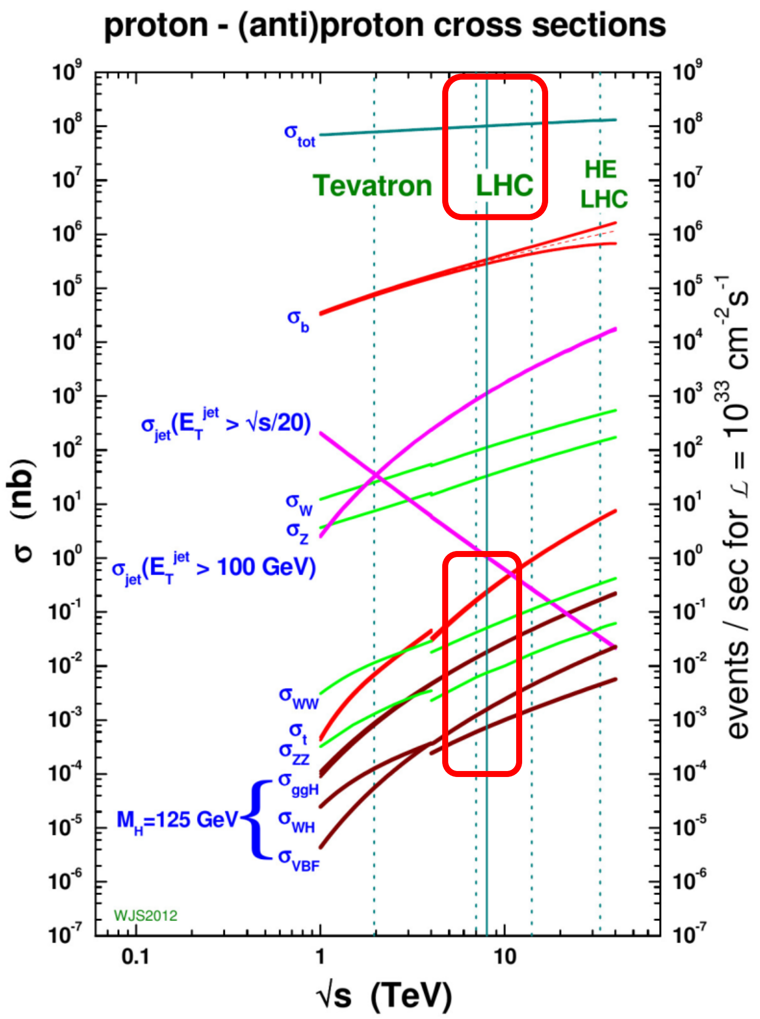
From discovery to precision physics: ATLAS Trigger and Data Acquisition evolution

Riccardo Scaglioni (University and INFN Pavia)

Supervisors:
Andrea Negri (University and INFN Pavia)
Gabriella Gaudio (INFN Pavia)

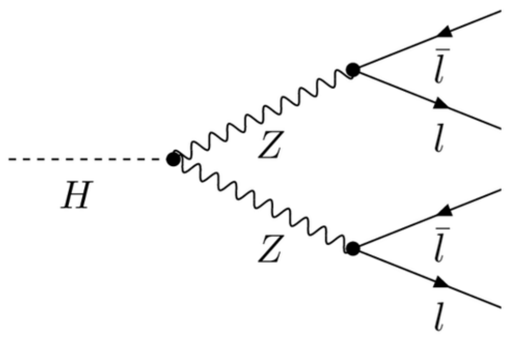
Physics at the Large Hadron Collider

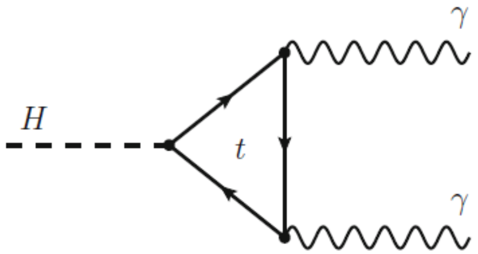


- Center of mass energy: $\sqrt{s}$ = 13.6 TeV
- High collision frequency: 40 MHz
- Lot of collisions data produced: > 60 TB/s
- **Very rare interesting events (Higgs ~ 10^{-10} σ_{tot})**
- **Designed to validate new physics models**

What does data taking mean?

What we are looking for:





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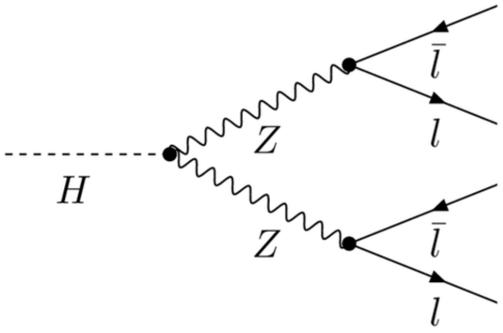
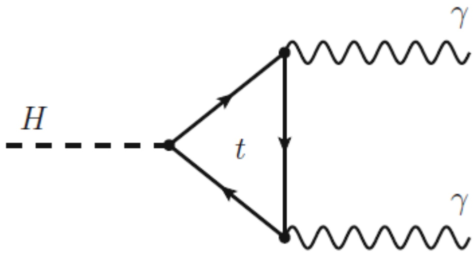
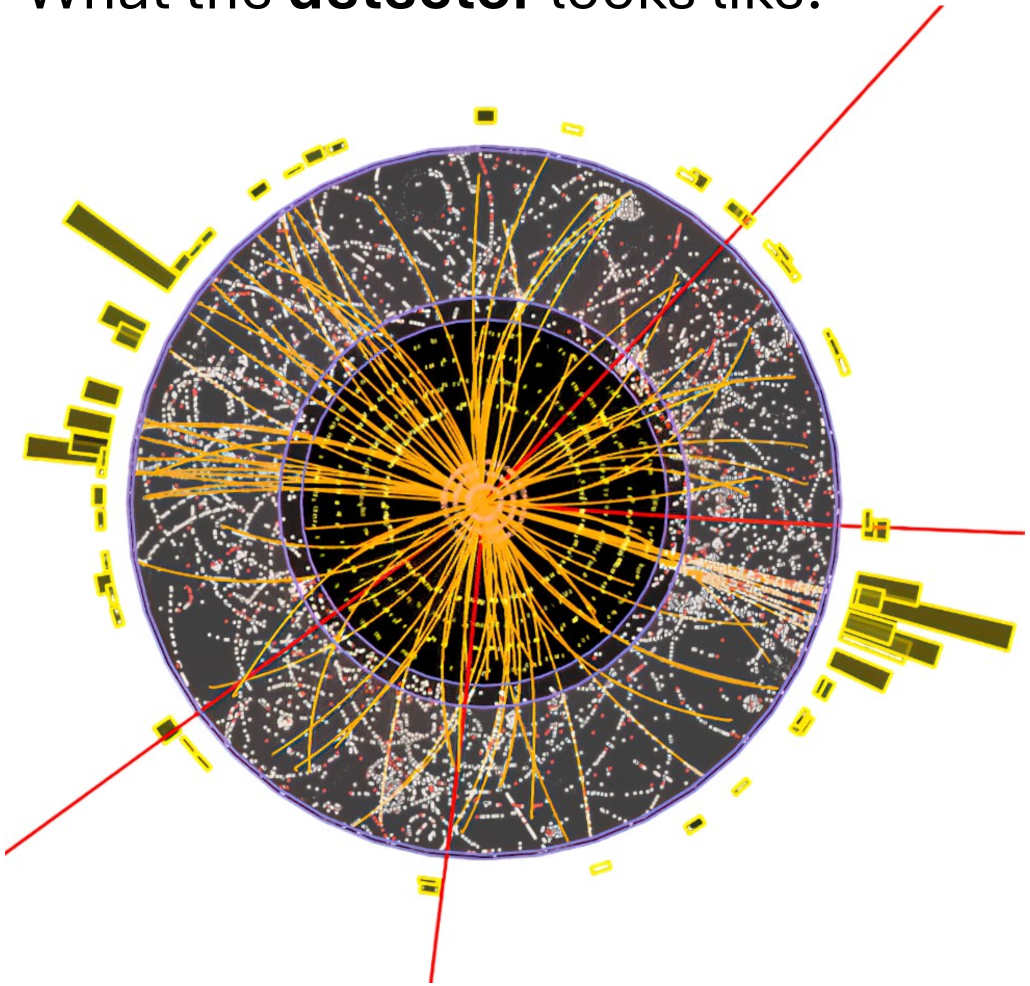


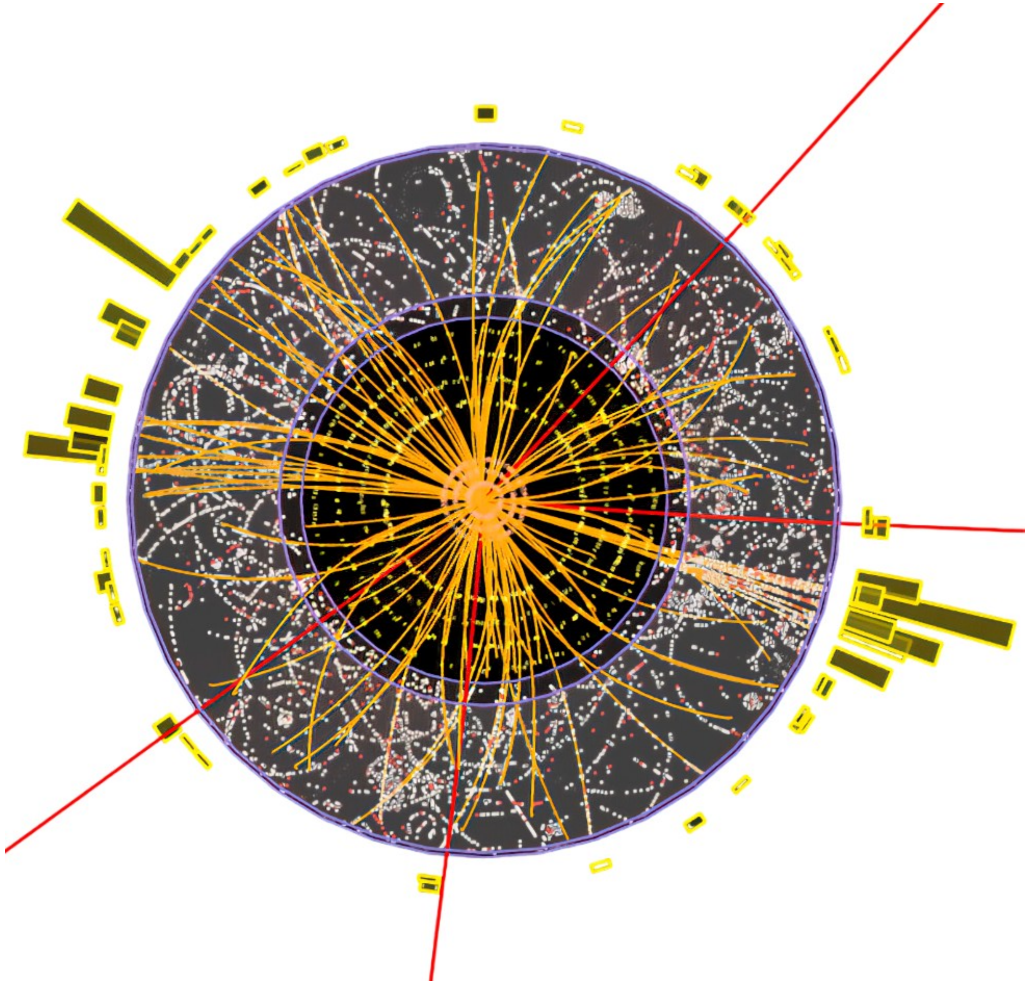


What the **detector** looks like:

