考核报告

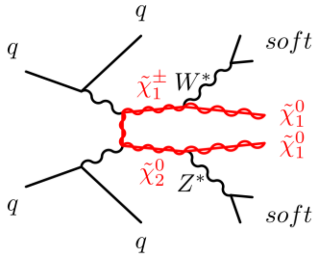
报告人: 翟明杰

导师：Joao Guimaraes da Costa, 徐达

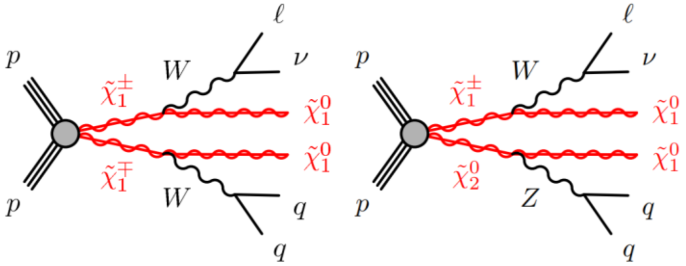
报告日期：2023.01.06

研究工作（2022.9 – 2022.12）

1. ATLAS实验超对称（SUSY）寻找
   1. 通过Compressed末态寻找gaugino

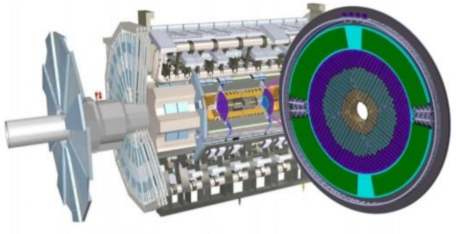


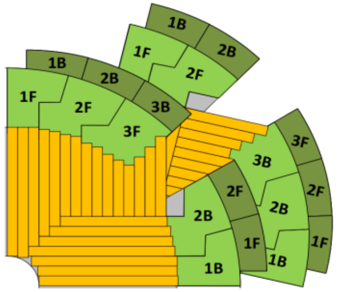
   2. 通过单轻子末态寻找gaugino



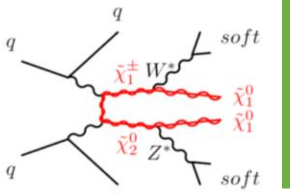
   3. 担任ATLAS SUSY HEPData coordinator

2. ATLAS实验高颗粒度时间探测器（HGTD）项目
   1. 研究周边电子学 (PEB) BPOL的效率和输出纹波。
   2. 研究PEB区域的辐照通量。



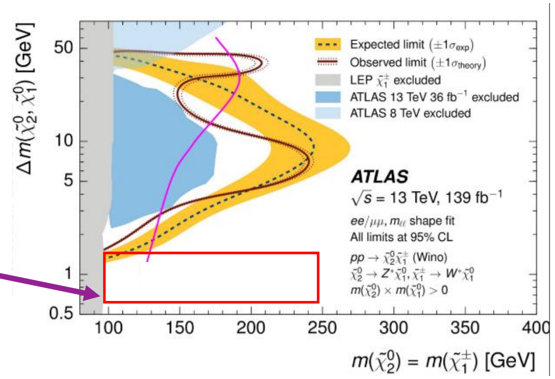


研究工作1-1: ATLAS SUSY Compressed分析

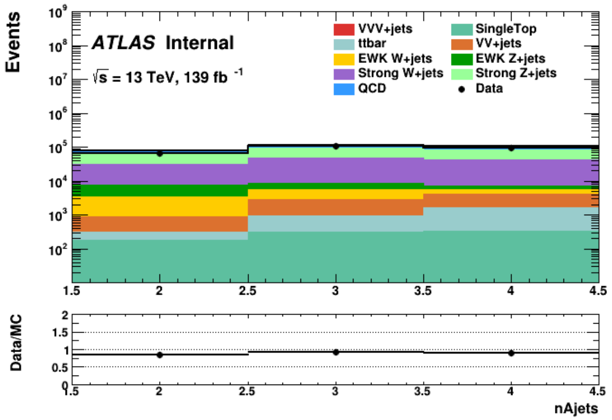


该分析主要研究质量压缩的SUSY空间；是寻找Higgsino粒子最适合的研究和热门课题。

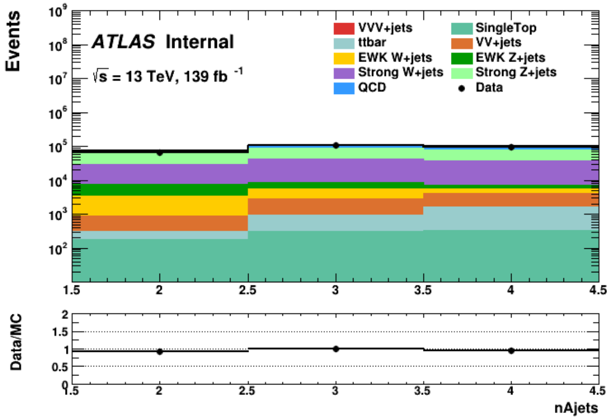
- 研究目标：通过新“矢量玻色子融合VBF进程”进一步拓展deltaM<1GeV空间。
  - 质量压缩空间的末态粒子动量很低->难以重建
  - 标记两个VBF jets->触发事例
  - 末态：2 VBF jets + MET（0 轻子）
- 该分析已于2021.06.11完成ATLAS的Partial Analysis Review；计划于明年发表。
- 本人目前担任该分析**主要分析人员。**
- **主要工作1：对主要本底V+jets的最新样本Sh2.2.11进行研究，包括NLO EWK修正效果的验证。**



Pre-selection	Without EWK correction	With EWK correction
VVV + jets	1.28 ± 0.06	1.28 ± 0.06
SingleTop	840 ± 10	840 ± 10
ttbar	2130 ± 22	2130 ± 22
VV+jets	4880 ± 51	4880 ± 51
EW_Wjets	6870 ± 21	6870 ± 21
EW_Zjets	8496 ± 21	8496 ± 21
Strong_Wjets	99494 ± 314	87587 ± 295
Strong_Zjets	131877 ± 228	122668 ± 221
QCD	46041 ± 4252	46041 ± 4252
Total background	300630 ± 4271	279514 ± 4269
data	268919	268919
data/MC	0.895	0.962

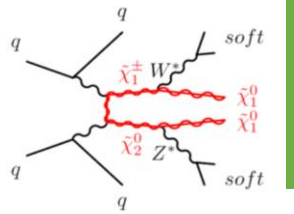


NLO EWK 修正

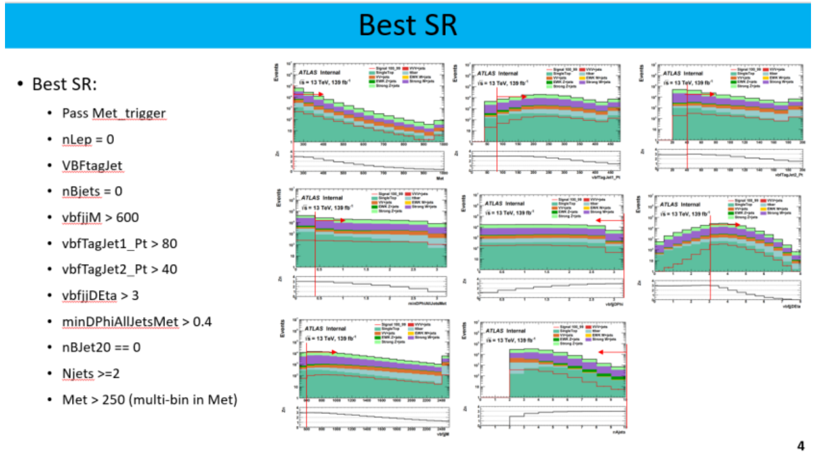


考虑NLO EWK修正之后，data/MC的符合程度变好。

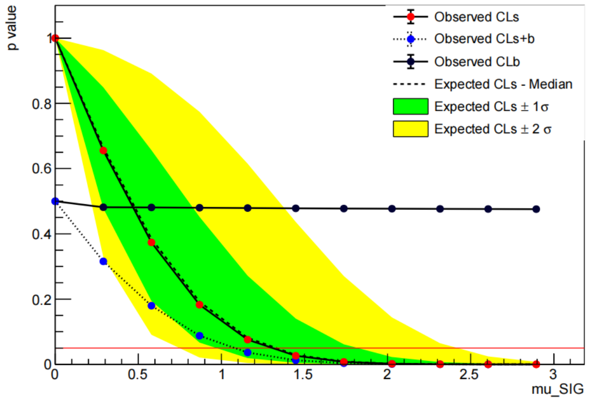
研究工作1-1: ATLAS SUSY Compressed分析



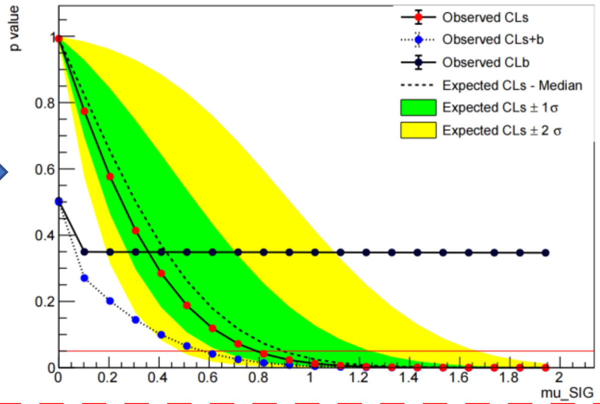
- 主要工作2：改善信号区优化，提高信号显著性。
- 主要工作3：搭建该分析的HF框架，产生和分析初步的拟合结果。



