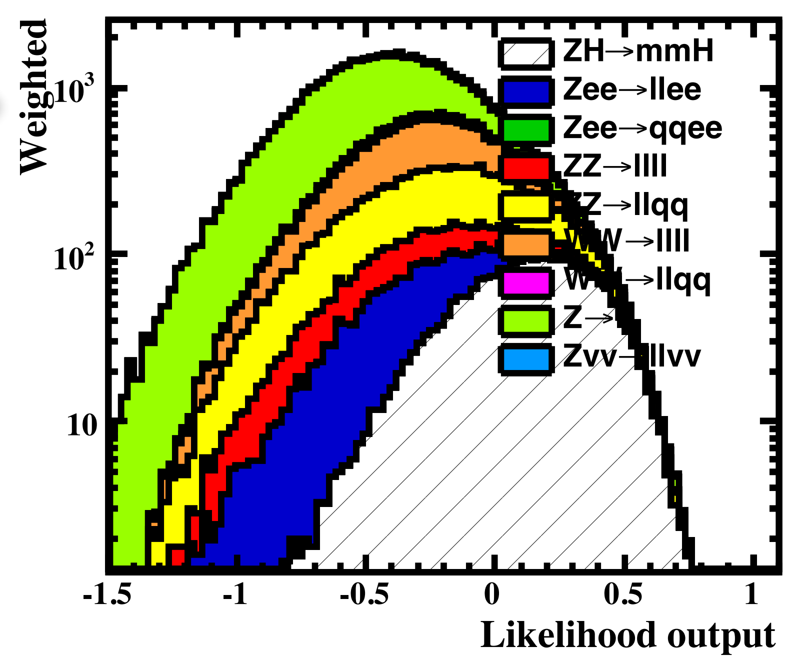
ex) 250 GeV

80 < E_Z < 120
70 < M_Z < 105
5 < P_t di-lep < 70
6 < P_t balance < 68
0.96 < fabs(cosθ_μ+ or μ-)
-0.96 < cosθ_μμ < -0.25
0.96 < fabs(cosθ_Z)
3.00 < acoplanarity
1.70 < acollinearity < 3.05



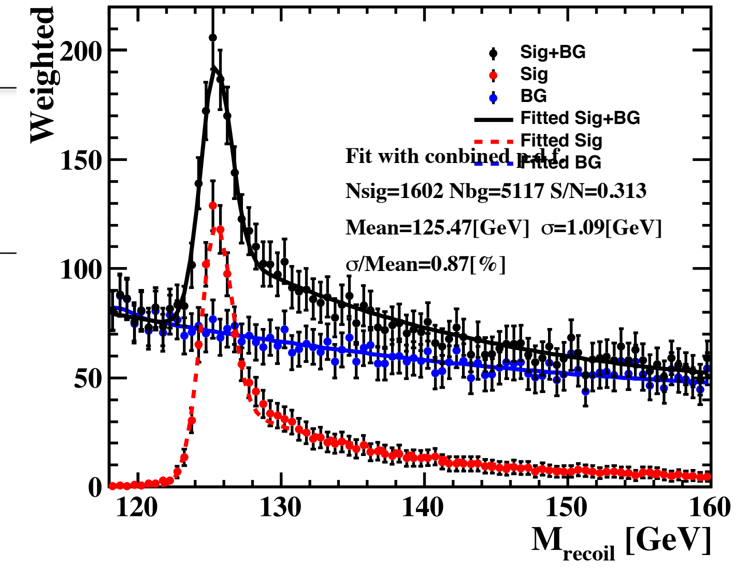
Do not use "recoil",
because this variable effects on
peak region strongly.
It will cause the bias of estimation.

— After applied all cut, input remaining events to MVA



Change
L output parameter
from -0.8 to 0.2

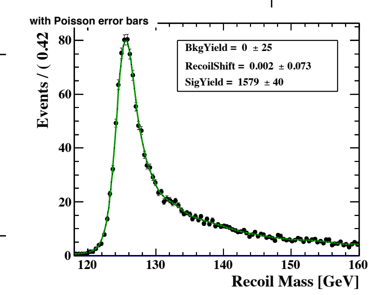
Fitting Functions

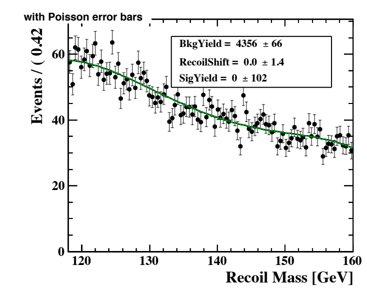


1. GPET(sig) + 4th Pol(bkg).

- Normalize Sig events to 1, and also Bkg.
- Fit Sig with GPET and Bkg with 4th Poly, respectively, to determine the shape of distributions.
- Combine two functions and make all parameters (except mean of gaussian) fix, and add two parameters ,"Yield-Sig", "Yield-Bkg" to combined function.

⇨ **Combined p.d.f. = YieldSig * GPET + YieldBkg * 4thPoly.**



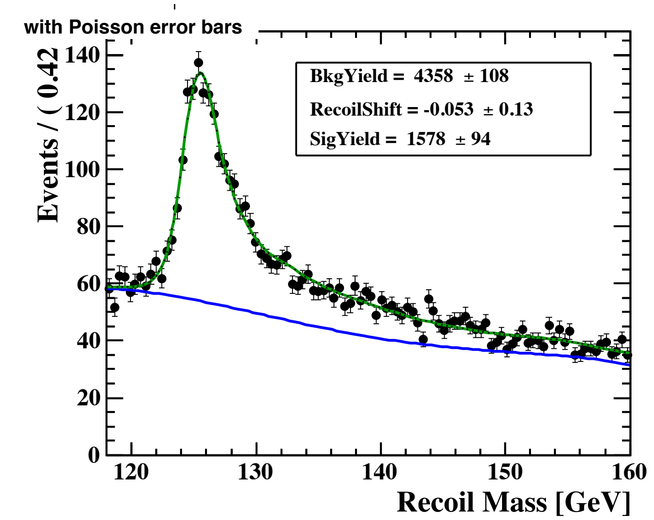


2. Kernel(sig) + 4th Poly(bkg).

Kernel is

From RooFit manual

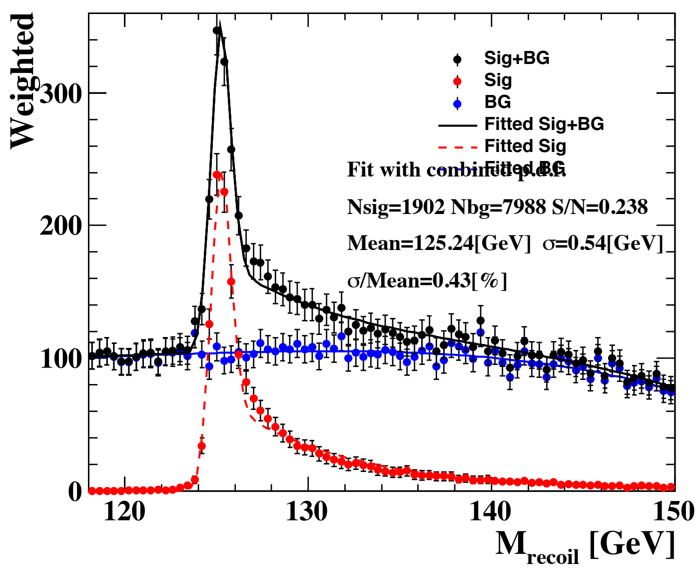
```
RooAddPdf model("model","model",RooArgList(sig,bkg),RooArgList(nsig,nbkg))

// shape: model(x) = nsig/(nsig+nbkg)*sig(x) + nbkg/(nsig+nbkg)*bkg(x)
// norm:  Nexpect  = nsig + nbkg

// Combined: Nexpect*model(x) = nsig*sig(*x) + nbkg*bkg(x)
```



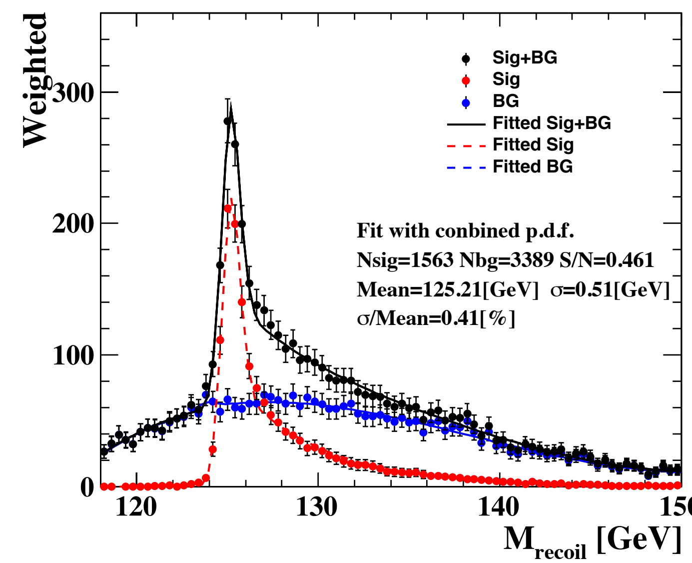
GPET(sig) + 4th Poly(bkg) $\sqrt{s}$=250GeV

1. Typical distribution of data & combined p.d.f.

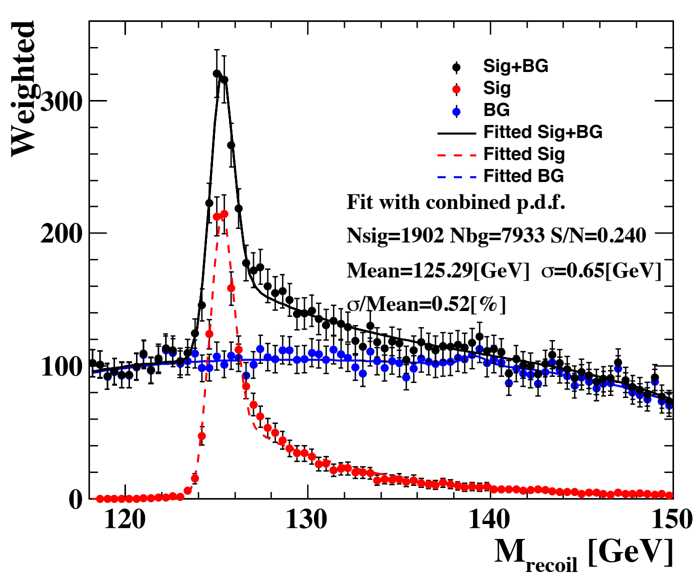
TPC Outer
Wall R_1818
Wall Z_2402
L cut = -0.72



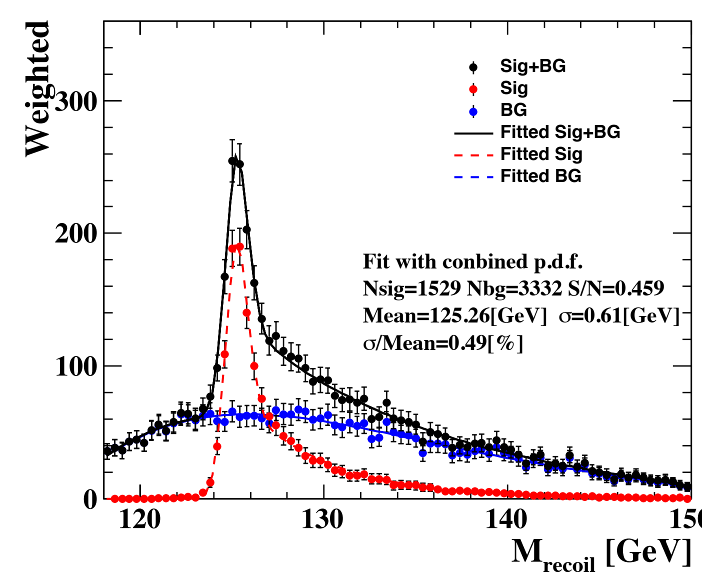
TPC
OuterR_1818
OuterZ_2402
L cut = -0.04