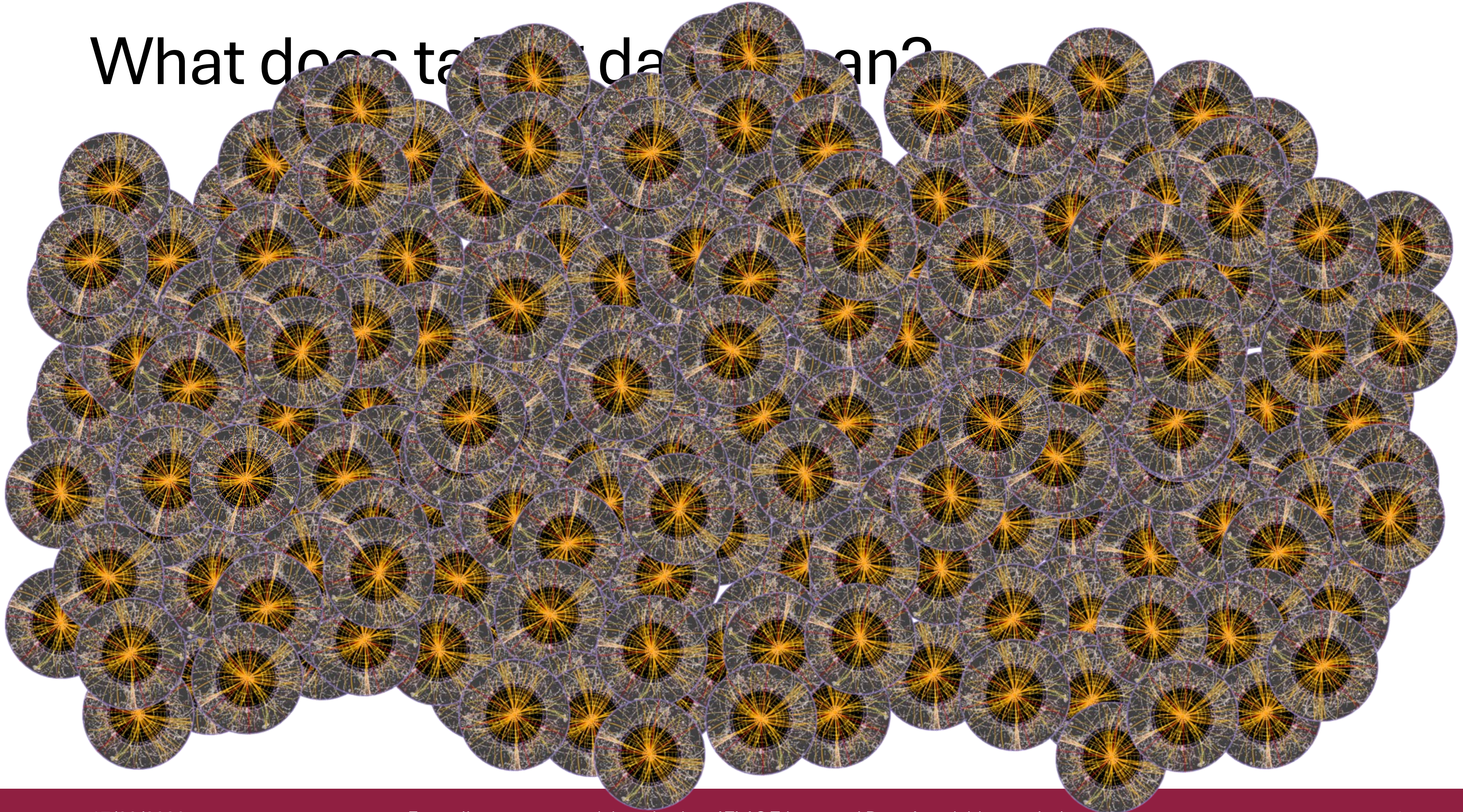


What does data taking mean?

LHC produces
40 million collisions
per seconds



What do… ta… da… an?



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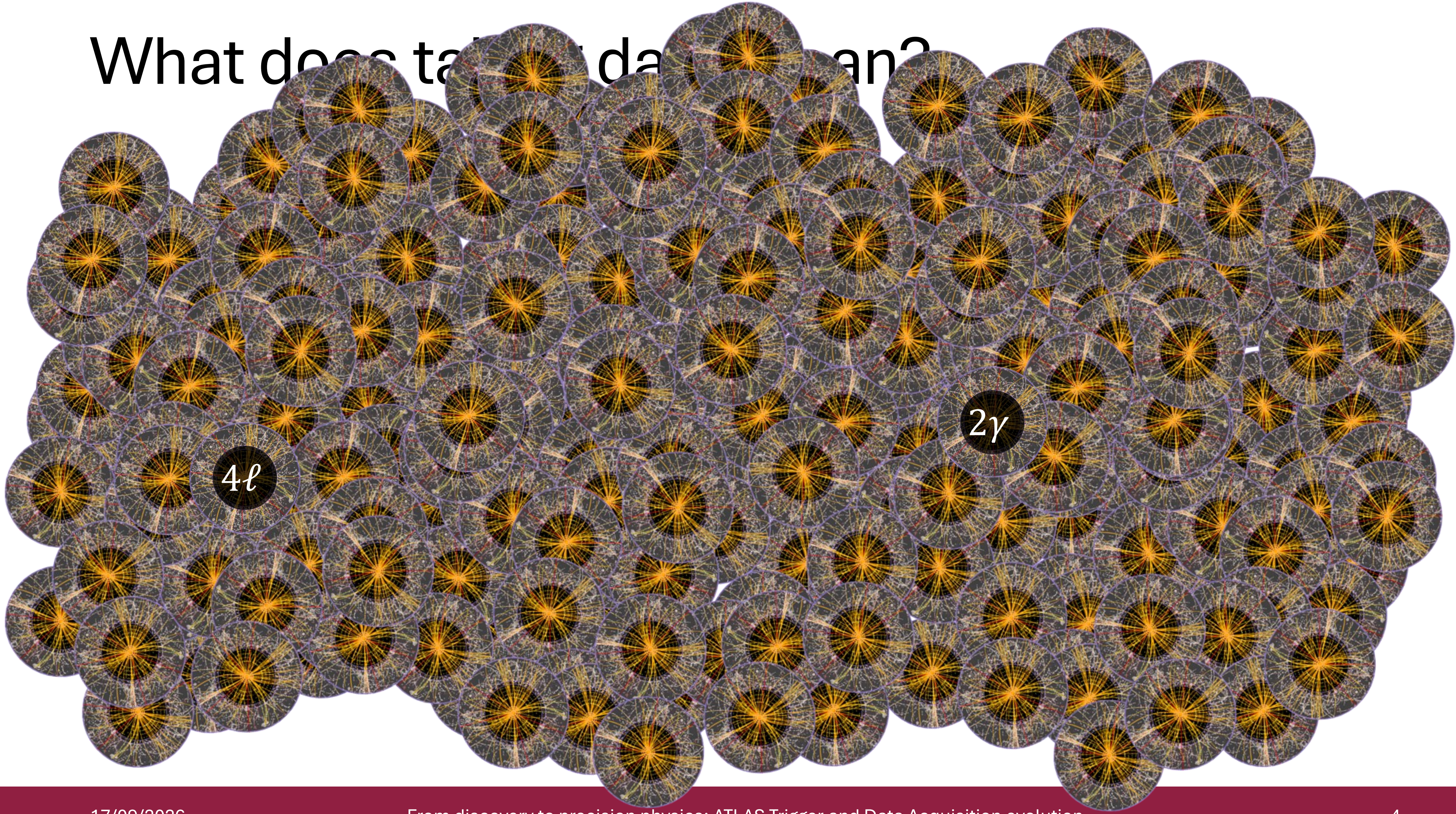