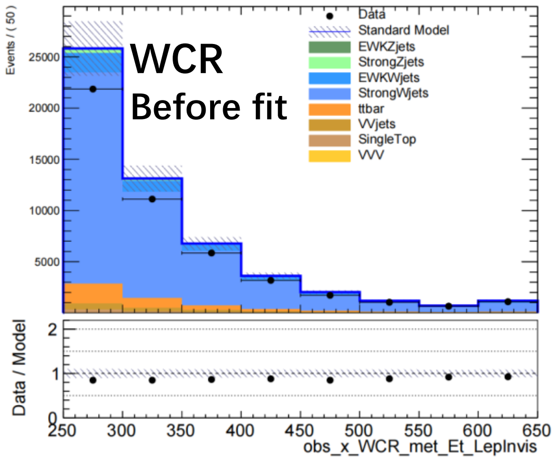
Old SR

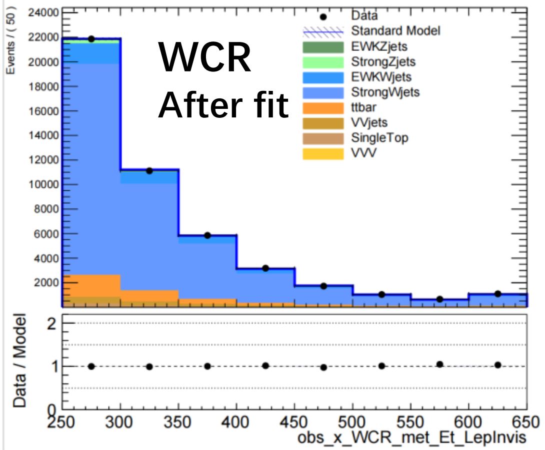


New SR

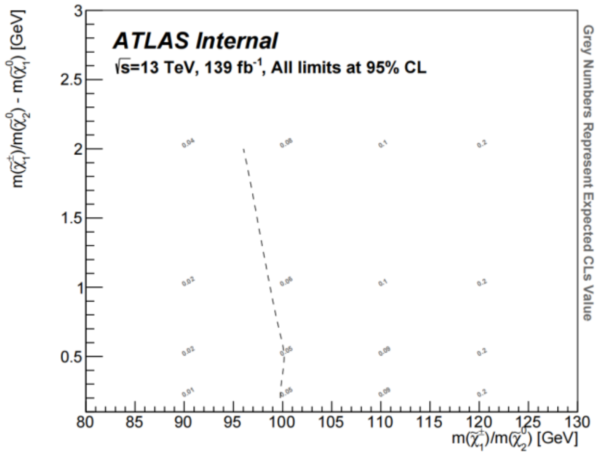


Bkg_only fit

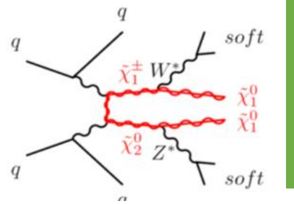




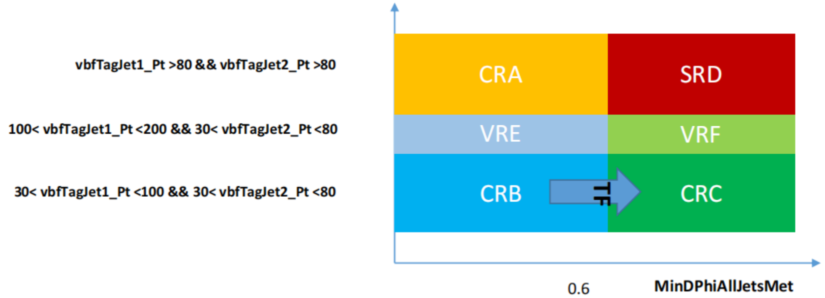
Model-dependent fit



研究工作1-1: ATLAS SUSY Compressed分析

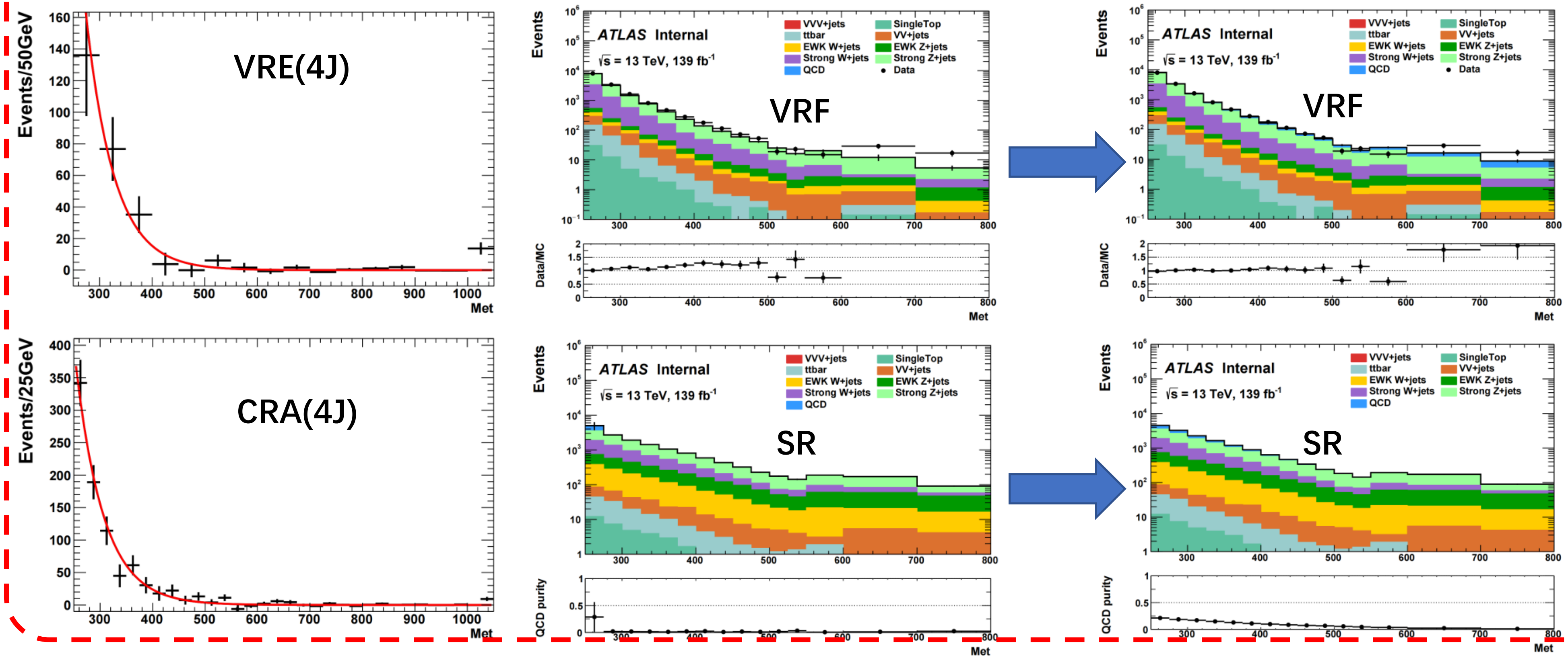


- 主要工作4：使用data driven的方法，估计QCD本底。
  - 目前已经得到了初步的QCD本底估计结果，VRF里面data/MC的符合程度变好。
  - 主要问题：目前的样本只包含high-Met区域，CR/VR里面的QCD纯度较低。
  - 解决方案：产生low-Met的样本，并进一步改善QCD的本底估计。



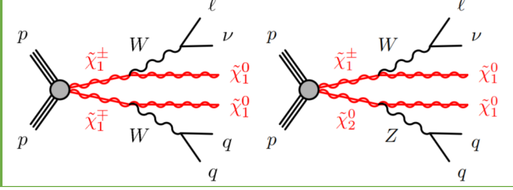
QCD MC

ABCD-Estimated QCD



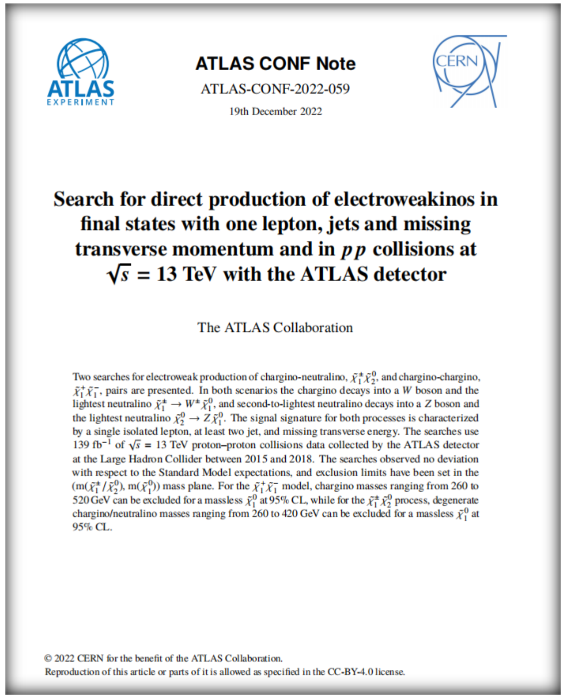
- 第1步：基于SR，设计CR+VR。
- 第2步：在CRB, CRC计算出TF。
- 第3步：对CRA和VRE里面的data-other MC 进行拟合，得出每个bin QCD的估计值。
- 第4步：使用$QCD_{SR} = QCD_{CRA} * TF$, $QCD_{VRF} = QCD_{VRE} * TF$, 估计SR和VRF每个bin的QCD。

研究方向1-2: ATLAS SUSY 单轻子分析



该分析首次研究1L末态的gaugino—>WW/WZ信号。

- 电弱相互作用的gaugino 通过 WW/WZ的衰变：
  - 该分析产生截面小/信号与SM本底类似->challenge->首次使用boost tagging技术
  - 末态： 1 lepton + 2-3 jets + MET
- 该分析通过了最终的ATLAS审核，于2022年9月发表公开的**ATLAS CONF Note**，预计今年上半年发表一篇期刊文章。**作为分析最主力分析人员，本人代表分析组进行SUSY物理大组审核报告和ATLAS合作组审核报告。**