TPC Outer
Wall R_1382
Wall Z_1694
L cut = -0.72

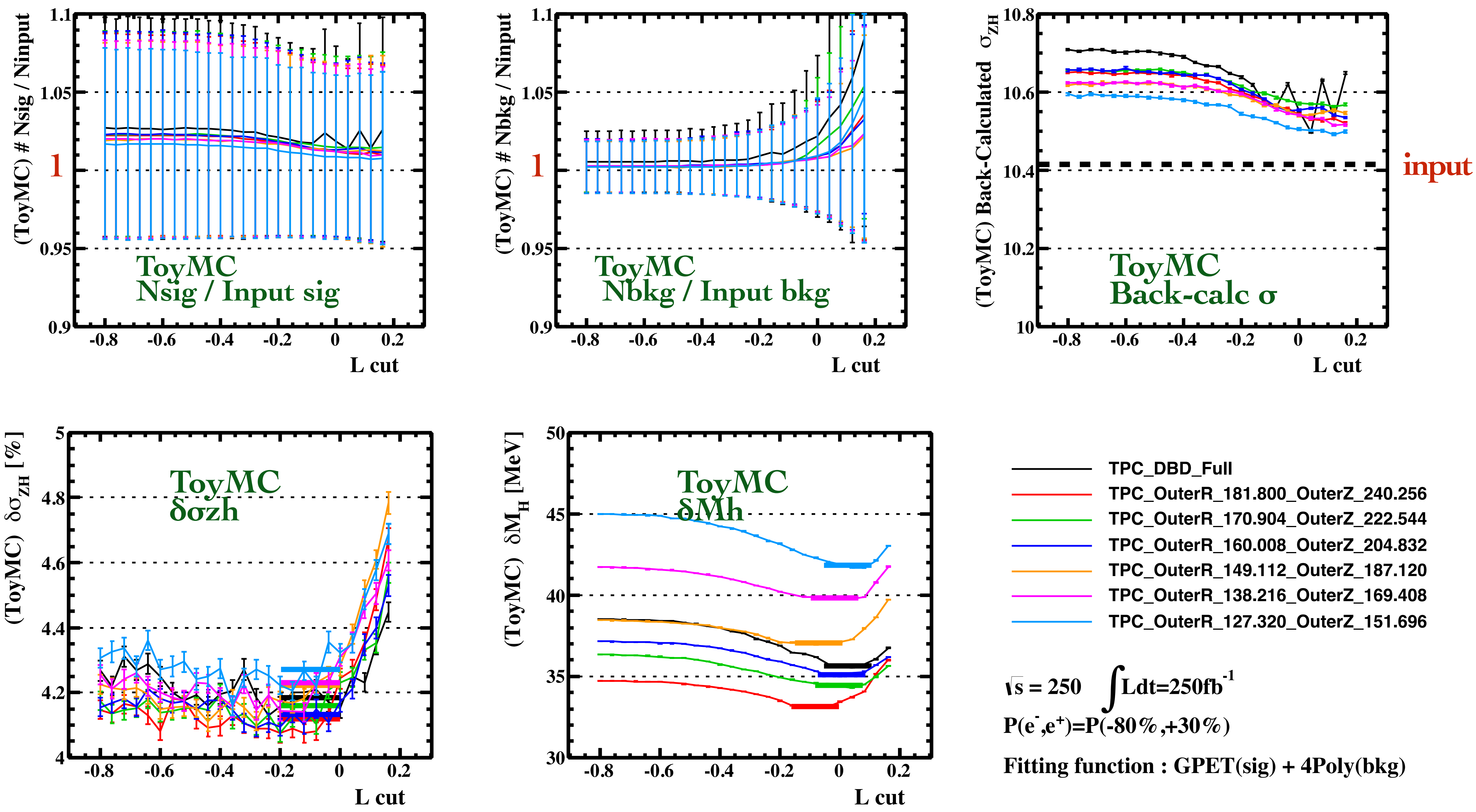


TPC Outer
Wall R_1382
Wall Z_1694
L cut = -0.04



GPET(sig) + 4th Poly(bkg) √s=250GeV

— Result from ToyMC.



Kernel(sig) + 4th Poly(bkg)   √s=250GeV

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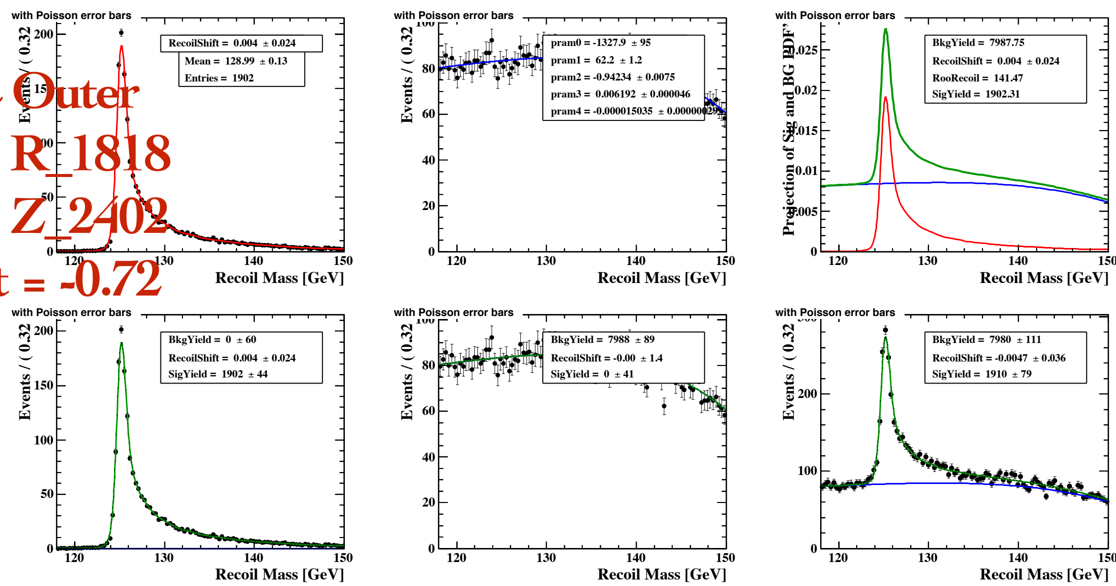

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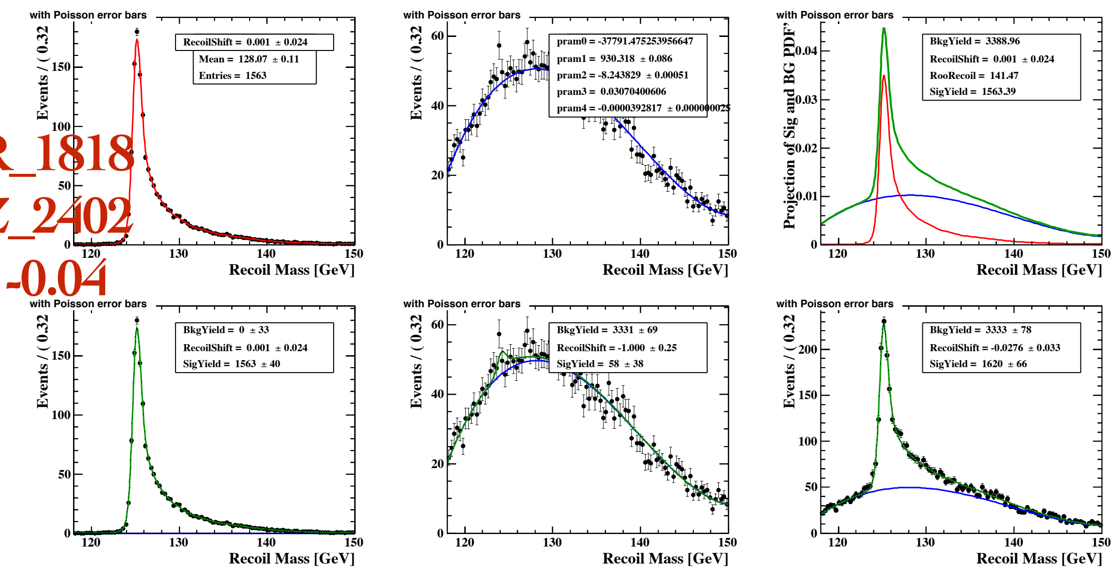

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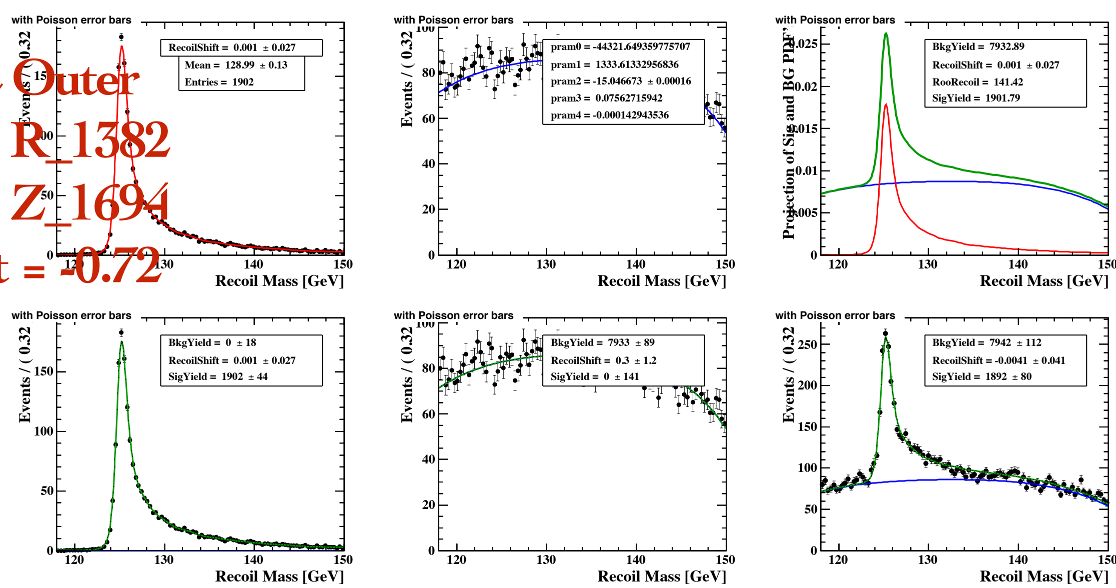

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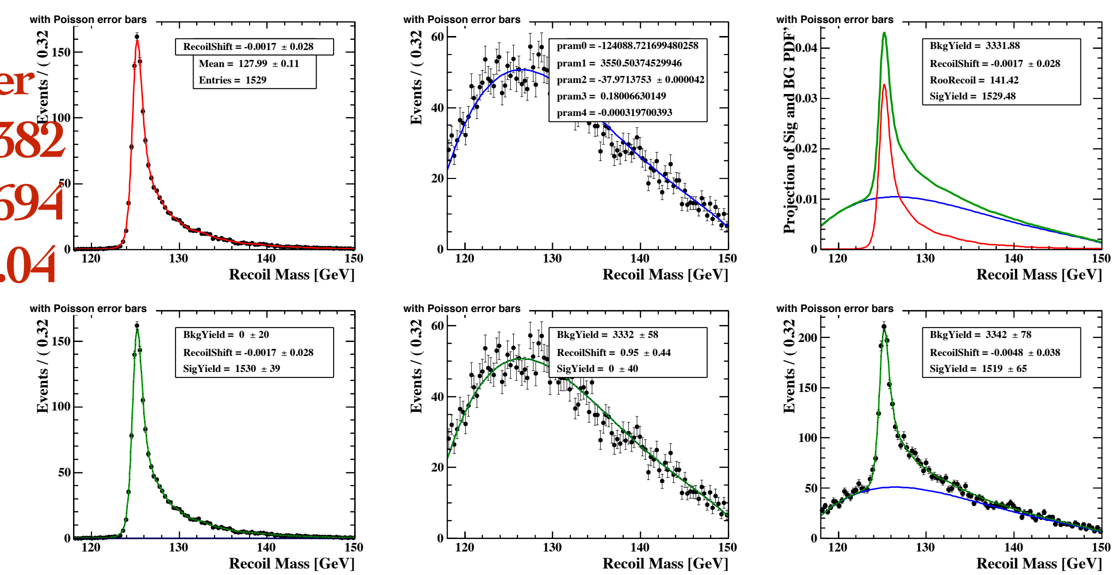

