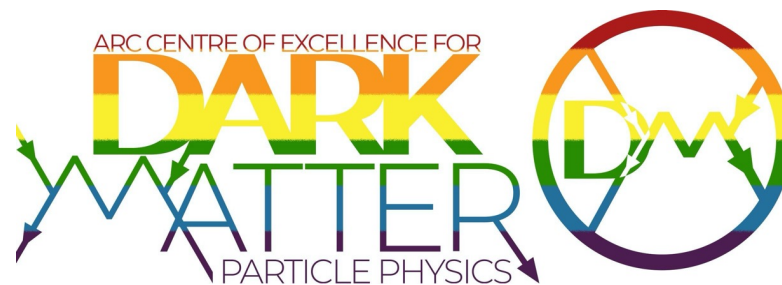


# LHC Theme: Dark Matter @ ATLAS

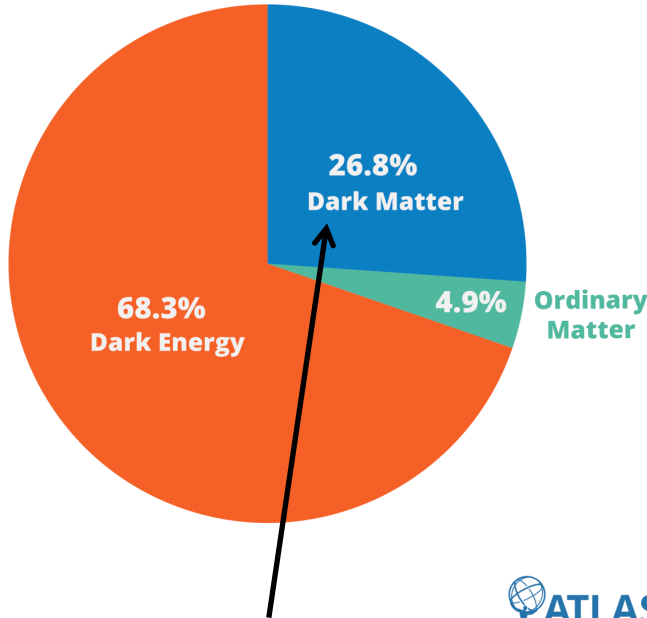


Paul Jackson, University of Adelaide  
CDMPP Annual Workshop, Glenelg SA.

November 29<sup>th</sup>, 2023

# Everything is made of Particles!

Estimated matter-energy content of the Universe

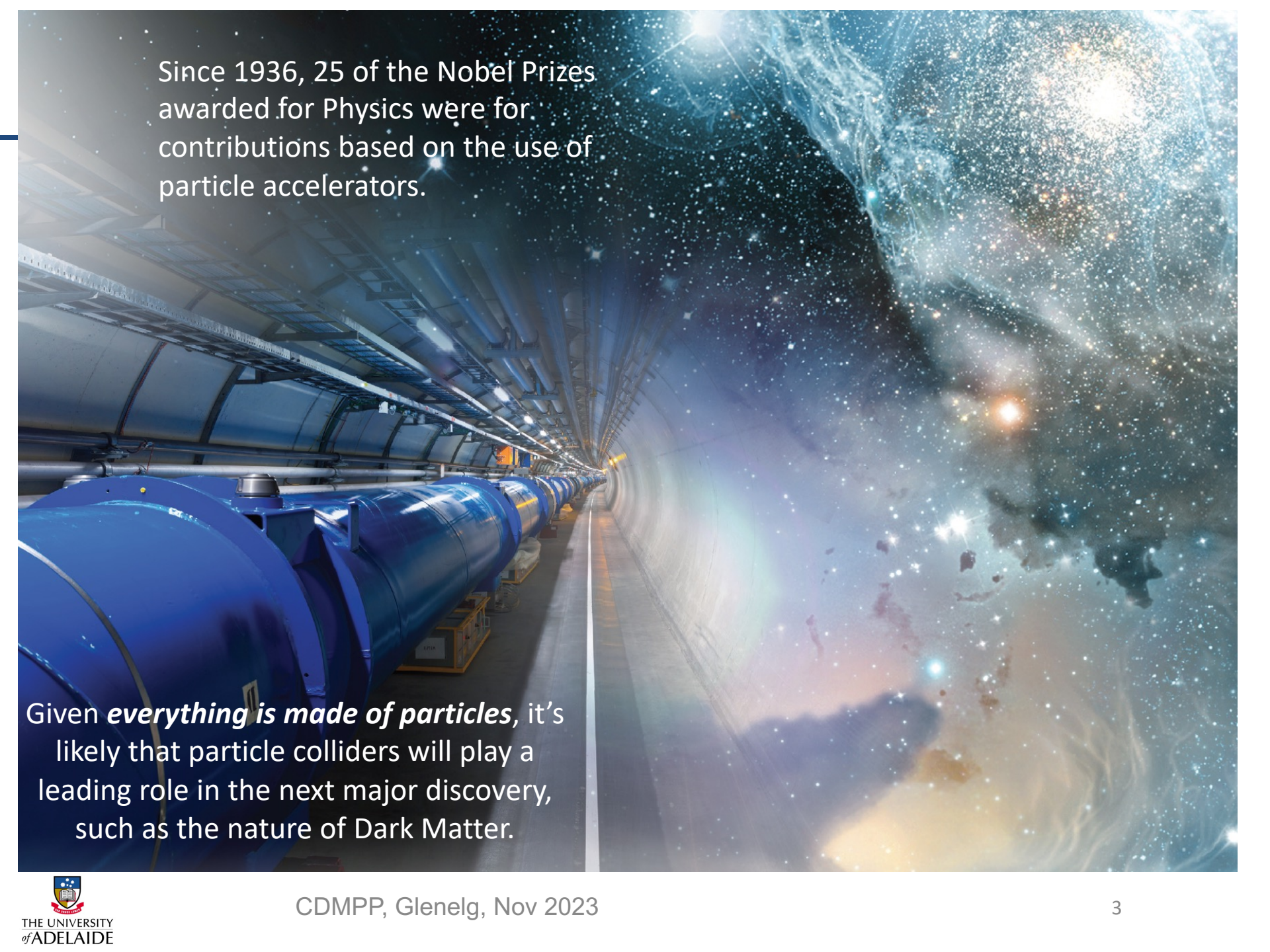


	mass →	charge →	spin →	Particle	mass	charge	spin	Particle
QUARKS	≈2.3 MeV/c <sup>2</sup>	2/3	1/2	u up	≈1.275 GeV/c <sup>2</sup>	2/3	1/2	c charm
					≈173.07 GeV/c <sup>2</sup>	2/3	1/2	t top
					0	0	1	g gluon
					≈126 GeV/c <sup>2</sup>	0	0	H Higgs boson
					≈4.8 MeV/c <sup>2</sup>	-1/3	1/2	d down
					≈95 MeV/c <sup>2</sup>	-1/3	1/2	s strange
LEPTONS					≈4.18 GeV/c <sup>2</sup>	-1/3	1/2	b bottom
					0	0	1	γ photon
					0.511 MeV/c <sup>2</sup>	-1	1/2	e electron
					105.7 MeV/c <sup>2</sup>	-1	1/2	μ muon
					1.777 GeV/c <sup>2</sup>	-1	1/2	τ tau
					91.2 GeV/c <sup>2</sup>	0	1	Z Z boson
GAUGE BOSONS					<2.2 eV/c <sup>2</sup>	0	1/2	ν <sub>e</sub> electron neutrino
					<0.17 MeV/c <sup>2</sup>	0	1/2	ν <sub>μ</sub> muon neutrino
					<15.5 MeV/c <sup>2</sup>	0	1/2	ν <sub>τ</sub> tau neutrino
					80.4 GeV/c <sup>2</sup>	±1	1	W W boson

We know this exists but don't know what it is yet. **One of the biggest challenges in fundamental physics.**

**As everything is made of particles, we assume Dark Matter is made of one or more particles**



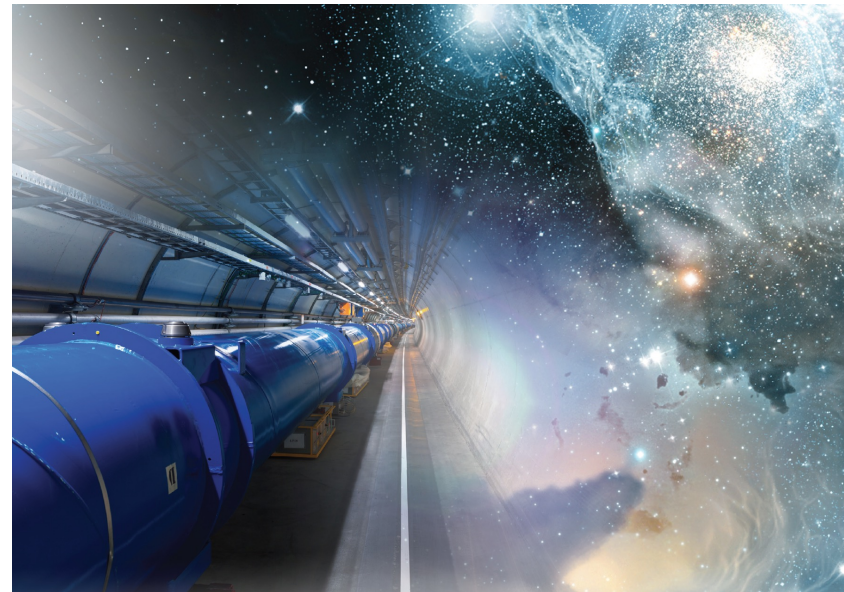
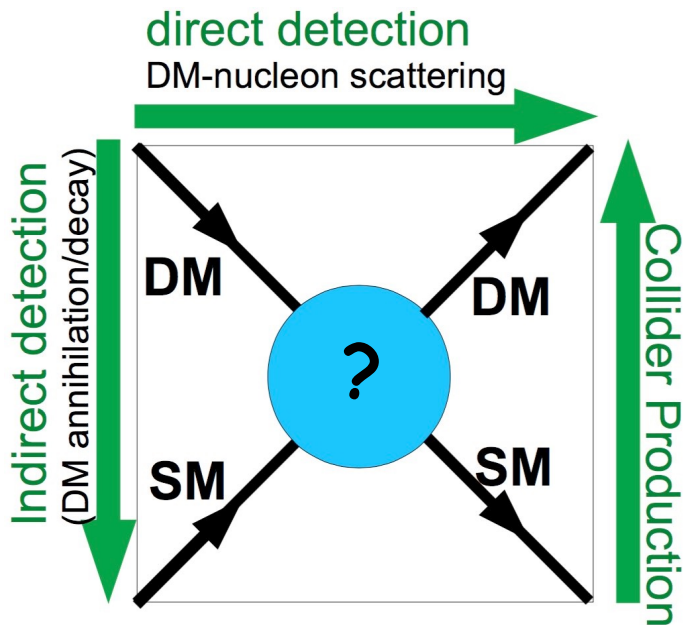


Since 1936, 25 of the Nobel Prizes awarded for Physics were for contributions based on the use of particle accelerators.

Given *everything is made of particles*, it's likely that particle colliders will play a leading role in the next major discovery, such as the nature of Dark Matter.

# A Dark Matter Search Strategy

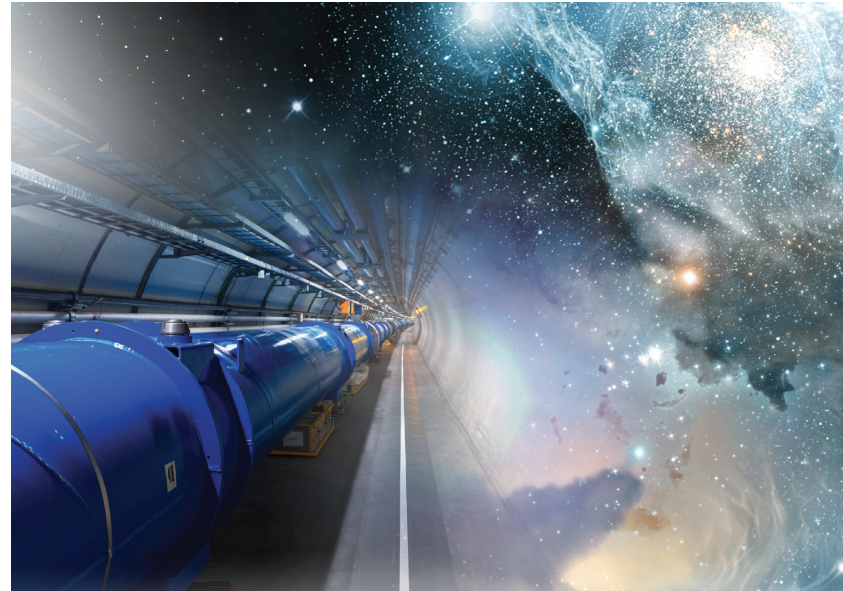
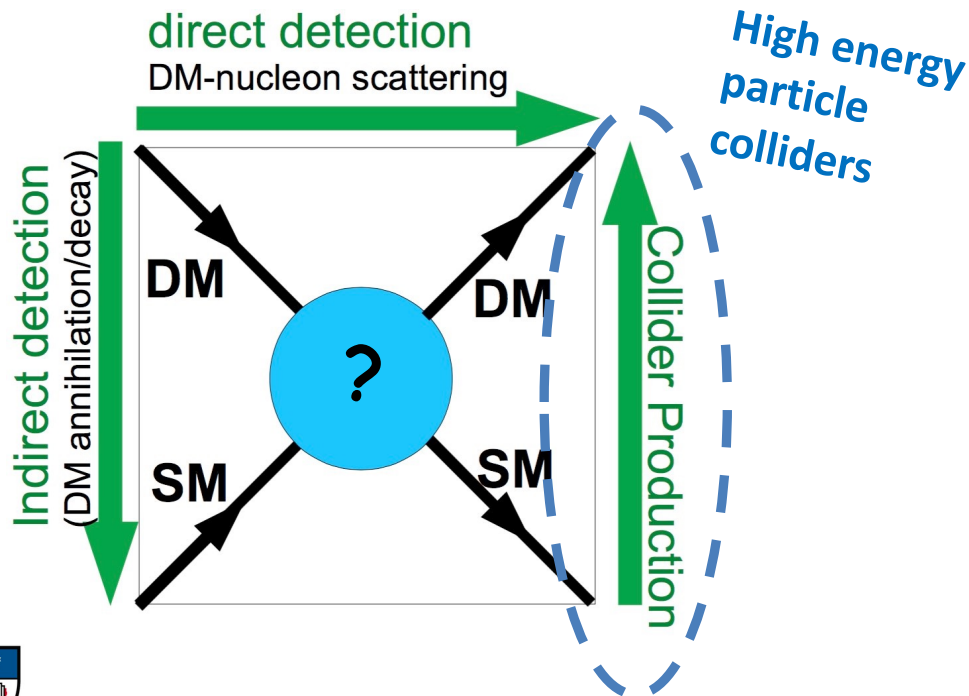
- ✓ Unknown dark/SM coupling -> dark particles mediators could have a range of properties
- ✓ Unknown dark/SM mediators -> probe unexplored mass scales (multi-TeV)
- ✓ A weakly interacting massive particle (WIMP) produced in thermal equilibrium could produce observed relic density -> probe weak scale masses (100s GeV)
- ✓ ....but actually, we have no idea what we're looking for! -> look for the unexpected