ATLAS CONF Note

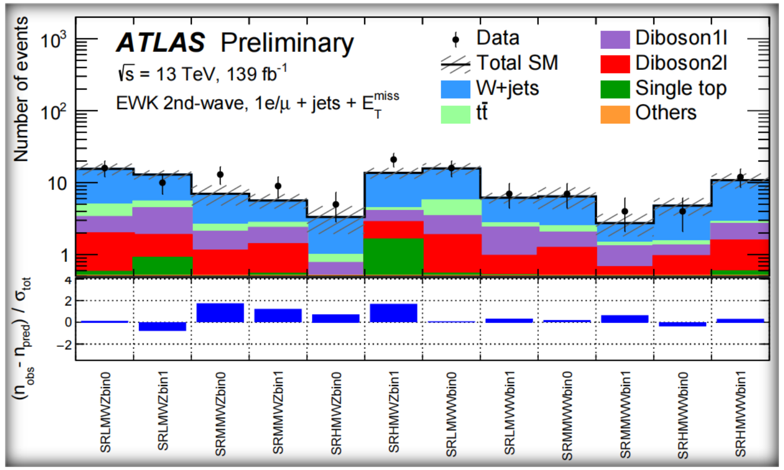
ATLAS-CONF-2022-059

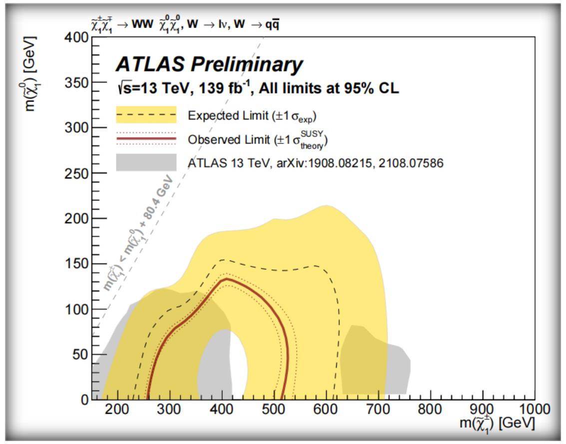
19th December 2022

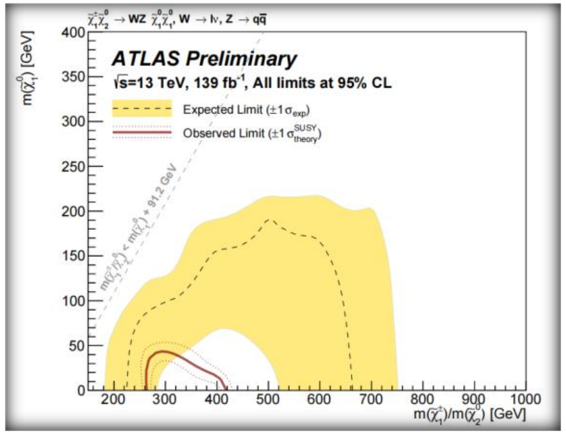
Search for direct production of electroweakinos in final states with one lepton, jets and missing transverse momentum and in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

The ATLAS Collaboration

Two searches for electroweak production of chargino-neutralino, $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$, and chargino-chargino, $\tilde{\chi}_1^{+}\tilde{\chi}_1^{-}$, pairs are presented. In both scenarios the chargino decays into a W boson and the lightest neutralino $\tilde{\chi}_1^{\pm} \to W^{\pm}\tilde{\chi}_1^0$, and second-to-lightest neutralino decays into a Z boson and the lightest neutralino $\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0$. The signal signature for both processes is characterized by a single isolated lepton, at least two jet, and missing transverse energy. The searches use 139 fb^{-1} of $\sqrt{s}$ = 13 TeV proton–proton collisions data collected by the ATLAS detector at the Large Hadron Collider between 2015 and 2018. The searches observed no deviation with respect to the Standard Model expectations, and exclusion limits have been set in the (m($\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)) mass plane. For the $\tilde{\chi}_1^{+}\tilde{\chi}_1^{-}$ model, chargino masses ranging from 260 to 520 GeV can be excluded for a massless $\tilde{\chi}_1^0$ at 95% CL, while for the $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ process, degenerate chargino/neutralino masses ranging from 260 to 420 GeV can be excluded for a massless $\tilde{\chi}_1^0$ at 95% CL.





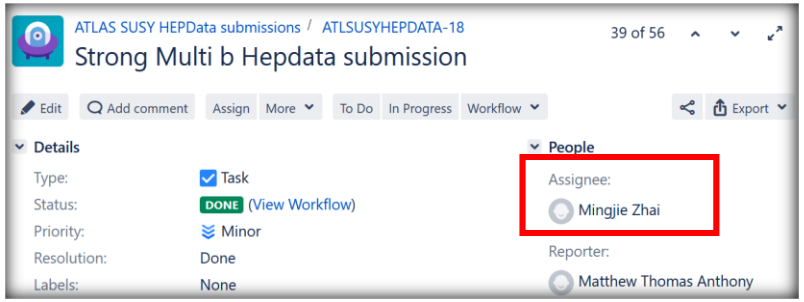


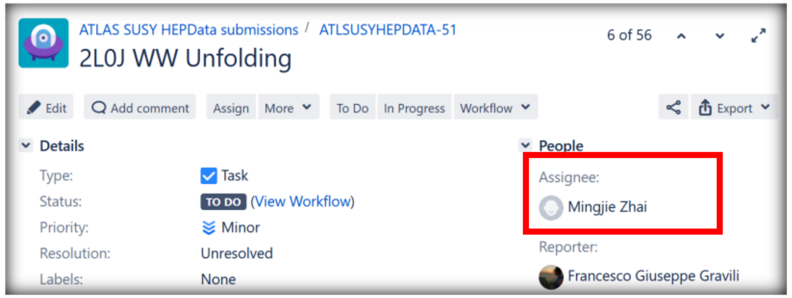
研究方向1-3: ATLAS SUSY HEPData负责人

HEPData
Repository for publication-related High-Energy Physics data

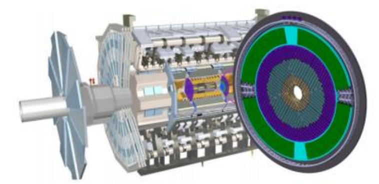
- HEPData (High Energy Physics Data Repository) 高能物理数据平台：https://www.hepdata.net/
  - 收集粒子物理实验发表的分析数据，将图表等结果转化为更精确的数字信息。
  - 提供理论家所需的各类分析细节（信号产生，粒子重建，误差，acc & eff）
- 本人自2022年7月1日开始**担任ATLAS实验SUSY大组的HEPData负责人**。
  - 组织管理各分析组的HEPData数据搜集转化等工作，并负责最终的审核。
  - 该季度(2022.09 – 2022.12)，**本人负责组织了3个分析的HEPData提交工作，并进行最终的审核**。

Francesco Giuseppe Gravili (francesco.giuseppe.gravili@cern.ch) and Mingjie Zhai (mingjie.zhai@cern.ch) are the HEPData coordinators for ATLAS SUSY. Any questions and issues concerning the preparation and upload of material should first be addressed to them.

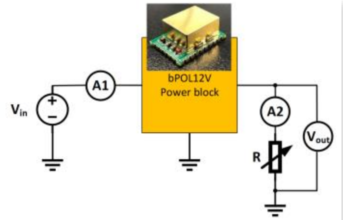




研究方向2-1: PEB BPOL12V的性能研究



- BPOL12V可以把12V的电压转化成1.2V或2.5V的电压，进而给module和PEB的其他部件供电。
- **主要工作1：研究BPOL12V的效率和温度、输出电流、输入电压之间的关系。**
  - **负责对4个BPOL效率的实验室测试、数据采集工作。**
  - **负责对4个BPOL效率的平均值、最小值、最大值的拟合以及拟合结果的检验。**



- Power efficiency = $\frac{V_{out} \times I_{A2}}{V_{in} \times I_{A1}}$

New fit strategy

- Step1: Fit I_{out} related parameters under fixed T and Vin condition --> derive fitted I_{out} parameters (p_0~ p_2 and q_0 ~ q_3)
  - $Eff = f\,(I_{out})$: (fix T = 0℃ and V_{in} = 10V)
    - $Eff = p_0 I_{out} + p_1 I_{out}^2 + p_2 I_{out}^3$ (0A< I_{out} <0.8A) *Move to 0.8 to make function continuous at 1A*
    - $Eff = q_0 + q_1 I_{out} + q_2 I_{out}^2 + q_3 I_{out}^3$ (0.8A< I_{out} <4A)
- Step2: Fit T under fixed V_{in} conditions, the I_{out} parameters are obtained from Step1 --> derive fitted T parameters (a_0~ a_2 and b_0 ~ b_3)
  - $Eff = g\,(I_{out}, T)$: (fix V_{in} = 10V)
    - $Eff = (1 + a_0 T) * p_0 I_{out} + (1 + a_1 T) * p_1 I_{out}^2 + (1 + a_2 T) * p_2 I_{out}^3$ (0A< I_{out} <0.8A)
    - $Eff = (1 + b_0 T) * q_0 + (1 + b_1 T) * q_1 I_{out} + (1 + b_2 T) * q_2 I_{out}^2 + (1 + b_3 T) * q_3 I_{out}^3$ (0.8A< I_{out} <4A)
    - *Different linear function fit parameters $a_0/a_1/a_2$ are used for $I/I^2/I^3$, instead of the same a. Similarly for other parameters.*
- Step3: Fit V_{in} under fixed T conditions, the I_{out} parameters are obtained from Step1 --> derive fitted V_{in} parameters (c_0~ c_2 and d_0 ~ d_3)
  - $Eff = g\,(I_{out}, V_{in})$: (fix T = 0℃)
    - $Eff = (1 + c_0 (V_{in} - 10)) * p_0 I_{out} + (1 + c_1 (V_{in} - 10)) * p_1 I_{out}^2 + (1 + c_2 (V_{in} - 10)) * p_2 I_{out}^3$ (0A< I_{out} <0.8A)
    - $Eff = (1 + d_0 (V_{in} - 10)) * q_0 + (1 + d_1 (V_{in} - 10)) * q_1 I_{out} + (1 + d_2 (V_{in} - 10)) * q_2 I_{out}^2 + (1 + d_3 (V_{in} - 10)) * q_3 I_{out}^3$ (0.8A< I_{out} <4A)
- Step4: Construct the full function using parameters obtained above. Then, perform validation
  - $Eff = h\,(I_{out}, V_{in}, T)$
    - $Eff = (1 + a_0 T) * (1 + c_0 (V_{in} - 10)) * p_0 I_{out} + (1 + a_1 T) * (1 + c_1 (V_{in} - 10)) * p_1 I_{out}^2 + (1 + a_2 T) * (1 + c_2 (V_{in} - 10)) * p_2 I_{out}^3$ (0A< I_{out} <0.8A)
    - $Eff = (1 + b_0 T) * (1 + d_0 (V_{in} - 10)) * q_0 + (1 + b_1 T) * (1 + d_1 (V_{in} - 10)) * q_1 I_{out} + (1 + b_2 T) * (1 + d_2 (V_{in} - 10)) * q_2 I_{out}^2 + (1 + b_3 T) * (1 + d_3 (V_{in} - 10)) * q_3 I_{out}^3$ (0.8A< I_{out} <4A)