Kernel(sig) + 4th Poly(bkg) √s=250GeV

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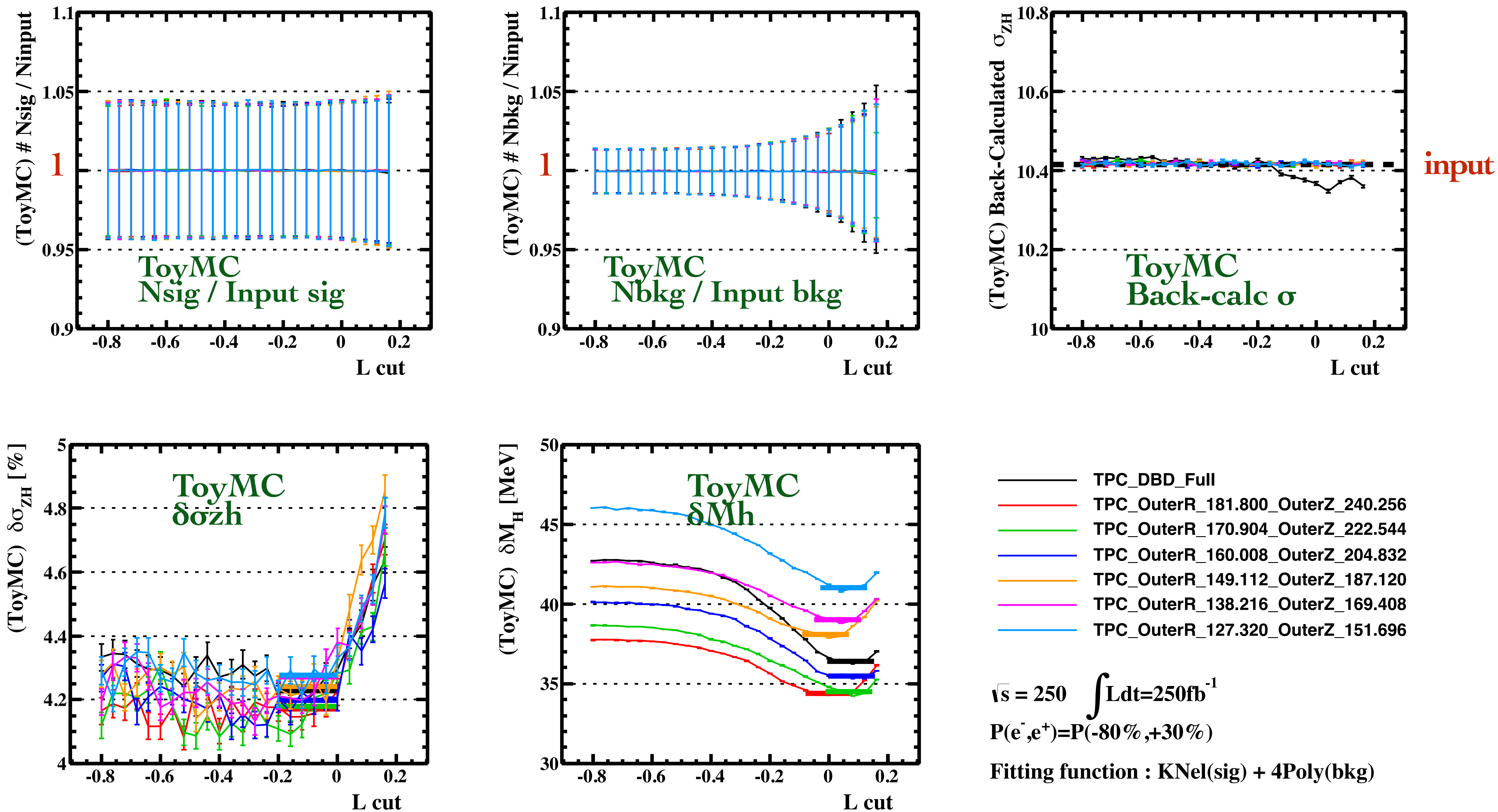
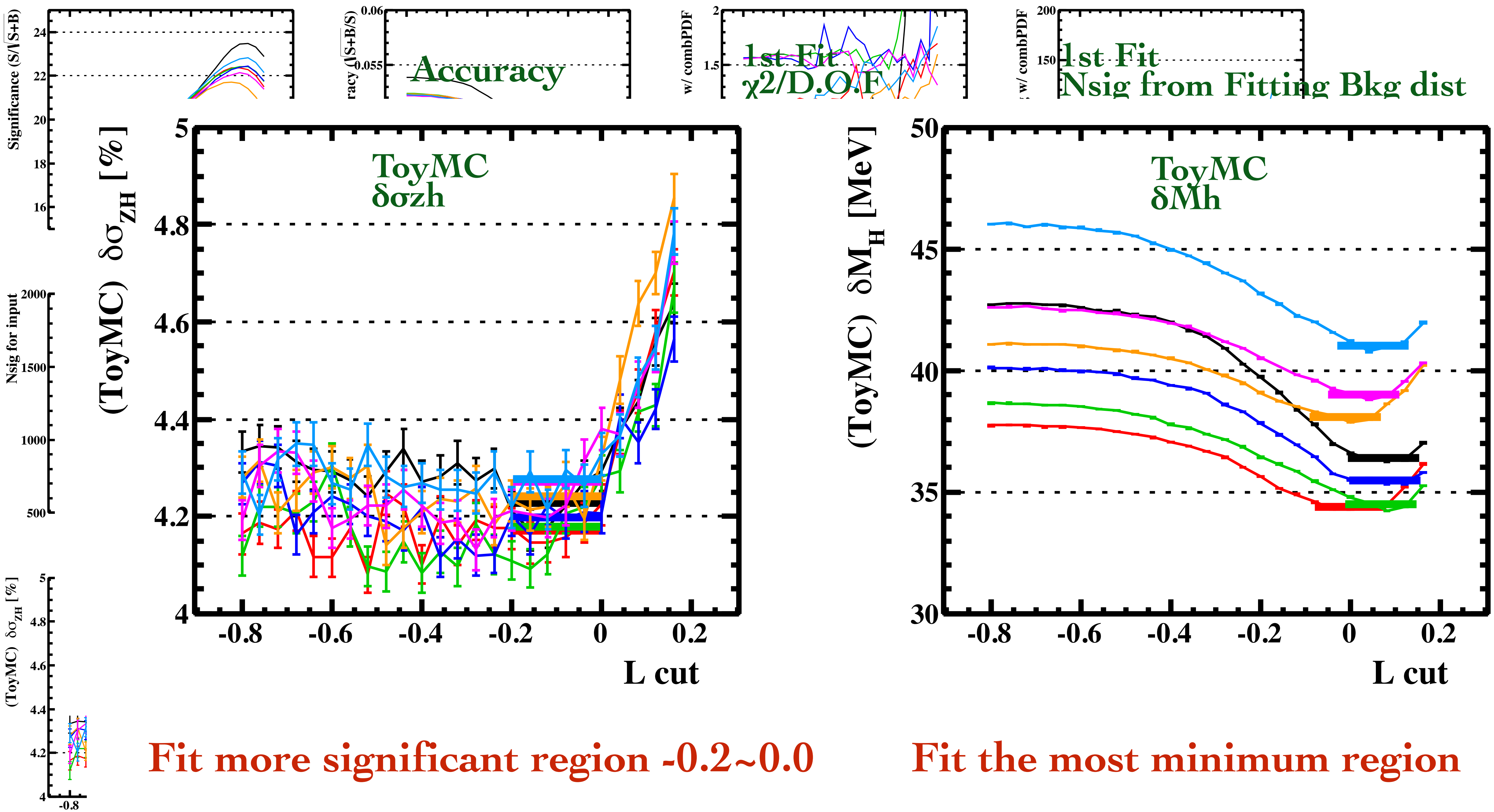


Kernel(sig) + 4th Poly(bkg) √s=250GeV

– All information from analysis.