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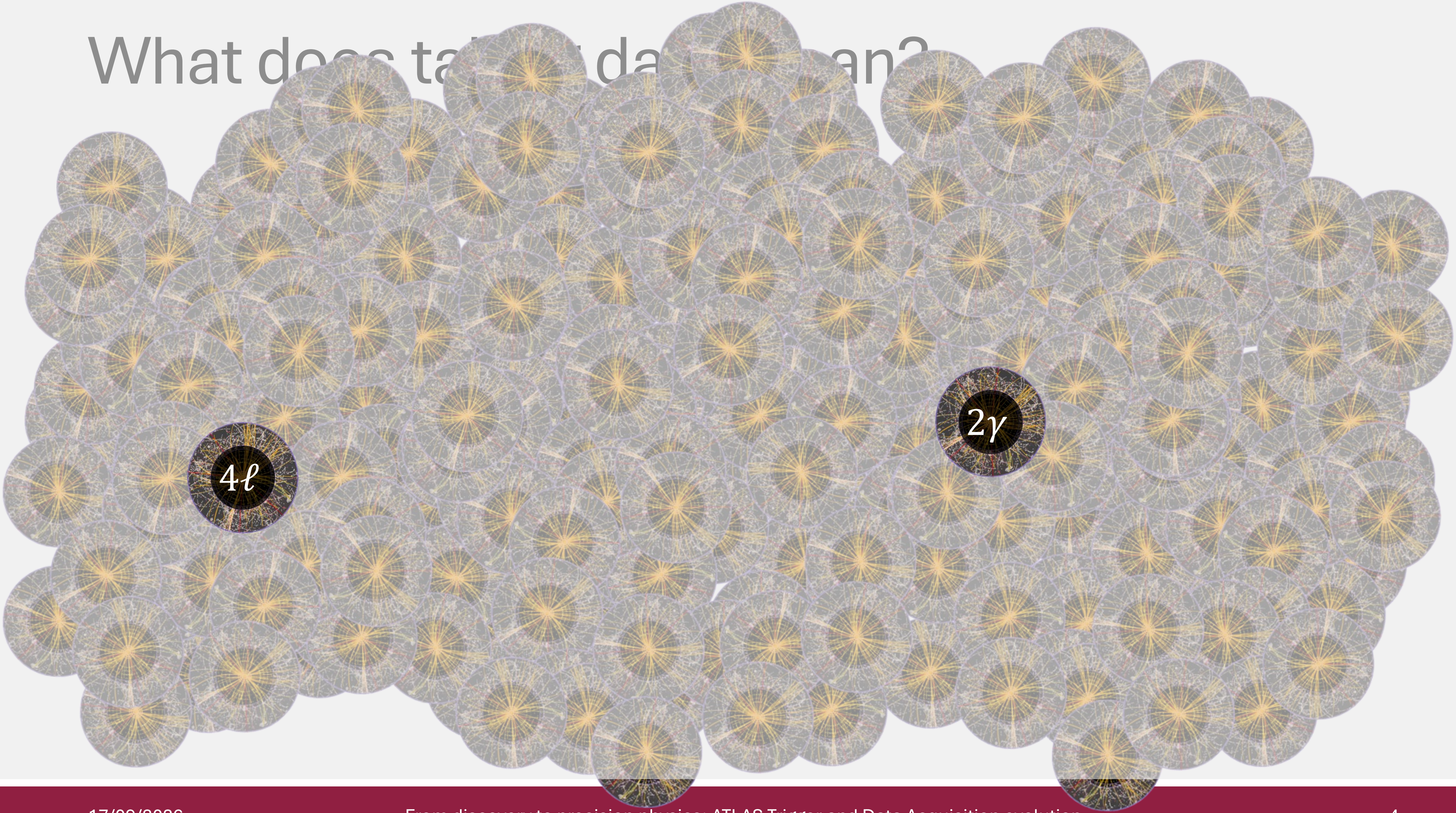

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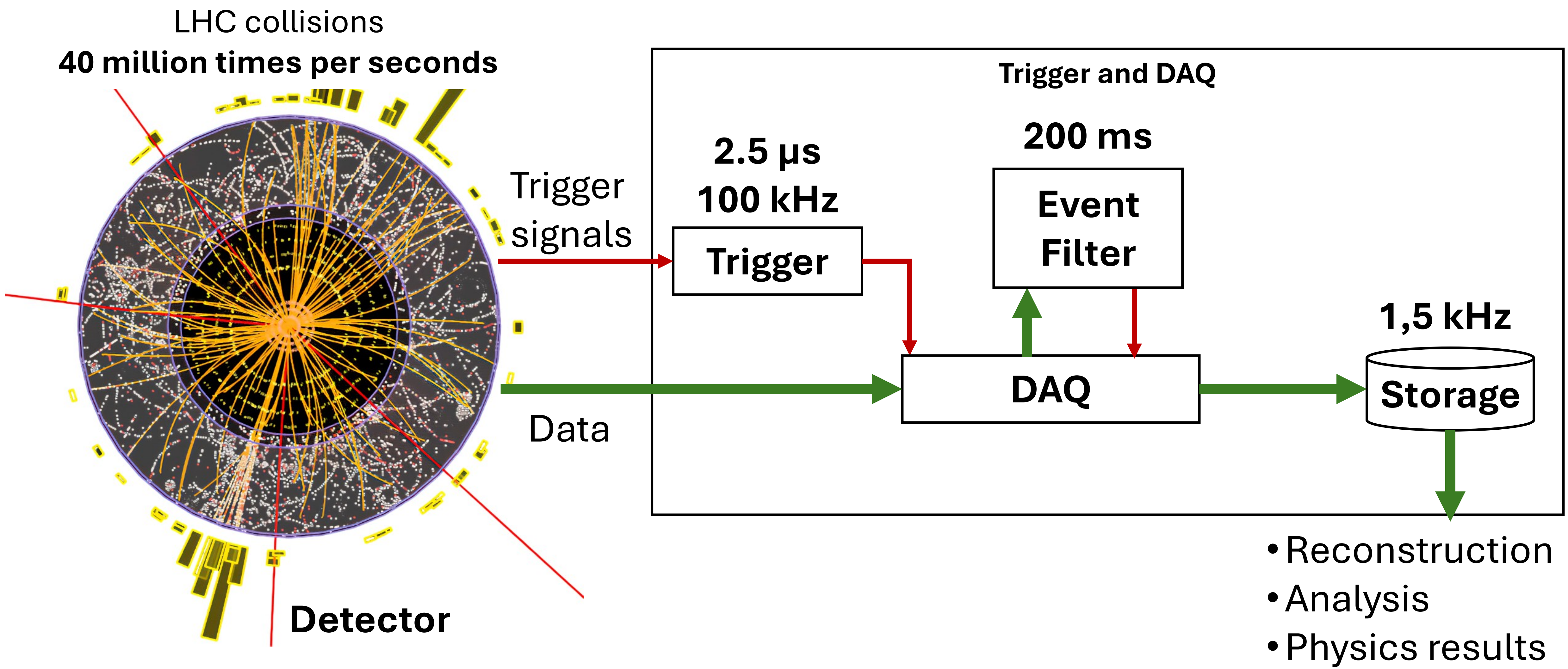
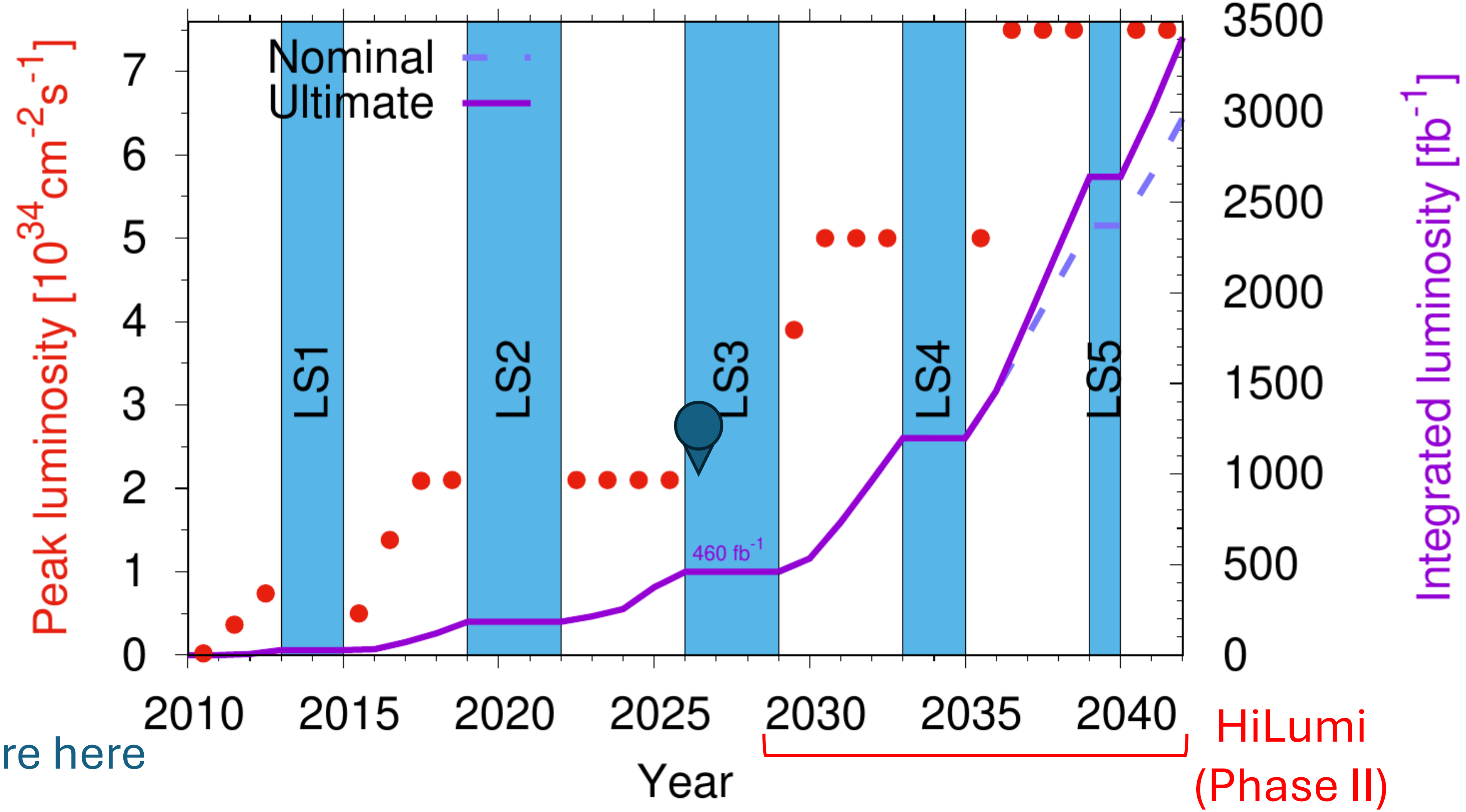