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Fit results : Step4(construct the full function)

- $Eff_{ave} = (1 - 0.000362702T) * (1 - 0.0696867(V_{in} - 10)) * 1.90203 I_{out} - (1 - 0.000428837T) * (1 - 0.108918(V_{in} - 10)) * 2.35165 I_{out}^2 + (1 - 0.000524723T) * (1 - 0.138047(V_{in} - 10)) * 1.10312 I_{out}^3$ (0A< I_{out} <0.8A)
- $Eff_{ave} = (1 - 0.000363404T) * (1 - 0.0712708(V_{in} - 10)) * 0.378258 + (1 + 0.000135934T) * (1 + 0.0279068(V_{in} - 10)) * 0.354078 I_{out} - (1 + 0.00142807T) * (1 + 0.0135724(V_{in} - 10)) * 0.137486 I_{out}^2 + (1 + 0.00213587T) * (1 + 0.00810716(V_{in} - 10)) * 0.0161732 I_{out}^3$ (0.8A< I_{out} <4A)
- $Eff_{min} = (1 - 0.000339204T) * (1 - 0.0686285(V_{in} - 10)) * 1.88097 I_{out} - (1 - 0.000423783T) * (1 - 0.106515(V_{in} - 10)) * 2.29841 I_{out}^2 + (1 - 0.000546777T) * (1 - 0.13504(V_{in} - 10)) * 1.06307 I_{out}^3$ (0A< I_{out} <0.8A)
- $Eff_{min} = (1 - 0.000201367T) * (1 - 0.0729479(V_{in} - 10)) * 0.371471 + (1 - 0.0000280726T) * (1 + 0.0280383(V_{in} - 10)) * 0.361619 I_{out} - (1 + 0.001291697T) * (1 + 0.0144376(V_{in} - 10)) * 0.141946 I_{out}^2 + (1 + 0.00202347T) * (1 + 0.00936406(V_{in} - 10)) * 0.0167928 I_{out}^3$ (0.8A< I_{out} <4A)
- $Eff_{max} = (1 - 0.000385686T) * (1 - 0.0707217(V_{in} - 10)) * 1.92309 I_{out} - (1 - 0.000433692T) * (1 - 0.111214(V_{in} - 10)) * 2.4049 I_{out}^2 + (1 - 0.000504172T) * (1 - 0.14084(V_{in} - 10)) * 1.14316 I_{out}^3$ (0A< I_{out} <0.8A)
- $Eff_{max} = (1 - 0.000519736T) * (1 - 0.0696528(V_{in} - 10)) * 0.385045 + (1 + 0.000307077T) * (1 + 0.0277695(V_{in} - 10)) * 0.346537 I_{out} - (1 + 0.00157358T) * (1 + 0.012649(V_{in} - 10)) * 0.133026 I_{out}^2 + (1 + 0.00225727T) * (1 + 0.00675217(V_{in} - 10)) * 0.0155535 I_{out}^3$ (0.8A< I_{out} <4A)

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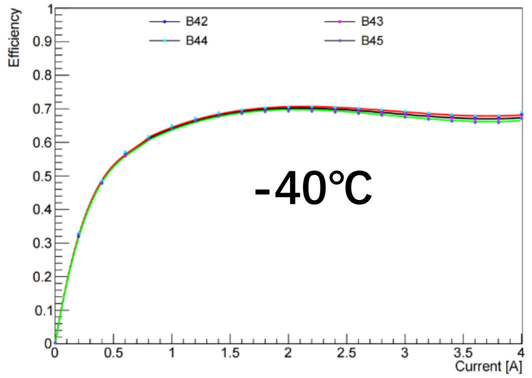
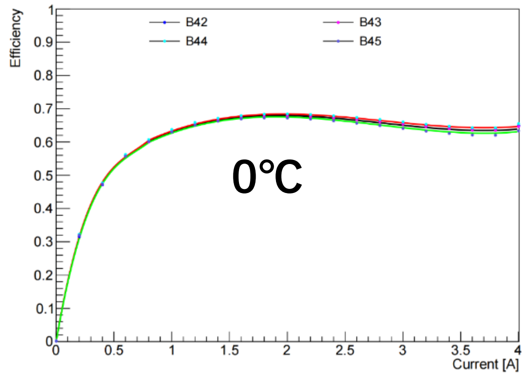
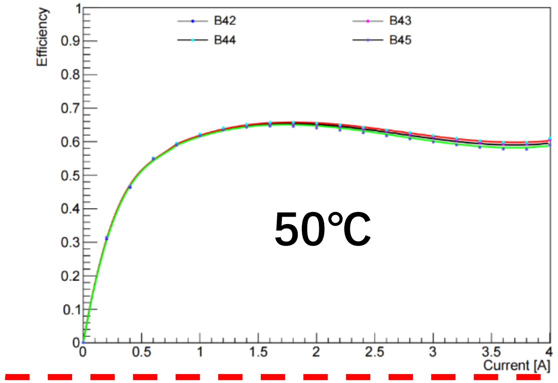
拟合结果检验(V_{in} = 9V为例)

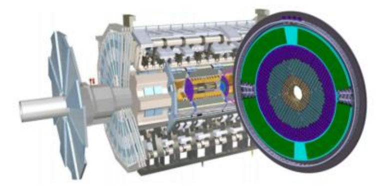


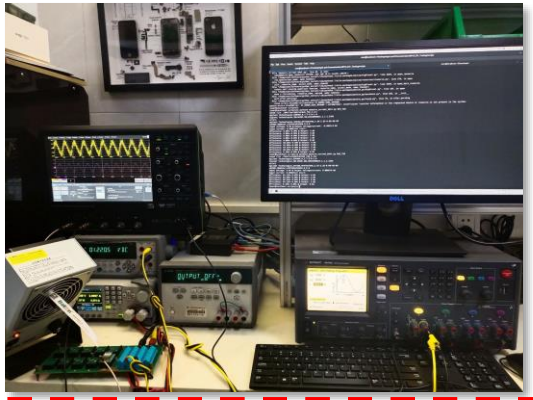




拟合的效率和测量值在各温度、输入电压下都符合的较好。

研究方向2-1: PEB BPOL12V的性能研究





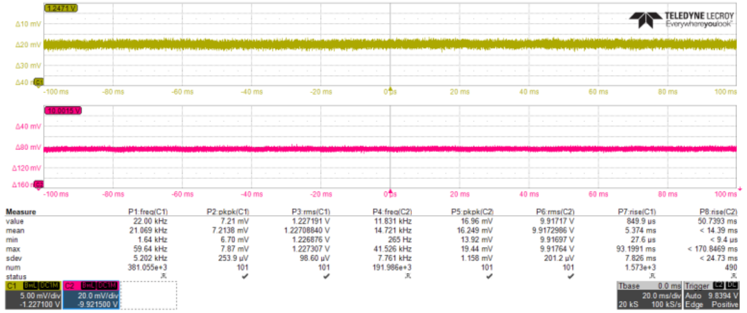
- 主要工作2：研究BPOL的纹波抑制性能。
  - 在输入端加入不同频率和振幅的纹波，测试输出纹波的大小。
- 主要工作3：研究BPOL的输出纹波和温度、输出电流、输入电压之间的关系。