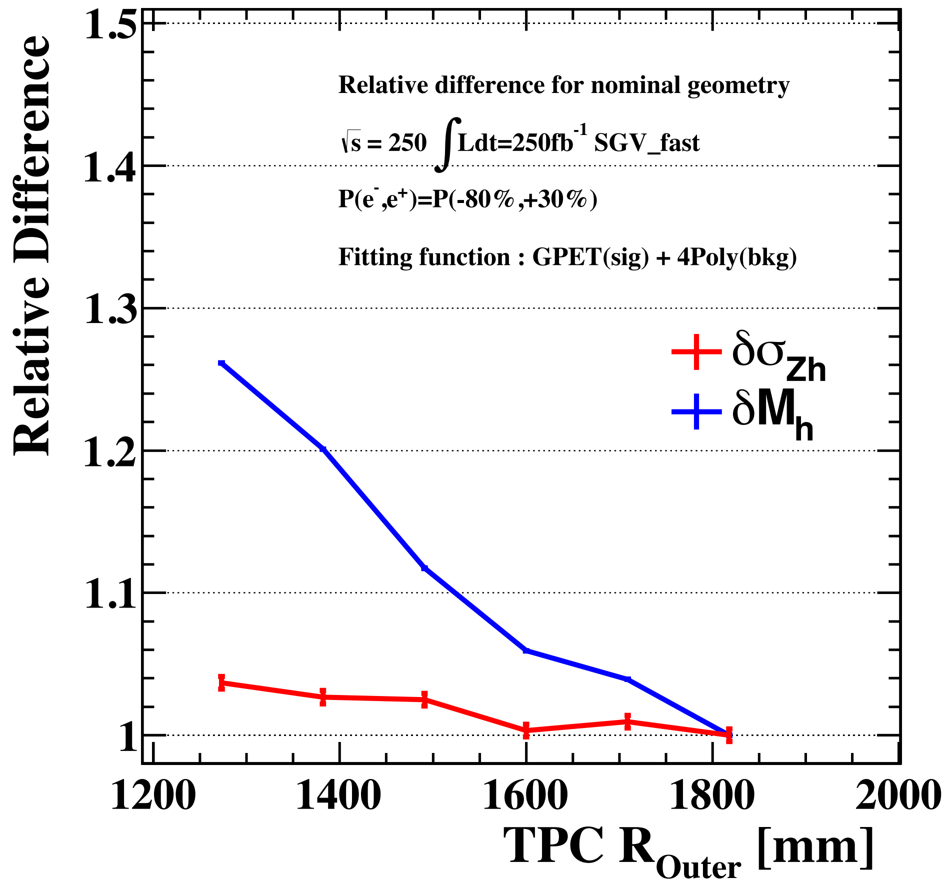


Fit more significant region -0.2~0.0

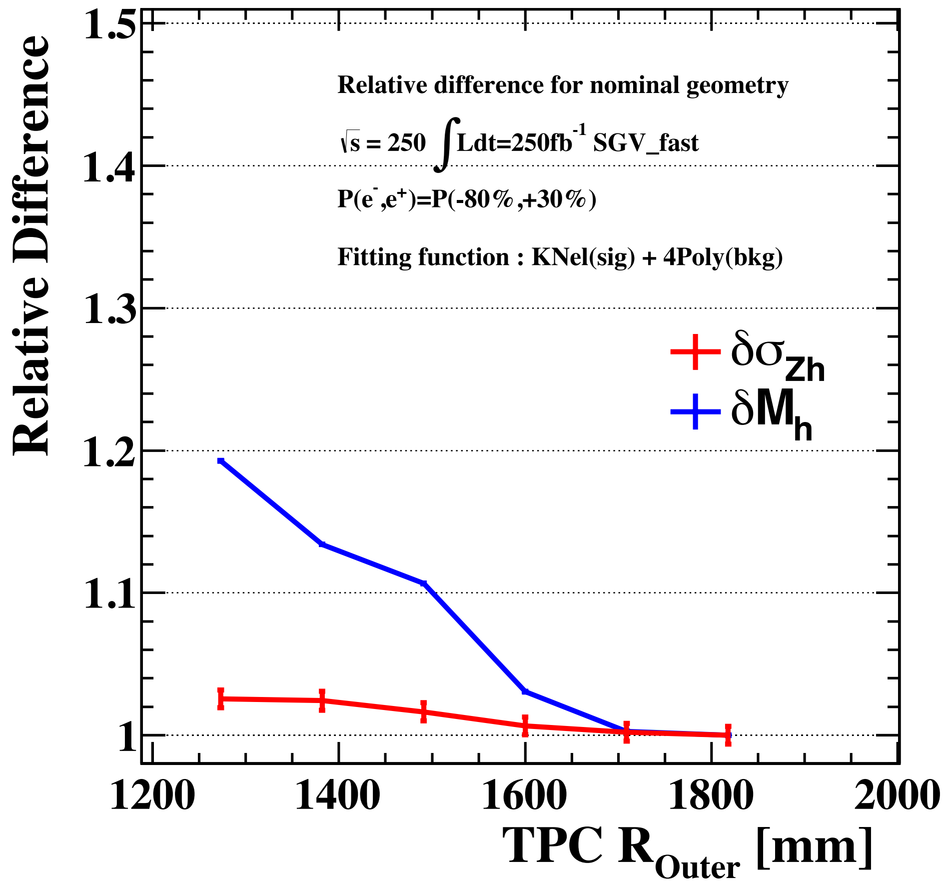
Fit the most minimum region

Relative Difference to nominal one ($\sqrt{s}$=250GeV)

– GPET(sig) + 4th Poly(bkg).



– Kernel(sig) + 4th Poly(bkg).



⇨ Kernel(sig) + 4th Poly(bkg).

- Precision of σzh degrades < 5 % (R: 1.8 m ⟹ 1.4 m)
- Precision of Mh degrades ~ 12 % (R: 1.8 m ⟹ 1.4 m)

GPET(sig) + 4th Poly(bkg) √s=350GeV

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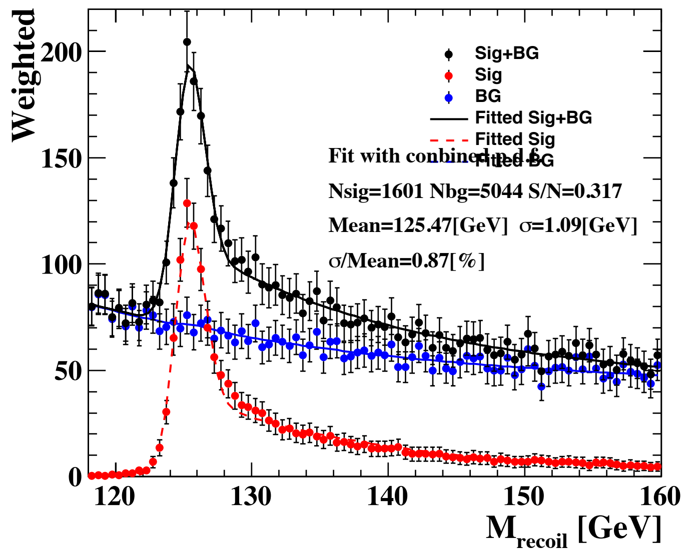

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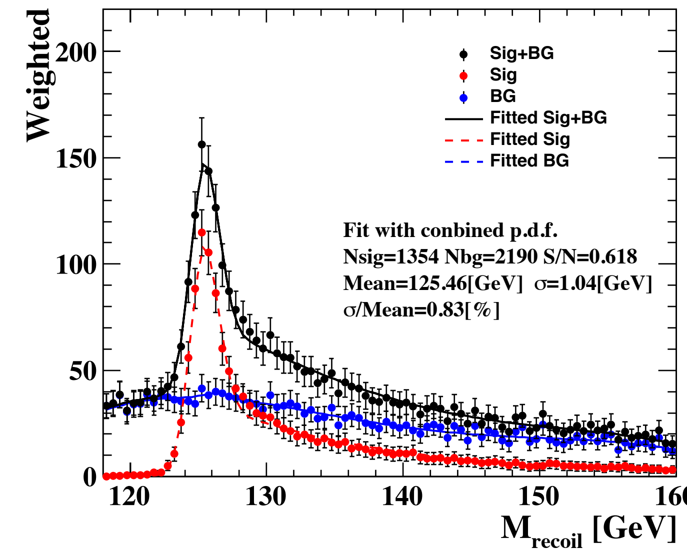

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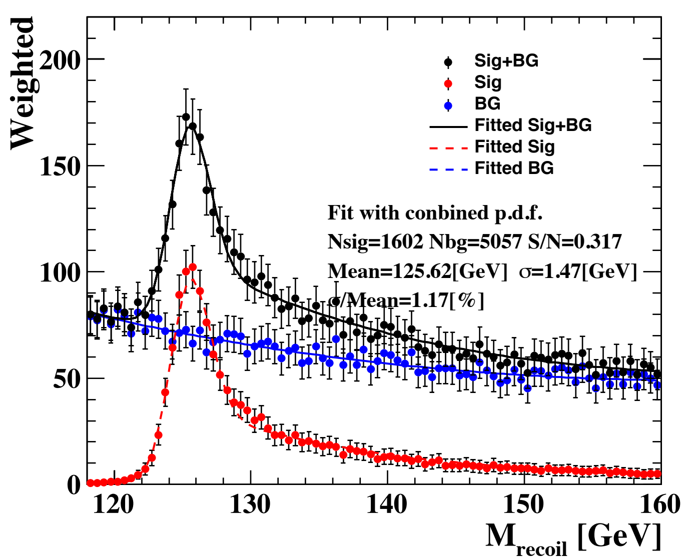

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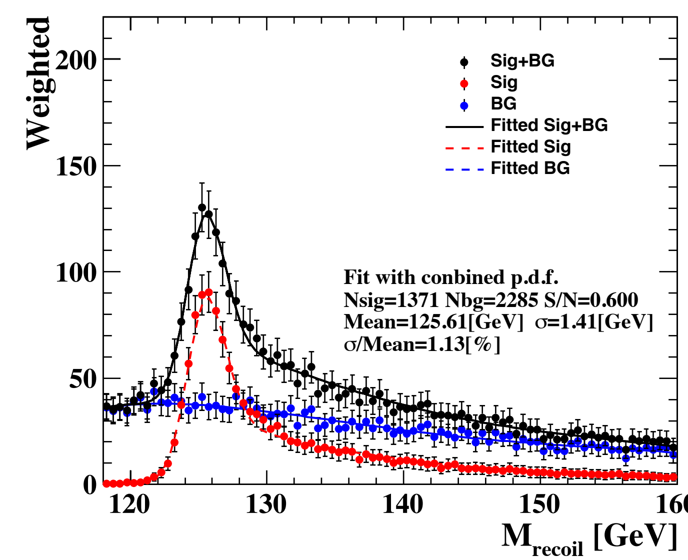
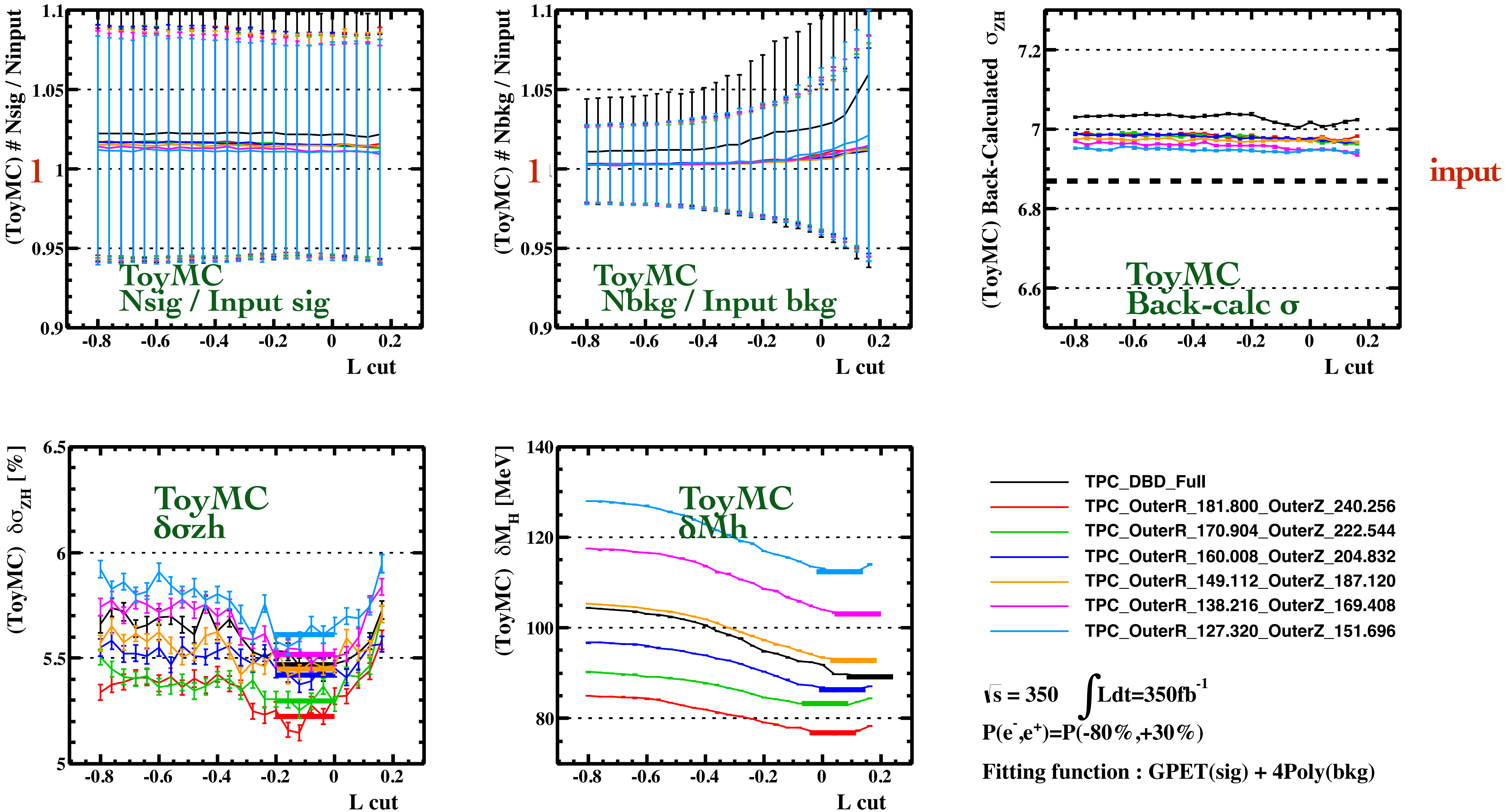


GPET(sig) + 4th Poly(bkg) √s=350GeV

– Result from ToyMC.



