考核报告

报告人: 翟明杰

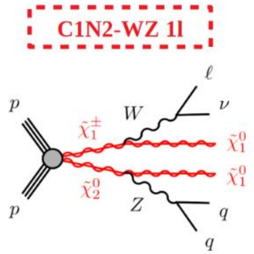
导师：Joao Guimaraes da Costa, 徐达

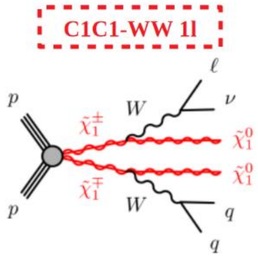
报告日期：2022.09.02

研究工作（2022.5 – 2022.8）

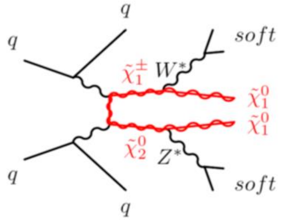
1. ATLAS实验超对称（SUSY）寻找

1. 单轻子分析



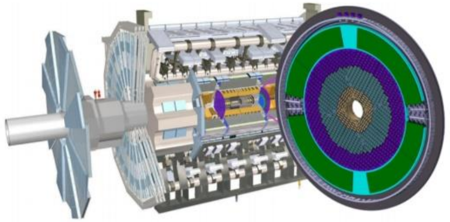


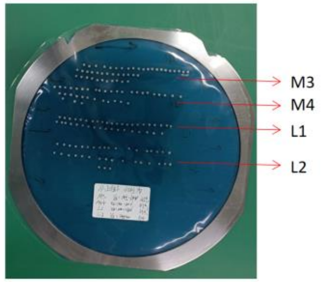
2. Compressed分析

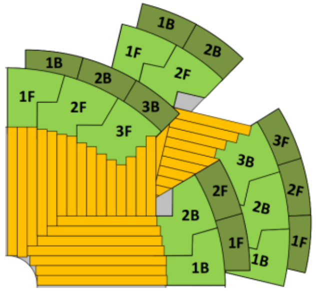


2. ATLAS实验高颗粒度时间探测器（HGTD）项目

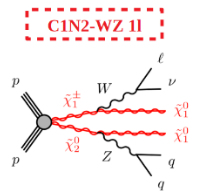
1. NDL 传感器的性能研究
2. PEB (周边电子学)的性能研究

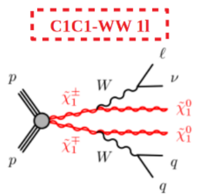






研究方向1-1: ATLAS SUSY 单轻子分析

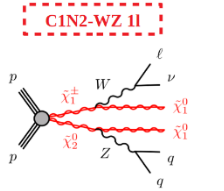


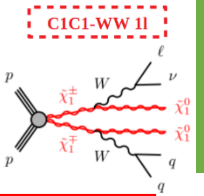


该分析首次研究1L末态的gaugino—>WW/WZ信号。

- 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
- 该分析于刚刚进行了最终的ATLAS审核，预计下周发表公开的ATLAS note。**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。**
- **本人主要工作1: 负责新一轮systematic ntuple的产生和检验。**
- **本人主要工作2: 对新的Sh2.2.11 V+jets样本进行研究:**
  - **与旧的Sh2.2.1 V+jets 样本进行比较，发现新的样本统计误差较小，初选条件下，data/MC的符合程度较好。**
  - **重新计算新样本各种理论误差。**
- **本人主要工作3: 基于新的样本，负责产生和分析所有的拟合结果。**
  - **Bkg-only fit: 对所有本底在控制区进行拟合，检验拟合后不同区域的data/MC符合程度。**
  - **Model-dependent fit: 对所有本底+信号在控制区+信号区进行拟合，得出排除域。**
  - **Model-independent fit: 对所有本底+dummy信号在在控制区+信号区进行拟合，得出dummy信号的上限。**

研究方向1-1: ATLAS SUSY 单轻子分析



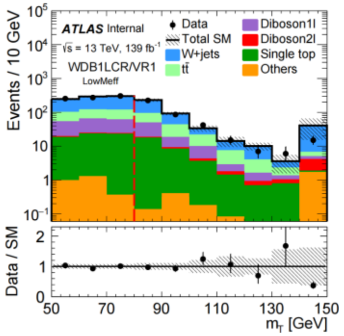


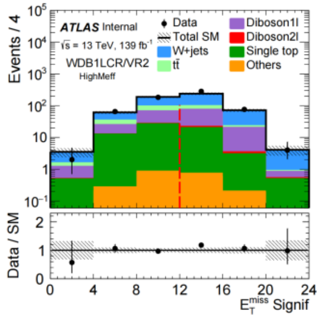
bkg-only fit

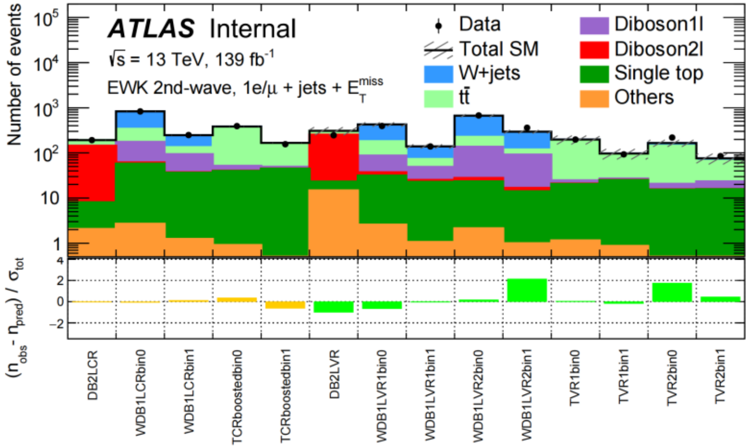
$$\text{mu\_DB2L} = 1.22^{+0.18}_{-0.18}$$

$$\text{mu\_ttbar} = 0.81^{+0.10}_{-0.09}$$

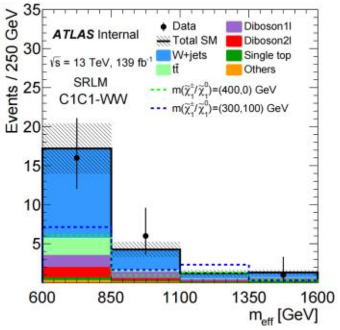
$$\text{mu\_WDB1L} = 1.05^{+0.09}_{-0.09}$$