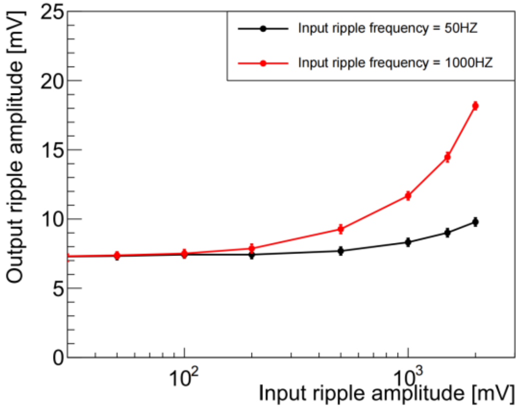
纹波抑制性能研究

输入端不加纹波

输出

输入

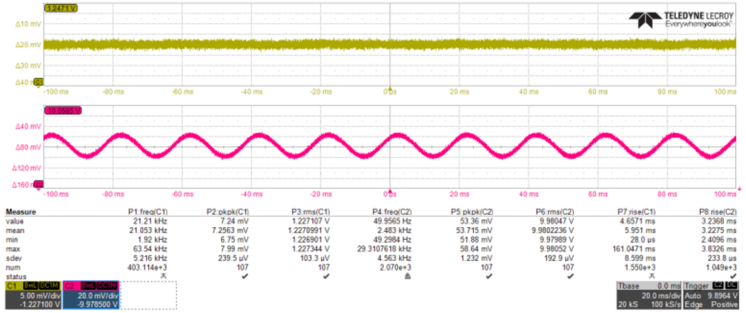


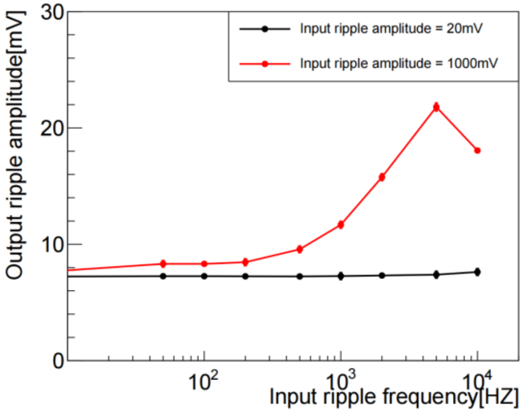


输入端加20mV,50HZ纹波

输出

输入





BPOL的纹波抑制性能较好。

输出纹波研究

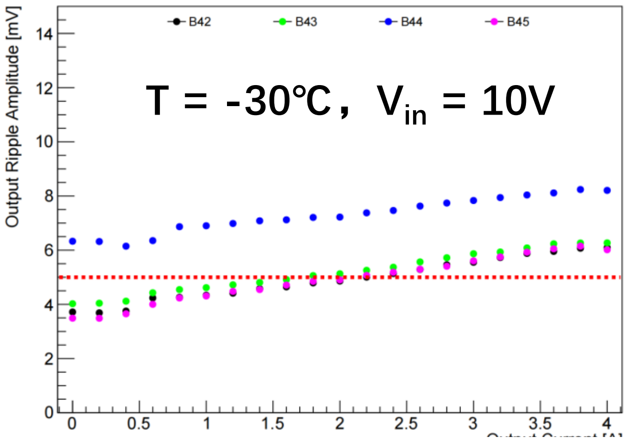
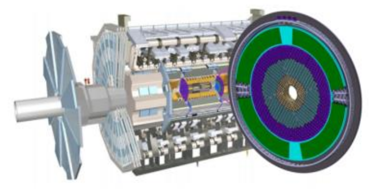


Table 4: Front-end electronics power supply requirement

	Min.	Typ.	Max.
Voltage range	1.15V	1.2V	1.25V
Analog current per ASIC	-	0.42A	
Digital current per ASIC	-	0.58A	
Ripple and noise @ Full load (0-20 MHz bandwidth)	-	-	5 mV pp (peak-to-peak)

正常工作条件(T≈-30℃, Vin≈10V, Iout≈2A)下，大多数BPOL的输出纹波符合ATLAS组要求。

研究方向2-2: PEB辐照通量



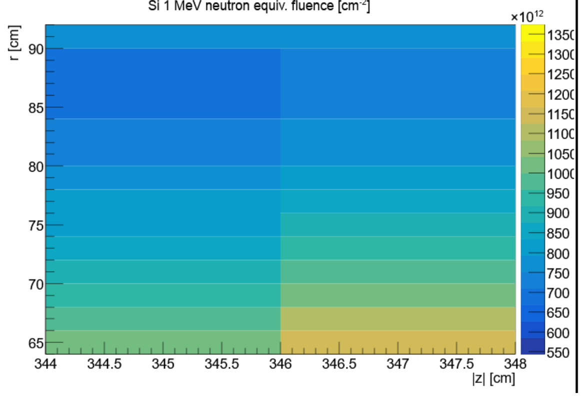
主要工作: 研究了PEB区域的辐照通量，包括Genta4 和FLUKA的模拟结果。

Si 1 MeV neutron equivalent (NIEL)

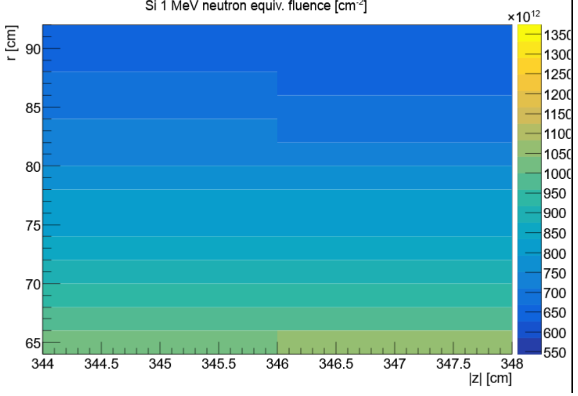
All values are calculated from the cells in the selected R-Z region, assuming an integrated luminosity of 4000.00 fb^{-1} and minbias cross section of 79.31 mb. N.B.: the uncertainty on the average value is computed from the sample-to-sample variations of the contributing bins, assuming the bins are uncorrelated. In contrast the standard deviation is the spread of the contributing bins without taking their individual sample-to-sample variations into account.

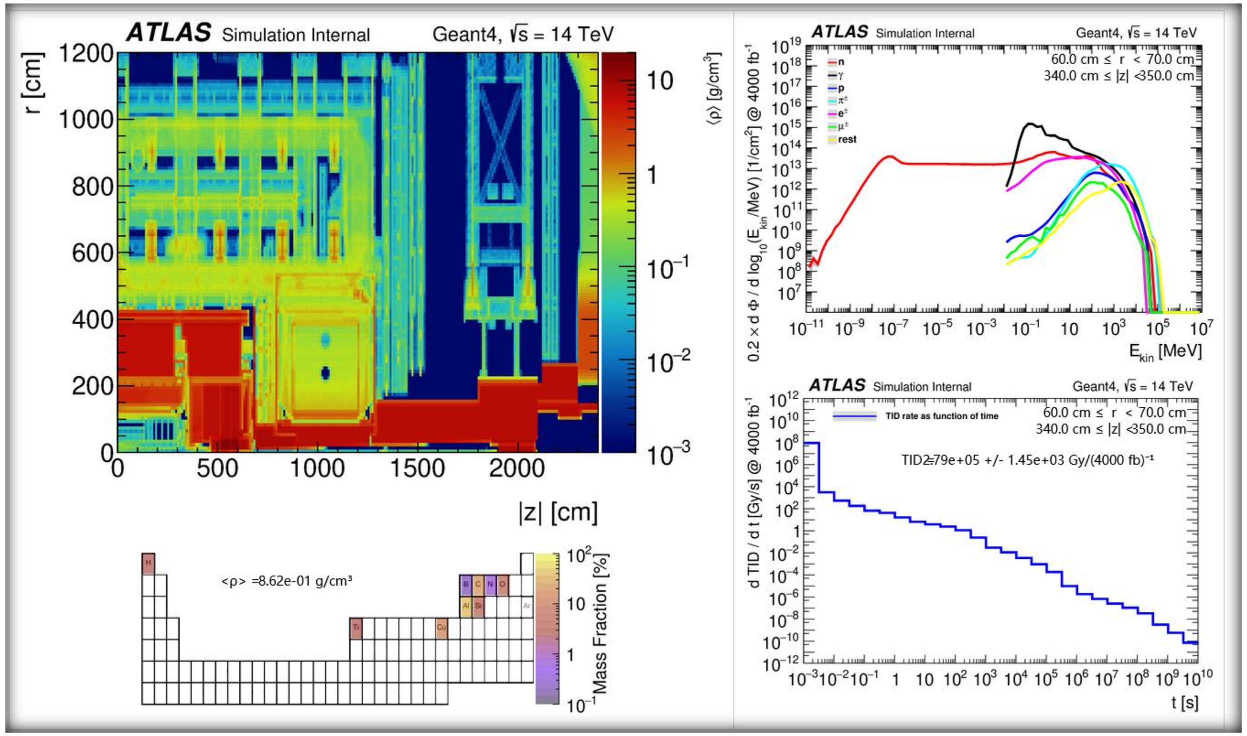
	Si 1 MeV neutron equivalent fluence [cm^{-2}]	
	FLUKA	**GEANT4**
Average:	8.46e+14 +/- 6.57e+11	8.04e+14 +/- 8.51e+11
Standard deviation:	1.28e+14	1.23e+14
Maximum:	1.14e+15 +/- 4.25e+12	1.05e+15 +/- 5.86e+12
R-Z location of maximum	64.00 < r < 66.00 cm 346.00 < |z| < 348.00 cm	64.00 < r < 66.00 cm 346.00 < |z| < 348.00 cm

FLUKA



GEANT4





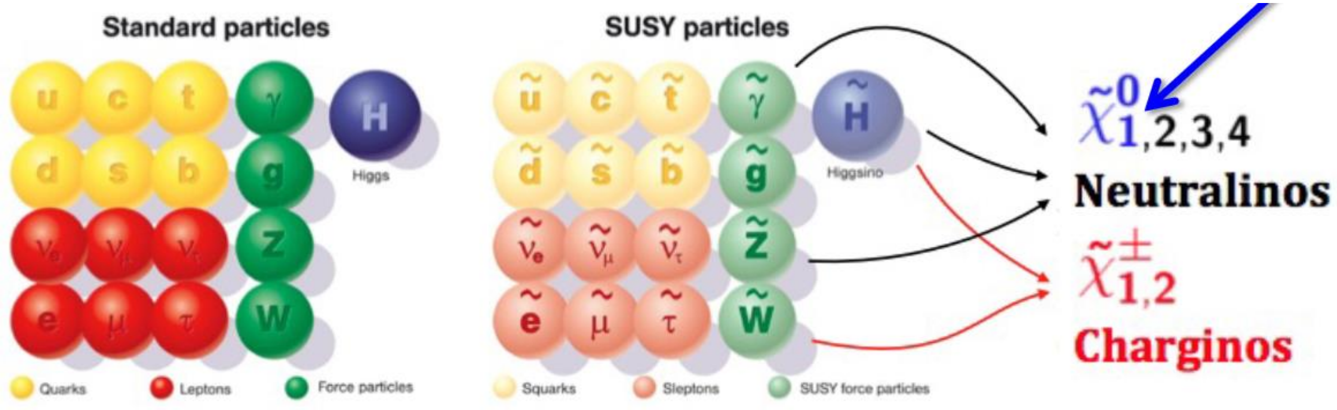
|z|_min (cm)	|z|_max (cm)	r_min (cm)	r_max (cm)	density (g/cm^3)	TID (Gy)	NIEL (n_eq/cm^2)	SEE (h_>20MeV/cm^2)	NEUT (n_>100keV/cm^2)	CHAD (h_chgd/cm^2)
340.0	350.0	80.0	90.0	8.32e-01	1.48e+05+/-8.14e+02	7.15e+14+/-3.59e+12	2.56e+14+/-1.29e+12	5.24e+14+/-2.66e+12	1.21e+14+/-6.25e+11