Kernel(sig) + 4th Poly(bkg) √s=350GeV

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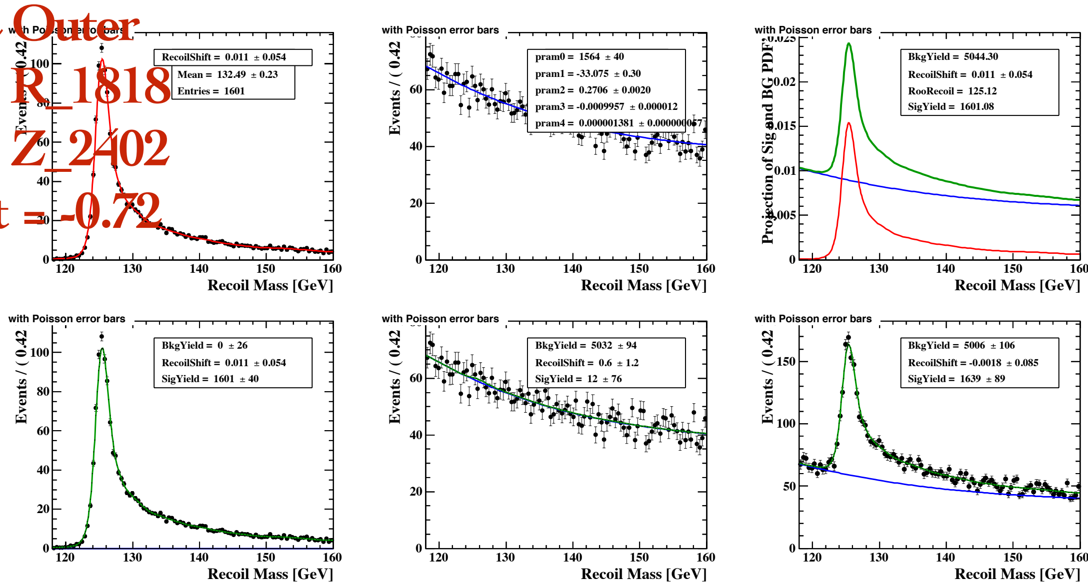

TPC
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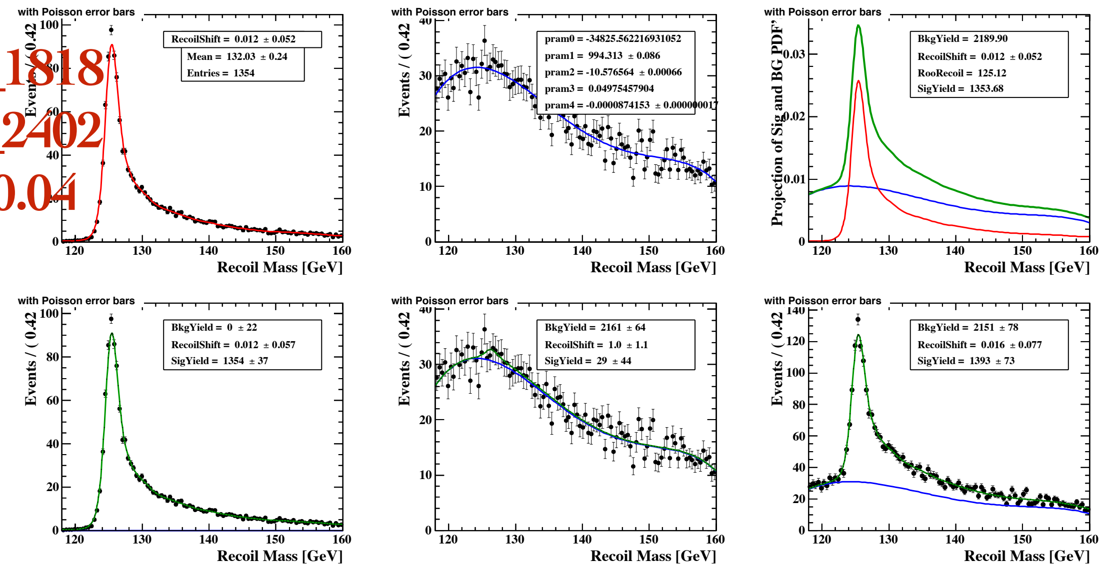

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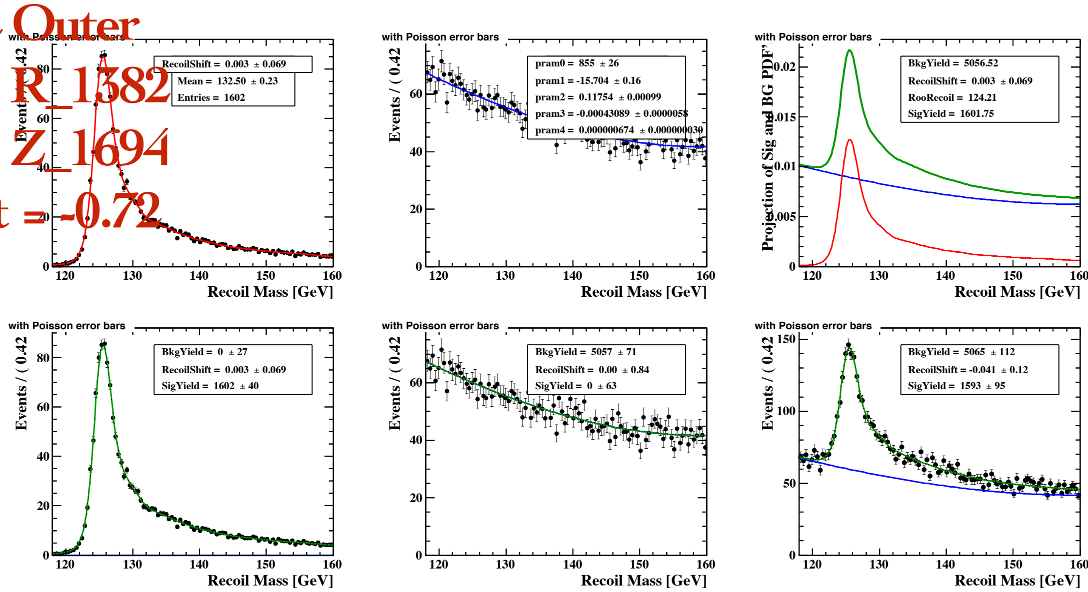

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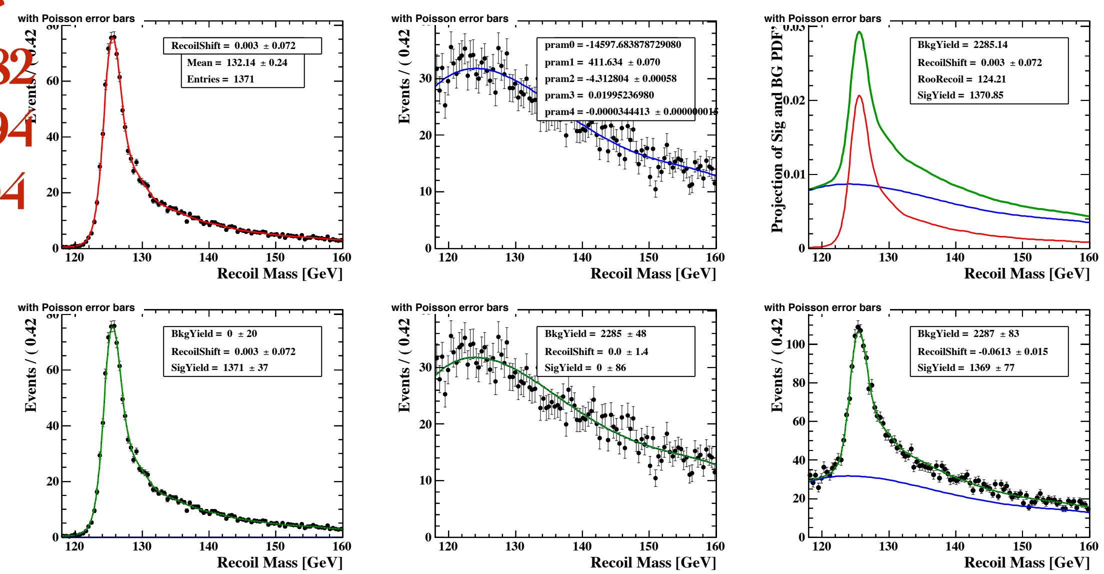

Kernel(sig) + 4th Poly(bkg) √s=350GeV

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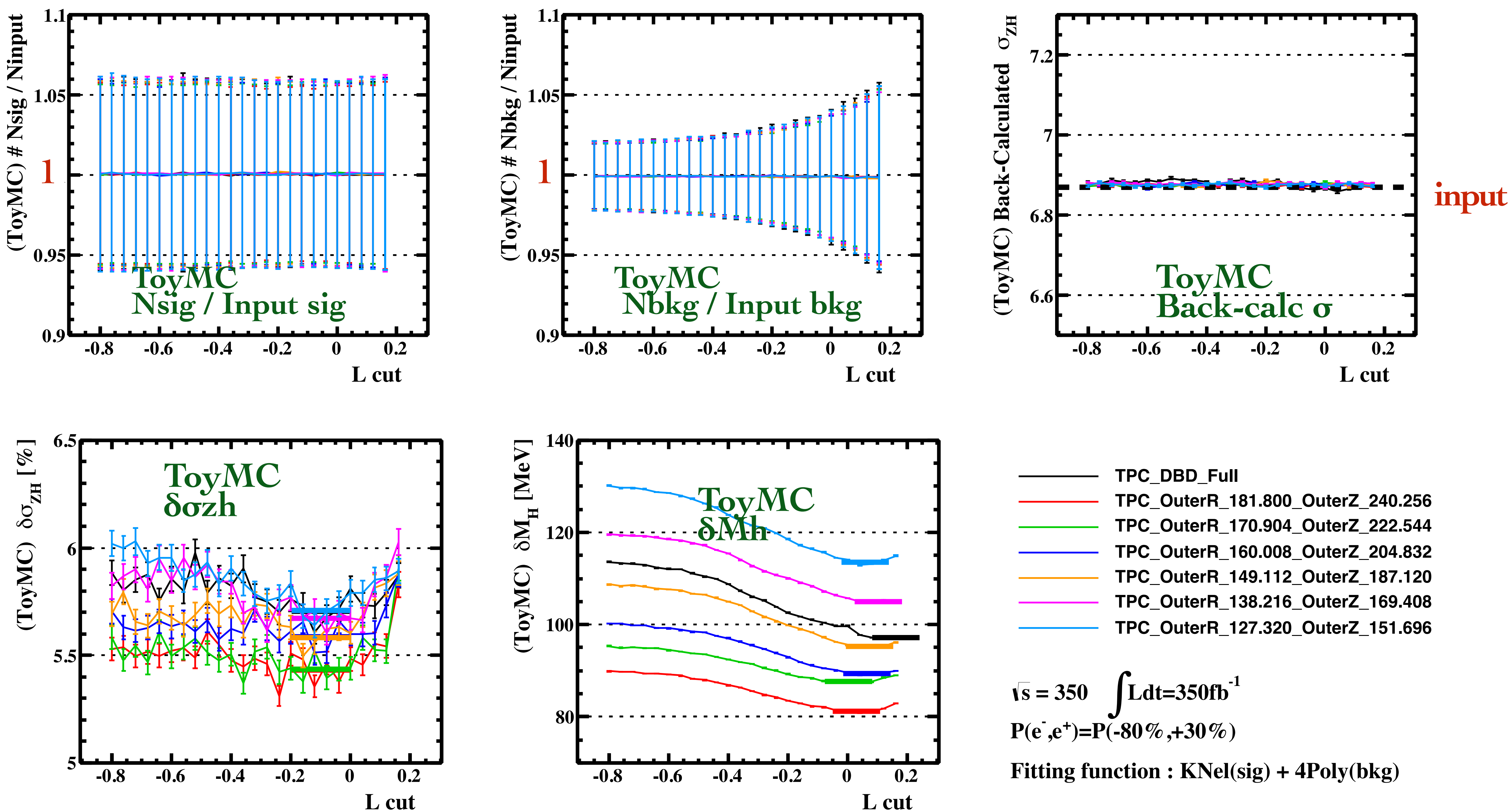