# A Dark Matter Search Strategy

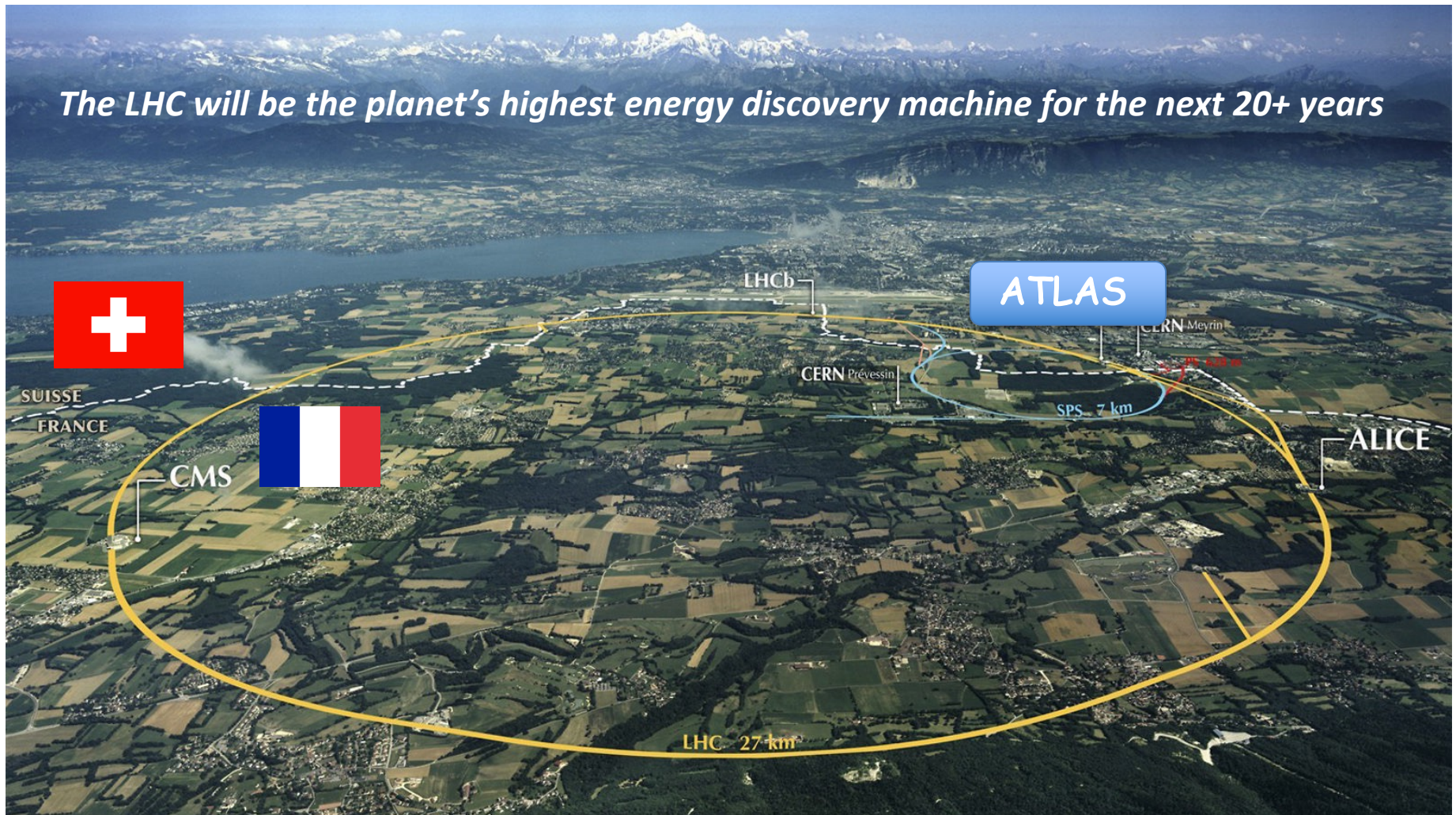
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- ✓ ....but actually, we have no idea what we're looking for! -> look for the unexpected





# The Large Hadron Collider

*The LHC will be the planet's highest energy discovery machine for the next 20+ years*



A 27 km synchrotron at CERN colliding protons at  $\sqrt{s} \geq 13$  TeV

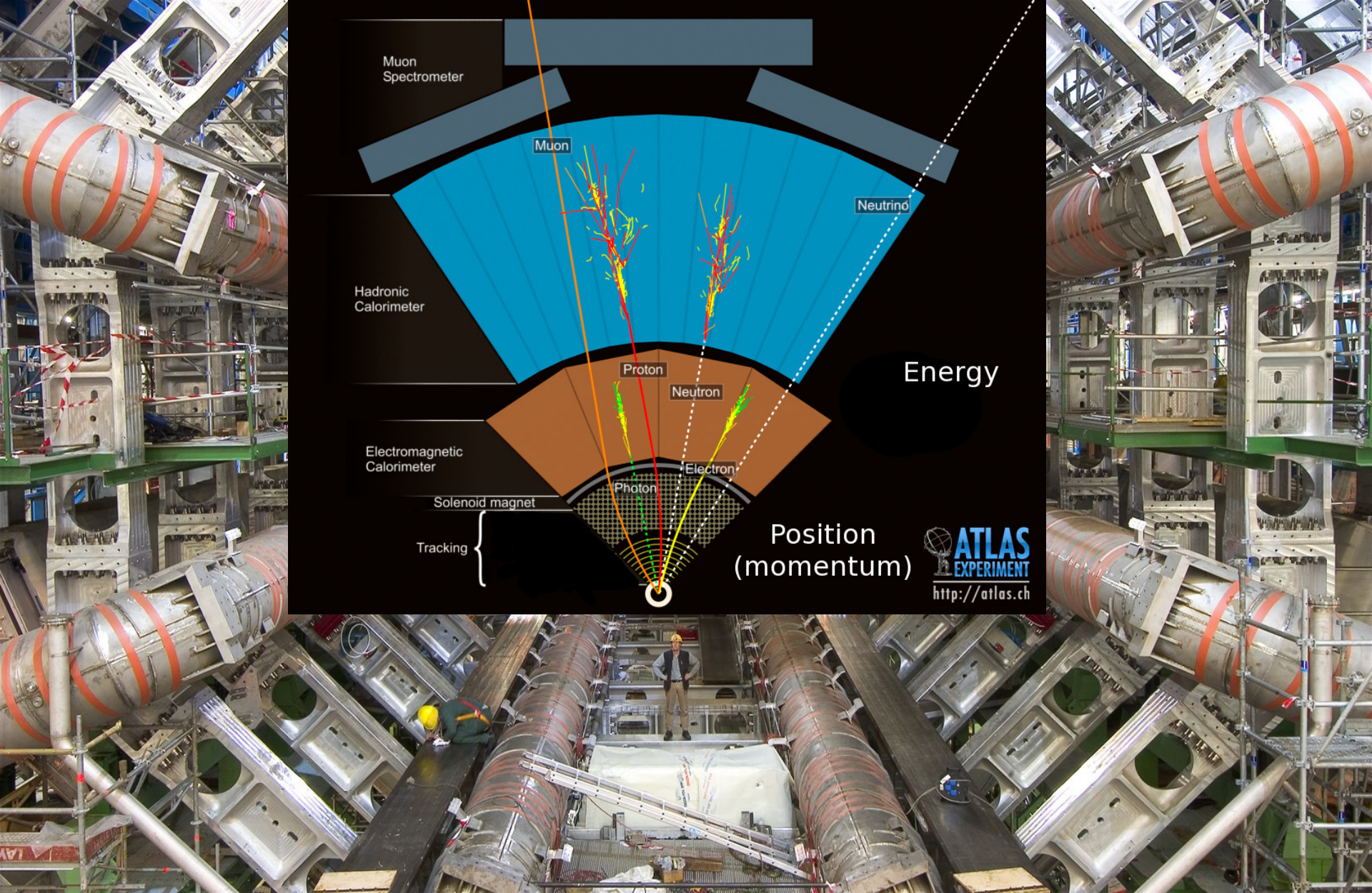
CDMPP, Glenelg, Nov 2023



# The ATLAS Detector









# ATLAS in the news

CERN DG Fabiola Gianotti welcomed President of the French Republic [Emmanuel Macron](#) and the President of the Swiss Confederation [Alain Berset](#) for an official visit from our host states to the Laboratory.



They had a lengthy visit to ATLAS and the new visitor centre. Positive feedback from both French and Swiss sides.



CDMPP, Glenelg, Nov 2023



# CDMPP ATLAS at this workshop



## Talks

- **Albert Kong** (Wednesday 16:15-16:30) – “Improving ATLAS Hadronic Object Performance with ML/AI Algorithms”
- **Emily Filmer** (Thursday 14:45 – 15:00) – “Hide and Super-Seek: Searching for Displaced Vertices with Missing Transverse Energy at the ATLAS Detector”
- **Tristan Ruggieri** (Thursday 16:45 – 17:00) – “Search for new physics in final states with objects originating from a top-quark, a charm-quark and large EmissT in pp collisions at  $\sqrt{s}=13\text{TeV}$ ”

## Posters

Hitarthi Pandya - Searching for Displaced Leptons at the ATLAS Detector

Judith Kull – Building and Testing the ATLAS Inner Tracker

Emily Filmer - Using Missing Energy to search for Missing Matter

Edmund Ting - Reuse, Repurpose, Reinterpret: Making the Most of LHC Results

Matthew Green - ParticleFlow Algorithm for LHC Physics

James Gallagher - Eta-Intercalibration at the ATLAS Detector

Matthew Fewell - Towards Improved Photon Isolation in the ATLAS Detector at CERN

Harish Potti - Run-3 operations of the ATLAS experiment



# CDMPP ATLAS at this workshop



### Searching for Displaced Leptons at the ATLAS Detector

Himathi Pandey, Martin Post, Paul Jackson

**Motivation**

- Can be further reduced by LRT module
- Not many dedicated searches for long-lived SUSY particles

**Large Radius Tracking (LRT) Improvements**

ATLAS Performance:  $\mu$  ATLAS Performance:  $\mu$  ATLAS Performance:  $\mu$

**Signal theory uncertainties**

- Entire process MC signal sample information - MC signal production
- Production Track deviation - plots
- Study impact on signal acceptance by varying normalization and factorization scales
- Helps find out systematic uncertainties
- Impact of theory systematic variations approximated using slepton distribution features
- Ph-V

**ABCD Signal Region**

3 ABCD Regions: cc, ep, pp

Region	Signal	Backgrounds
A	Signal	Major Backgrounds: $\mu$ Interactions from detector, Heavy Resonance background, Cosmic muons
B	Signal	Major Backgrounds: $\mu$ Interactions from detector, Heavy Resonance background, Cosmic muons
C	Signal	Major Backgrounds: $\mu$ Interactions from detector, Heavy Resonance background, Cosmic muons
D	Signal	Major Backgrounds: $\mu$ Interactions from detector, Heavy Resonance background, Cosmic muons

### Eta-Intercalibration at the ATLAS Experiment

James Gallagher, Paul Jackson, Magda Damiannopolou, Denis Deryagin, Sait Chaf Azzam

**1. Dijet events are identified**

- Back to back hadrons - not collected for analysis
- Expect the momenta of each to be equal as a result of momentum conservation
- Not expected to be so at high pseudorapidity
- Require calibration

**2. Asymmetry is determined**

Define a measure of momentum asymmetry

$$A = \frac{p_{T1} - p_{T2}}{p_{T1} + p_{T2}}$$

**3. Response ratio is calculated**

Define the response ratio between the two jets

$$R = \frac{2 + A}{2 - A} = \frac{p_{T1}}{p_{T2}}$$

**4. Intercalibration factors found**

Minimization techniques are used to simultaneously solve for intercalibration factors

**5. Data to simulation calibration is obtained**

Do the above for both observed collider data and simulated events

### The Particle Flow Algorithm: Unifying Particle Reconstruction in the ATLAS Detector

Matthew Green, Martin White, Paul Jackson, Mark Hodgkinson, Edmund Ting

**WHY**

The ATLAS detector has multiple components. The tracker has higher granularity at low transverse momentum but cannot detect neutral particles. The calorimeter measures all energy depositions but suffers from noise contamination at low energy. So, the question remains: How can we use data from each component to reconstruct jets, but not double count?

One answer is the **Particle Flow Algorithm**

**ALGORITHM**

- Tracks from the tracker hits
- Select Tracks (Need to have two tracks that are not in the same event)
- Match Tracks to Clusters (Calculate the distance between the track and the clusters and rank them by distance)
- Compute  $E_{clus}/P_{trk}$  (This is how we estimate the energy deposition by the track into the cluster)
- Cell Subtraction (Starting from the jet of highest energy density, the cells are removed until the track is fully accounted for)
- Remnant Removal (In the cases where the cluster has too much energy left, instead of subtracting off cells in the jet, the energy is evenly removed)
- Charged Flow Elements (Remnant tracks)
- Neutral Flow Elements (Remnant/Unassigned Clusters)

**PERFORMANCE**

Jet resolution using Flow compared to using only the calorimeter clusters (Top)

How much neutral energy removed (left) vs how much charged energy kept (clear right)

**FUTURE**

With the HL-LHC on the horizon, the Particle Flow algorithm will need a serious makeover to keep up, with many performance studies ongoing. There is an effort to see if machine learning can be used to replace individual steps in the current algorithm or even replacing it with an end-to-end ML approach like CMS.

### Building and Testing the ATLAS Itk

**WH-ITK?**

The inner detector subsystem of the ATLAS Detector will be replaced with the Inner Tracker (ITk) in preparation for the High-Luminosity LHC in 2026.

The ITk will more than triple the active silicon area of the current system, and is comprised of strip and pixel subsystems. These are further comprised of barrel (parallel) and endcap (perpendicular) geometries.

Australia will build and test 108 Strip EndCap modules over the next 3 years, 14% of production volume.