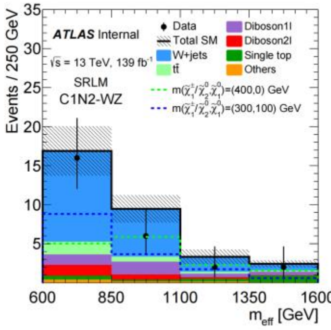


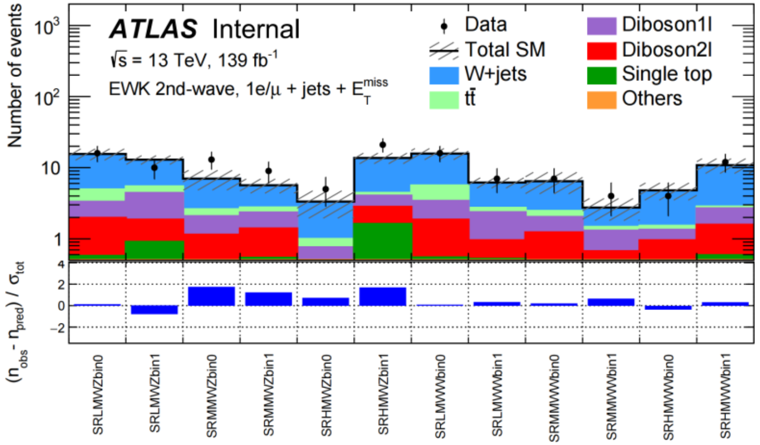




Data/MC在CR/VR符合程度很好。

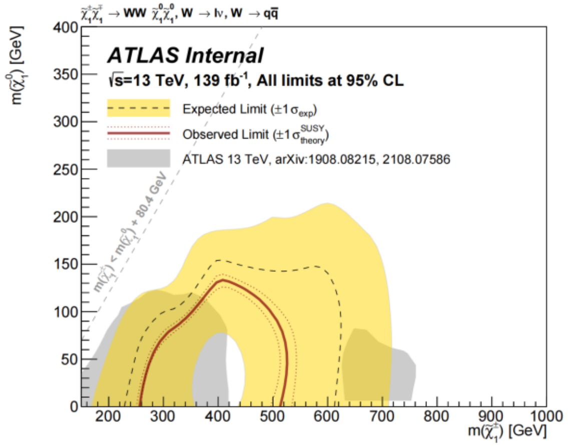


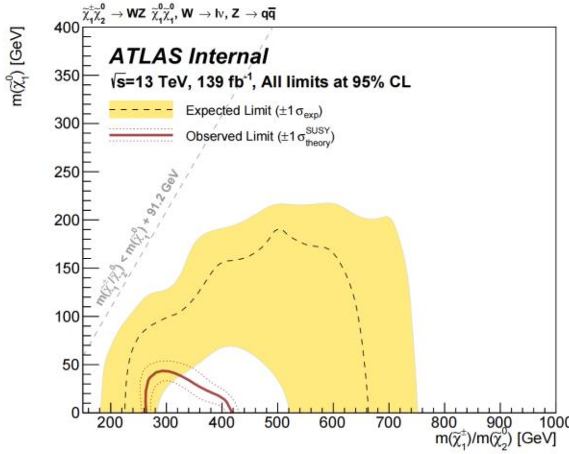




- ✓ C1C1_WW的信号区里面，没有明显的超出。
- ✓ C1N2_WZ的信号区里面，有一些小的超出(<2σ)。

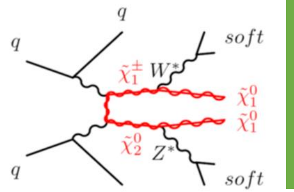
Model-dependent fit





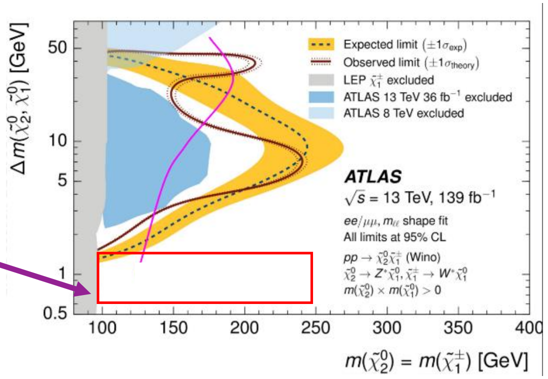
对于C1C1_WW过程，$\tilde{\chi}_1^{\pm}$排除域相较于之前的结果提升了100GeV。

研究工作1-2: ATLAS SUSY Compressed分析

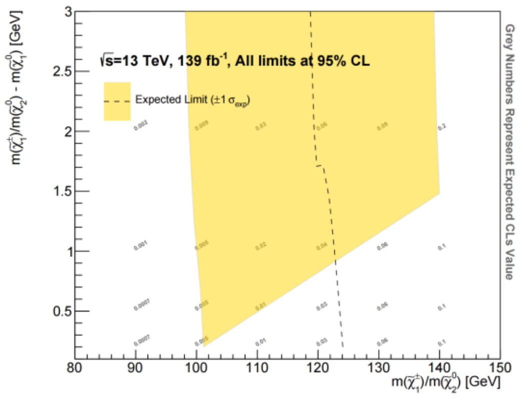


该分析主要研究质量压缩的SUSY空间；是寻找Higgsino粒子最适合的研究和热门课题。

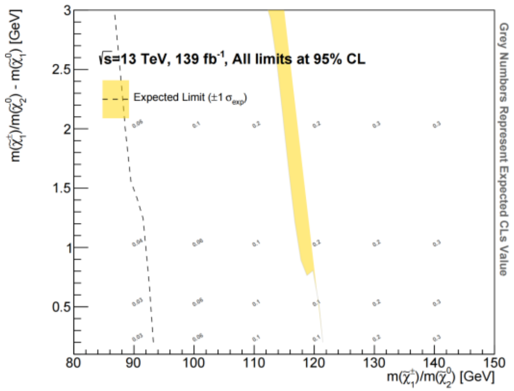
- 研究目标：通过新“矢量玻色子融合VBF进程”进一步拓展deltaM<1GeV空间。
  - 质量压缩空间的末态粒子动量很低->难以重建
  - 标记两个VBF jets->触发事例
  - 末态：2 VBF jets + MET（0 轻子）
- 该分析已于2021.06.11完成ATLAS的Partial Analysis Review；计划于明年发表。
- 本人目前担任该分析**主要分析人员。**
- **主要工作1：对信号区的信号显著性进行研究。**
- **主要工作2：对QCD本底过程进行估计。**



SR fit (0% sys)

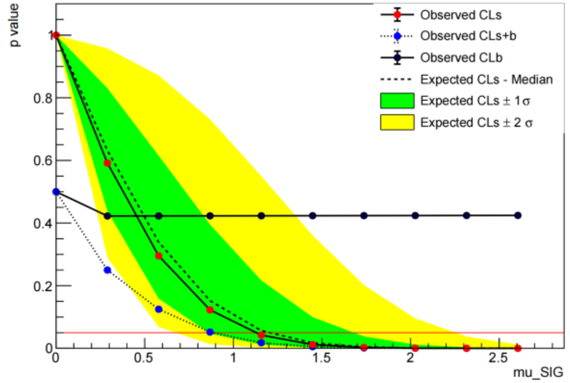


SR fit (JET sys)

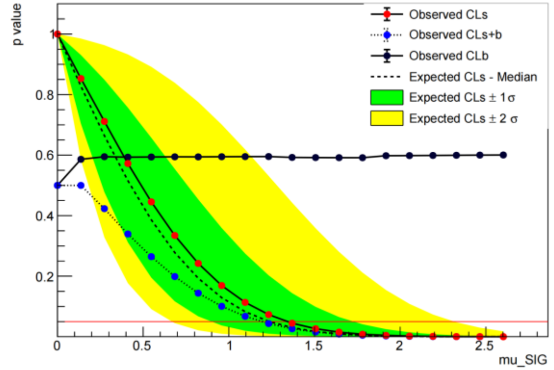


对不同信号点，在信号区进行model-dependent fit，得出理论的排除域。

CR+SR fit (NF sys)

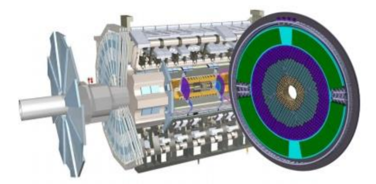


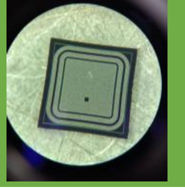
SR+CR fit (NF sys+JET sys)