Kernel(sig) + 4th Poly(bkg) √s=350GeV

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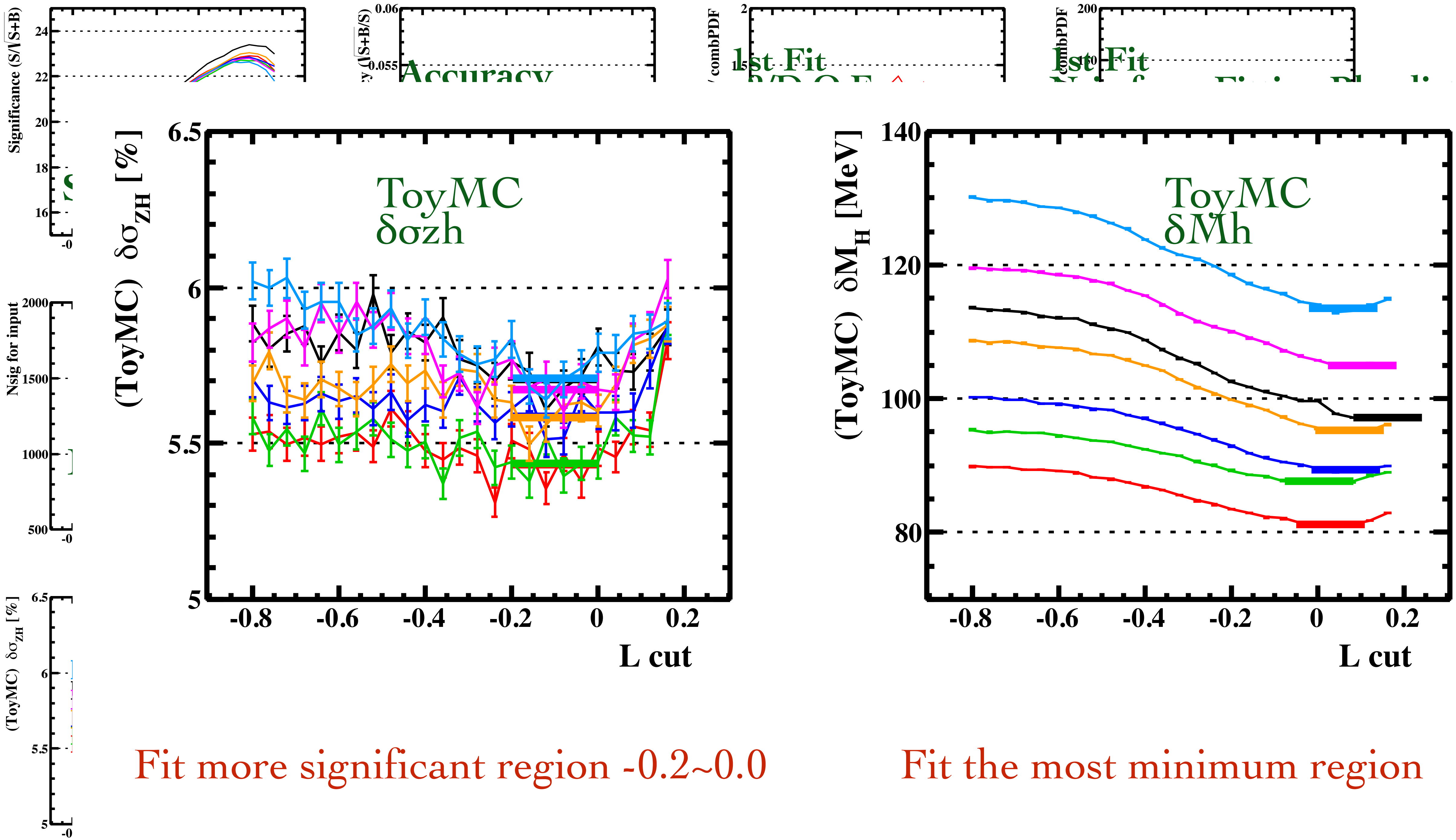
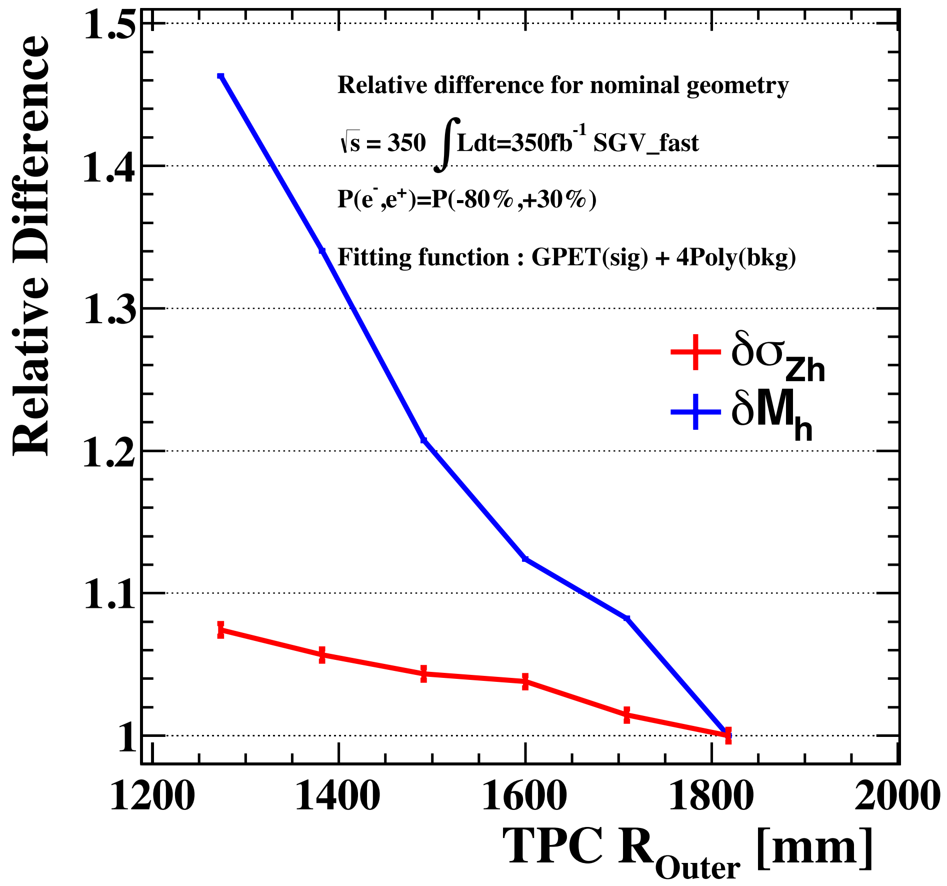


Fit more significant region -0.2~0.0

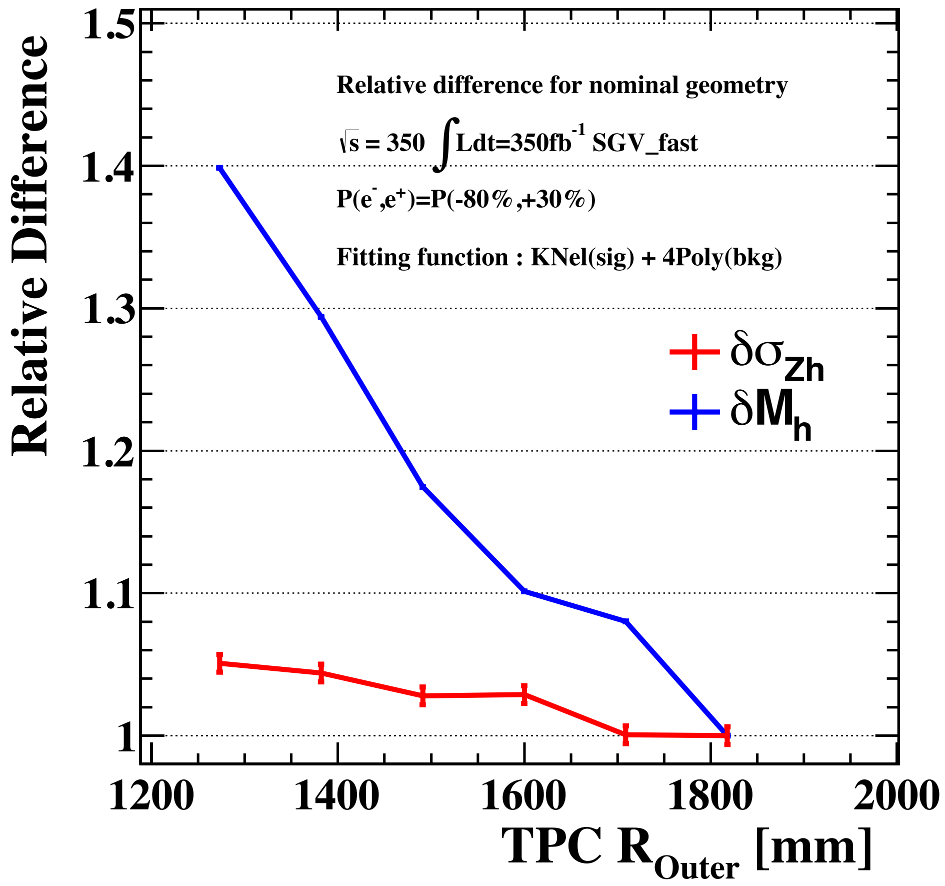
Fit the most minimum region

Relative Difference to nominal one ($\sqrt{s}$=350GeV)

– GPET(sig) + 4th Poly(bkg).



– Kernel(sig) + 4th Poly(bkg).



⇨ Kernel(sig) + 4th Poly(bkg).

- Precision of σzh degrades > 5 % (R: 1.8 m ⇒ 1.4 m)
- Precision of Mh degrades ~ 30 % (R: 1.8 m ⇒ 1.4 m)

Summary (w/ Kernel + 4th Poly) on μ-channel

1. $\sqrt{s}$=250 GeV, L=250fb^-1

⇨ If we change R: 1.8 m ⇒ 1.4 m

my DBD full-simu:
$\delta\sigma zh$ = 4.22 ± 0.02 [%], δMh = 36.4 ± 0.01 [MeV]

⇨ Detector resolution degrades	~	10 %.
⇨ Precision of σzh degrades	<	5 %.
⇨ Precision of Mh degrades	~	12 %.

2. $\sqrt{s}$=350 GeV, L=350fb^-1

my DBD full-simu:
$\delta\sigma zh$ = 5.70 ± 0.03 [%], δMh = 97.1 ± 0.03 [MeV]