总结与展望

- 超对称物理探寻：
  - 担任**SUSY 单轻子分析的最主力分析人员**和**SUSY compressed分析的主力分析人员**。数次在这两个分析的组会作报告。
  - **文章/会议报告**：
    - Search for direct production of electroweakinos in final states with one lepton, jets and missing transverse momentum and in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector, ATLAS-CONF-2022-059 (link)
    - Search for direct production of electroweakinos in final states with one lepton, jets and missing transverse momentum, Nov 23 – 27, 2022 , Nanjing/Online, CLHCP2022 (link)
  - 另外，本人还担任了**ATLAS SUSY hepdata的负责人**，该季度负责审核3个分析的hepdata。
  - 下一步：推动以上两分析，单轻子分析预计今年上半年发表一篇期刊文章。Compressed分析预计明年发表一篇文章。
- HGTD 研究：
  - 对PEB BPOL12V的纹波和效率进行研究。研究成果均在**ATLAS HGTD Week** (link)汇报。
  - 对PEB区域的辐照通量进行研究。
  - 下一步：继续参与PEB的研究工作。

Backup

超对称简介


Standard particles
SUSY particles
Higgs
Higgsino
Quarks
Leptons
Force particles
Squarks
Sleptons
SUSY force particles
$\tilde{\chi}^0_{1,2,3,4}$
Neutralinos
$\tilde{\chi}^{\pm}_{1,2}$
Charginos


Bino LSP
Higgsino LSP
Wino LSP
higgsino
wino
bino
μ
M1
M2

Compressed: Sh2.2.11 EWK correction study

- Compared to Sh2.2.1, NLO EWK correction has to be applied to Sh2.2.11.
- There are three correction weights stored as LHE_weight in ntuple, the smallest should be applied. While the difference between the smallest and largest should be treated as EWK correction theory uncertainty later.
  - additive approach: `(B + VI_QCD + VI_EW) * PS = B * (1 + delta_QCD + delta_EW) * PS`
  - multiplicative approach: `(B + VI_QCD) * (1 + delta_EW) * PS = B * (1 + delta_QCD) * (1 + delta_EW) * PS`
  - exponentiated approach: `(B + VI_QCD) * exp(delta_EW) * PS = B * (1+delta_QCD) * exp(delta_EW) * PS`
- Currently I picked the smallest weight based on nominal ntuple by hand. Considering the future usage (i.e. HF will directly compare nominal vs systematic tree, in that case, all systematic trees need to apply weight correctly), it would be better to store ordered weight in ntuple (i.e. keep smallest and largest weights)
- Pre-selection used for this check:
  - nLep_signal = 0
  - 2<= nAjets<=4
  - nBJet == 0
  - Passes MET trigger
  - **MET > 250 GeV (because of trigger efficiency)**
  - Valid VBF tag
  - M_jj > 500 GeV

Table 1: Summary of the Sherpa 2.2.1 and 2.2.11 configurations.

Configuration	Sherpa 2.2.1	Sherpa 2.2.11
Generator version	Sherpa 2.2.1	Sherpa 2.2.11
PDF set	NNPDF3.0nnlo	NNPDF3.0nnlo
EW input scheme	Effective	$\sin^2\theta_{\text{eff}}$
QCD accuracy	0–2j@NLO+3,4j@LO	0–2j@NLO+3,4,5j@LO
NLO EW_{virt} corrections	No	Yes
Subtraction scheme	Default	Modified Catani–Seymour
Unordered histories allowed	Yes	No
Scale for $\mathbb{H}$-events	STRICT_METS	H'_{T}
Gluon colour/spin exact matching	Yes	No
Core process for K-factor	$2 \to 4$	$2 \to 2$
Phase-space strategy	Sliced in $\max(H_{\text{T}}, p_{\text{T}}^{V})$	Analytic enhancement

Pre-selection	Without EWK correction	With EWK correction
VVV + jets	1.28 ± 0.06	1.28 ± 0.06
SingleTop	840 ± 10	840 ± 10
ttbar	2130 ± 22	2130 ± 22
VV+jets	4880 ± 51	4880 ± 51
EW_Wjets	6870 ± 21	6870 ± 21
EW_Zjets	8496 ± 21	8496 ± 21
Strong_Wjets	99494 ± 314	87587 ± 295
Strong_Zjets	131877 ± 228	122668 ± 221
QCD	46041 ± 4252	46041 ± 4252
Total background	300630 ± 4271	279514 ± 4269
data	268919	268919
data/MC	0.895	0.962

HF strategy: 0L SR

- HF setup:
  - Samples: Strong and EWK V+jets, ttbar, singletop, Vvjets, VVV
    - EWK correction for V+jets is not applied.
  - JET syst uncertainties are applied to the fit.
- Bkg_only fit (CR_only).
  - Fit parameter, kinematic plots, yields table and syst table. (Only for new CC SR)
- Model-dependent fit (SR+CR).
  - Limits and contour plots. (Compare different SRs)
  - More fit results in backup.

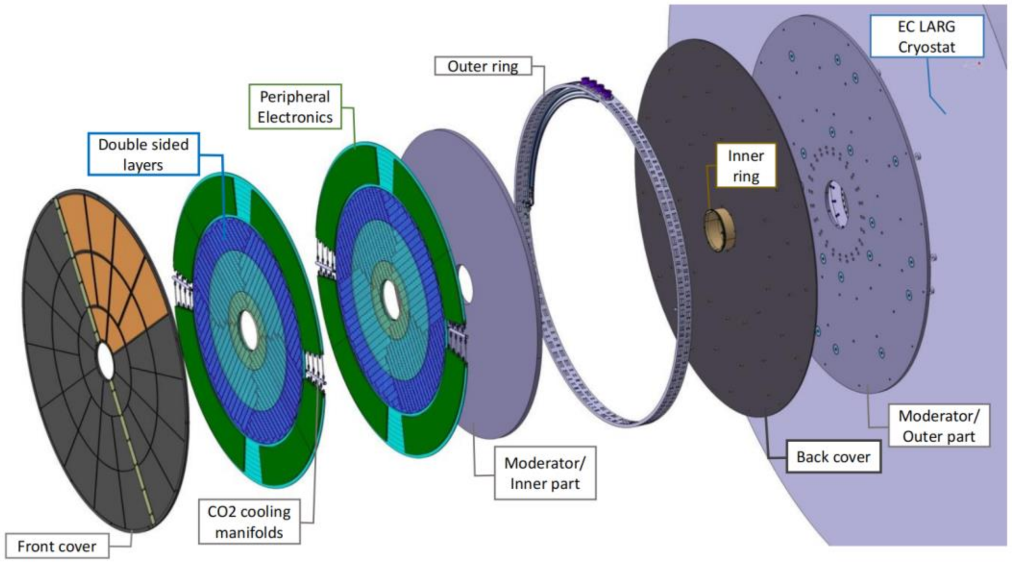
WCR

- vbfjjM, vbfTagJet1_Pt, vbfTagJet2_Pt, vbfjjDEta, nBJet20, Njets cut: The same as SR
- Met, minDPhiAllJetsMet, BDT_score cut: The same as SR, but use XXX_LepInvis.
- nLep_signal == 1
- SMET>4
- trigMatch_singleElectronTrig == 1|| trigMatch_singleMuonTrig == 1

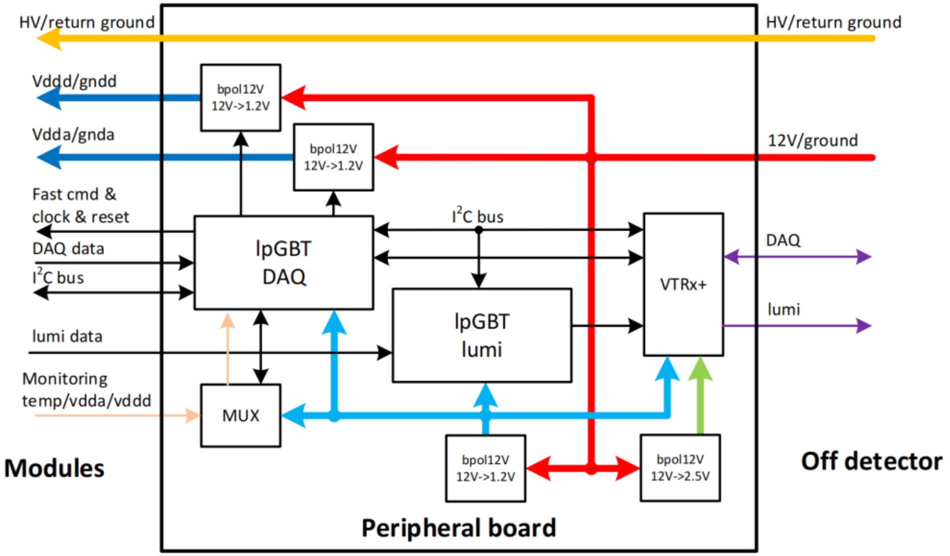
ZCR

- vbfjjM, vbfTagJet1_Pt, vbfTagJet2_Pt, vbfjjDEta, nBJet20, Njets cut: The same as SR
- Met, minDPhiAllJetsMet, BDT_score cut: The same as SR, but use XXX_LepInvis.
- nLep_signal == 2
- 81.2 < Mll < 101.2
- trigMatch_diElectronTrig == 1||trigMatch_diMuonTrig == 1