对信号点(100,99)在信号区+控制区进行model-dependent fit，得出理论的limit。

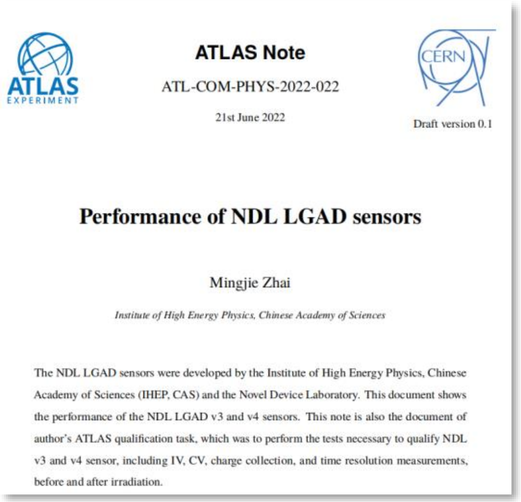
研究方向2-1: NDL_v4传感器性能研究





NDL传感器是高能所联合北师大设计制作的一款用于HGTD探测器的LGAD传感器。

- NDL第四版传感器包括三种不同注入的设计(高注入的过早击穿，主要研究**低、中注入**),本人**负责**对其进行性能的研究。
- **主要工作1: 完成了辐照后的性能测试**
  - **低温的IV 测试。**
  - **常温下CV测试。(上次考核已汇报)**
  - **低温的beta测试，得出传感器的电荷收集和时间分辨等性能。**
- **主要工作2：汇总NDL第三版和第四版传感器研究成果。**
  - **将全部的研究成果总结到ATLAS COM note里面。**
  - **在HGTD long week里面总结汇报所有成果，顺利完成了本人的qualification task。**



ATLAS EXPERIMENT

ATLAS Note

ATL-COM-PHYS-2022-022

21st June 2022

CERN

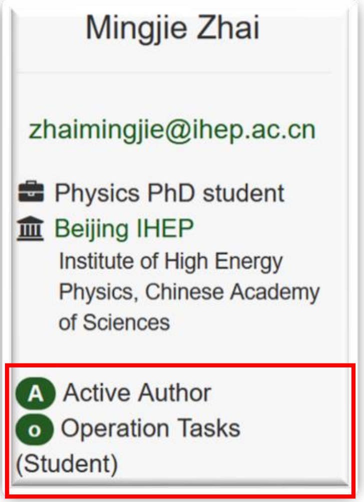
Draft version 0.1

Performance of NDL LGAD sensors

Mingjie Zhai

Institute of High Energy Physics, Chinese Academy of Sciences

The NDL LGAD sensors were developed by the Institute of High Energy Physics, Chinese Academy of Sciences (IHEP, CAS) and the Novel Device Laboratory. This document shows the performance of the NDL LGAD v3 and v4 sensors. This note is also the document of author's ATLAS qualification task, which was to perform the tests necessary to qualify NDL v3 and v4 sensor, including IV, CV, charge collection, and time resolution measurements, before and after irradiation.



Mingjie Zhai

zhaimingjie@ihep.ac.cn

Physics PhD student

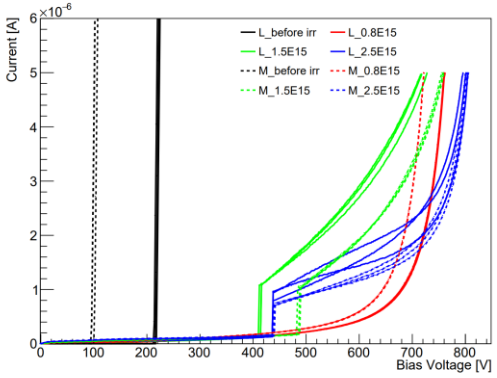
Beijing IHEP

Institute of High Energy Physics, Chinese Academy of Sciences

A Active Author

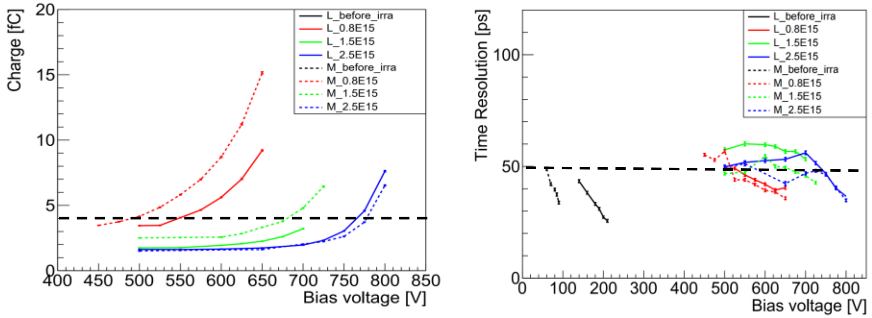
o Operation Tasks (Student)

低温下的IV研究



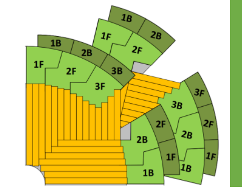
- ✓ **辐照之后，漏电流增大，击穿电压变高。**

低温下的beta测试

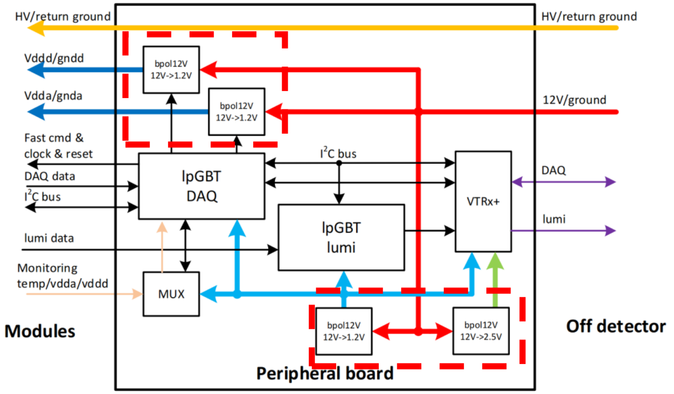


- ✓ **辐照剂量较低时，中注入的传感器性能更好。剂量提高后，中注入和低注入的性能接近。**
- ✓ **结论：通过提高注入的方法，不能有效提高传感器的抗辐照性能。**

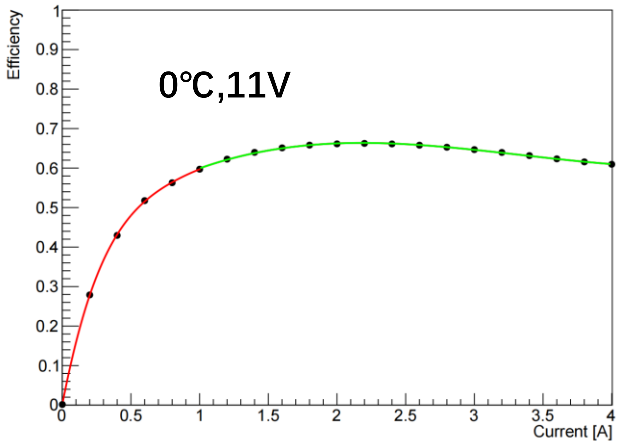
研究方向2-2: PEB(周边电子学)的性能研究



- 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。
- 通过对BPOL12V的效率进行研究，有利于各部件的散热和电流输入进行优化。
- **本人主要工作：研究BPOL12V的效率和输出电流、输入电压、温度的之间关系。**
- 下一步：对BPOL12V的效率进行多维拟合，同时测量并收集更多的数据。