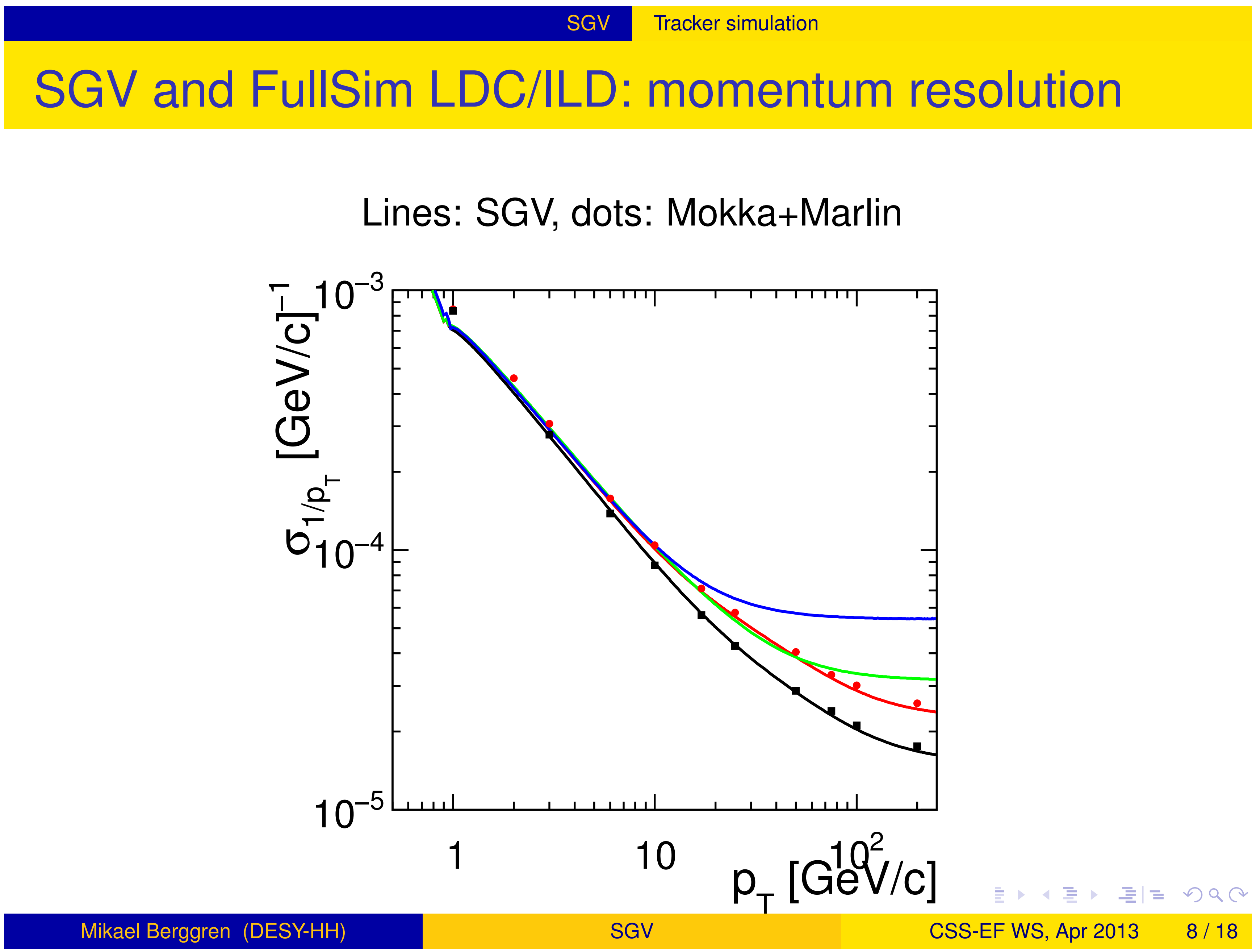
⇨ If we change R: 1.8 m ⇒ 1.4 m

⇨ Detector resolution degrades	~	25 %.
⇨ Precision of σzh degrades	>	5 %.
⇨ Precision of Mh degrades	~	30 %.

Back up

SGV momentum resolution

From Mikael(DESY) slides

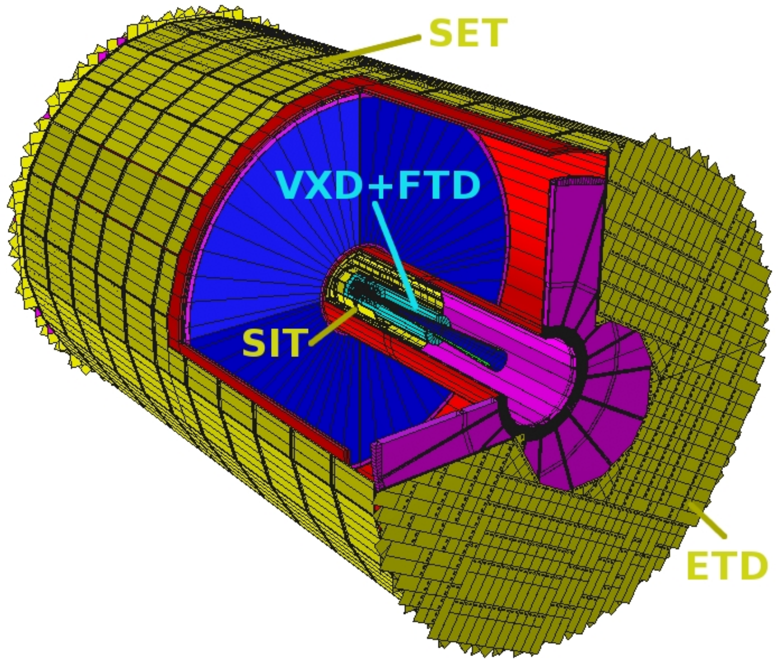


SET & ETD

The silicon part of the ILD tracking system is made of four components:
two barrel components, the Silicon Inner Tracker (SIT) and the Silicon External Tracker (SET),
one end cap component behind the endplate of the TPC (ETD), and the forward tracker (FTD). They form the Silicon Envelope [31].

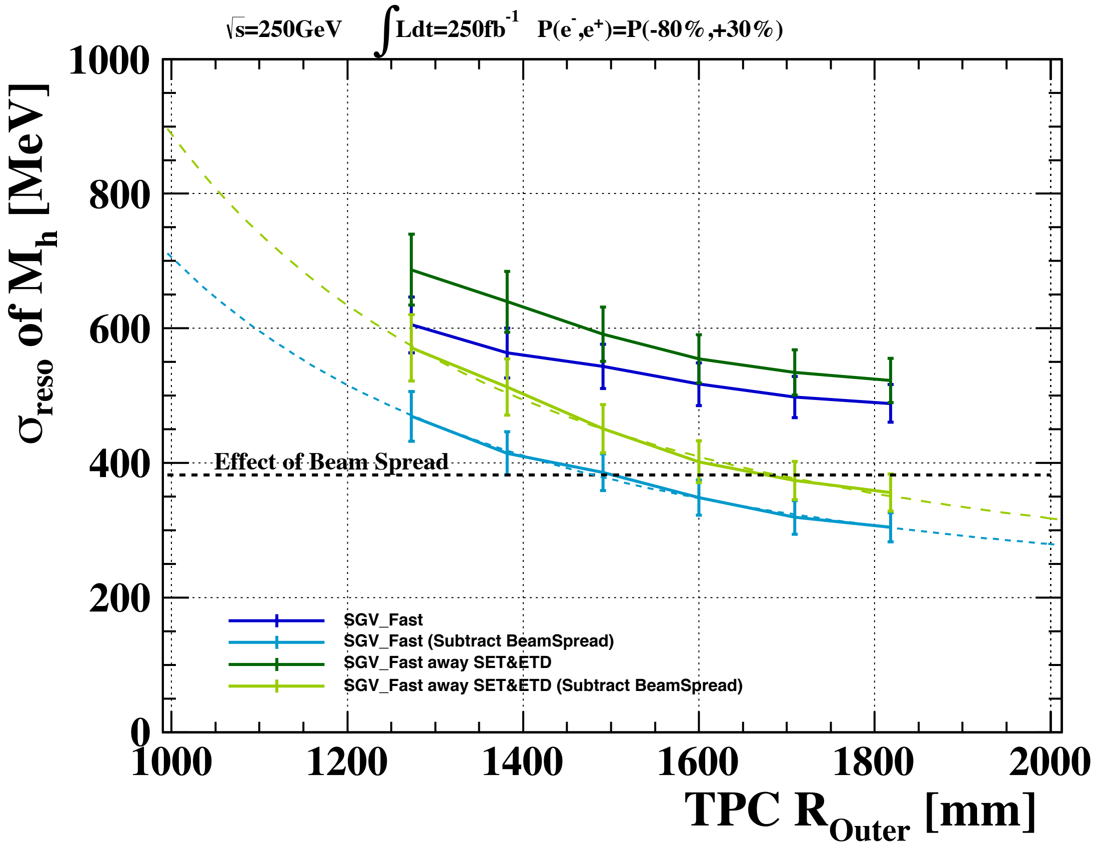
The barrel silicon parts SIT and SET provide precise space points before and after the TPC;
this improves the overall momentum resolution, helps in linking the VTX detector with the TPC,
and in extrapolating from the TPC to the calorimeter.
The coverage of the TPC with silicon tracking is completed by the ETD,
located within the gap separating the TPC and the end-cap calorimeter.
Together these systems help in calibrating the overall tracking system, in particular the TPC.
The good timing resolution of the silicon detectors relative to the time
between bunches in the ILC together with the high spatial precision helps
in time-stamping tracks and assigning them to a given bunch within an ILC bunch train.

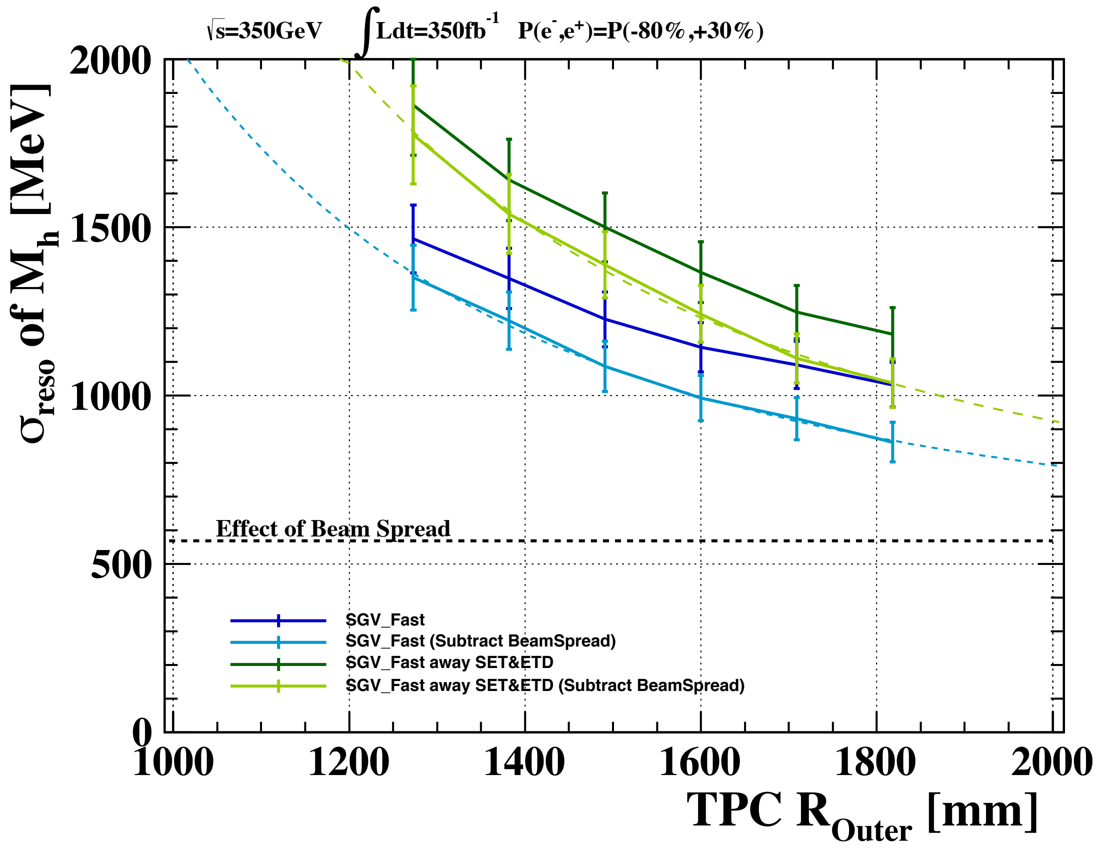
SIT characteristics (current baseline = false double-sided Si microstrips)					
Geometry			Characteristics		Material
R [mm]	Z [mm]	cos θ	Resolution R-ϕ [μm]	Time [ns]	RL [%]
153	368	0.910	R: σ=7.0,	307.7 (153.8)	0.65
300	644	0.902	z: σ=50.0	σ=80.0	0.65
SET characteristics (current baseline = false double-sided Si microstrips)					
Geometry			Characteristics		Material
R [mm]	Z [mm]	cos θ	Resolution R-ϕ [μm]	Time [ns]	RL [%]
1811	2350	0.789	R: σ=7.0,	307.7 (153.8)	0.65
ETD characteristics (current baseline = single-sided Si micro-strips, same as SET ones)					
Geometry			Characteristics		Material
R [mm]	Z [mm]	cos θ	Resolution R-ϕ [μm]		RL [%]
419.3-1822.7	2420	0.985-0.799	x: σ=7.0		0.65