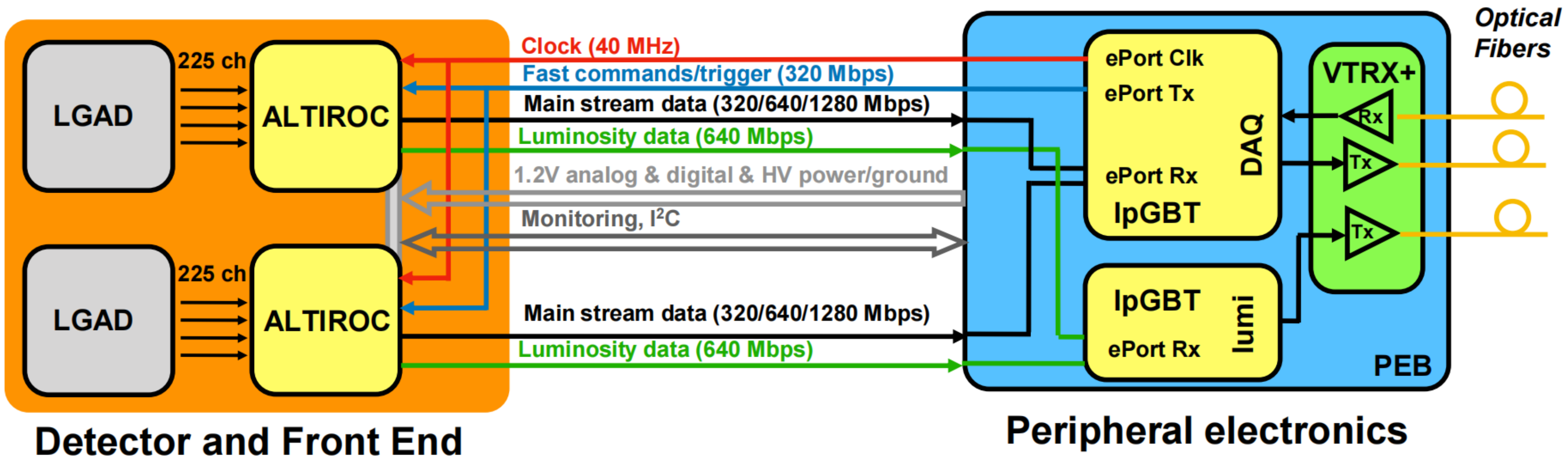
PEB结构



EC LARG Cryostat
Outer ring
Peripheral Electronics
Double sided layers
Inner ring
Moderator/ Outer part
Back cover
Moderator/ Inner part
CO2 cooling manifolds
Front cover



HV/return ground
HV/return ground
Vddd/gndd
bpol12V 12V->1.2V
Vdda/gnda
bpol12V 12V->1.2V
12V/ground
Fast cmd & clock & reset
I2C bus
DAQ data
I2C bus
lpGBT DAQ
VTRx+
DAQ
lumi
lpGBT lumi
lumi data
Monitoring temp/vdda/vddd
MUX
bpol12V 12V->1.2V
bpol12V 12V->2.5V
Modules
Off detector
Peripheral board



LGAD
225 ch
ALTIROC
LGAD
225 ch
ALTIROC
Clock (40 MHz)
Fast commands/trigger (320 Mbps)
Main stream data (320/640/1280 Mbps)
Luminosity data (640 Mbps)
1.2V analog & digital & HV power/ground
Monitoring, I2C
Main stream data (320/640/1280 Mbps)
Luminosity data (640 Mbps)
ePort Clk
ePort Tx
ePort Rx
lpGBT
DAQ
VTRX+
Rx
Tx
Tx
Optical Fibers
lpGBT
ePort Rx
lumi
PEB
Detector and Front End
Peripheral electronics

New fit strategy

- Step1: Fit I_{out} related parameters under fixed T and Vin condition --> derive fitted **I_{out} parameters (p_0~ p_2 and q_0 ~ q_3)**
  - $\boldsymbol{Eff = f\ (Iout)}$: (fix T = 0℃ and V_{in} = 10V)
    - $Eff\ = p_0 I_{out} + p_1 I_{out}^2 + p_2 I_{out}^3$ (0A< I_{out} <0.8A) *Move to 0.8 to make function continuous at 1A*
    - $Eff\ = q_0 + q_1 I_{out} + q_2 I_{out}^2 + q_3 I_{out}^3$(0.8A< I_{out} <4A)
- Step2: Fit T under fixed V_{in} conditions, the I_{out} parameters are obtained from Step1 --> derive fitted **T parameters (a_0~ a_2 and b_0 ~ b_3)**
  - $\boldsymbol{Eff = g\ (I_{out}, T)}$: (fix V_{in} = 10V)
    - $Eff\ = (1 + a_0 T) * p_0 I_{out} + (1 + a_1 T) * p_1 I_{out}^2 + (1 + a_2 T) * p_2 I_{out}^3$ (0A< I_{out} <0.8A)
    - $Eff\ = (1 + b_0 T) * q_0 + (1 + b_1 T) * q_1 I_{out} + (1 + b_2 T) * q_2 I_{out}^2 + (1 + b_3 T) * q_3 I_{out}^3$ (0.8A< I_{out} <4A)

Different linear function fit parameters $a_0/a_1/a_2$ are used for $I/I^2/I^3$, instead of the same a . Similarly for other parameters.

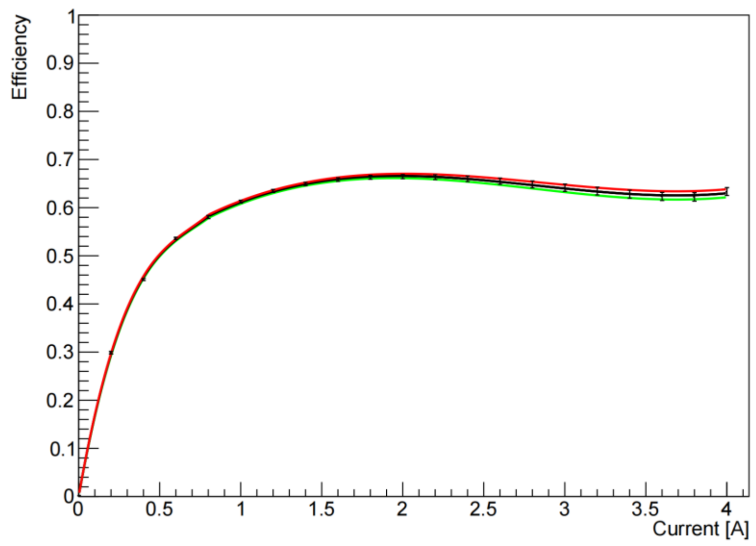
- Step3: Fit V_{in} under fixed T conditions, the I_{out} parameters are obtained from Step1 --> derive fitted **V_{in} parameters (c_0~ c_2 and d_0 ~ d_3)**
  - $\boldsymbol{Eff = g\ (I_{out}, V_{in})}$: (fix T = 0℃)
    - $Eff\ = (1 + c_0\ (V_{in} - 10)\ ) * p_0 I_{out} + (1 + c_1\ (V_{in} - 10)\ ) * p_1 I_{out}^2 + (1 + c_2 (V_{in} - 10)) * p_2 I_{out}^3$ (0A< I_{out} <0.8A)
    - $Eff\ = (1 + d_0 (V_{in} - 10)) * q_0 + (1 + d_1 (V_{in} - 10)) * q_1 I_{out} + (1 + d_2 (V_{in} - 10)) * q_2 I_{out}^2 + (1 + d_3 (V_{in} - 10)) * q_3 I_{out}^3$ (0.8A< I_{out} <4A)
- Step4: Construct the full function using parameters obtained above. Then, perform validation
  - $\boldsymbol{Eff = h\ (Iout, V_{in}, T)}$
    - $Eff\ = (1 + a_0 T) * (1 + c_0 (V_{in} - 10)) * p_0 I_{out} + (1 + a_1 T) * (1 + c_1 (V_{in} - 10)) * p_1 I_{out}^2 + (1 + a_2 T) * (1 + c_2 (V_{in} - 10)) * p_2 I_{out}^3$ (0A< I_{out} <0.8A)
    - $Eff\ = (1 + b_0 T) * (1 + d_0 (V_{in} - 10)) * q_0 + (1 + b_1 T) * (1 + d_1 (V_{in} - 10)) * q_1 I_{out} + (1 + b_2 T) * (1 + d_2 (V_{in} - 10)) * q_2 I_{out}^2 +$
      $(1 + b_3 T) * (1 + d_3 (V_{in} - 10)) * q_3 I_{out}^3$ (0.8A< I_{out} <4A)

Fit results: Step1

Calculate Eff_{ave}, Eff_{min} (Eff_{ave} - RMS) and Eff_{max} (Eff_{ave} + RMS) using data from B42, B43, B44 and B45.

Perform fit for Eff_{ave}, Eff_{min} and Eff_{max} respectively.