**ENDCAP STRIP MODULES**

- Sensor: Silicon strips with a width of 80  $\mu$ m
- Hybrid PCB to mount ASICs
- ASIC and HVC ASIC chips: Read out data from the sensor
- Power board: Biases the module, covers ASICs

**PRODUCTION**

A global effort, including Melbourne, Perth/Sydney, and Adelaide testing.

**Electrical Testing and Thermal Cycling**

**ELECTRICAL TESTING**

Each module is tested at a series of voltages from 0 V to the maximum bias of -350 V to ensure proper electrical function. These tests are compared for each module after every transport or handling cycle to ensure consistency.

The noise and charge responses are tested for each of the 2380 channels in the sensors, as well as measuring the sensor's response to different voltages.

After all tests have been performed, the module undergoes HV Stabilisation, during which the sensor is held biased at -350 V for 2 hours to look for anomalous (high) leakage current, which might indicate a damaged or malfunctioning sensor.

**THERMAL CYCLING**

Modules are tested at various temperatures between -55°C and +40°C to mimic potential operational conditions within the detector.

This is done in the **cellbox**, a custom-built piece of equipment, designed for thermal cycling strip modules.

Current tests are performed at an air mixture of temperature to calibrate noise and ensure the fabricated modules are working correctly.

After 10 temperature cycles, we can check for electrical and mechanical breakdowns in the sensors.

### REUSE, REPURPOSE, REINTERPRET

Making the Most of ATLAS Results

**HOW DO WE SEARCH FOR NEW PHYSICS?**

Identify new physics signatures, remove background, publish findings.

**WHAT DO WE PROVIDE?**

Analysis logic, cutflow tables, region occupancies and efficiencies; readable SimpleAnalysis (S) code; SHANA files. Numerical values of results. Breakdown of systematic uncertainties and correlations. The full likelihood.

Integrally, ATLAS implements RECAP (R). Creates not just a historical record of the analysis, but allows for future re-use.

**THE IMPORTANCE OF REINTERPRETATION**

- Increases visibility and interest in our results
- Engages the theory community - potentially generating new ideas for future analyses
- Greater coverage of model landscape - many hands make light work!

**From SUSY to LEPTOQUARKS**

- Supersymmetric proton decay
- motivation: strongly produced pair of supersymmetric top or charm quarks
- each parent quark decays to a SM charm quark and a neutralino
- event signature: two charm quarks and missing transverse momentum
- alternative model: pair production of leptoquarks, each decaying into a charm quark and a neutrino
- produces the same observable final state
- analysis can be reinterpreted to place limits on leptoquark model parameter space!

**REFERENCES**

ATLAS Collaboration, 2022. Reinterpreting TopQuark Analyses. ATLAS-CONF-2022-017

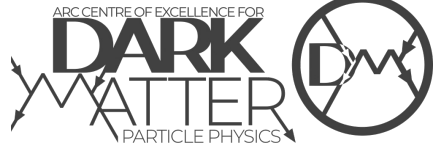
ATLAS Collaboration, 2021. Analysis Framework and Systematic Uncertainties for the ATLAS experiment. J. Phys. Conf. Ser. 1883 06001.

EDMUND TING, DARK MATTER, SUBATOM





People



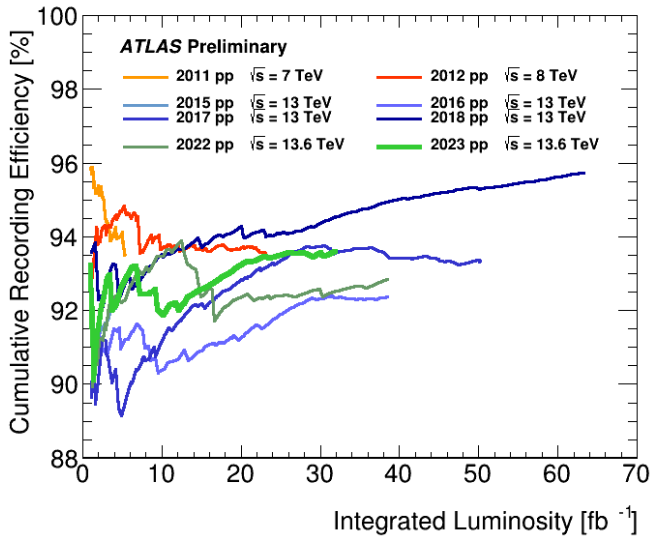
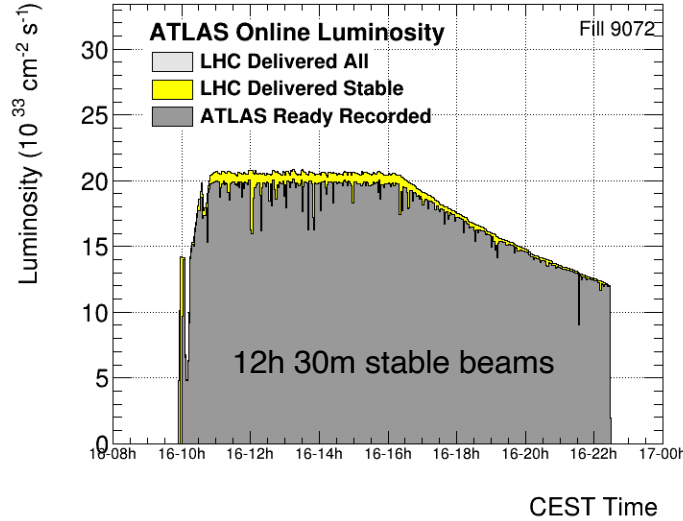
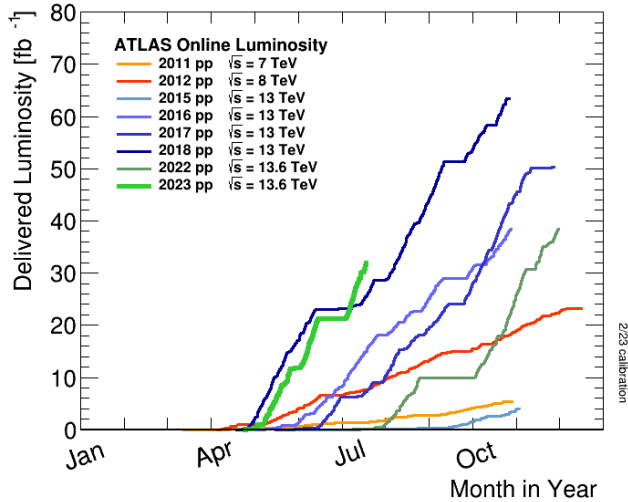
Former: Abhishek, Anna.  
Current: Joni, Harish, Emily, Steve,  
Paul, Albert, Charles, Frederic





# LHC/ATLAS data taking

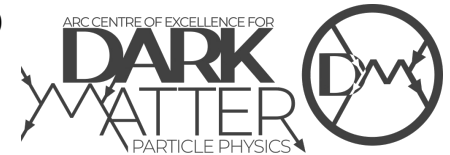
See Harish Potti's poster for more details



Excellent data taking efficiency throughout Run 3.

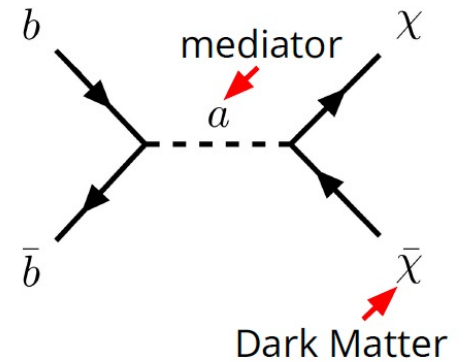
Highest energy collisions ever recorded!

CDMPP researchers involved in trigger/DAQ shifts, inner detector, luminosity, computing and Jet/MET and photon performance group



# DM at Colliders

- Small interaction cross section of Dark Matter with detectors at colliders



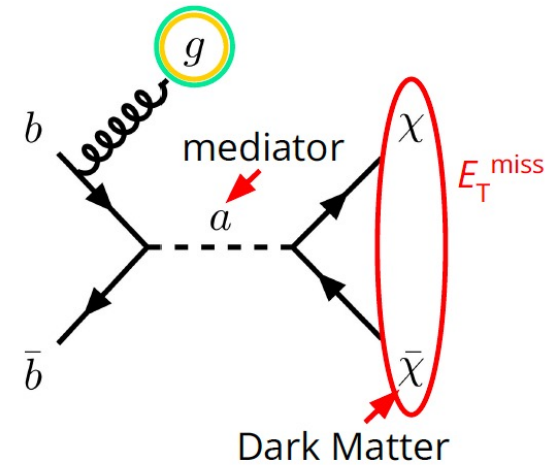
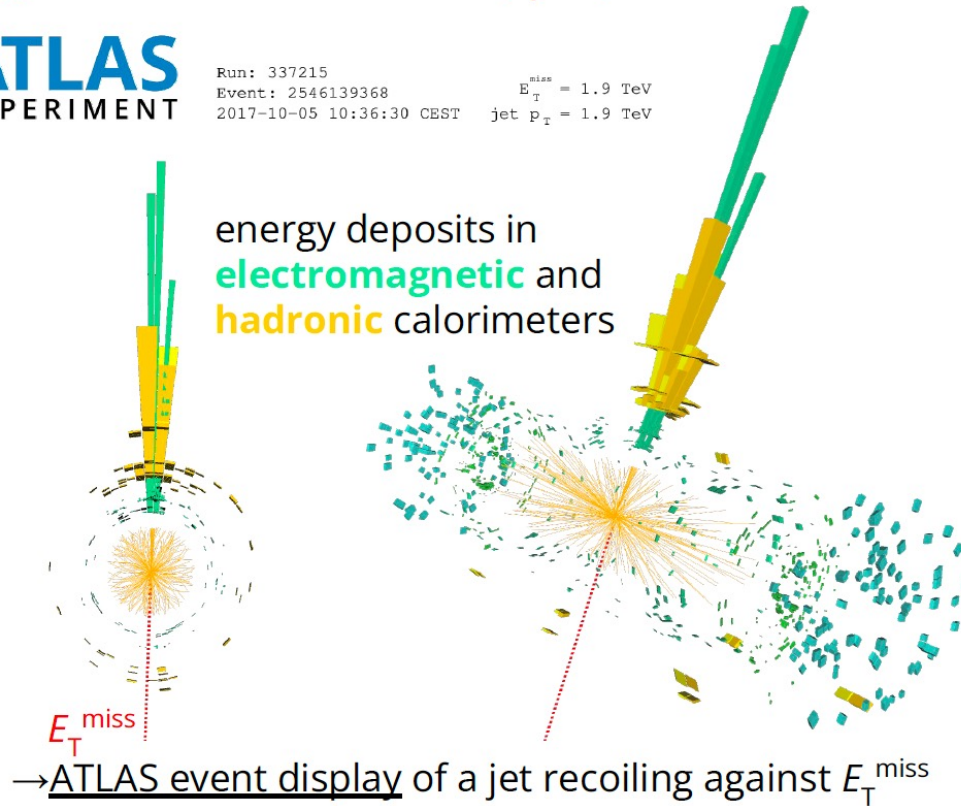
# DM at Colliders

- Small interaction cross section of Dark Matter with detectors at colliders
- Need recoil against **detector-visible object**
- **Missing transverse momentum ( $E_T^{\text{miss}}$ )**

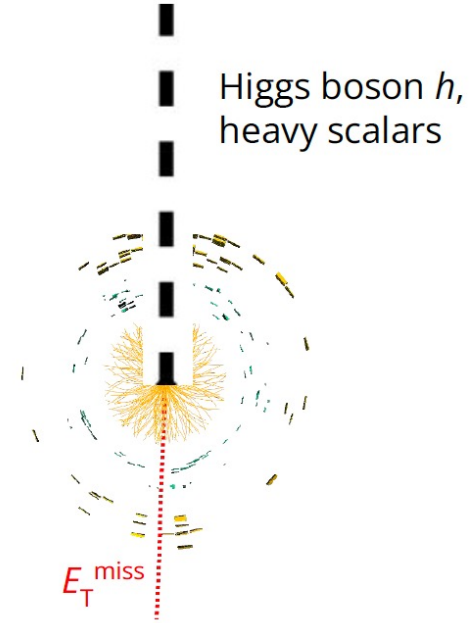
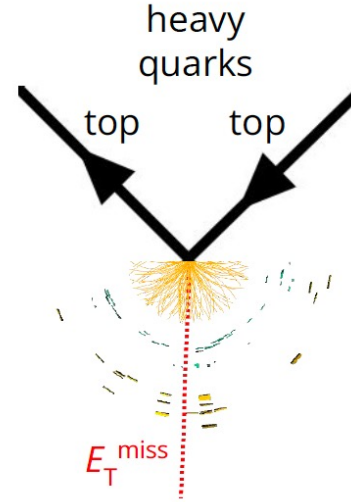
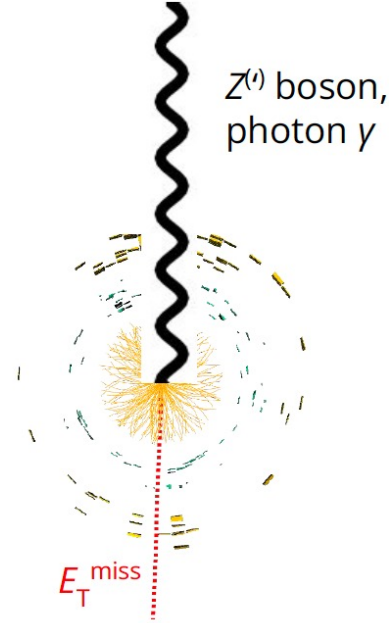
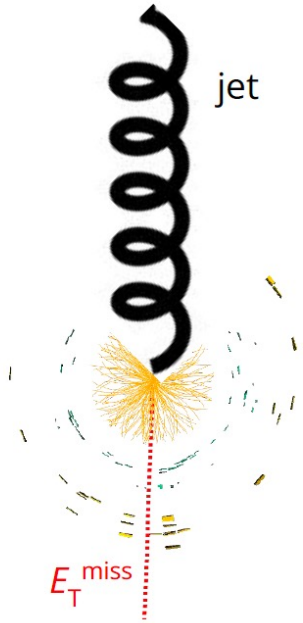