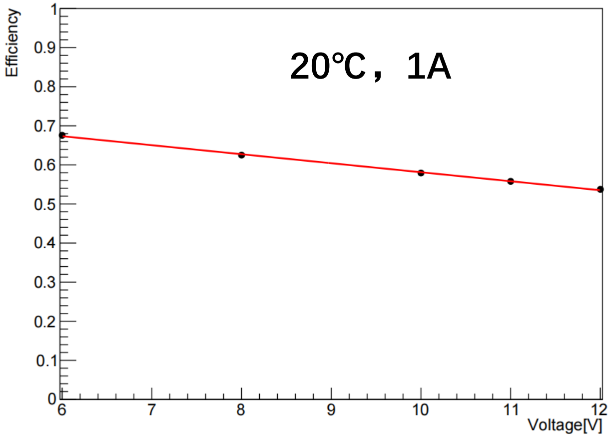


效率 – 输出电流



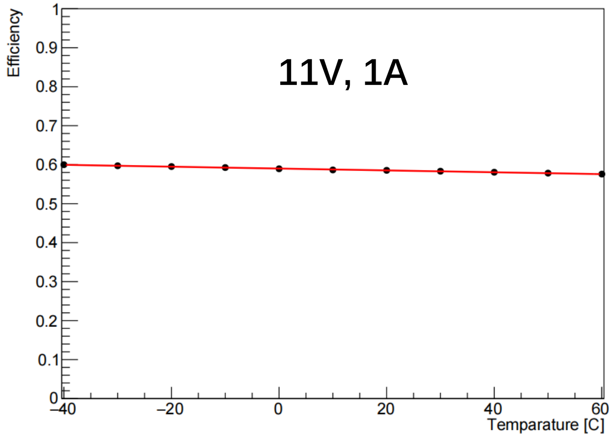
$$Eff = p0 + p1I + p2\,I^2 + p3\,I^3 + p4I^4 \quad (0A < I < 1A)$$
$$Eff = p0 + p1I + p2\,I^2 + p3\,I^3 \quad (1A < I < 4A)$$

效率 – 输入电压



$$Eff = p0 + p1V$$

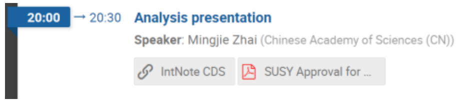
效率 – 温度

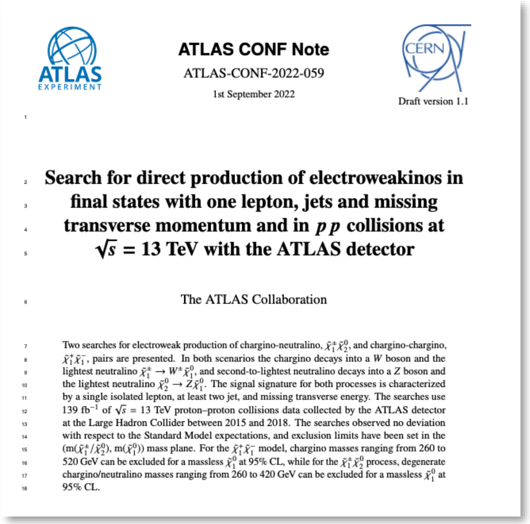


$$Eff = p0 + p1T$$

总结与展望

- 超对称物理探寻：
  - 担任**SUSY 1L分析的最主力分析人员**和**SUSY compressed组分析的主力分析人员**。数次在这两个分析的组会作报告，同时在会议上给出**重要**报告如下：
    - **代表EWK 1L 组进行SUSY approval报告: https://indico.cern.ch/event/1177814/**
    - **代表EWK 1L 组进行ATLAS approval报告: https://indico.cern.ch/event/1194429/**
  - 下一步：推动以上两分析，1L分析预计下周发表ATLAS CONF Note (**ATLAS-CONF-2022-059**)，年底发表一篇期刊文章。Compressed分析预计明年发表一篇文章。





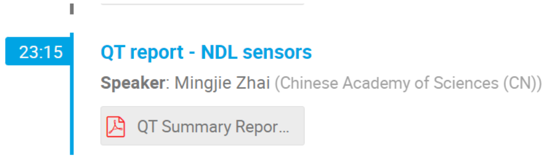
ATLAS CONF Note
ATLAS-CONF-2022-059
1st September 2022
Draft version 1.1

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

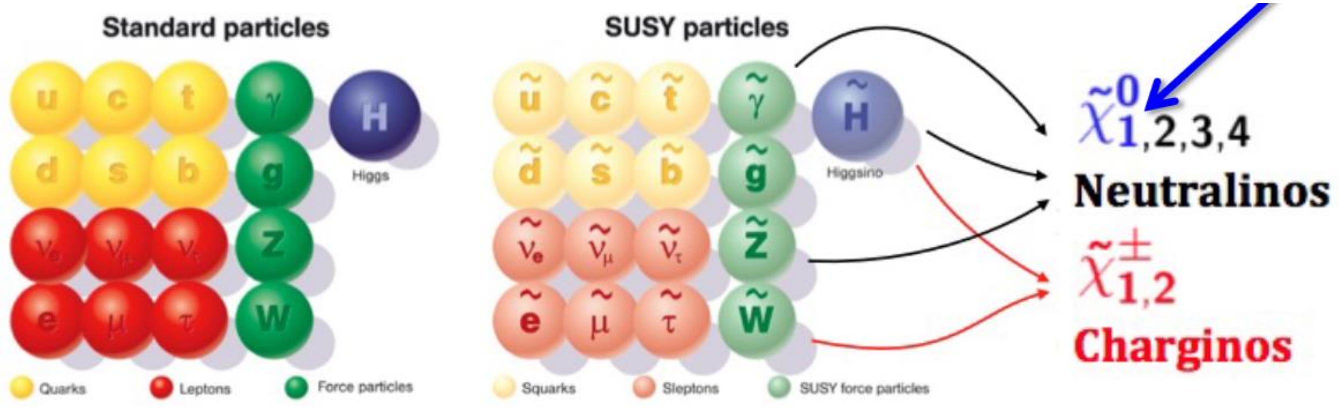
Two searches for electroweak production of chargino-neutralino, $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$, and chargino-chargino, $\tilde{\chi}_1^+\tilde{\chi}_1^-$, pairs are presented. In both scenarios the chargino decays into a W boson and the lightest neutralino $\tilde{\chi}_1^\pm \to W^\pm\tilde{\chi}_1^0$, 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.

- HGTD 研究：
  - 本人对新一版的NDL传感器进行辐照前后IV、CV、电荷收集、时间分辨等性能的研究。
    - **在ATLAS HGTD long week汇报了本人所有的NDL sensor的研究结果(https://indico.cern.ch/event/1127322/#128-qt-report-ndl-sensors)，并将所有结果总结在 ATL-COM-HGTD-2022-023中。顺利完结了本人的qualification task。**
  - 正在进行PEB BPOL12V的效率研究。
  - 下一步：继续参与PEB的研究工作。



Backup

超对称简介


Standard particles
u
c
t
d
s
b
γ
g
Z
W
H
Higgs
e
μ
τ
Quarks
Leptons
Force particles
SUSY particles
Higgsino
Squarks
Sleptons
SUSY force particles
$\tilde{\chi}^0_{1,2,3,4}$
Neutralinos
$\tilde{\chi}^\pm_{1,2}$
Charginos


Bino LSP
μ
higgsino
$\tilde{\chi}^0_3, \tilde{\chi}^0_4, \tilde{\chi}^\pm_2$
M_2
wino
$\tilde{\chi}^0_2, \tilde{\chi}^\pm_1$
M_1
bino
$\tilde{\chi}^0_1$
Higgsino LSP
M_1
bino
$\tilde{\chi}^0_4$
M_2
wino
$\tilde{\chi}^0_3, \tilde{\chi}^\pm_2$
μ
higgsino
$\tilde{\chi}^0_1, \tilde{\chi}^0_2, \tilde{\chi}^\pm_1$
Wino LSP
M1
bino
$\tilde{\chi}^0_4$
μ
higgsino
$\tilde{\chi}^0_2, \tilde{\chi}^0_3, \tilde{\chi}^\pm_2$
M2
wino
$\tilde{\chi}^0_1\ \tilde{\chi}^\pm_1$