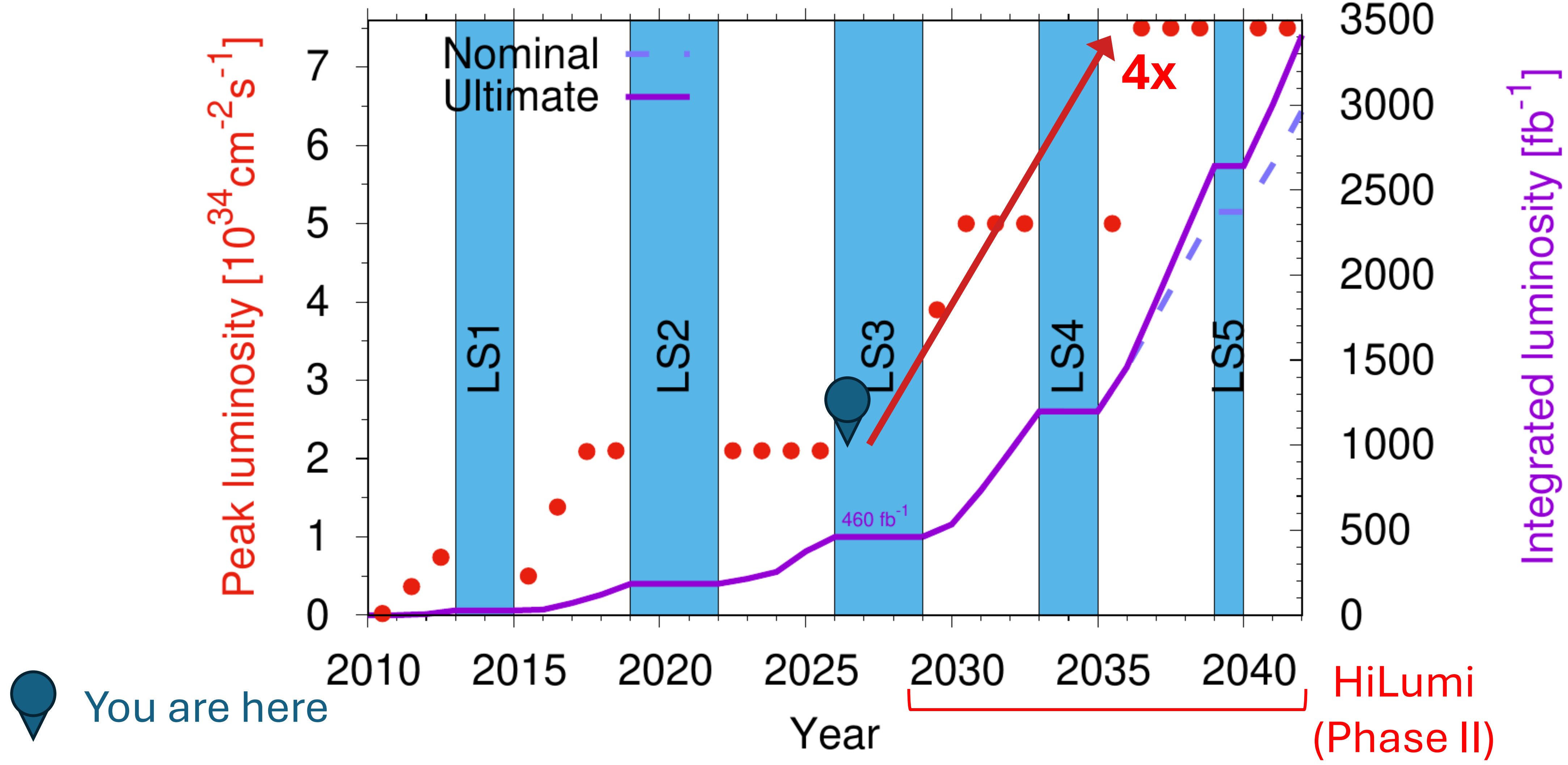
The High Luminosity Upgrade



HiLumi (Phase II)

You are here

The High Luminosity Upgrade



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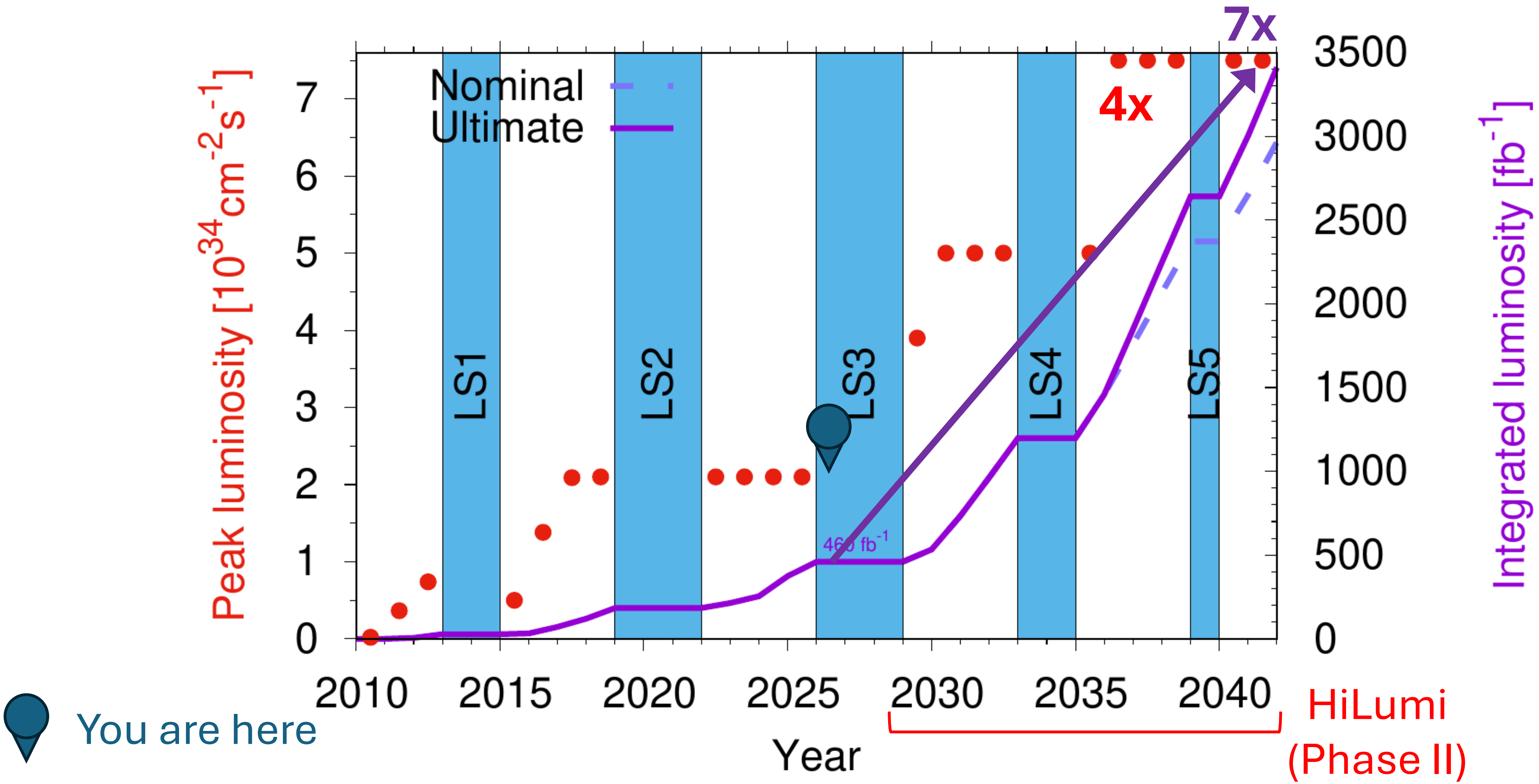
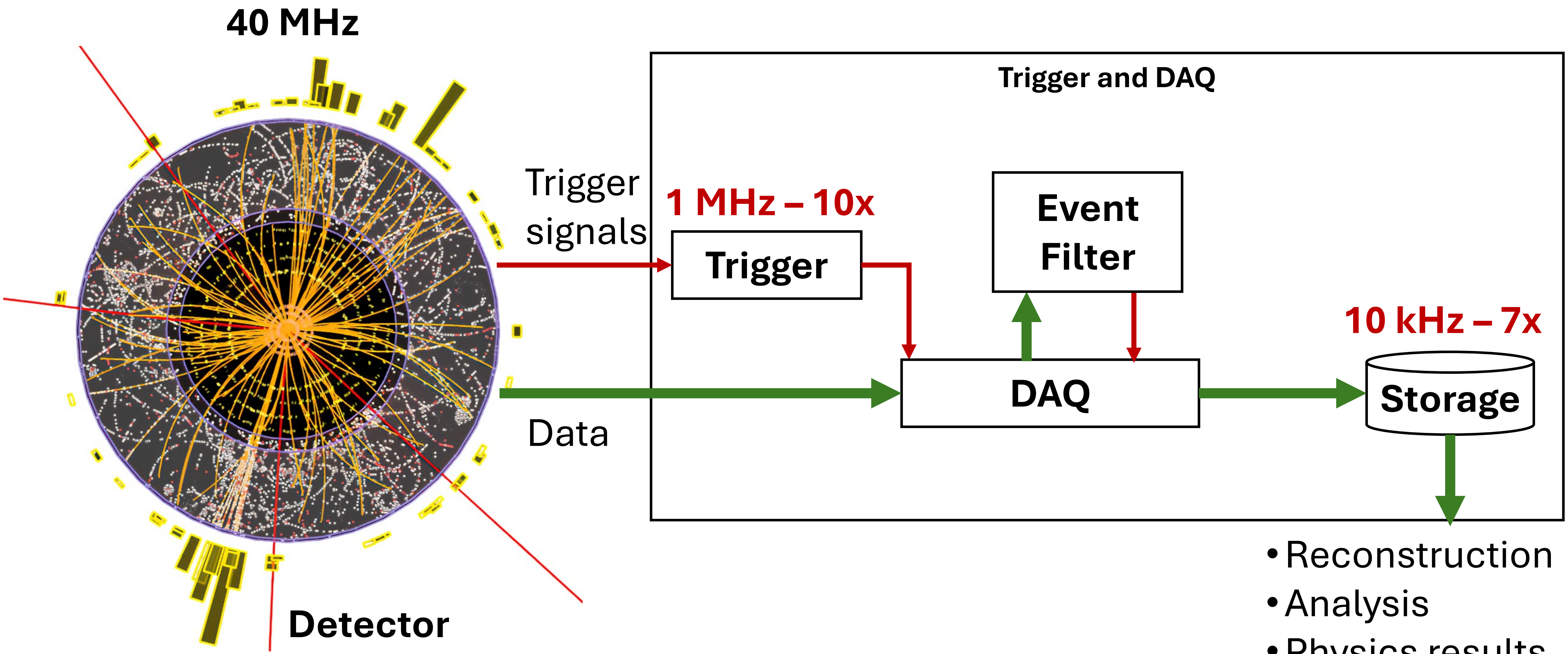