Run: 337215  
 Event: 2546139368  
 2017-10-05 10:36:30 CEST

$E_T^{\text{miss}} = 1.9 \text{ TeV}$   
 jet  $p_T = 1.9 \text{ TeV}$



# DM signatures @ Colliders



jet+ $E_T^{\text{miss}}$ : → 2102.10874

$Z(\rightarrow \ell\ell)+E_T^{\text{miss}}$ : → 2111.08372

$\gamma+E_T^{\text{miss}}$ : → 2011.05259

$Z'(\rightarrow \ell\ell)+E_T^{\text{miss}}$ : → EPS last week

$tW+E_T^{\text{miss}}$ : → 2211.13138

$tt+E_T^{\text{miss}}$ : → 2211.05426

$h(\rightarrow \tau\tau)+E_T^{\text{miss}}$ : → 2305.12938

$h(\rightarrow bb)+E_T^{\text{miss}}$ : → 2108.13391

$h(\rightarrow \gamma\gamma)+E_T^{\text{miss}}$ : → 2104.13240

$s(\rightarrow WW)+E_T^{\text{miss}}$ : → 2211.07175

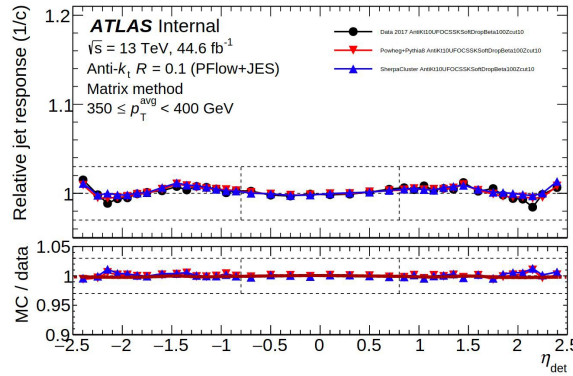
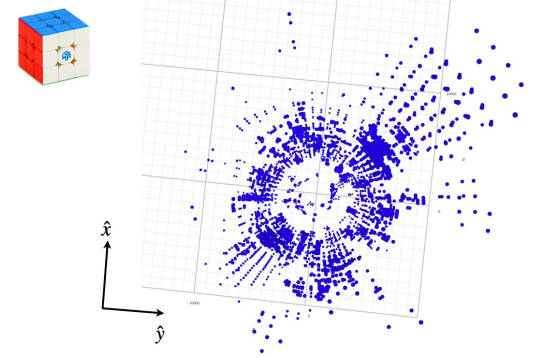
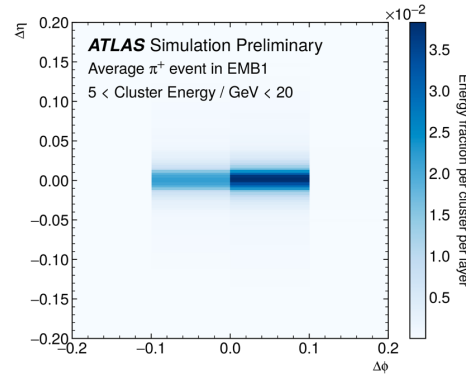
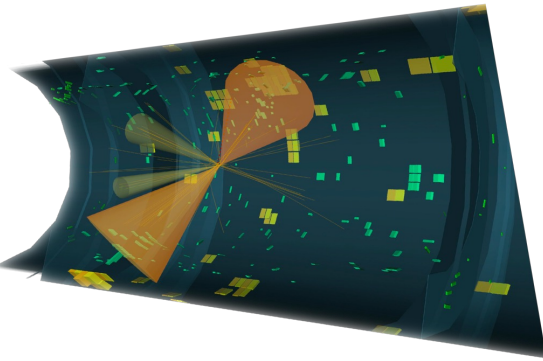
... and many more!

A vast array of results with increasingly sophisticated methods used!

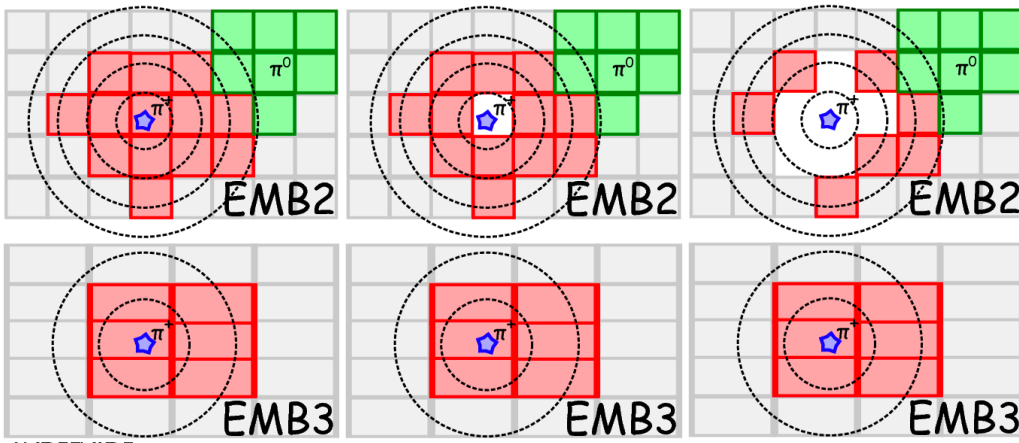


# DM signatures need jets and missing ET

**Albert Kong** is exploring deep learning techniques using different types of data, image-based (left) and point cloud (right)



**James Gallagher** is looking at the eta inter-calibration of large radius jets. This is the first step of the ATLAS in-situ jet-calibration.



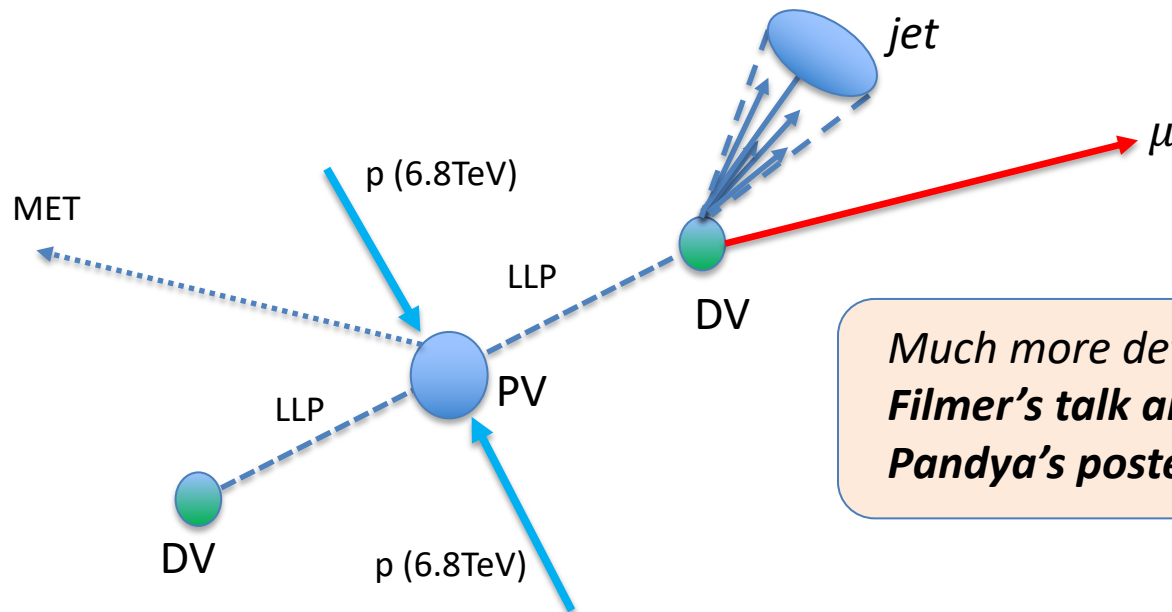
**Matthew Green** is studying a particle flow algorithm to leverage the high granularity of low pT tracks in jets while ensuring to not double-count the energy of clusters in the calorimeter.

# Displaced Vertices

Non-SM particles with long-lifetimes compared to SM, give rise to long-lived particles.

If these objects decay in the detector volume there will be a displaced vertex signature.

Natural to take the powerful search program at the LHC.....and displace it!



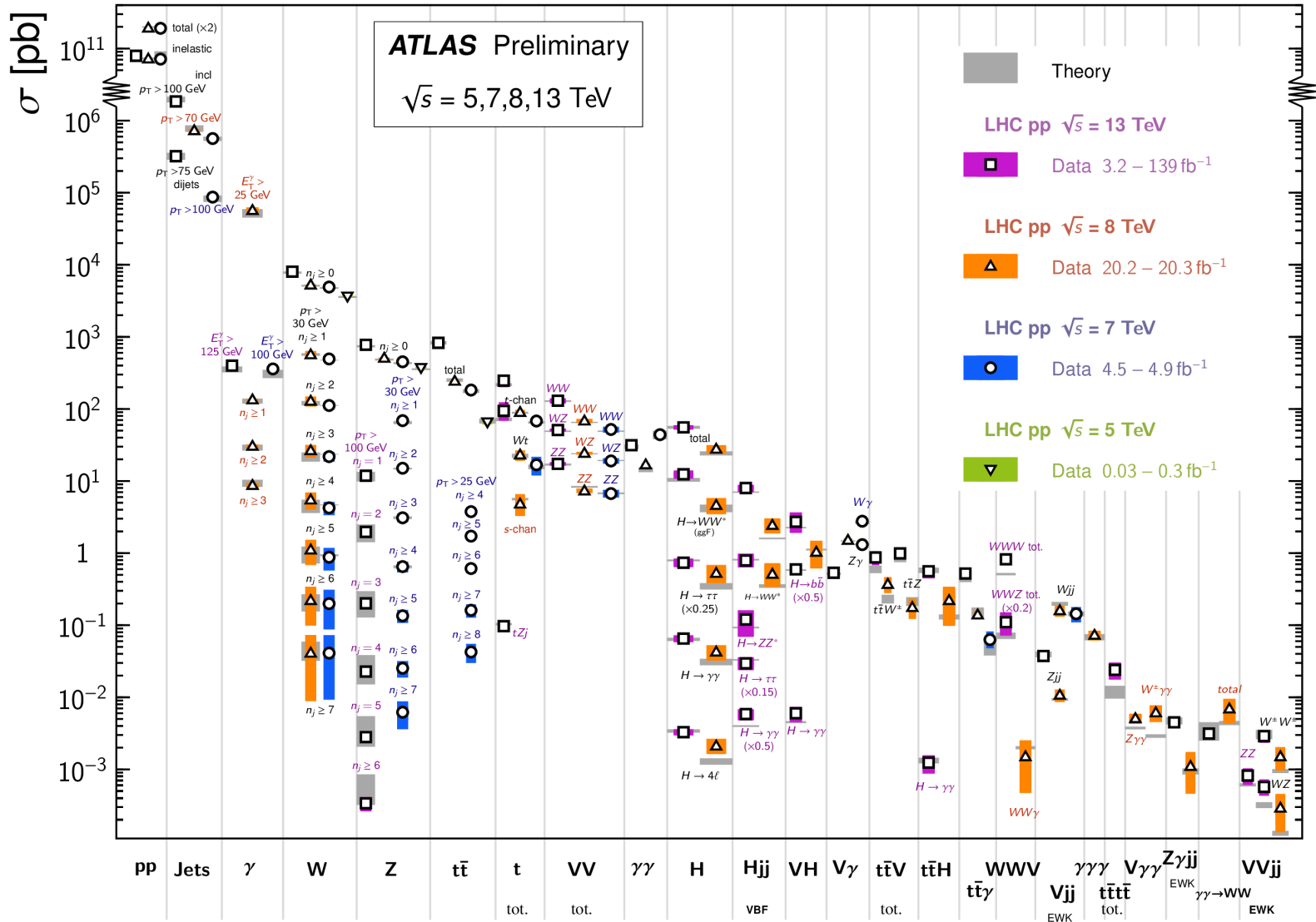
*Much more detail in Emily Filmer's talk and Hitarthi Pandya's poster for details*

- PV = Primary Vertex
- DV = Displaced Vertex
- LLP = Long-lived Particle
- MET = Missing Transverse Momentum