ATLAS SUSY Compressed分析 --- region

- **0L Preselection:**
  - Passes MET trigger
  - MET > 200 GeV
  - Valid VBF tag(i.e. at least 2 non-btagged jets with pt > 30, eta < 5 that have eta1 * eta2 < 0)
  - M_jj > 500 GeV
  - nLep_signal = 0

SR

- **nLep_signal == 0**
- **trigMatch_metTrig == 1**
- vbfjjM > 1000
- vbfTagJet1_Pt > 80
- vbfTagJet2_Pt > 80
- vbfjjDEta > 3
- vbfjjDPhi < 2
- minDPhiAllJetsMet > 0.6
- nBJet20 == 0
- **nJets = {2,3,4}**
- **Met = {200,225,250,275,300, 325,350,375,400,425,450,475,500,525,550, 600,700,+∞}**

WCR

- **nLep_signal == 1**
- **trigMatch_singleElectronTrig == 1|| trigMatch_singleMuonTrig == 1**
- vbfjjM > 1000
- vbfTagJet1_Pt > 80
- vbfTagJet2_Pt > 80
- vbfjjDEta > 3
- vbfjjDPhi < 2
- minDPhiAllJetsMet_LepInvis > 0.6
- nBJet20 == 0
- nJets = {2,3,4}
- met_Et_LepInvis > 200

ZCR

- **nLep_signal == 2**
- **trigMatch_diElectronTrig == 1|| trigMatch_diMuonTrig == 1**
- vbfjjM > 1000
- vbfTagJet1_Pt > 80
- vbfTagJet2_Pt > 80
- vbfjjDEta > 3
- vbfjjDPhi < 2
- minDPhiAllJetsMet_LepInvis > 0.6
- nBJet20 == 0
- nJets = {2,3,4}
- met_Et_LepInvis > 200

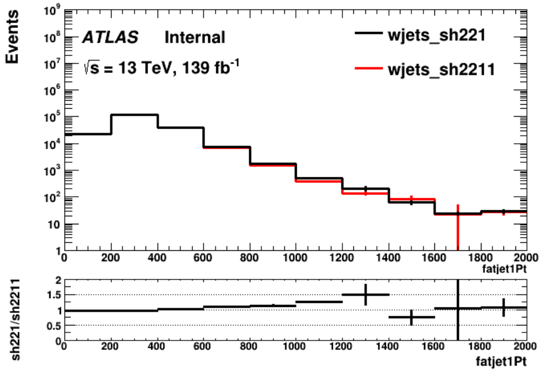
ATLAS SUSY 单轻子分析 --- region

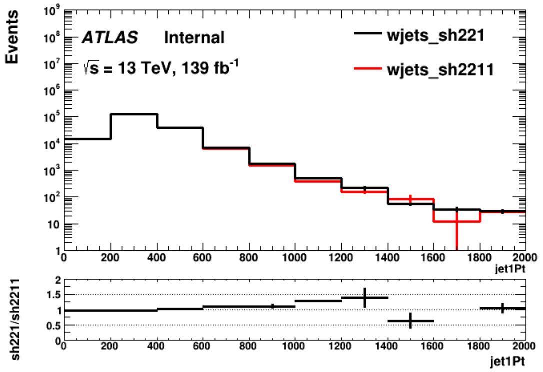
Variable	C1C1-WW model SRLM	C1C1-WW model SRMM	C1C1-WW model SRHM	C1N2-WZ model SRLM	C1N2-WZ model SRMM	C1N2-WZ model SRHM
N_{lep} ($p_T > 25$ GeV)	1					
N_{jet} ($p_T > 30$ GeV)	1 – 3					
$N_{large-Rjet}$ ($p_T > 250$ GeV)	≥ 1					
E_T^{miss} [GeV]	> 200					
$\Delta\phi(\ell, E_T^{miss})$	< 2.6					
large-R jet type	W-tagged			Z-tagged		
m_T [GeV]	120–200	200–300	> 300	120–200	200–300	> 300
	Exclusion SR					
m_{eff} [GeV] (excl.)	[600–850, > 850]			[600–850, > 850]		
m_{jj}[GeV] (excl.)	[70–90, -]			[80–100, -]		
$\sigma_{E_T^{miss}}$ (excl.)	[> 12, > 15]			[> 12, > 12]		
	Discovery SR					
m_{eff} [GeV] (disc.)	> 600	> 600	> 850	> 600	> 850	> 850
m_{jj}[GeV] (disc.)	-	-	-	80–100	-	-
$\sigma_{E_T^{miss}}$ (disc.)	> 15	> 15	> 15	> 12	> 12	> 12

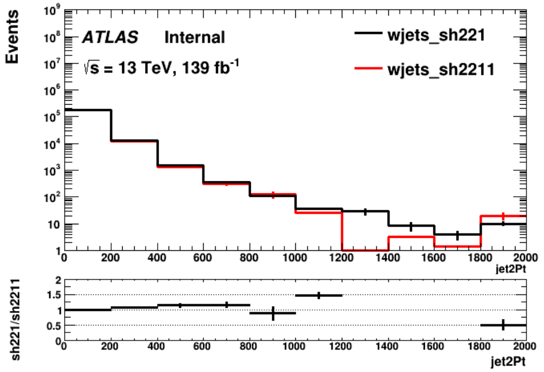
Variable	WDB1L and T CR	WDB1L and T VR1	WDB1L and T VR2
N_{lep} ($p_T > 25$ GeV)	1		
N_{jet} ($p_T > 30$ GeV)	1 - 3		
N_{b-jet} ($p_T > 30$ GeV)	0 for WDB1L; > 0 for Top		
$N_{large-Rjet}$ ($p_T > 250$ GeV)	≥ 1		
E_T^{miss} [GeV]	> 200		
$\Delta\phi(\ell, E_T^{miss})$	< 2.9		
large-R jet type	W-tagged		
m_{eff} [GeV]	[600-850,> 850]		
$\sigma_{E_T^{miss}}$	< 12	< 12	> 12
m_T [GeV]	50 – 80	> 80	50 – 120

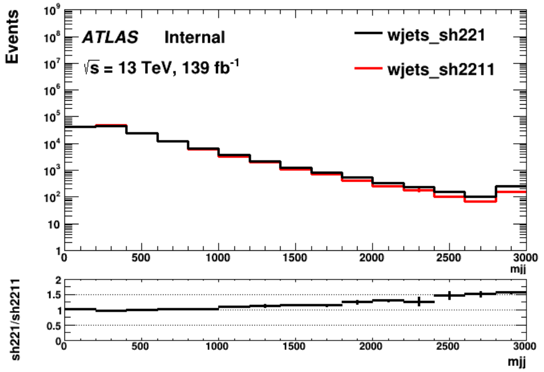
Variable	DB2L CR	DB2L VR
N_{lep} ($p_T > 25$ GeV)	2	
N_{jet} ($p_T > 30$ GeV)	1 - 3	
N_{b-jet} ($p_T > 30$ GeV)	0	
E_T^{miss} [GeV]	> 200	
$\Delta\phi(\ell, E_T^{miss})$	< 2.9	
$m_{\ell\ell}$ [GeV]	70 – 100	
m_{jj} veto [GeV]	75 – 95	
$\sigma_{E_T^{miss}}$	> 12	> 10
m_T [GeV]	50 – 200	200 – 350