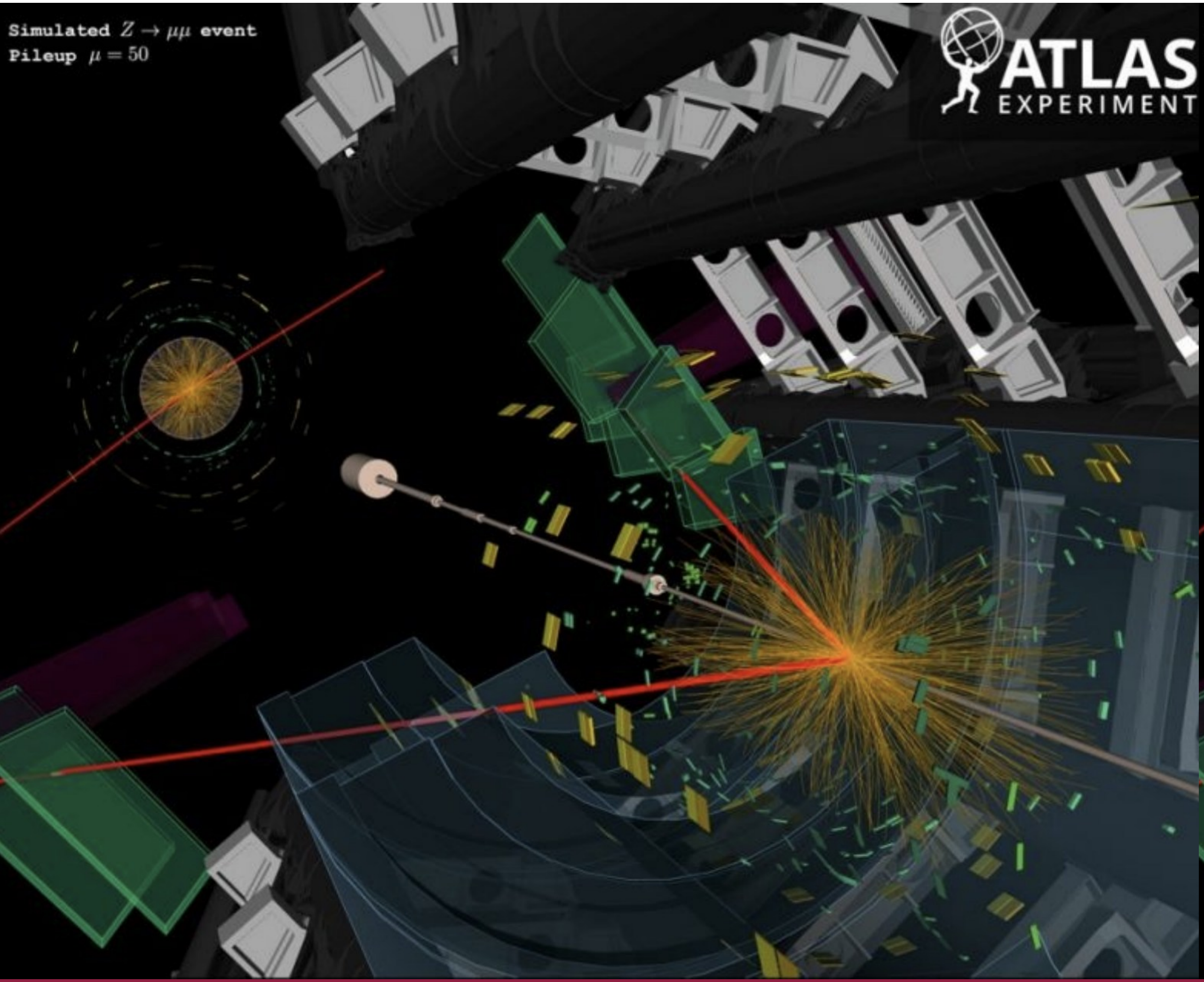
High Luminosity challenges



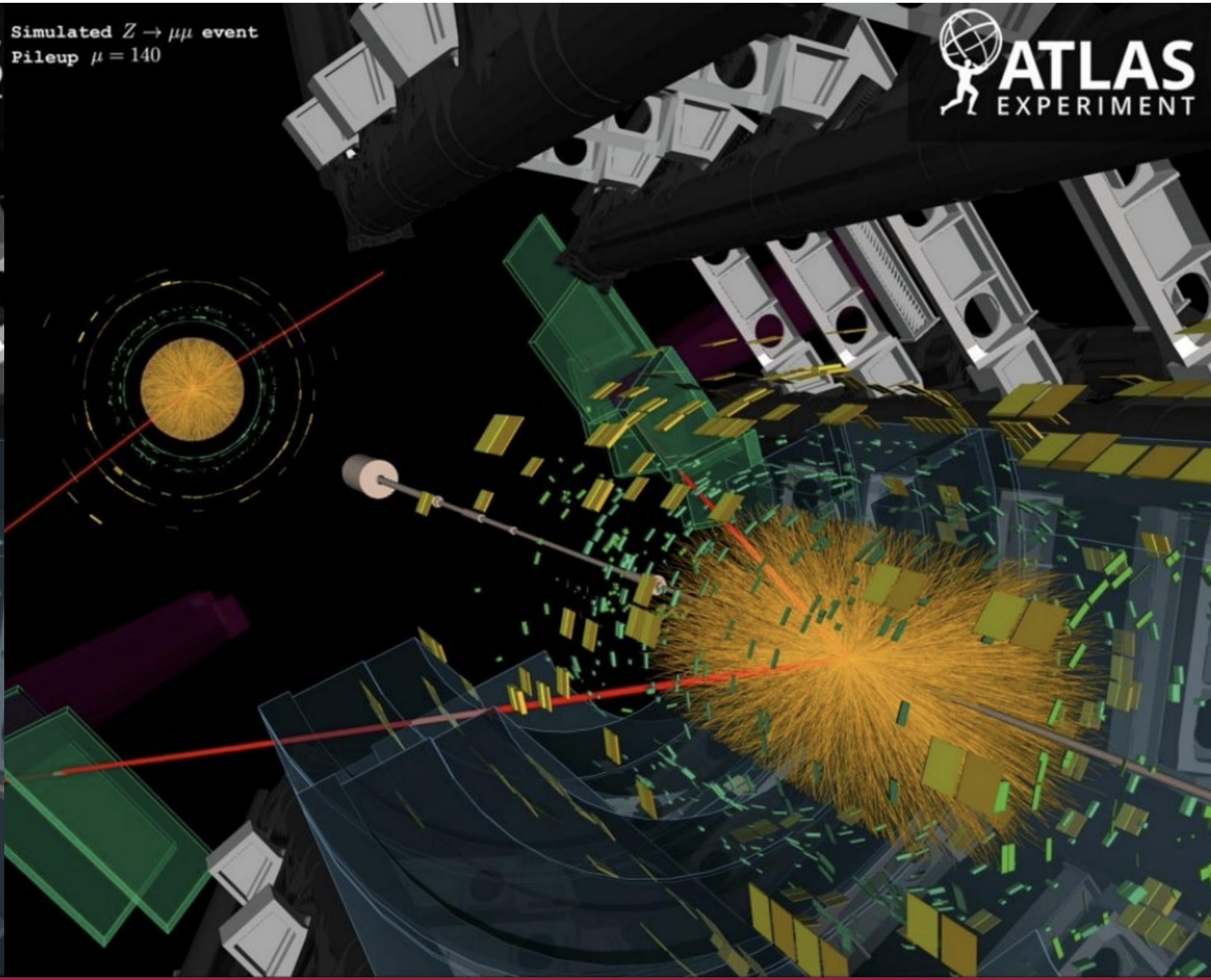
- Reconstruction
- Analysis
- Physics results

High Luminosity challenges

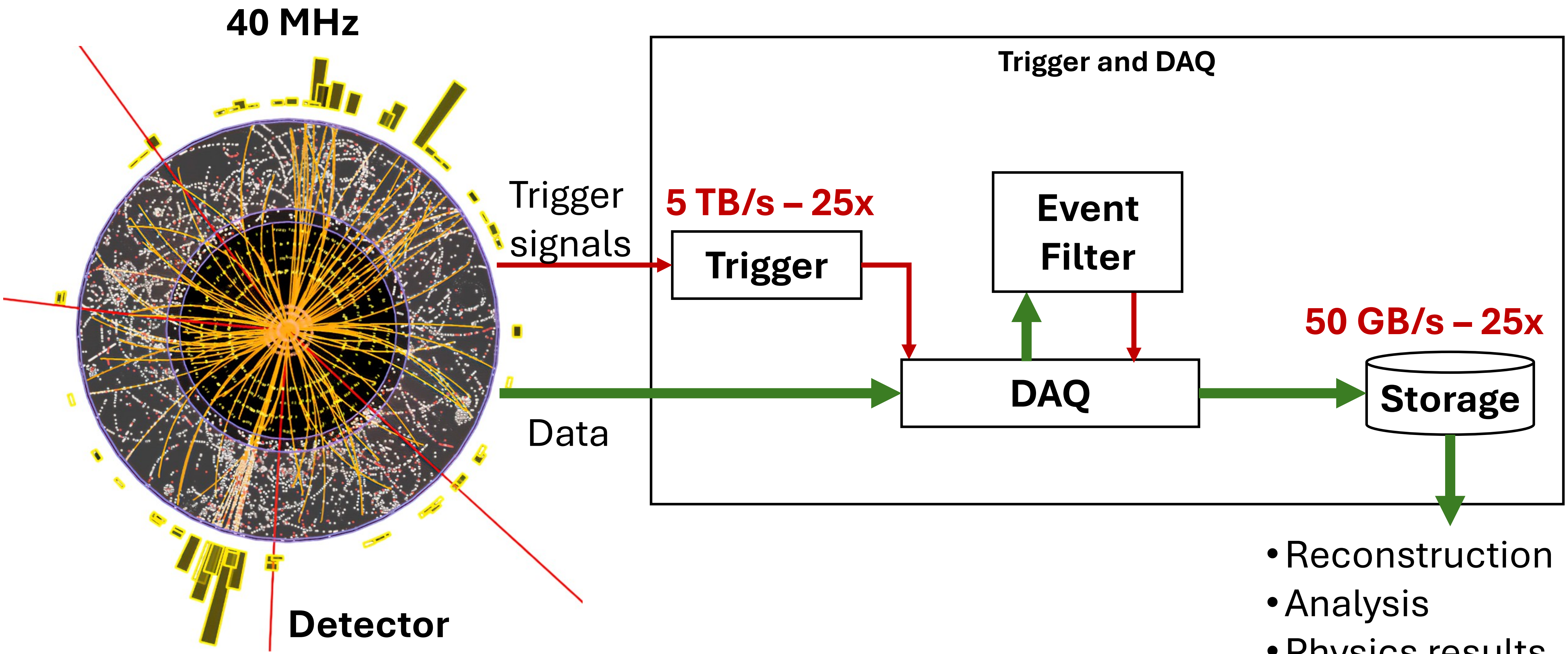
Montecarlo simulations: Run 3 equivalent



Run 4 equivalent



Rate but also data



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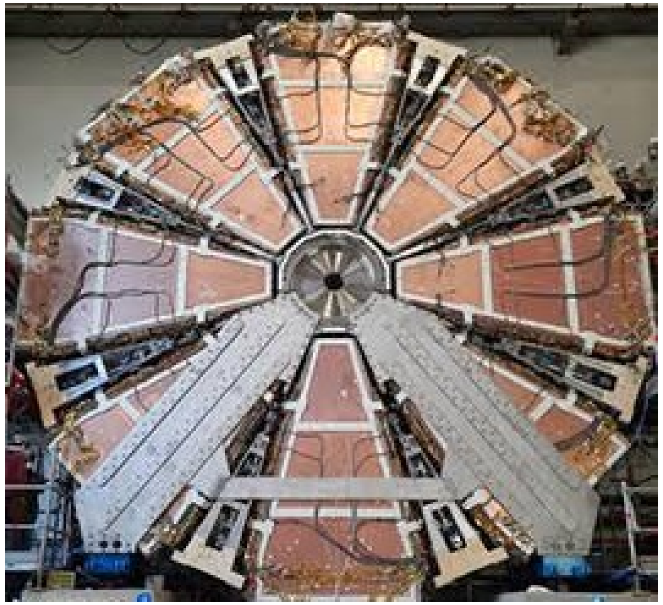
What do we do?