# Standard Model Summary

## Standard Model Production Cross Section Measurements

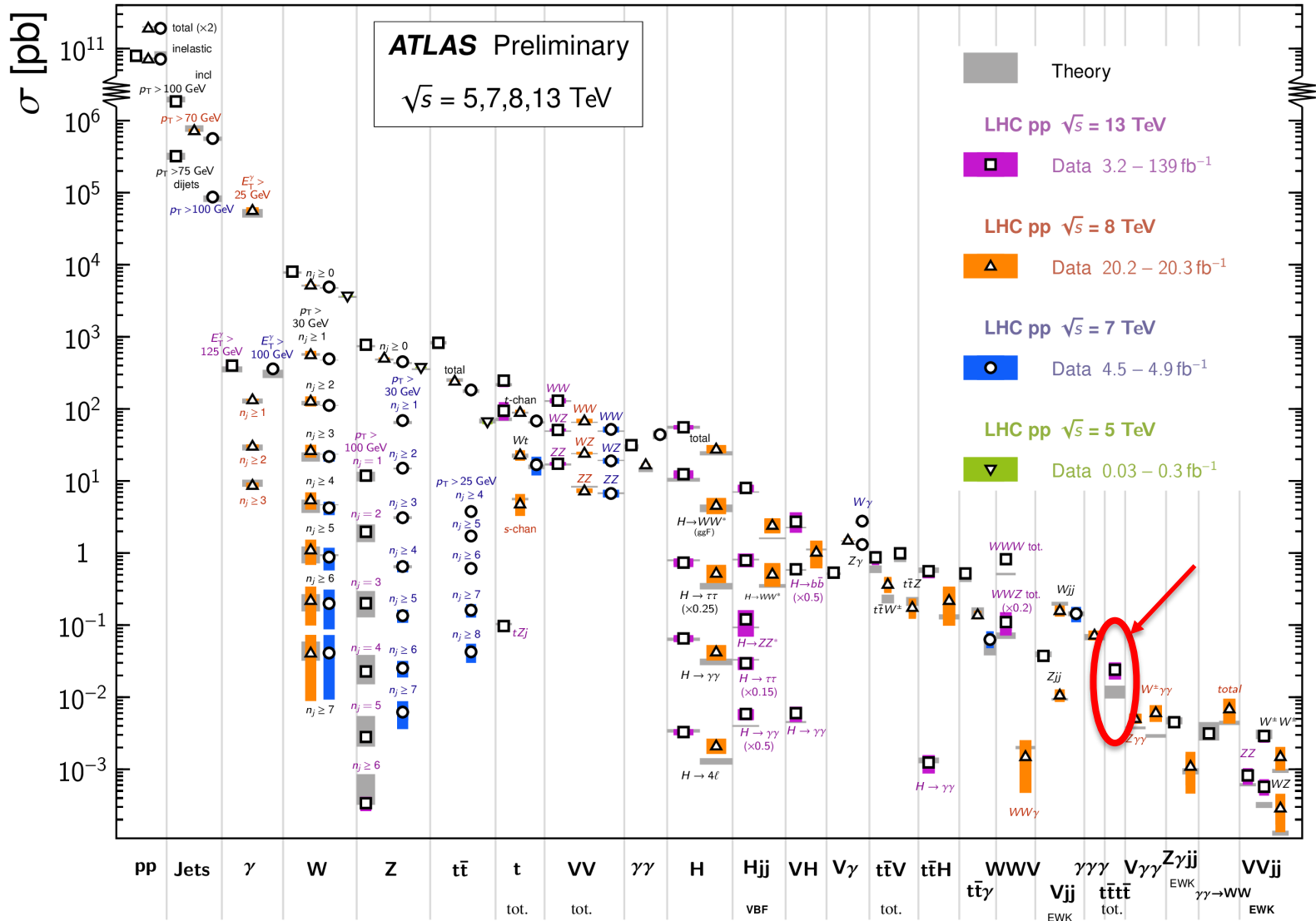
Status: February 2022



# Standard Model Summary

## Standard Model Production Cross Section Measurements

Status: February 2022



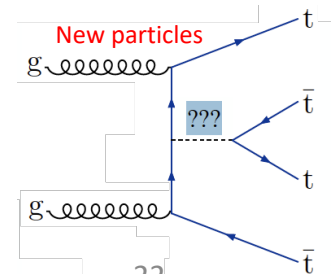
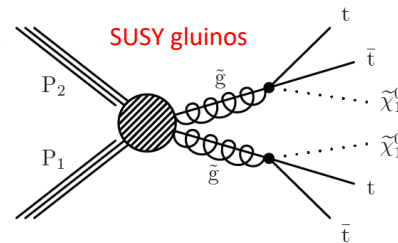
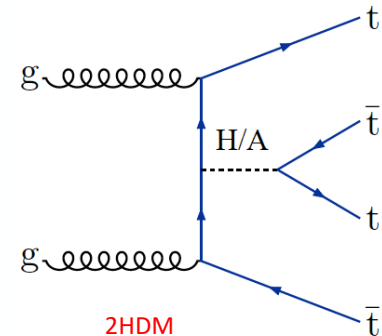
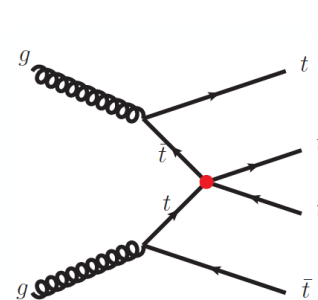
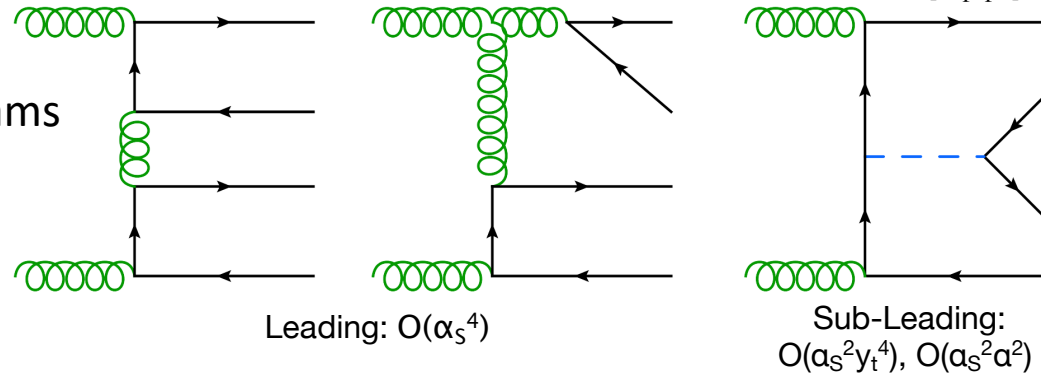
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# The Four Tops



# $t\bar{t}t\bar{t}$ predictions

- *Very complicated process*
  - at LO 72 gg+12 qq' initiated diagrams
- Sensitive to top-Yukawa coupling ( $y_t$ )
  - non-SM value can dramatically change the production via off-shell Higgs
- Extremely high energy scale production makes it naturally sensitive to many BSM physics models
  - EFTs, incl four-fermion **contact interaction**
  - **Higgs physics**: 2HDM scalar/ pseudoscalar
  - **SUSY**: gluinos, sgluons
  - **New particles** coupling to top quark



# $t\bar{t}\bar{t}$ production

Tiny cross section in SM.

$\sigma$  NLO( $t\bar{t}\bar{t}$ ) = 11.97 fb at NLO QCD + NLO QED at 13 TeV

O(100M)  $t\bar{t}$  events

O(1k)  $t\bar{t}\bar{t}$  events

## Signatures:

The  $t \rightarrow Wb$  decay means the detector signature is defined by:

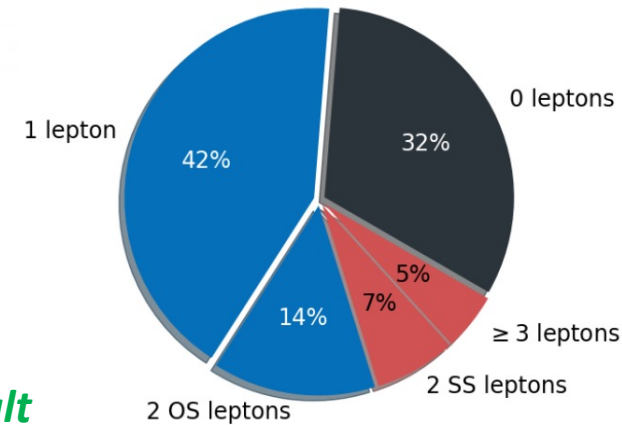
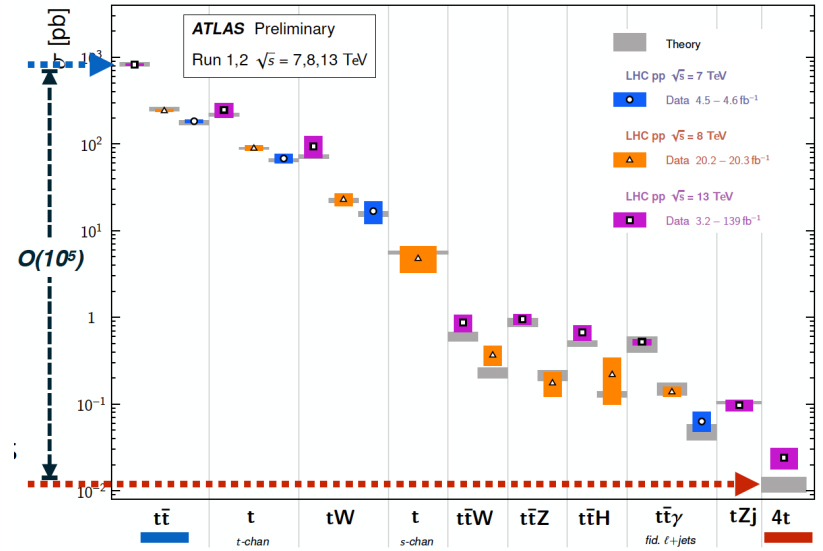
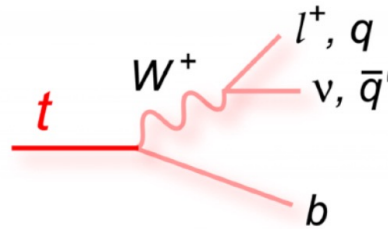
- The presence of several (up to 4) b-quarks
- The decays of the W bosons.

**1 $\ell$ /2 $\ell$ OS: 1 $\ell$**  (42%) / **2 $\ell$ OS** (14%)

- Dominant branching fraction, but large irreducible background from  $t\bar{t}$ +jets,  $t\bar{t}$ +heavy flavour jets

**2 $\ell$ SS/3 $\ell$ : 2 $\ell$ SS** (7%) / **3 $\ell$**  (5%)

- Low branching fraction, but small background ( $t\bar{t}W$ ,  $t\bar{t}Z$ , non-prompt leptons, charge misidentification)
- *Most sensitive channel*



*I will briefly discuss this result*

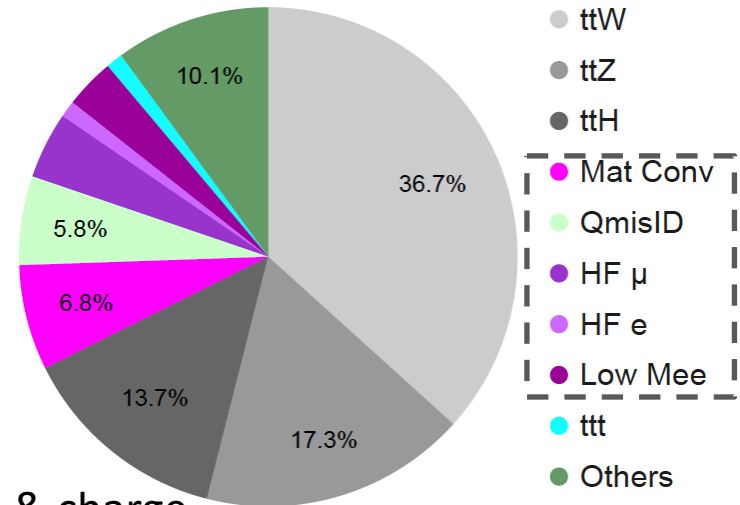


# $t\bar{t}t\bar{t}$ : 2ISS/3l channel strategy

- Targets clean leptonic signatures where at least 2 W bosons decay leptonically
- Selection requirements:
  - ○ 2 same-sign leptons *or* 3 leptons ( $\ell=e,\mu$ )
  - ○  $\geq 6$  jets ( $p_T > 25$  GeV)
  - ○  $\geq 2$  **b-tagged jets** (77% efficiency w.p.)
  - ○  $H_T > 500$  GeV

$$H_T = \sum_{leptons} P_T + \sum_{jets} P_T$$

Backgrounds:



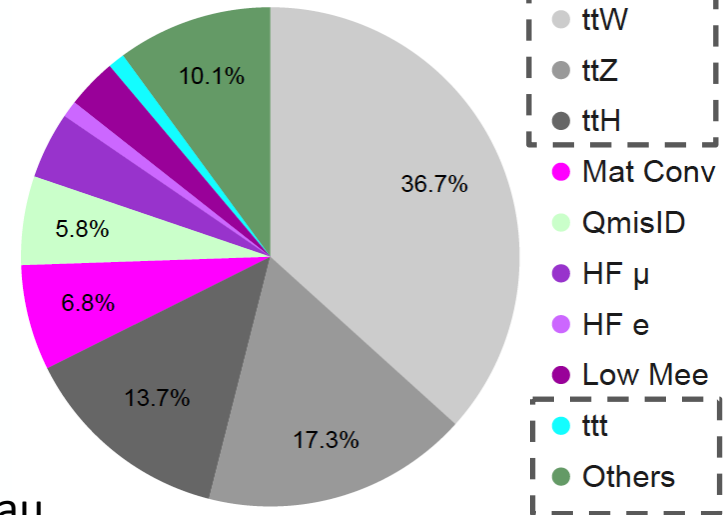
- Reducible backgrounds: fake/non-prompt leptons & charge misidentified leptons
  - electrons(muons) from heavy-flavour decay, HF e/ $\mu$
  - Electrons from  $\gamma$  conversions in detector, Mat Conv
  - a virtual photon leading to an  $e^+e^-$  pair, Low M<sub>ee</sub>
- Charge mis-assignment, **Q mis-ID (5.8%)**:
  - Relevant for the 2ISS channel (mostly for electrons)

# $t\bar{t}t\bar{t}$ : 2ISS/3l channel strategy

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  - ○  $\geq 6$  jets ( $p_T > 25$  GeV)
  - ○  $\geq 2$  b-tagged jets (77% efficiency w.p.)
  - ○  $H_T > 500$  GeV

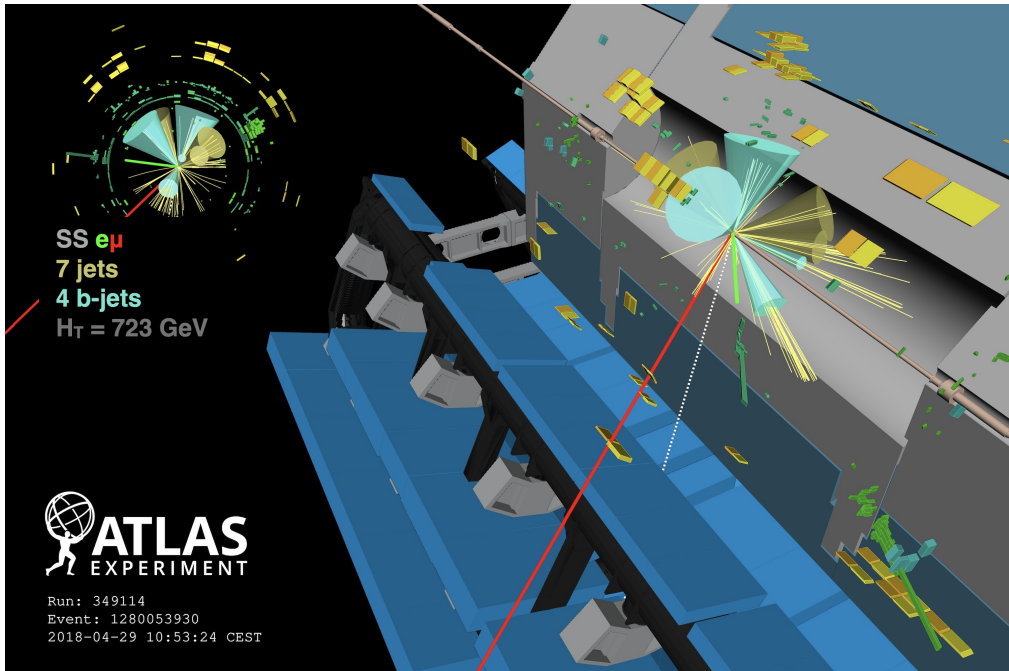
$$H_T = \sum_{leptons} P_T + \sum_{jets} P_T$$

Backgrounds:



- Irreducible backgrounds: Leptons from W, Z and tau
  - **ttW (36.7%), ttZ (17.3%), and ttH (13.7%)**
    - Processes with SS and multi-lepton+jets (with additional light and b-tagged jets)
  - **Smaller backgrounds: (10% Others) + ttt**  
Diboson, triboson, VH+jets, ttWW, tWZ, tZq
- Evaluated using MC normalised to SM cross section, except ttW which is floating in the fit