I_{out} parameters (p_0~ p_2 and q_0 ~ q_3) are obatined



	$Eff = p_0 I_{out} + p_1 I_{out}^2 + p_2 I_{out}^3$ (0A<I<0.8A)	$Eff = q_0 + q_1 I_{out} + q_2 I_{out}^2 + q_3 I_{out}^3$ (0.8A<I<4A)
min	Minimizer is Minuit / Migrad Chi2 = 3.65181e-05 NDf = 2 Edm = 1.77484e-23 NCalls = 66 p0 = 1.88097 +/- 0.0434357 p1 = -2.29841 +/- 0.156658 p2 = 1.06307 +/- 0.133319	Minimizer is Minuit / Migrad Chi2 = 5.04025e-05 NDf = 13 Edm = 4.37053e-17 NCalls = 86 p0 = 0.371471 +/- 0.00704625 p1 = 0.361619 +/- 0.0106099 p2 = -0.141946 +/- 0.00477618 p3 = 0.0167928 +/- 0.000658668
ave	Minimizer is Minuit / Migrad Chi2 = 4.19847e-05 NDf = 2 Edm = 1.03736e-22 NCalls = 66 p0 = 1.90203 +/- 0.0465734 p1 = -2.35165 +/- 0.167974 p2 = 1.10312 +/- 0.14295	Minimizer is Minuit / Migrad Chi2 = 4.92997e-05 NDf = 13 Edm = 1.74912e-16 NCalls = 86 p0 = 0.378258 +/- 0.00696874 p1 = 0.354078 +/- 0.0104932 p2 = -0.137486 +/- 0.00472364 p3 = 0.0161732 +/- 0.000651423
max	Minimizer is Minuit / Migrad Chi2 = 4.8562e-05 NDf = 2 Edm = 7.8305e-21 NCalls = 66 p0 = 1.92309 +/- 0.0500888 p1 = -2.4049 +/- 0.180653 p2 = 1.14316 +/- 0.15374	Minimizer is Minuit / Migrad Chi2 = 4.87168e-05 NDf = 13 Edm = 5.84615e-17 NCalls = 86 p0 = 0.385045 +/- 0.00692743 p1 = 0.346537 +/- 0.0104309 p2 = -0.133026 +/- 0.00469564 p3 = 0.0155535 +/- 0.00064756

The chi2 for each parameters is ~10^{-5}

Fit results: Step2 & Step3

Calculate Eff_{ave}, Eff_{min} (Eff_{ave} - RMS) and Eff_{max} (Eff_{ave} + RMS) using data from B42, B43, B44 and B45.

Perform fit for Eff_{ave}, Eff_{min} and Eff_{max} respectively.

$$\boldsymbol{Eff = g\,(Iout, T)}$$

T parameters (a_0~ a_2 and b_0 ~ b_3) are obatined

	$Eff = (1 + a_0T) * p_0I_{out} + (1 + a_1T) * p_1I_{out}^2 + (1 + a_2T) * p_2I_{out}^3$ **(0A<I<0.8A)**	$Eff = (1 + b_0T) * q_0 + (1 + b_1T) * q_1I_{out} + (1 + b_2T) * q_2I_{out}^2 + (1 + b_3T) * q_3I_{out}^3$ **(0.8A<I<4A)**
min	Minimizer is Minuit / Migrad Chi2 = 0.000376321 NDf = 47 Edm = 5.60832e-23 NCalls = 59 p0 = -0.000339204 +/- 0.000165609 p1 = -0.000423783 +/- 0.000488741 p2 = -0.000546777 +/- 0.00089909	Minimizer is Minuit / Migrad Chi2 = 0.000589326 NDf = 166 Edm = 8.38907e-21 NCalls = 90 p0 = -0.00020136 +/- 0.000196651 p1 = -2.80726e-05 +/- 0.000304181 p2 = 0.00129169 +/- 0.000348838 p3 = 0.00202347 +/- 0.000406633
ave	Minimizer is Minuit / Migrad Chi2 = 0.0004144 NDf = 47 Edm = 9.16229e-23 NCalls = 59 p0 = -0.000362702 +/- 0.000171862 p1 = -0.000428837 +/- 0.000501261 p2 = -0.000524723 +/- 0.000909228	Minimizer is Minuit / Migrad Chi2 = 0.000535011 NDf = 166 Edm = 2.74279e-18 NCalls = 90 p0 = -0.000363404 +/- 0.000184008 p1 = 0.000135934 +/- 0.000295997 p2 = 0.00142807 +/- 0.000343156 p3 = 0.00213587 +/- 0.000402285
max	Minimizer is Minuit / Migrad Chi2 = 0.000459901 NDf = 47 Edm = 3.98189e-22 NCalls = 59 p0 = -0.000385686 +/- 0.000179069 p1 = -0.000433692 +/- 0.000516371 p2 = -0.000504172 +/- 0.000924296	Minimizer is Minuit / Migrad Chi2 = 0.000522138 NDf = 166 Edm = 4.63988e-19 NCalls = 90 p0 = -0.000519736 +/- 0.000178577 p1 = 0.000307077 +/- 0.000298778 p2 = 0.00157358 +/- 0.000350368 p3 = 0.00225727 +/- 0.00041325

$$\boldsymbol{Eff = g\,(I_{out}, Vin)}$$

V_{in} parameters (c_0~ c_2 and d_0 ~ d_3) are obatined

	$Eff = (1 + c_0\,(V_{in} - 10)) * p_0I_{out} + (1 + c_1\,(V_{in} - 10)) * p_1I_{out}^2 + (1 + c_2(V_{in} - 10)) * p_2I_{out}^3$ **(0A<I<0.8A)**	$Eff = (1 + d_0(V_{in} - 10)) * q_0 + (1 + d_1(V_{in} - 10)) * q_1I_{out} + (1 + d_2(V_{in} - 10)) * q_2I_{out}^2 + (1 + d_3(V_{in} - 10)) * q_3I_{out}^3$ **(0.8A<I<4A)**
min	Minimizer is Minuit / Migrad Chi2 = 0.000157407 NDf = 17 Edm = 2.751e-20 NCalls = 53 p0 = -0.0686285 +/- 0.00672056 p1 = -0.106515 +/- 0.0198337 p2 = -0.13504 +/- 0.0364862	Minimizer is Minuit / Migrad Chi2 = 0.000238281 NDf = 64 Edm = 1.70394e-20 NCalls = 82 p0 = -0.0729479 +/- 0.00761568 p1 = 0.0280383 +/- 0.0117842 p2 = 0.0144376 +/- 0.0135188 p3 = 0.00936406 +/- 0.0157631
ave	Minimizer is Minuit / Migrad Chi2 = 0.000169294 NDf = 17 Edm = 1.26987e-20 NCalls = 53 p0 = -0.0696867 +/- 0.00689254 p1 = -0.108918 +/- 0.0201033 p2 = -0.138047 +/- 0.0364651	Minimizer is Minuit / Migrad Chi2 = 0.00022986 NDf = 64 Edm = 4.00801e-21 NCalls = 82 p0 = -0.0712708 +/- 0.00734569 p1 = 0.0279068 +/- 0.0118206 p2 = 0.0135724 +/- 0.0137085 p3 = 0.00810716 +/- 0.0160752
max	Minimizer is Minuit / Migrad Chi2 = 0.000184419 NDf = 17 Edm = 3.64775e-22 NCalls = 53 p0 = -0.0707217 +/- 0.00711507 p1 = -0.111214 +/- 0.0205176 p2 = -0.14084 +/- 0.0367262	Minimizer is Minuit / Migrad Chi2 = 0.000223913 NDf = 64 Edm = 2.56714e-20 NCalls = 82 p0 = -0.0696528 +/- 0.00712225 p1 = 0.0277695 +/- 0.0119206 p2 = 0.012649 +/- 0.0139836 p3 = 0.00675217 +/- 0.016498

The chi2 for each parameters is ~10^{-4}, improved much compared to old results. (~10^{-3})

Fit results : Step4(construct the full function)

- $Eff_{ave} = (1 - 0.000362702T) * \left(1 - 0.0696867(V_{in} - 10)\right) * 1.90203I_{out} - (1 - 0.000428837T) * (1 - 0.108918(V_{in} - 10)) * 2.35165I_{out}^2 + (1 - 0.000524723T) * (1 - 0.138047(V_{in} - 10)) * 1.10312I_{out}^3$ (0A< I_{out} <0.8A)
- $Eff_{ave} = (1 - 0.000363404T) * \left(1 - 0.0712708(V_{in} - 10)\right) * 0.378258 + (1 + 0.000135934T) * \left(1 + 0.0279068(V_{in} - 10)\right) * 0.354078I_{out} - (1 + 0.00142807T) * (1 + 0.0135724(V_{in} - 10)) * 0.137486I_{out}^2 + (1 + 0.00213587T) * (1 + 0.00810716(V_{in} - 10)) * 0.0161732I_{out}^3$ (0.8A< I_{out} <4A)

- $Eff_{min} = (1 - 0.000339204T) * \left(1 - 0.0686285(V_{in} - 10)\right) * 1.88097I_{out} - (1 - 0.000423783T) * (1 - 0.106515(V_{in} - 10)) * 2.29841I_{out}^2 + (1 - 0.000546777T) * (1 - 0.13504(V_{in} - 10)) * 1.06307I_{out}^3$ (0A< I_{out} <0.8A)
- $Eff_{min} = (1 - 0.00020136T) * \left(1 - 0.0729479(V_{in} - 10)\right) * 0.371471 + (1 - 0.0000280726T) * \left(1 + 0.0280383(V_{in} - 10)\right) * 0.361619I_{out} - (1 + 0.001291697T) * (1 + 0.0144376(V_{in} - 10)) * 0.141946I_{out}^2 + (1 + 0.00202347T) * (1 + 0.00936406(V_{in} - 10)) * 0.0167928I_{out}^3$ (0.8A< I_{out} <4A)

- $Eff_{max} = (1 - 0.000385686T) * \left(1 - 0.0707217(V_{in} - 10)\right) * 1.92309I_{out} - (1 - 0.000433692T) * (1 - 0.111214(V_{in} - 10)) * 2.4049I_{out}^2 + (1 - 0.000504172T) * (1 - 0.14084(V_{in} - 10)) * 1.14316I_{out}^3$ (0A< I_{out} <0.8A)
- $Eff_{max} = (1 - 0.000519736T) * \left(1 - 0.0696528(V_{in} - 10)\right) * 0.385045 + (1 + 0.000307077T) * \left(1 + 0.0277695(V_{in} - 10)\right) * 0.346537I_{out} - (1 + 0.00157358T) * (1 + 0.012649(V_{in} - 10)) * 0.133026I_{out}^2 + (1 + 0.00225727T) * (1 + 0.00675217(V_{in} - 10)) * 0.0155535I_{out}^3$ (0.8A< I_{out} <4A)