Better detector



Faster trigger

Improved selection

Each with some upper limit: technology, availability, cost

We can just go bigger

More computing power and storage...

We can('t) just go bigger

More computing power and storage… comes with huge drawbacks:

- Size
- Costs (~ Milions €)

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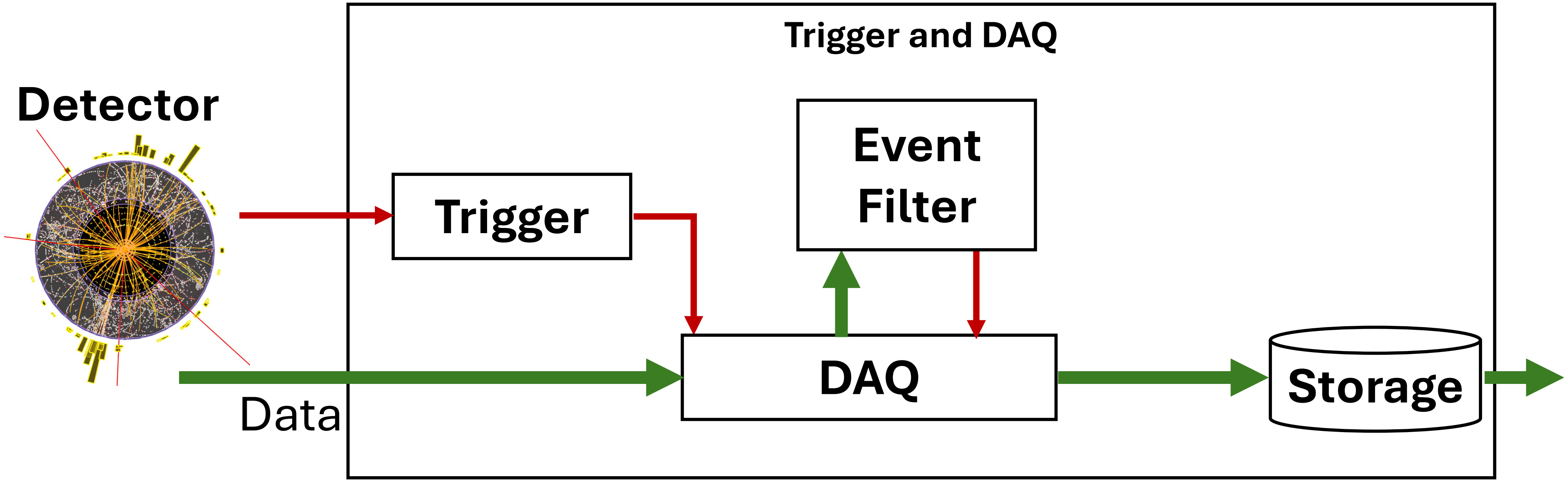
We need be smart about **resource usage!**

The PhD project

My research approaches this problem from two sides:



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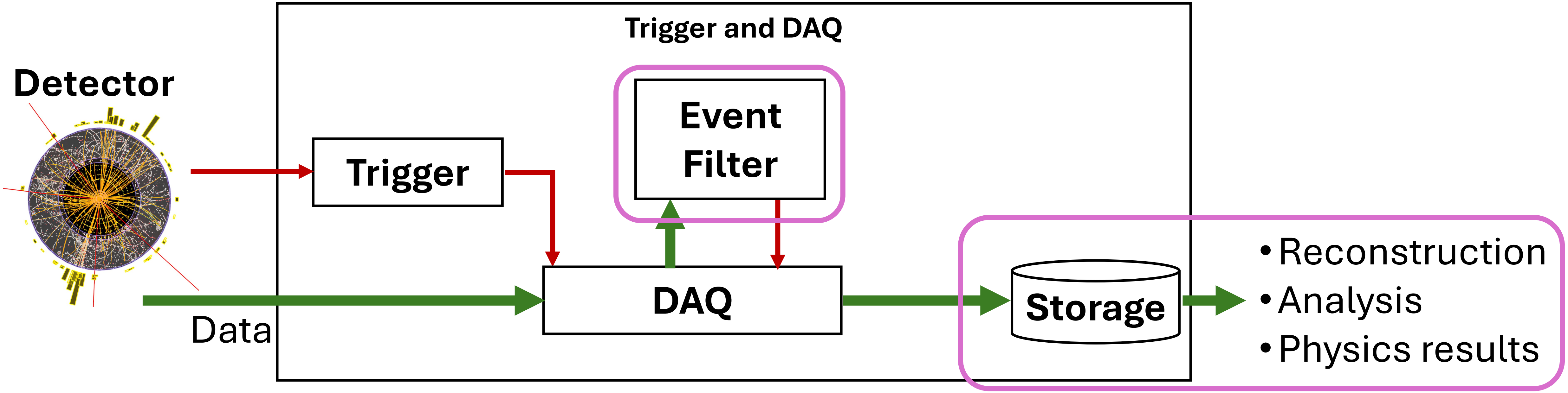
Trigger Level Analysis



The PhD project

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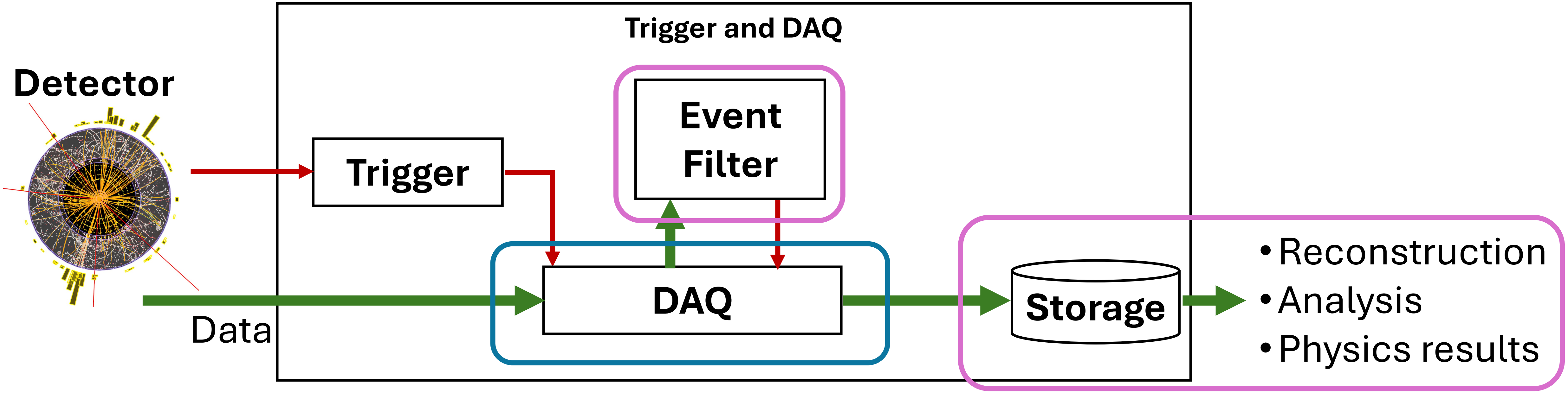
Trigger Level Analysis

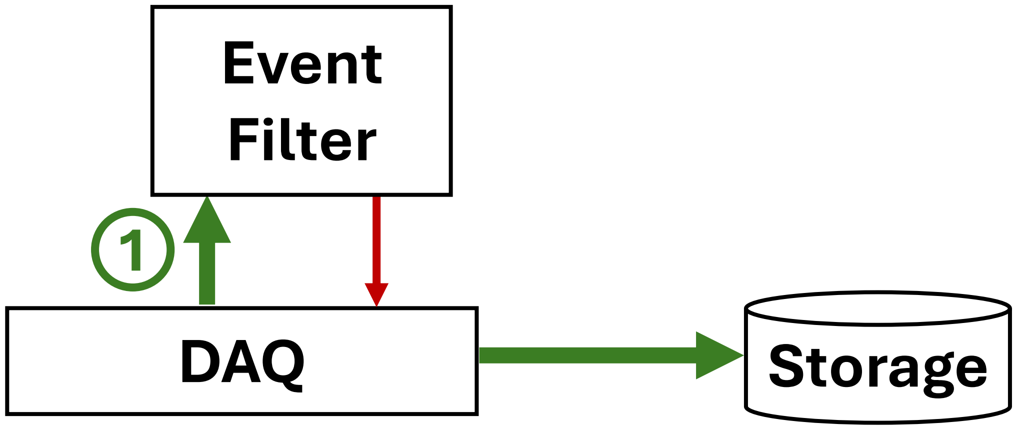
Data Acquisition Optimization



Trigger Level Analysis, a new paradigm

Normal data taking:

1. DAQ sends **full raw event data** to Event Filter



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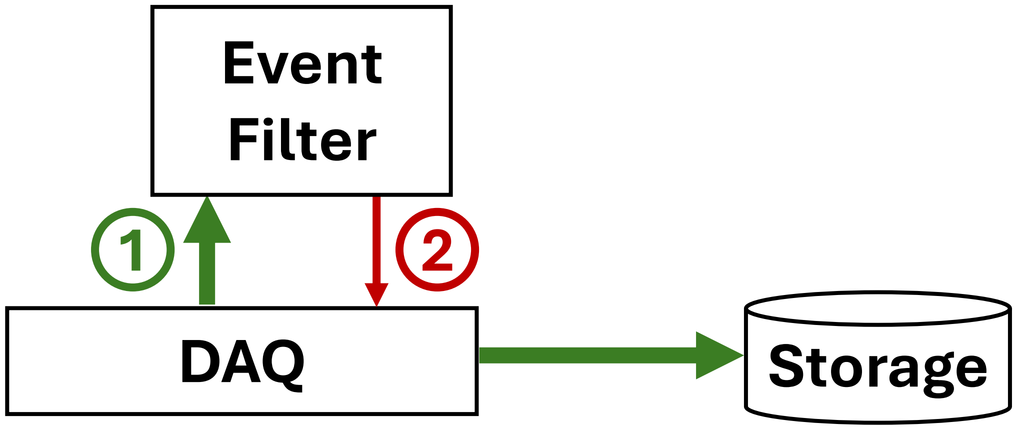