# 4-top observation



We measured events containing four top quarks for the first time – 2x larger than SM prediction

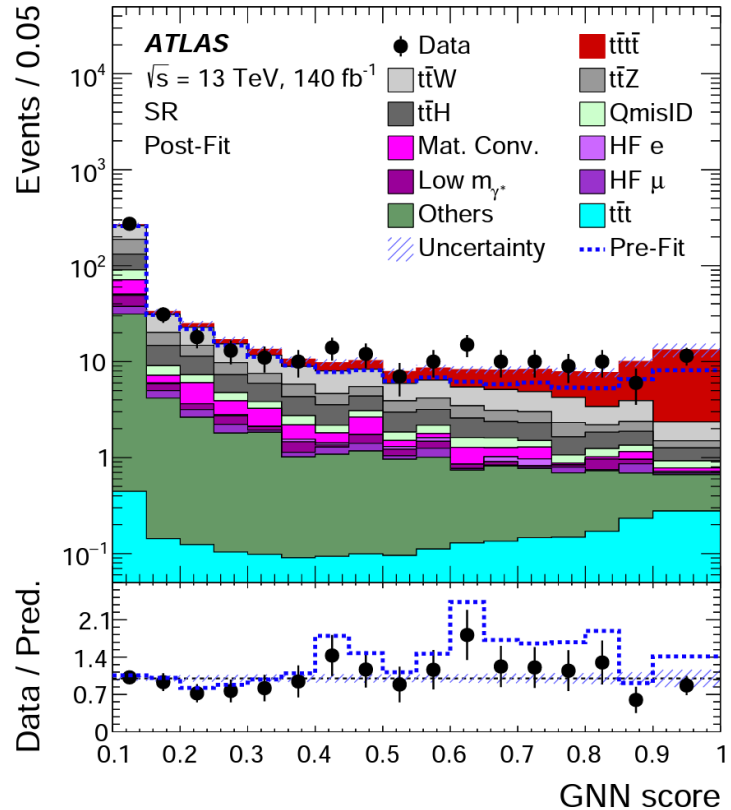
$$\mu = 1.9 \pm 0.4(\text{stat})_{-0.4}^{+0.7}(\text{syst}) = 1.9_{-0.5}^{+0.8}$$

$$\sigma_{t\bar{t}t\bar{t}} = 22.5_{-4.3}^{+4.7}(\text{stat})_{-3.4}^{+4.6}(\text{syst}) \text{ fb} = 22.5_{-5.5}^{+6.6} \text{ fb.}$$

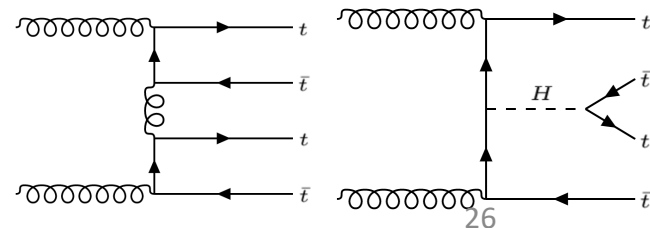
**Strong 6.1σ (4.3σ expected) discovery**

Eur. Phys. J. C 83 (2023) 496

CDMPP, Glenelg, Nov 2023

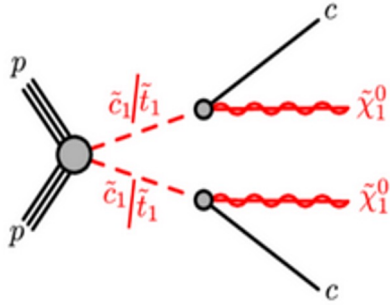


Complex process, potentially sensitive to new physics interactions via new particles and/or forces



# cc+MET and tc+MET

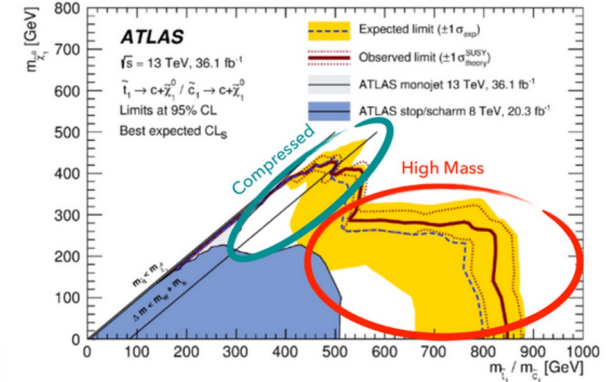
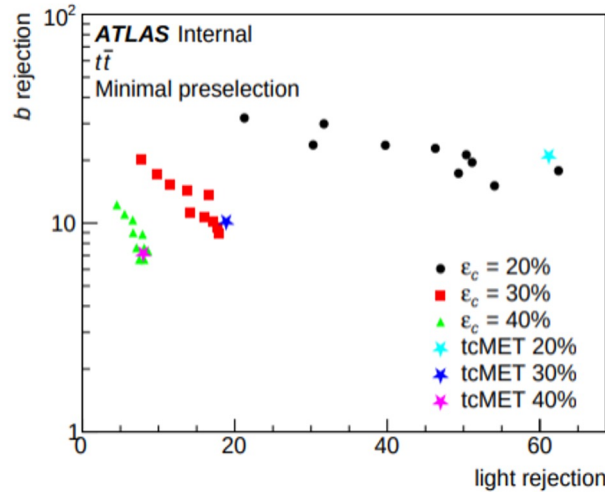
Supersymmetry



Search for top/charm squarks decaying to charm + neutralinos using full Run 2 dataset

- Also performing a Leptoquark reinterpretation search

## Using novel charm-tagging method



Two strategies for different  $\Delta m$  (squark, neutralino)

### $E_T^{miss}$ significance selection for high $m(sq)$

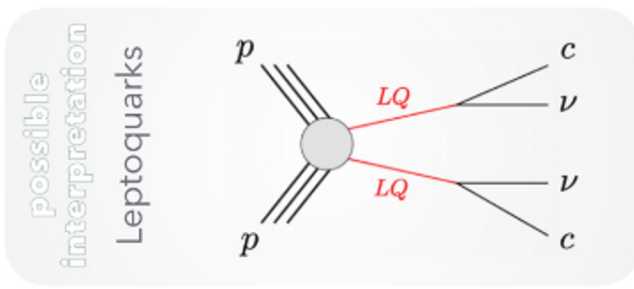
- Parameterizing how important the missing energy is while accounting for detector resolution effects

### Recursive Jigsaw Reconstruction based selections for low $\Delta m$ (compressed) signals

- Reconstruction of assumed decay with resolution of ambiguities based on well-founded physical assumptions

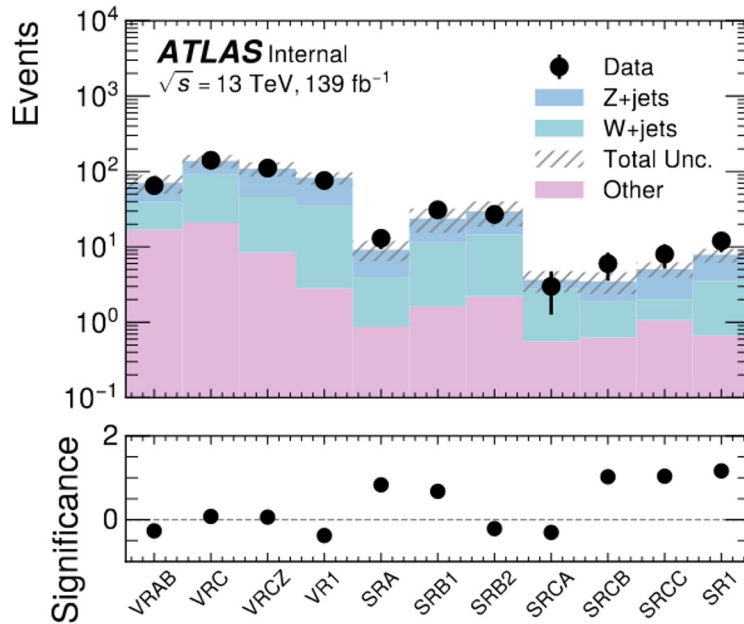
Use 20% tagging efficiency working point

- Most effective and efficient working point - background rejection is very powerful

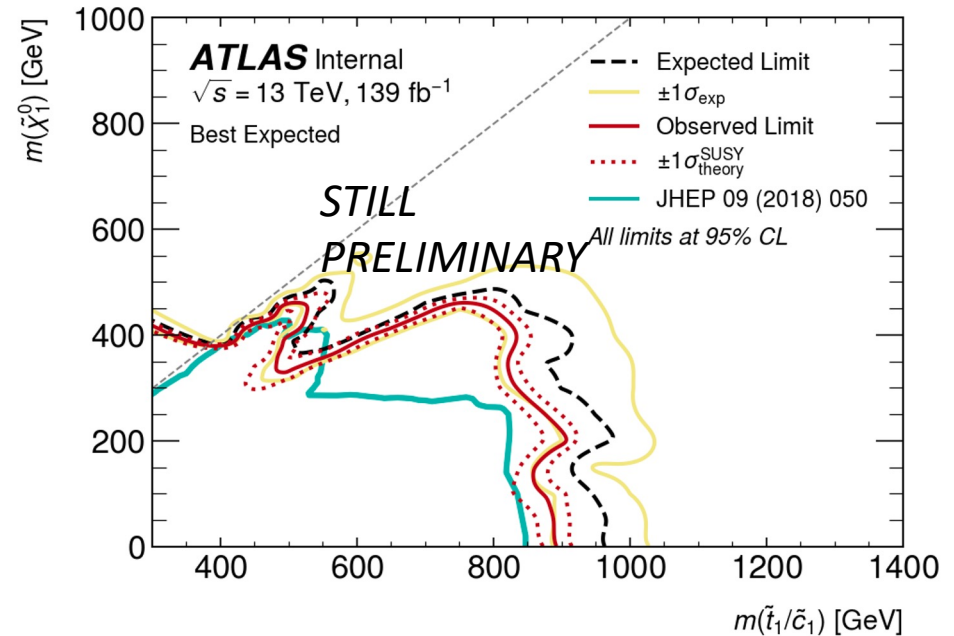


# cc+MET and tc+MET

Yields in signal regions consistent with SM-only hypothesis



Details on tc+MET in  
 Tristan Ruggieri's talk



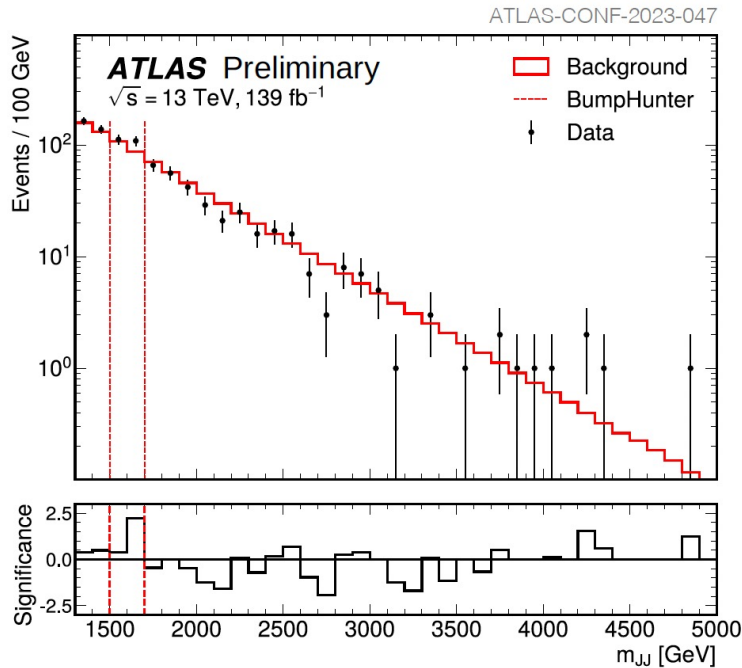
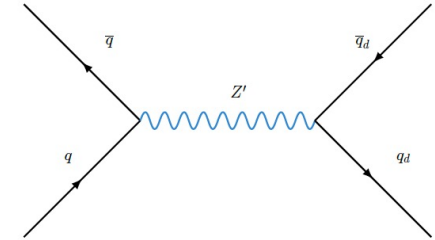
Exclusion contours extended significantly from  
 early Run 2 dataset results

Future work: Pursuing statistical combination with  
 similar tc+MET analysis. Both close to becoming public!

# Search for Strongly interacting Dark Sector

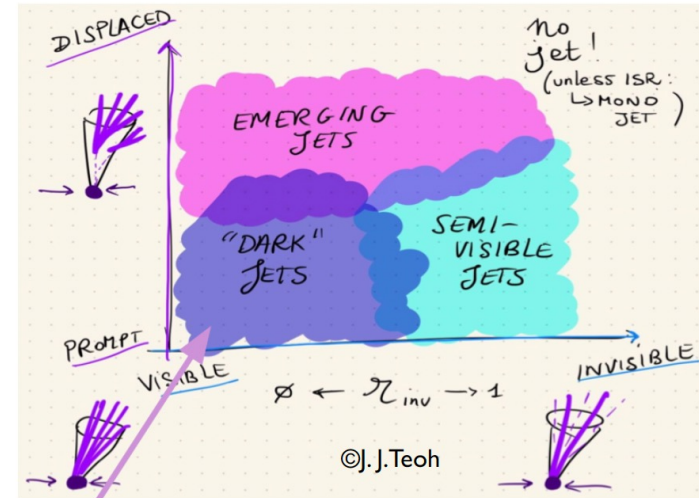
## Search for dark hadrons produced via $Z'$ and decaying promptly in visible SM particles

Signature of wider jets with larger track multiplicity than SM jets (hadronization first in dark sector, then in SM)



Look for bump in mass spectrum of two large-R & high-multiplicity jets

No excess observed





# Culture Break



I'm from Bolton in Northern England whose history dates back almost 900 years.