ATLAS SUSY 单轻子分析 --- Sh221 vs Sh2211







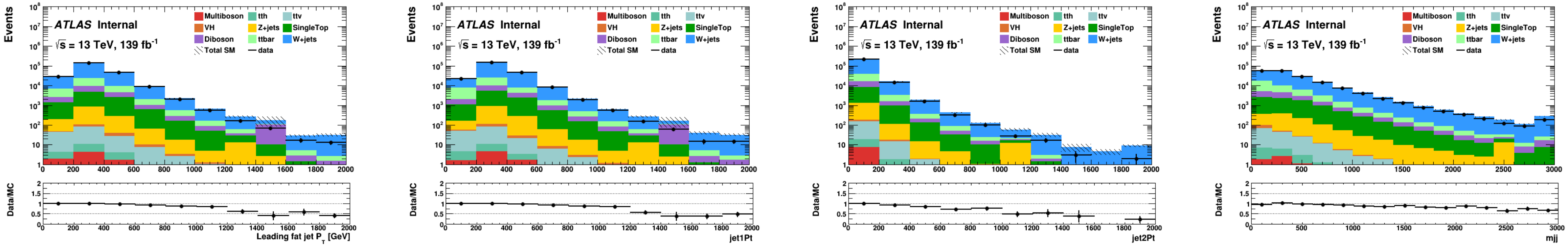


	raw	weighted
wjets_sh2211	5965846	192020 ± 244
wjets_sh221	2310017	190936 ± 473

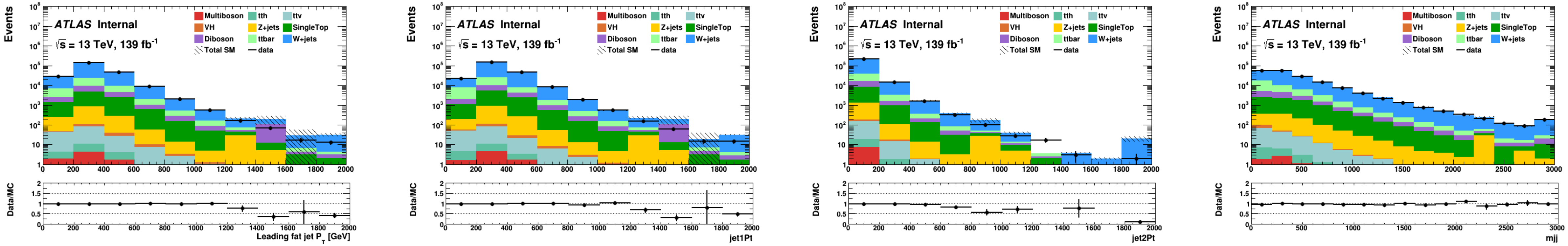
- **At preselection level, Sh2.2.11 has lower estimation comparing to Sh2.2.1 in high jet Pt region (>400GeV).**
- **The conclusion agrees with the discussion in note.**
- **Sh2.2.11 has 2.6 times more stats than Sh2.2.1.**