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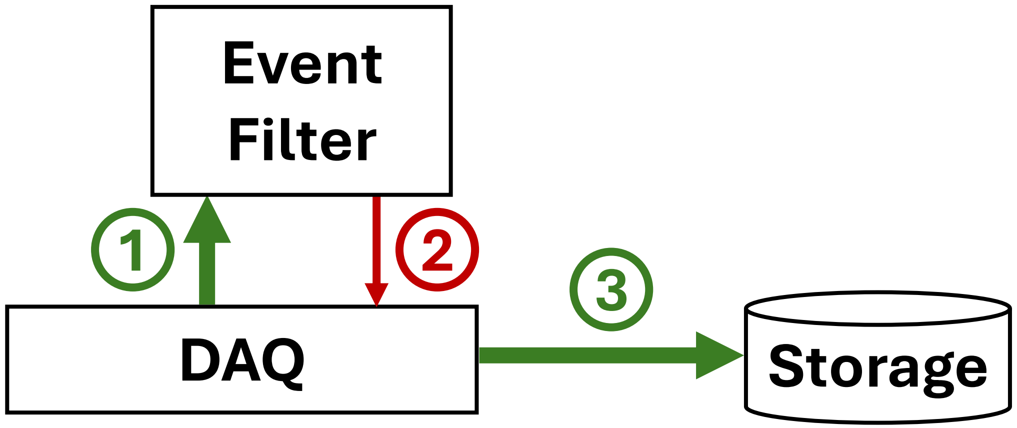

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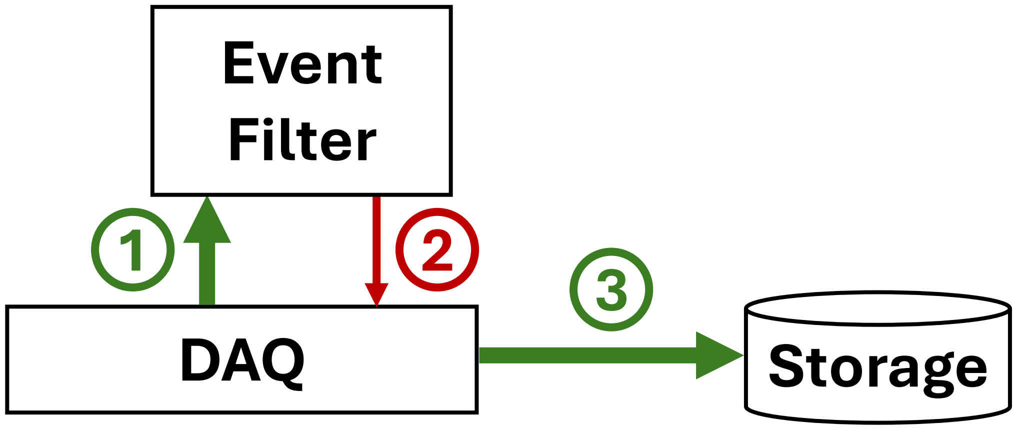
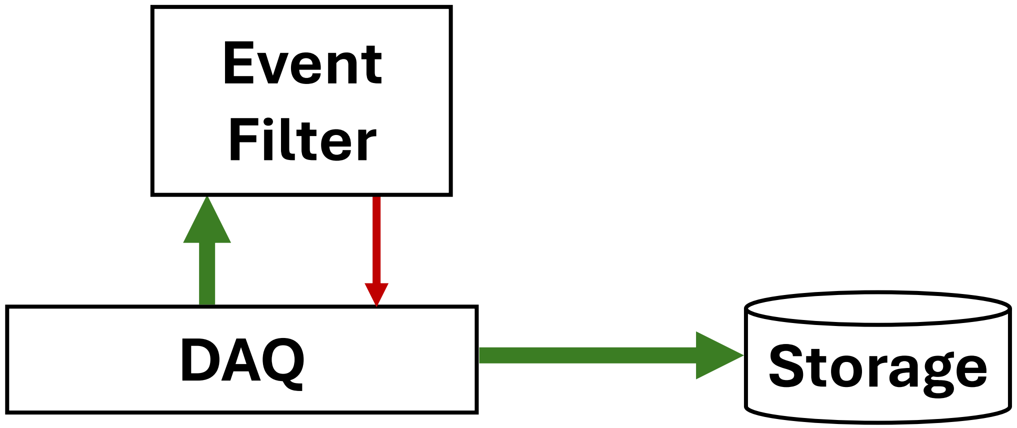


Storage Bandwidth (Data/s) is limited:

- **Raw Events** are heavy (~5 MB)
- Hard limit on how many events we can record (or not?)

Trigger Level Analysis, a new paradigm

What if we don't record full events?



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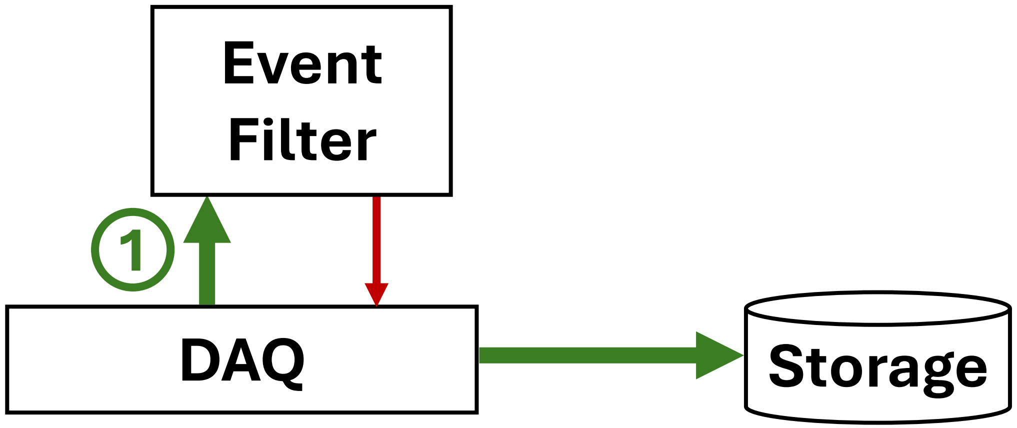

Trigger Level Analysis, a new paradigm

What if we don’t record full events?

1. DAQ sends **full raw event data** to Event Filter
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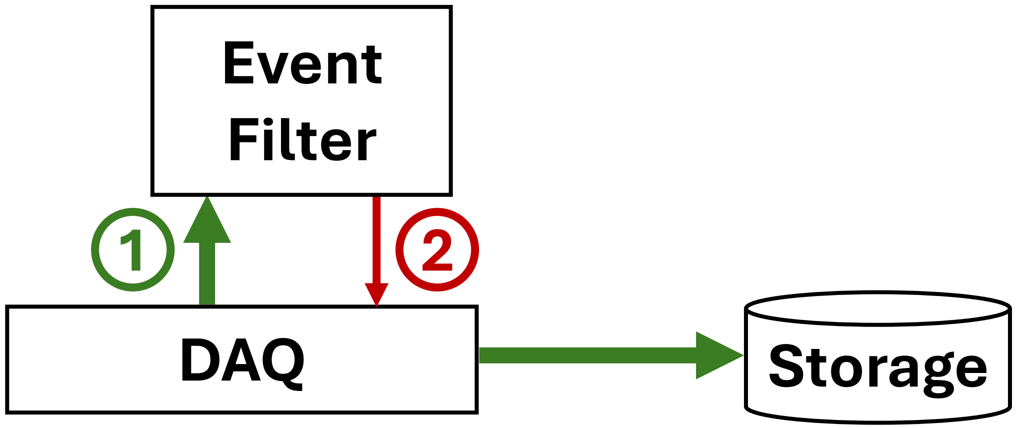
   - Select interesting events
   - Sends **decision and reconstructed event** to DAQ



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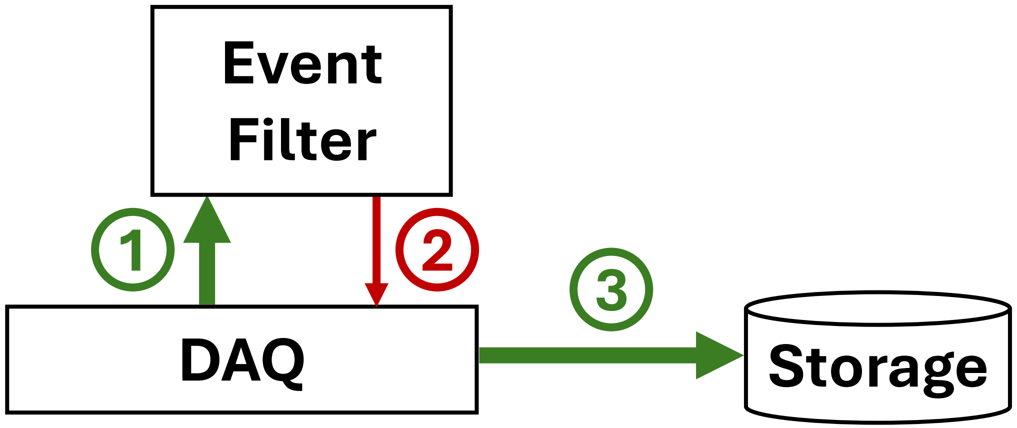

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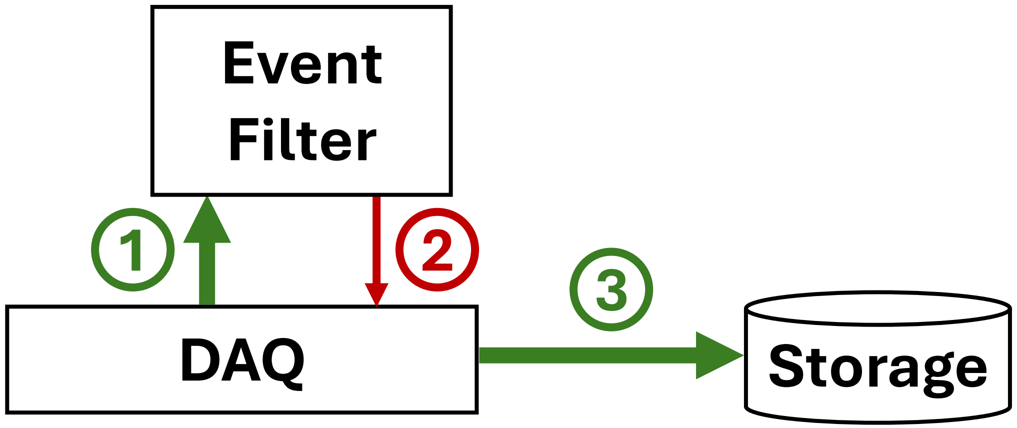