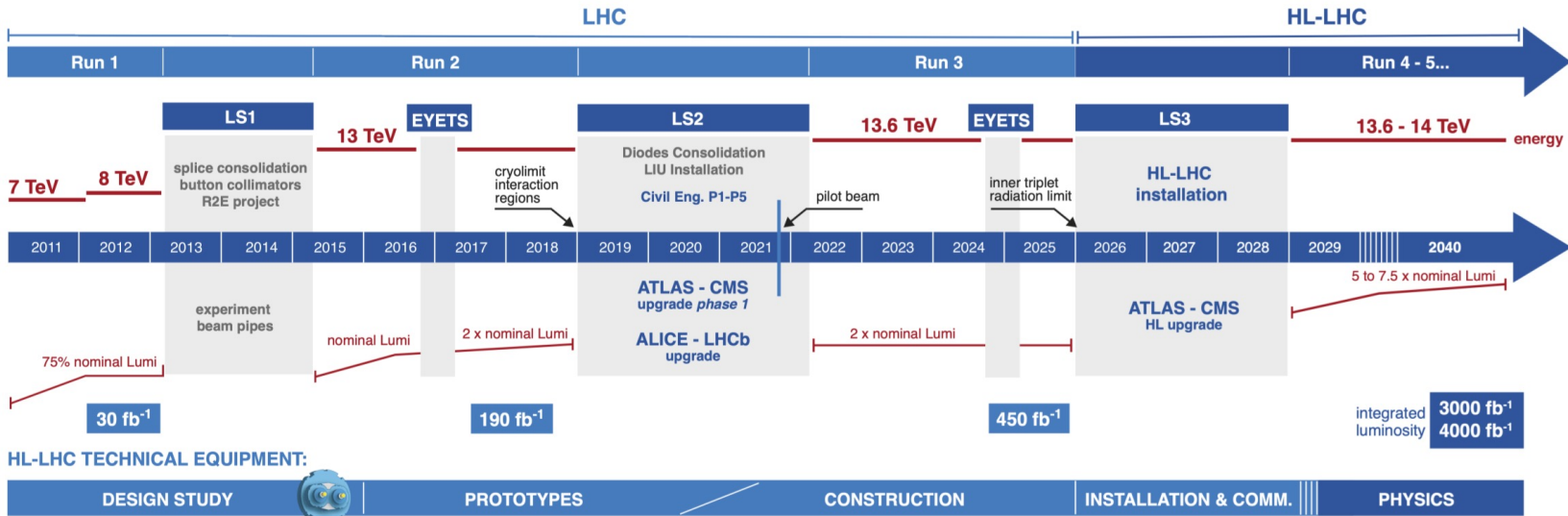
During the English civil war Bolton was known as the "Geneva of the North".

According to a recent survey of the [British Association for the Advancement of Science](#), Boltonians are the friendliest people in Britain.





# LHC / HL-LHC Plan



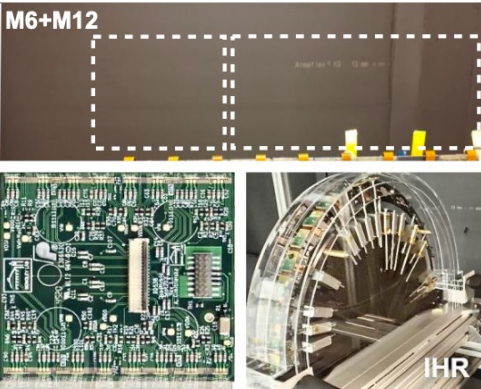
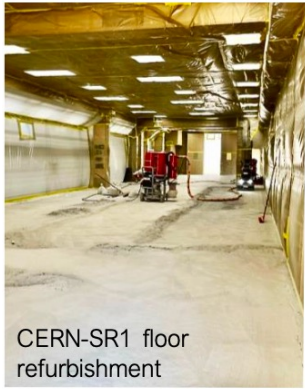
## HL-LHC CIVIL ENGINEERING:

DEFINITION	EXCAVATION	BUILDINGS
------------	------------	-----------

- LHC Run1 and Run 2 have been completed
  - Data analyses in full progress
- LS2 (Long Shutdown 2019-2021) is complete
  - ATLAS phase I upgrade done!
- LS3 (Long Shutdown 2026 -2028) after Run 3
  - LHC major upgrade to HL-LHC (High Luminosity LHC)
  - ATLAS Phase II upgrade
- **Run 4 and beyond (2029-): The future of particle physics!**



# HL-LHC Upgrade



CERN-SR1 floor refurbishment

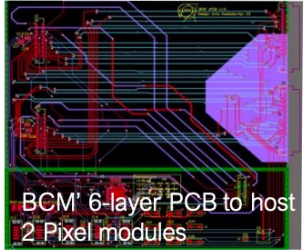
SXS N1 (CO2-cooling) building well advanced

M6+M12

ITk Pixel flex loading, flex module, and loaded support longerons & inner half ring

HGTD ALTIROC3 diced wafer

IHR



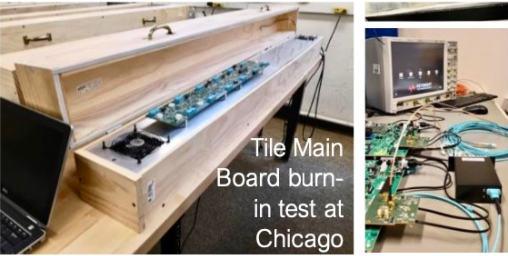
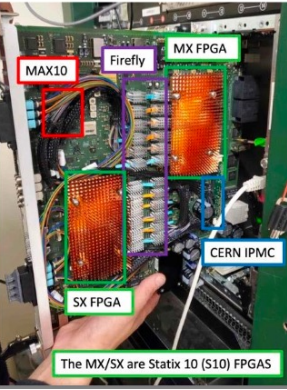
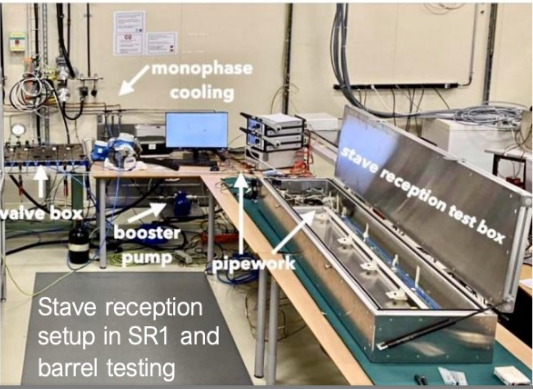
BCM 6-layer PCB to host 2 Pixel modules

First ITk Strip PPB petal loaded in Vancouver

MPI Munich

Michigan

SMDT chambers at CERN (BB5)



ITk Strip L3 structure with locking brackets mounted (A and C side)

Stave reception setup in SR1 and barrel testing

DAQ new PCIe bracket, LTI test setup

Tile Main Board burn-in test at Chicago

monophase cooling  
valve box  
booster pump  
pipework

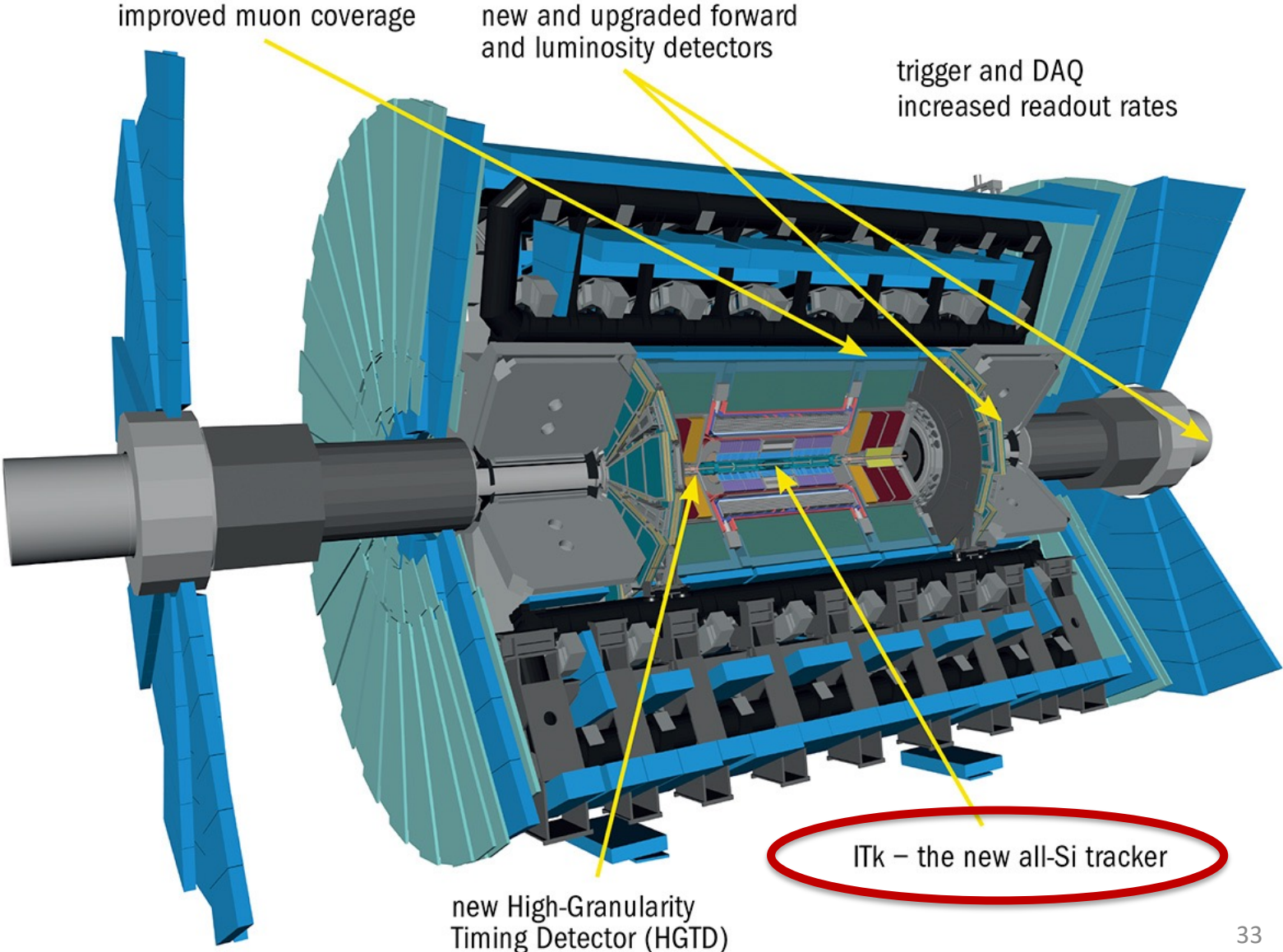
The MX/SX are Statix 10 (S10) FPGAS

Top right: DAQ new PCIe bracket, LTI test setup

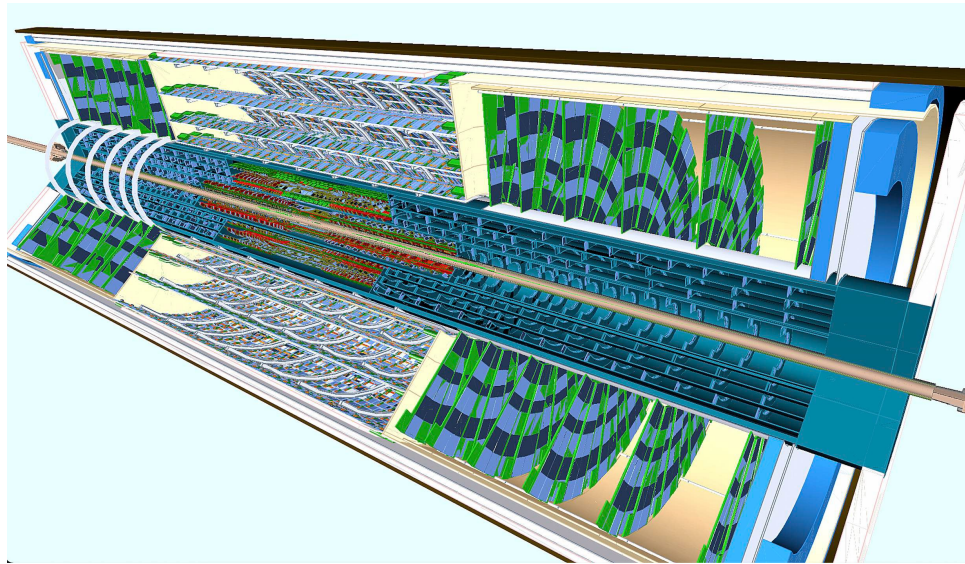
Left: LAr LASP board at EMF at P1



# HL-LHC Upgrade

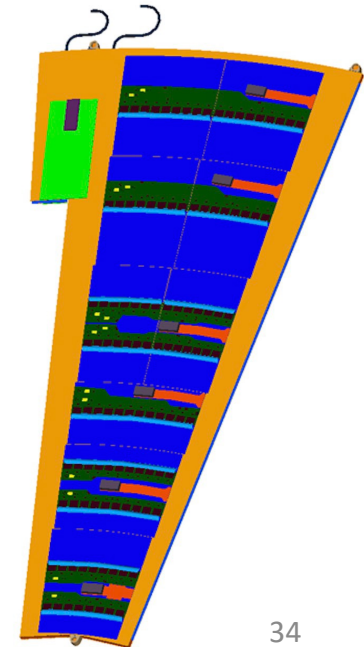


# ITK Strips



- Strip detector is comprised of two sections: barrel and the end-cap
- Redesign of inner tracker, extending geometry, sensitivity to larger  $\Delta\eta$
- New readout chips (ABCstar) and increased strip granularity

- **End-caps comprised of petals**
- 32 petals comprise a single end-cap disk.
- Each consists of six modules denoted R0 – R5
- Melbourne to build R1 and R4 modules
  - 122 R1 (at expected 85% yields resulting in 108 modules required for installation)
  - 261 R4 (at expected 79% yields resulting in 216 modules required for installation)





# Building next generation detectors: ITk



@ TRIUMF

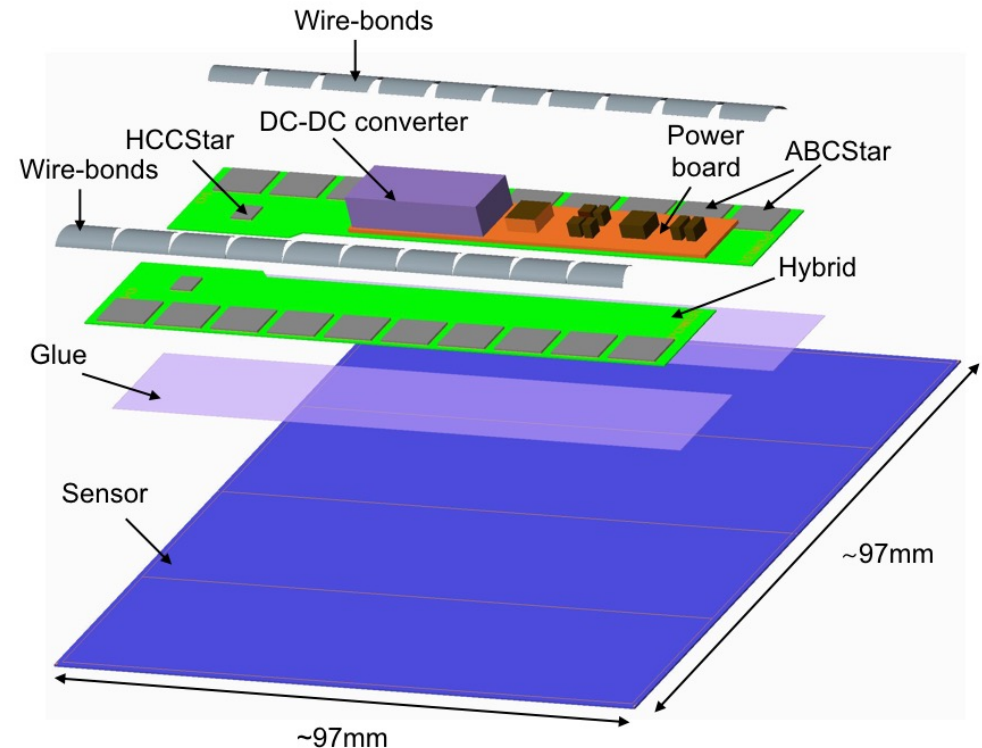
Building and testing an all-new silicon particle detector

@ UBC



# Module Assembly

- Relatively simple design, full assembly requires only a few jigs.
- Gluing performed with stencil - squeegee jig system.
- Hybrids to arrive pre-populated with ASICs (Not for prototyping).