ATLAS SUSY 单轻子分析 --- Sh221 vs Sh2211

Sh2.2.1 for V+jets

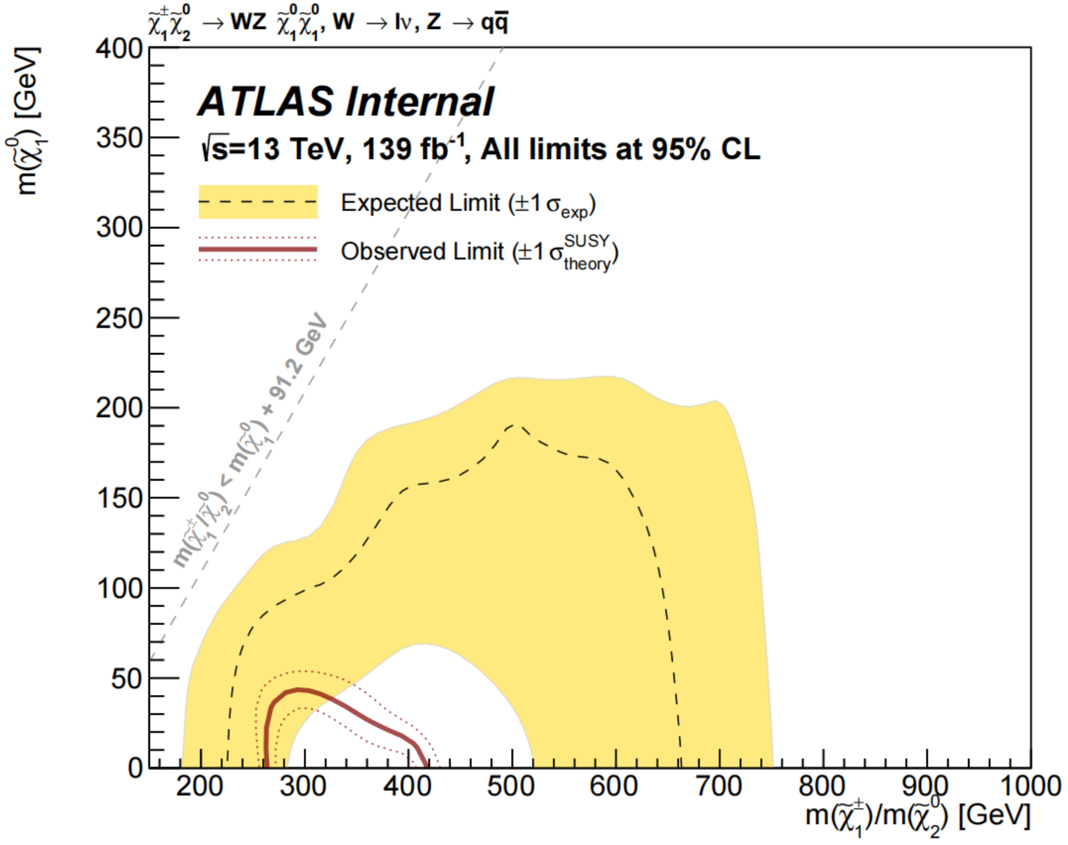


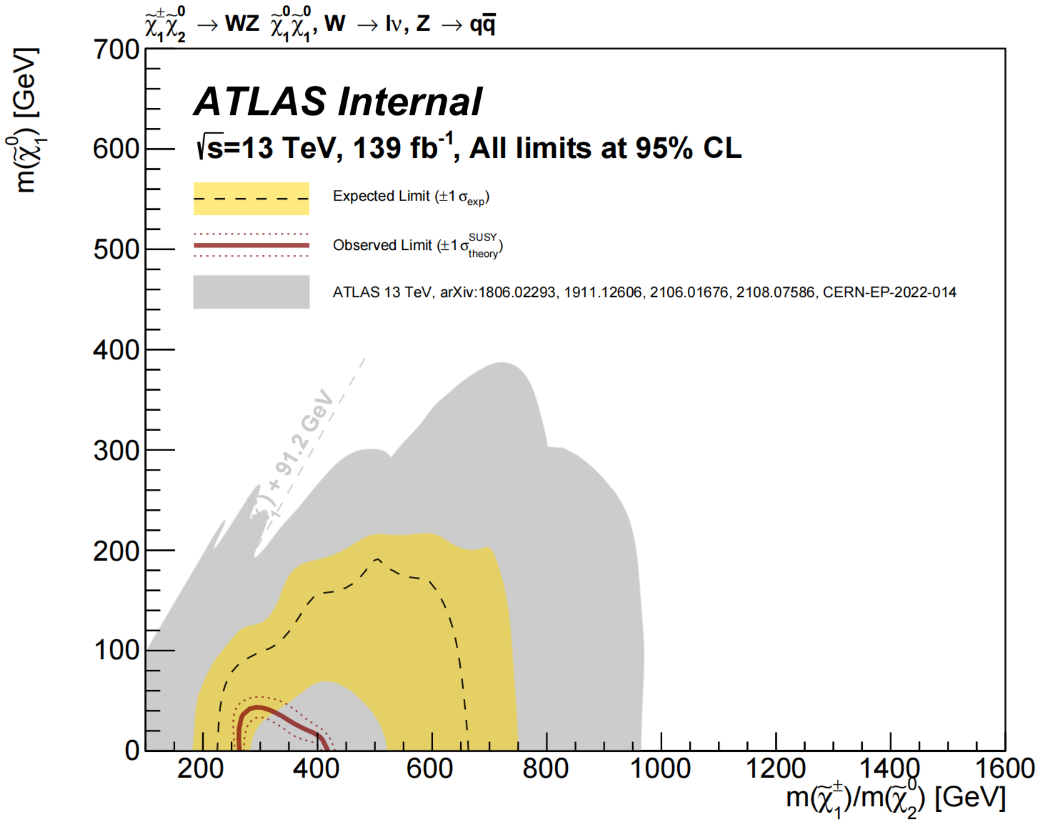
Sh2.2.11 for V+jets



Improved data/MC agreement in high jet Pt region (esp. 400-1200GeV.)

ATLAS SUSY 单轻子分析 --- Limit (C1N2-WZ)





ATLAS HGTD sensor Specifications

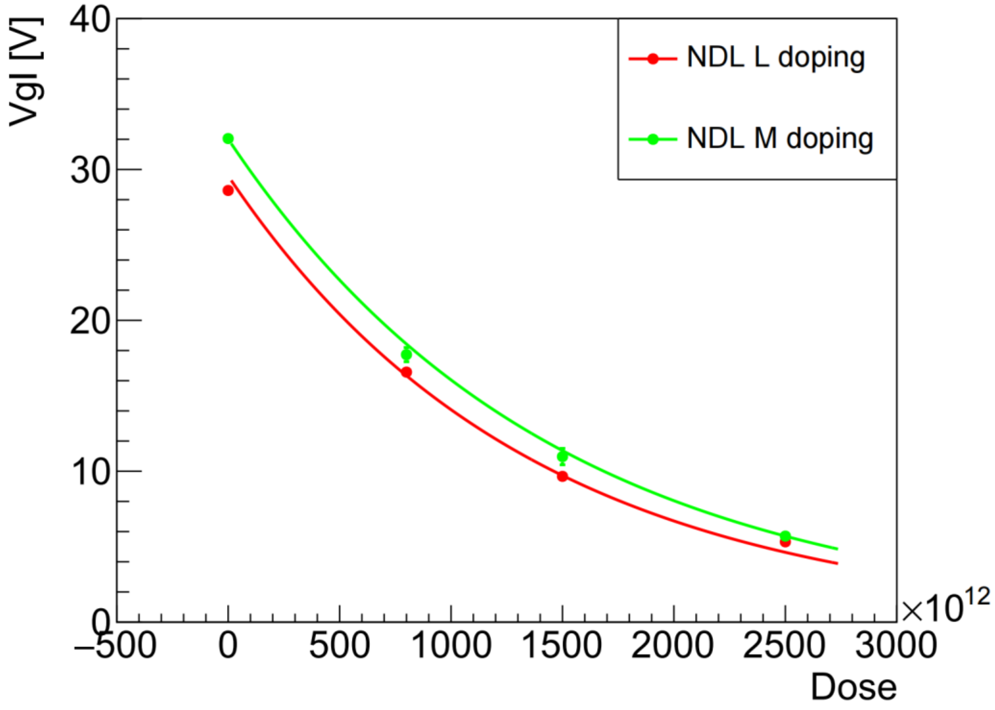
Technology Pad size Pad array (rows × columns)	Silicon Low Gain Avalanche Detector (LGAD) 1.3 ×1.3 mm^2 15 × 15
Substrate Thickness (D)	p-type 50±5 μm (active), 300±30 μm (total)
HV biasing	back side
Time resolution	~35 ps at V_{op} (as produced)
Charge collection	>15 fC at V_{op} (as produced)
Passivation thickness Bump-bonding pad opening	between 0.8 μm and 5 μm 90 μm diameter
Bump-bonding pad size	95 μm diameter
Inactive edge Dicing chipping Dicing line	<300 μm <20 μm 80 μm
Target pad capacitance	<4.5 pF (backplane+inter-pad)
Gain layer depletion (V_{gl})	< 60 V
Full depletion (V_{fd})	< V_{gl} + 90 V
Breakdown voltage (V_{bd}) (-30ºC) Breakdown condition (-30ºC) Device leakage current (-30ºC)	(V_{bd}-V_{gl})/D>0.7 V/μm, V_{bd}>V_{fd}+30 V >200 nA/pad < 2 μA/cm^2 at V_{op} (~35 ps, >15 fC)
Pad leakage current (-30ºC) Inter-pad gap (IP) Fraction of good sensors per wafer (all pads within specifications)	< 200 nA at V_{op} (~35 ps, >15 fC) 40 μm < IP <100 μm (region with <4 fC , time resolution < 50 ps) 70 % if the UBM is not done at fabrication site
Optical inspection	no stains, residues or scratches on sensor area.

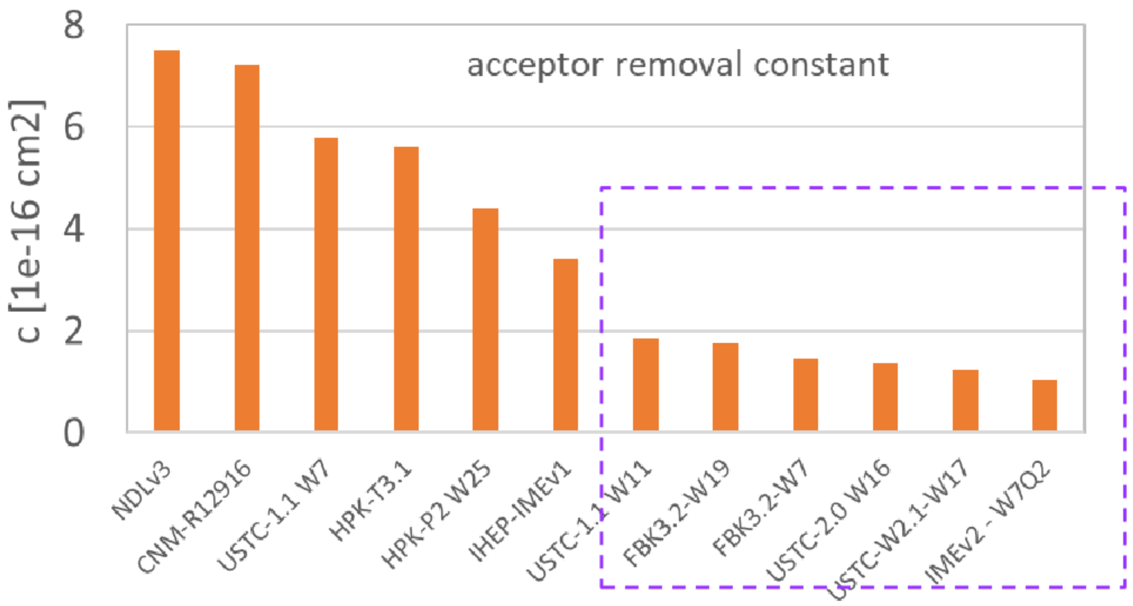
Pad leakage current (V_{bd} condition)	< 500 nA
Breakdown voltage requirement	(V_{bd}-V_{gl})/D>1.7 V/μm
Device leakage current $V_{gl,pad}$ spread over the sensor	< 5 μA/cm^2 at bias voltage<V_{bd} (Max($V_{gl,pad}$)-Min($V_{gl,pad}$))/<$V_{gl,pad}$> <0.01
$V_{bd,pad}$ spread over the sensor Pad leakage current spread at 0.9·V_{bd}	RMS($V_{bd,pad}$)/<$V_{bd,pad}$> <0.05 Peak-to-Peak within a factor of 3x