Throw away SET & ETD

1. Contributions from the beam spread and the uncertainty of detector response.

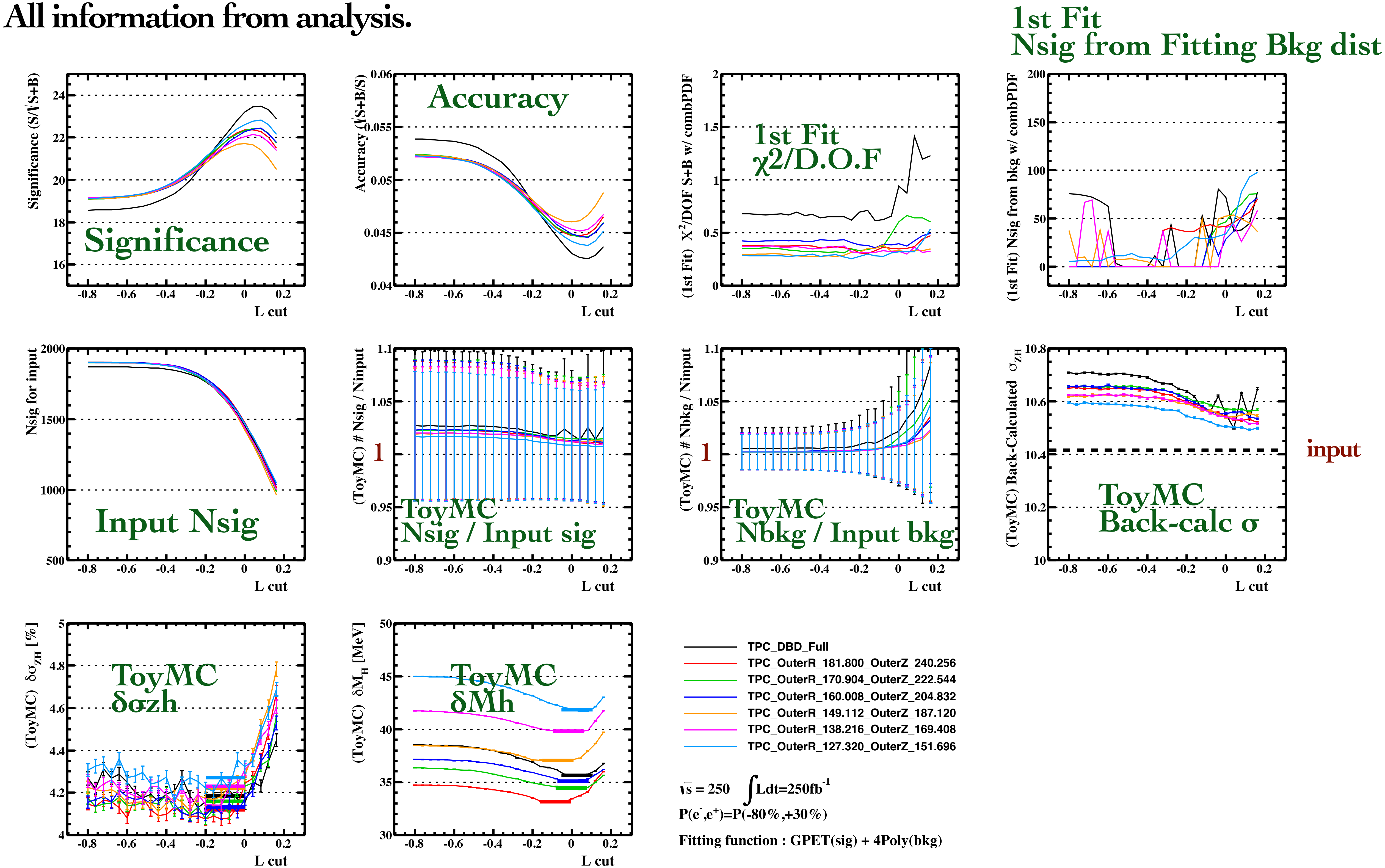




— If we throw away the outer Si tracker SET & ETD,
(250GeV) detector resolution will be more worse ~ + 15% (R: 1.8 m 300MeV ➡ 1.8 m 350 MeV)
(350GeV) detector resolution will be more worse ~ + 24% (R: 1.8 m 850MeV ➡ 1.8 m 1050 MeV)

GPET(sig) + 4th Poly(bkg) √s=250GeV

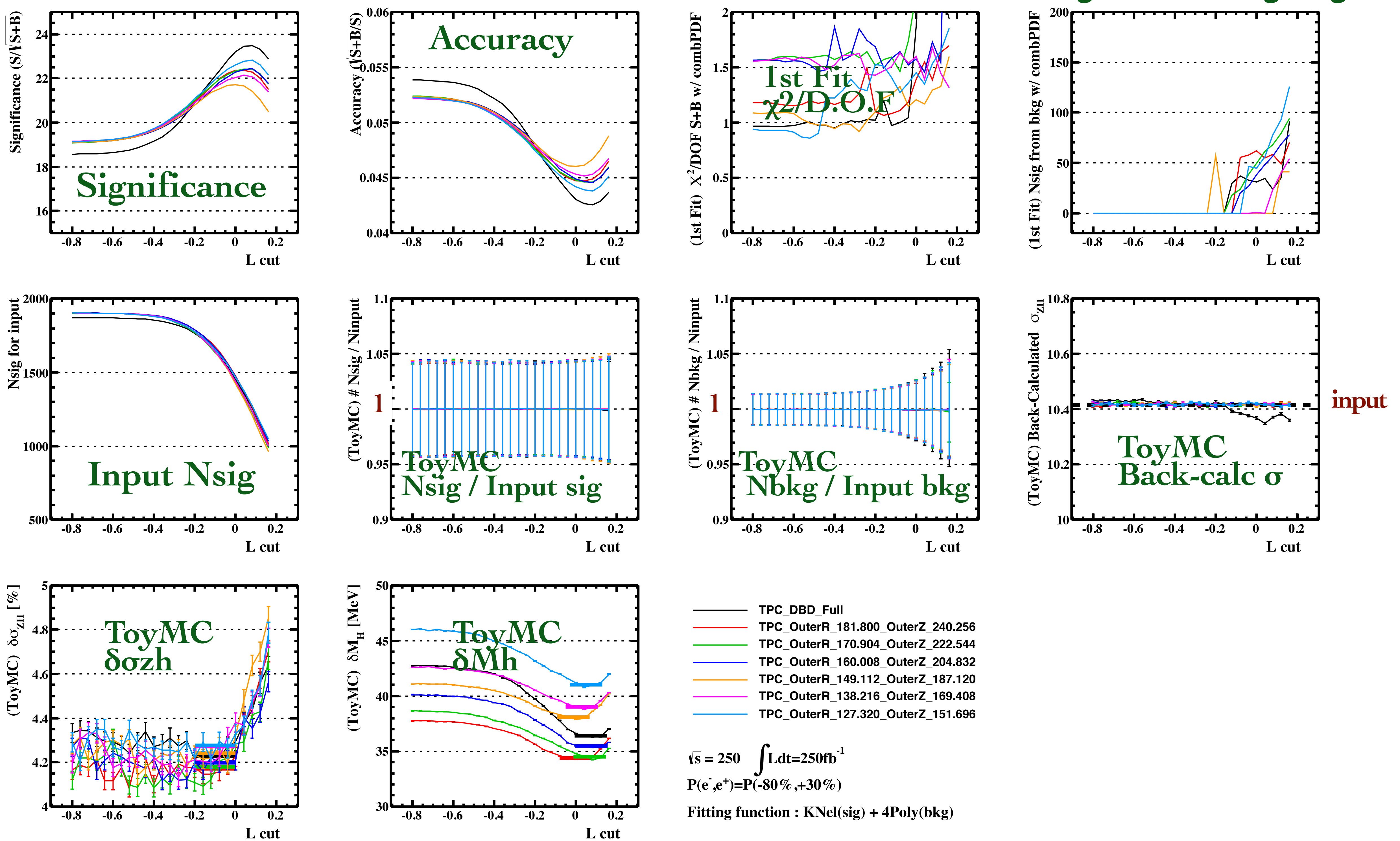
1. All information from analysis.



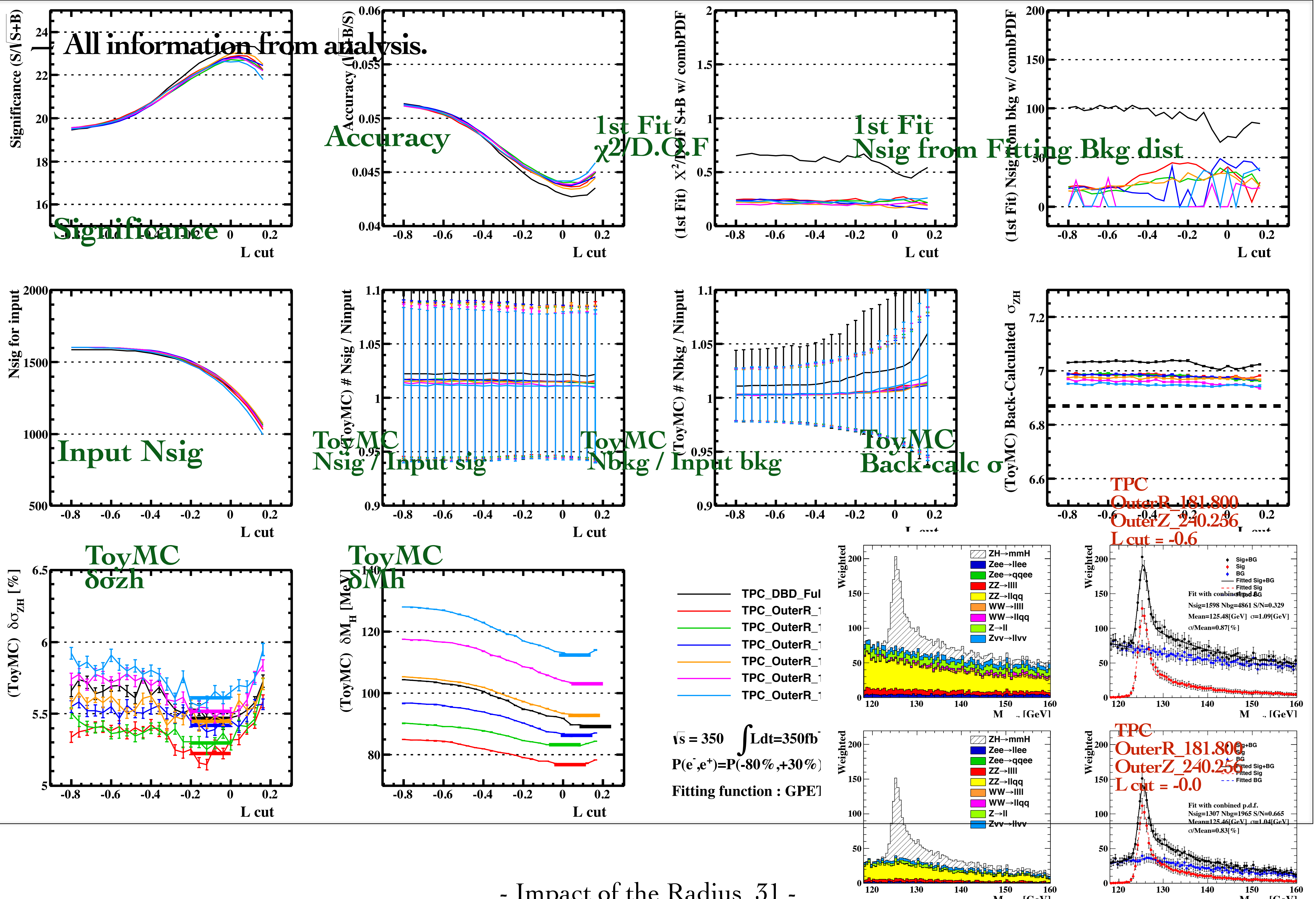
Kernel(sig) + 4th Poly(bkg) √s=250GeV

1. All information from analysis.

1st Fit
Nsig from Fitting Bkg dist



GPET(sig) + 4th Poly(bkg)   √s=350GeV



Kernel(sig) + 4th Poly(bkg) √s=350GeV