# Module Testing

- All electrical testing performed with generic FPGA boards
- Electrical characterisation and thermal cycling to be performed at Adelaide.
- Cold-box for thermal cycling installed in Adelaide and ready.
- Module received from CERN last week!!



- ✓ Site qualification near complete.
- ✓ 2024 we should be making ITk-ready modules

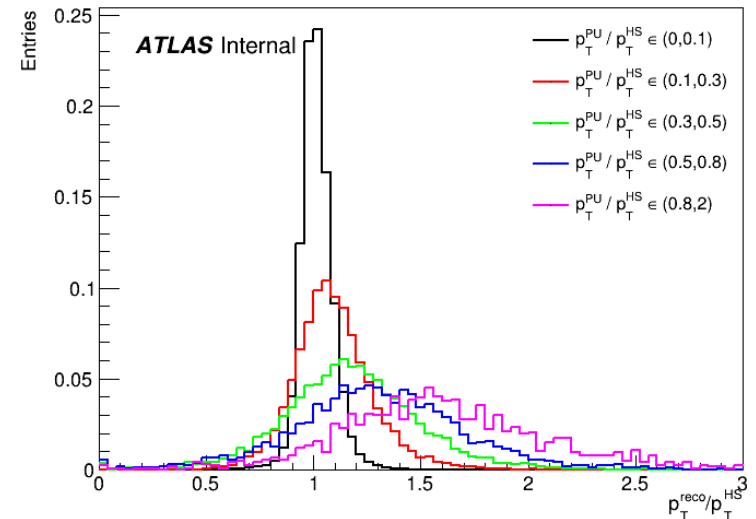
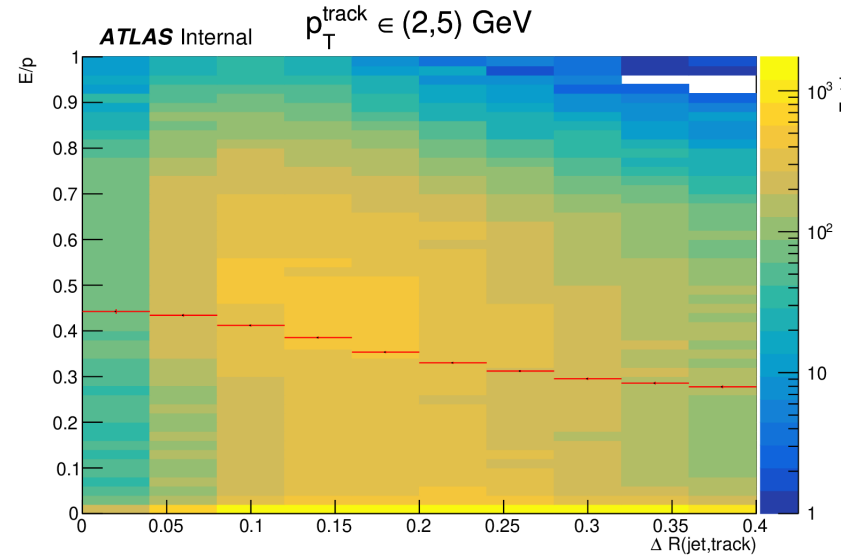




# Future jets @ HL-LHC



- In the High Luminosity era of the LHC, the collision environment will experience increased pile-up conditions, including contributions from hard-QCD pile-up.
- 200 interactions per bunch crossing
- Two ongoing threads of study relating to hadronic object reconstruction:
  1. characterisation of low-momentum charged particle behaviour in dense environments (important component of Particle Flow)
  2. identifying and correcting for overlaps between hard scatter jets and hard-QCD pile-up jets



work of Edmund Ting

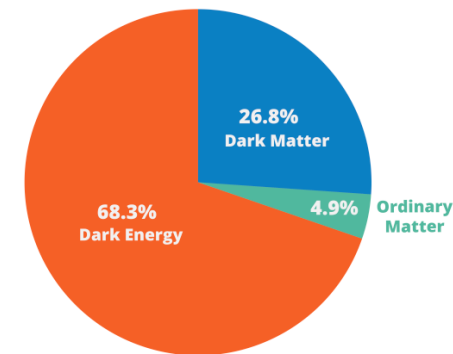
CDMPP, Glenelg, Nov 2023



## Summary

- The LHC will remain the highest energy particle collider on the planet for the next 20+ years with a broad sensitivity to a wide array of potential DM candidates
- In CDMPP we are:
  - playing our role in the upgrade of the inner tracker in preparation for HL-LHC
  - improving jets and missing transverse momentum performance
  - leading analyses to search for invisibles with heavy flavour-tagged jets and multiple top quarks
  - developing new analysis techniques
  - developing new trigger ideas and contributing to computing

Estimated matter-energy content of the Universe



***LHC and ATLAS: a uniquely sensitive environment to produce and measure Dark Matter.***

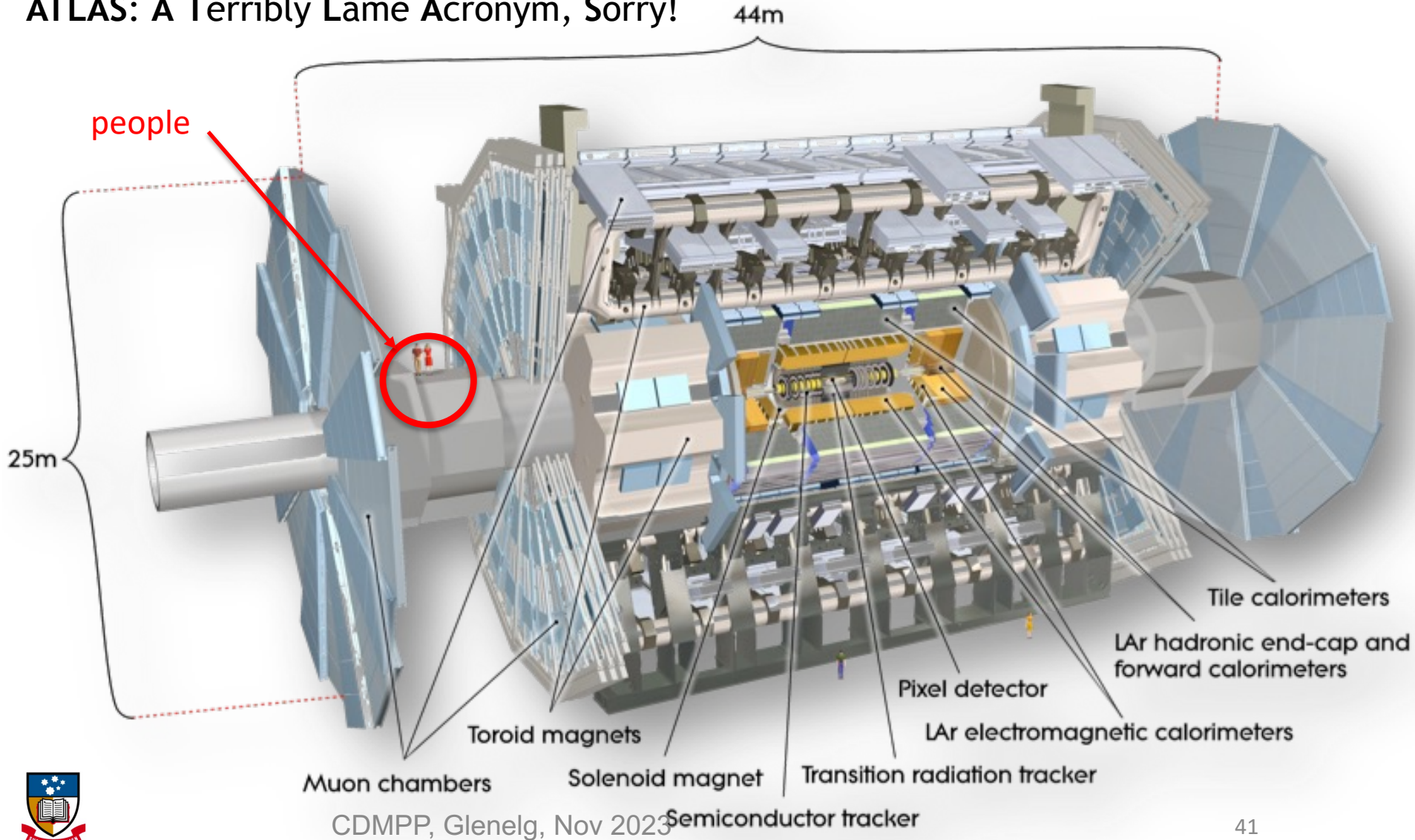
## More material



# ATLAS Experiment



ATLAS: A Terribly Lame Acronym, Sorry!



CDMPP, Glenelg, Nov 2023

Semiconductor tracker

# CDMPP Roles in ATLAS

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Albert Kong – Jet ETmiss Working Group Early-data task force Contact Person Run3

Harish Potti – Early-Career Scientist Board member

Harish Potti – Exotics Working Group Derivations Contact

Edmund Ting – Jet ETmiss Working Group Derivations Contact

Tristan Ruggeri – Analysis contact on cc + MET

Paul Jackson – Recently: Executive Board, Publications Committee, Computing Speakers Committee Chair

ECRs undergoing/completed qualification tasks in:

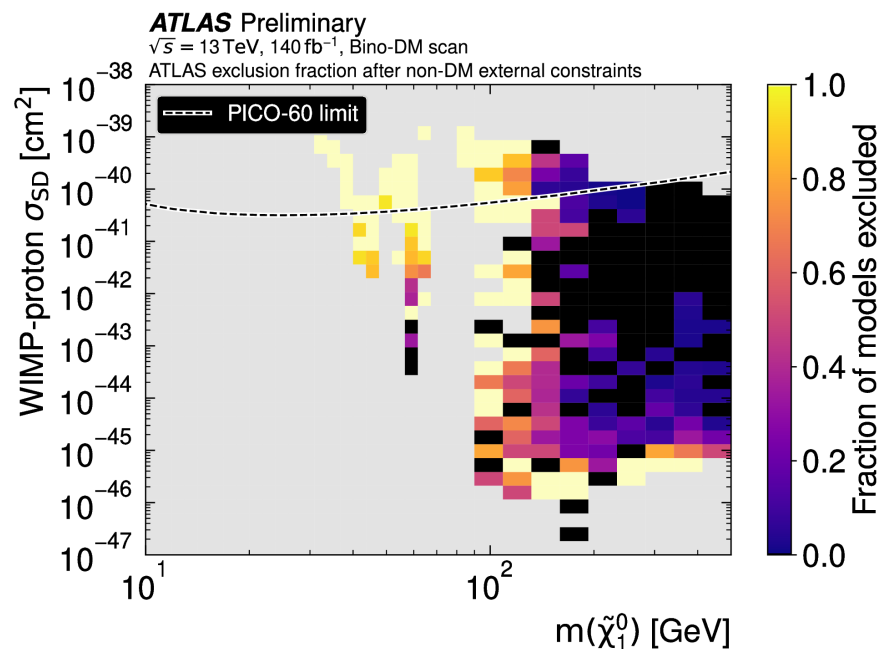
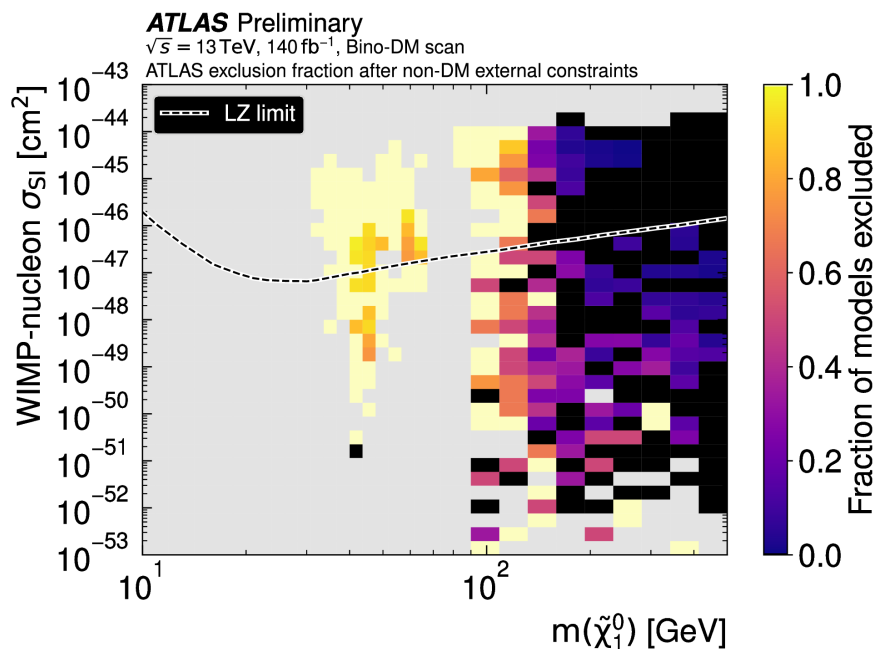
Jet ETmiss, ITK hardware, ITK software, Photon isolation, Luminosity





# DM in recent SUSY searches

- Continue to produce some of the most stringent limits on Dark Matter candidates
- Colliders are the best place to search for *laboratory produced Dark Matter*



<https://atlas.cern/Updates/Physics-Briefing/SUSY-Dark-Matter>

<https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2023-055/>

[ATLASHighlights\\_EPS](#)