Hit efficiency at normal incidence (central part of pad)	> 97% (>95%) before (after) irradiation
Time resolution	<35 ps (<70 ps) before (after) irradiation
Power consumption at V_{op} Total leakage current	< 100 mW/cm^2 <125 μA/cm^2
Collected charge Maximum pad leakage current	>15 fC (start), >4 fC (end of lifetime) 5 μA
Maximum bias voltage at the sensor	800 V

NDL 传感器 --- 抗辐照性能

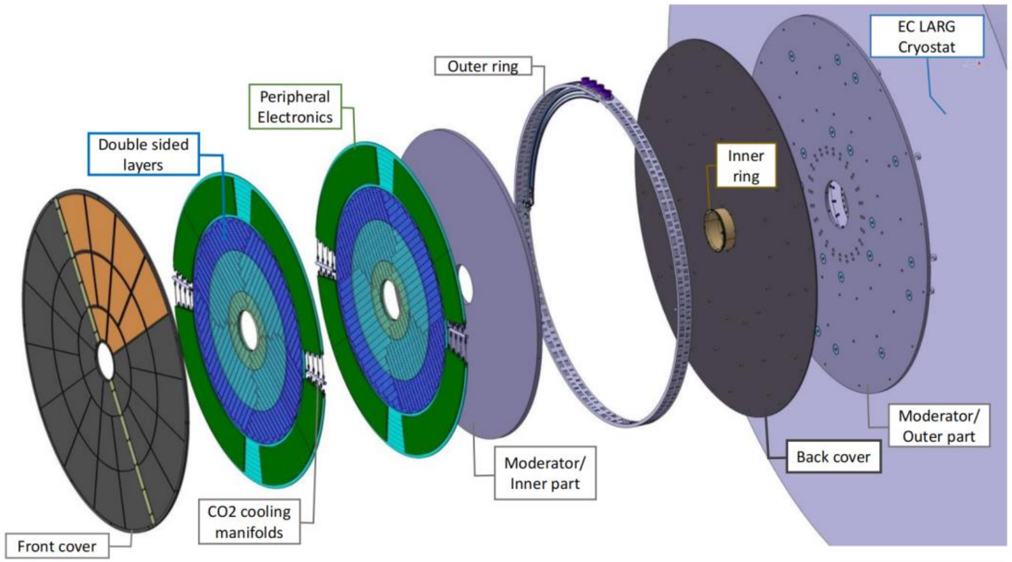
Fit the function using Vgl = const * Exp (-c factor * dose)

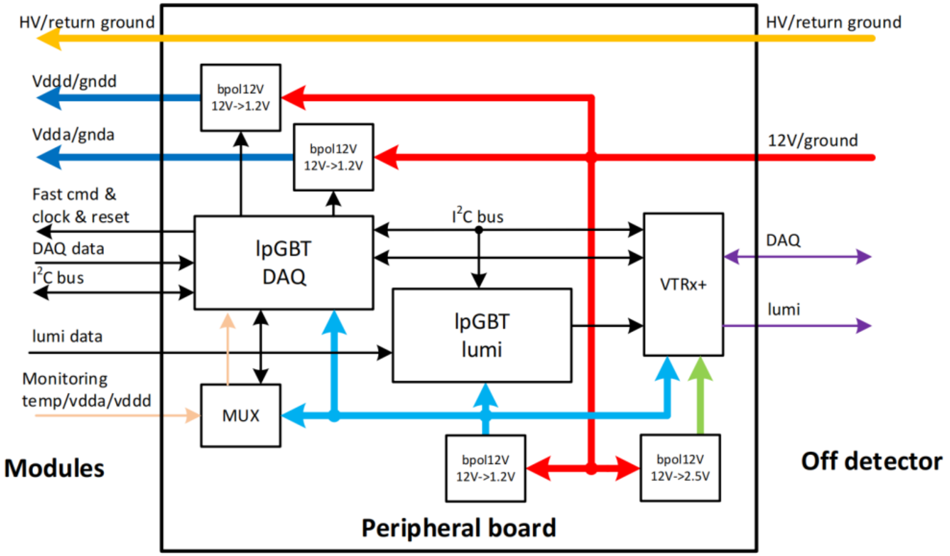


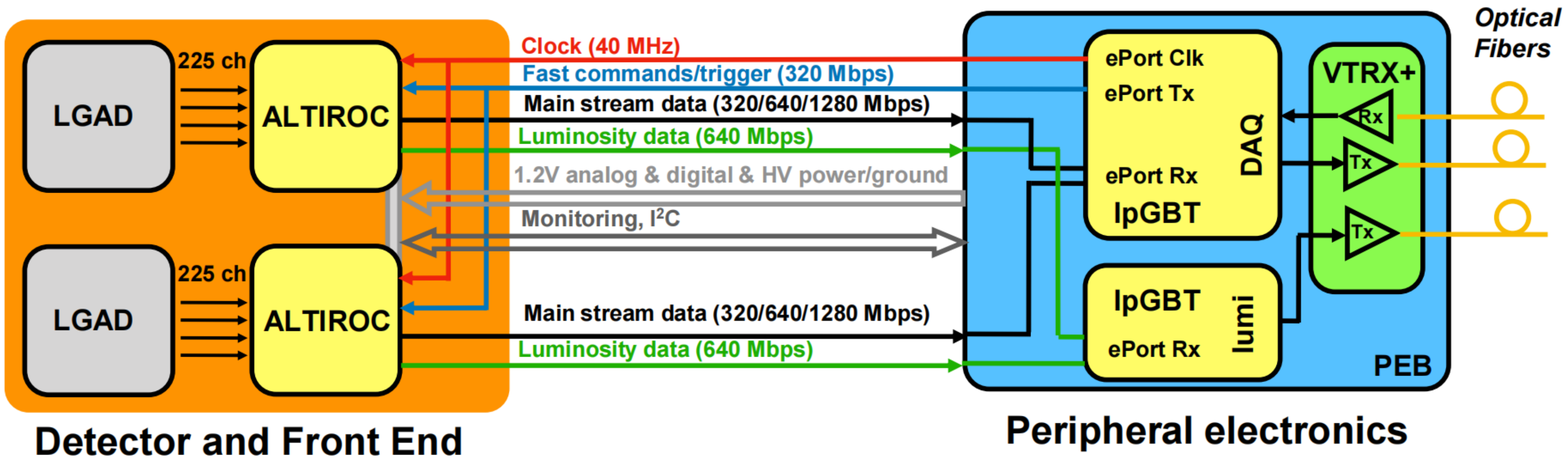


	cons	err(cons)	c factor	err (c factor)
L doping	29.57	0.06	7.422*10-16	0.016*10-16
M doping	32.02	0.15	6.905*10-16	0.023*10-16

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
Modules
bpol12V 12V->1.2V
bpol12V 12V->2.5V
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
lpGBT
ePort Rx
lumi
VTRX+
Rx
Tx
Tx
Optical Fibers
PEB
Detector and Front End
Peripheral electronics