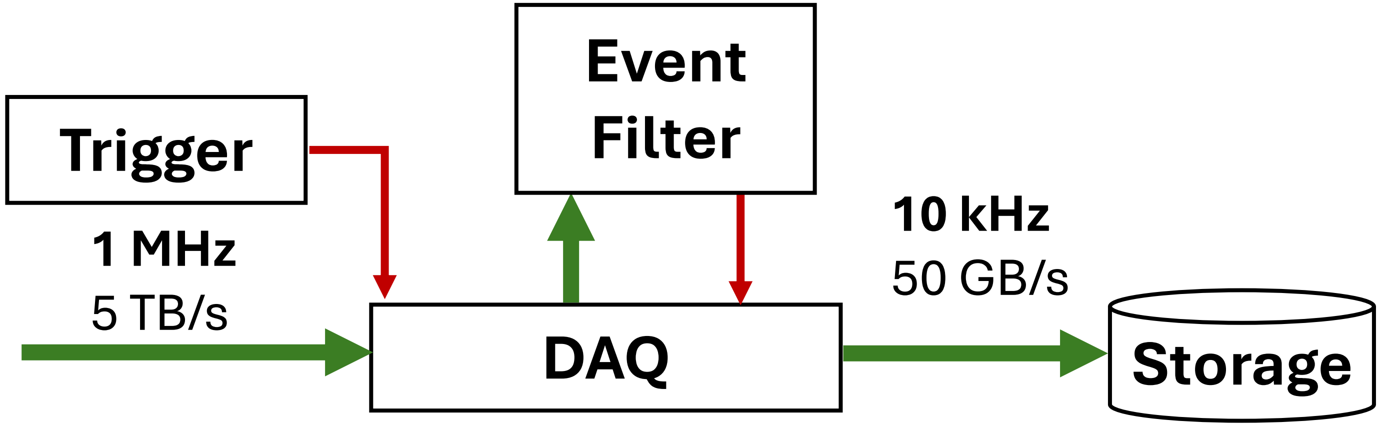
Storage Bandwidth (Data/s) is limited:

- ➢ **Reconstructed events** are much lighter(~50 kB)
- ➢ Up to **x100 events recorded**

Trigger Level Analysis, a new paradigm

What do we gain from this?

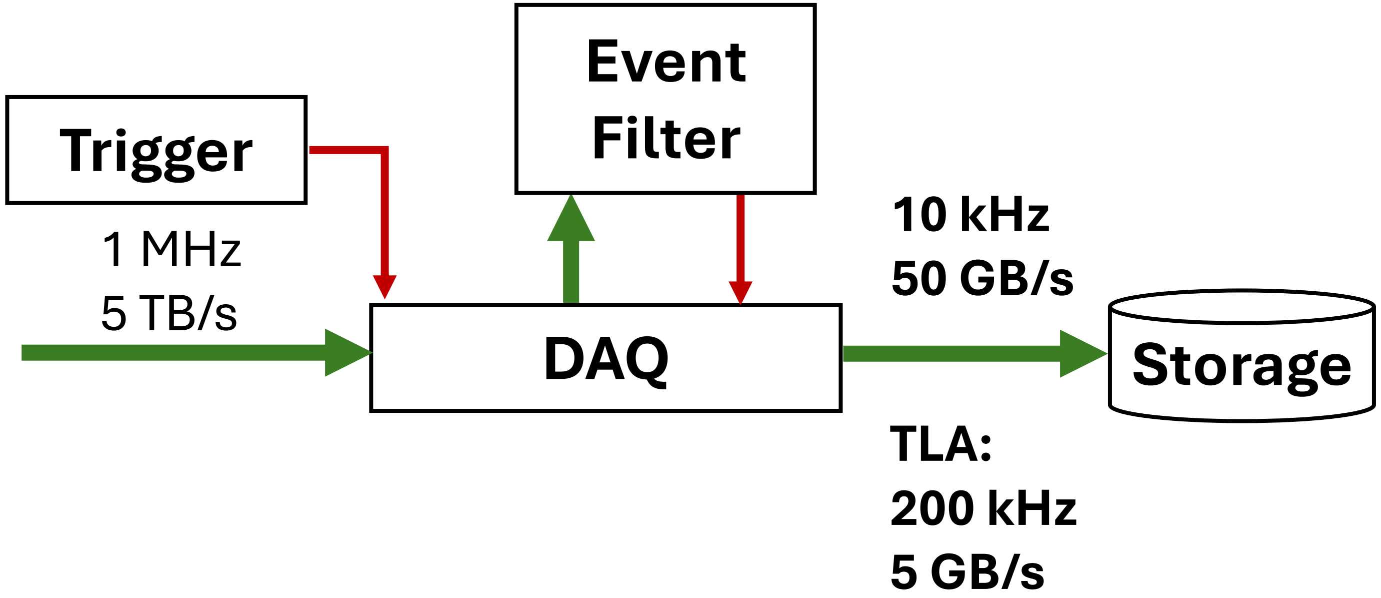
- We discard around **99% of trigger selected events**



Trigger Level Analysis, a new paradigm

What do we gain from this?

- We discard around **99% of trigger selected events**
- We can recover up to ~200 kHz using 10% more bandwidth



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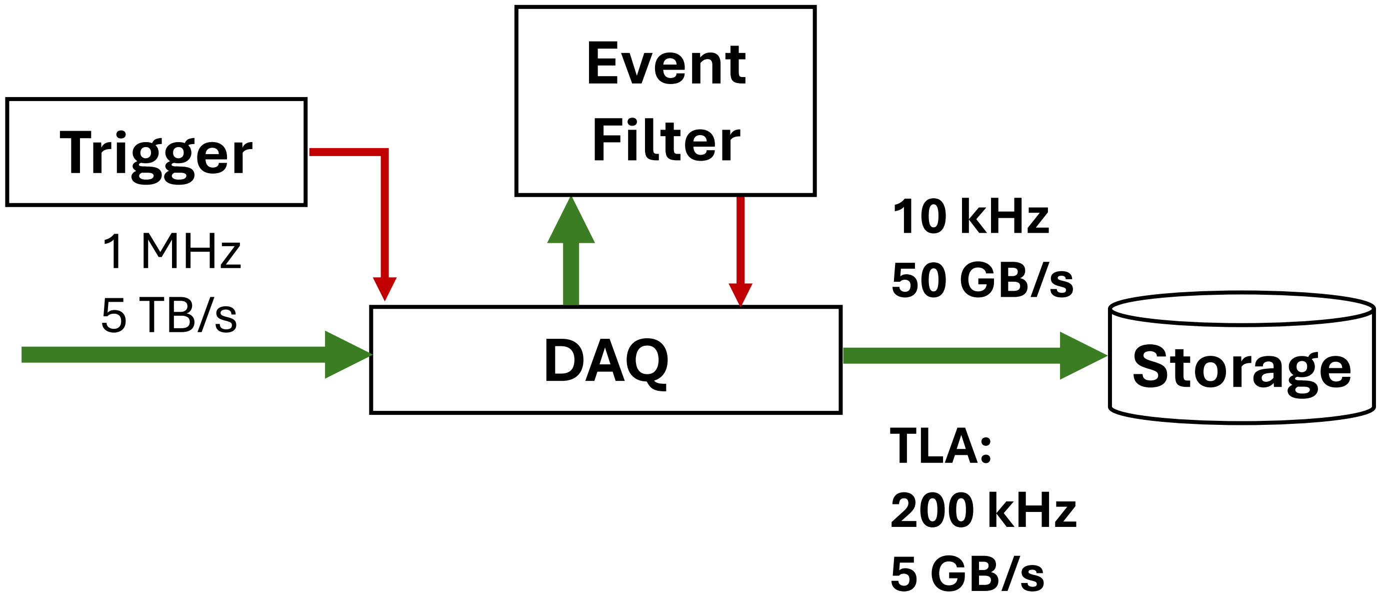

Low cost, high gain… **x20 Event rate, only 10% more data stored**

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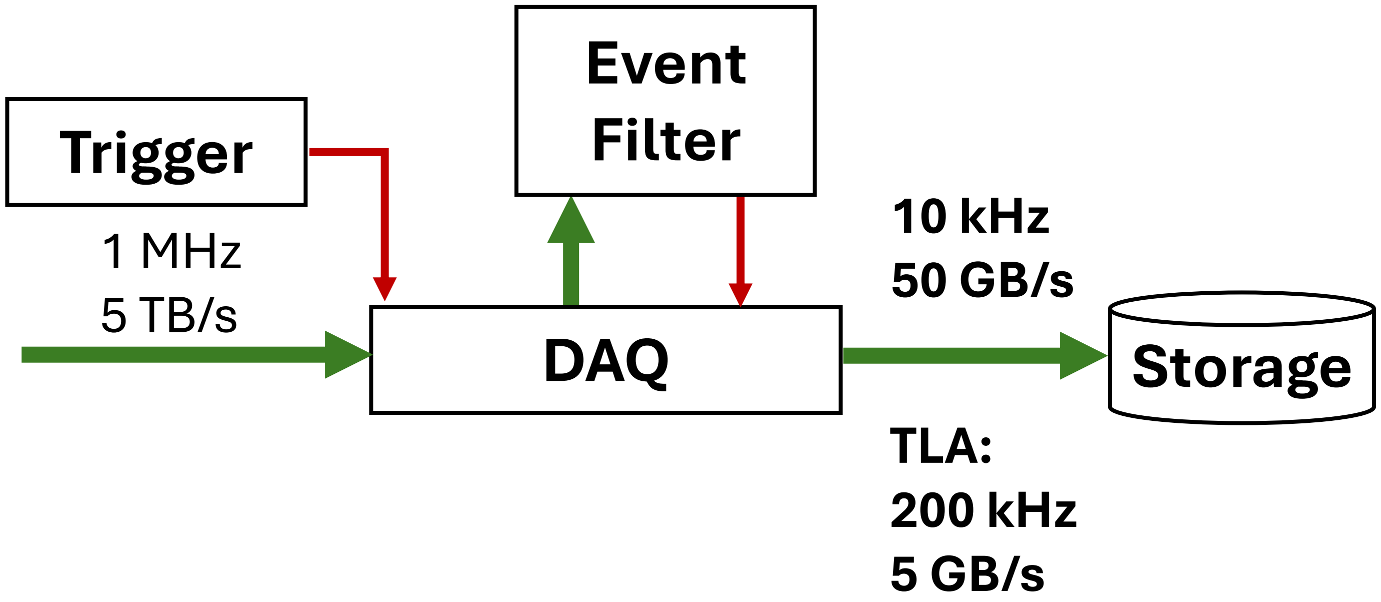
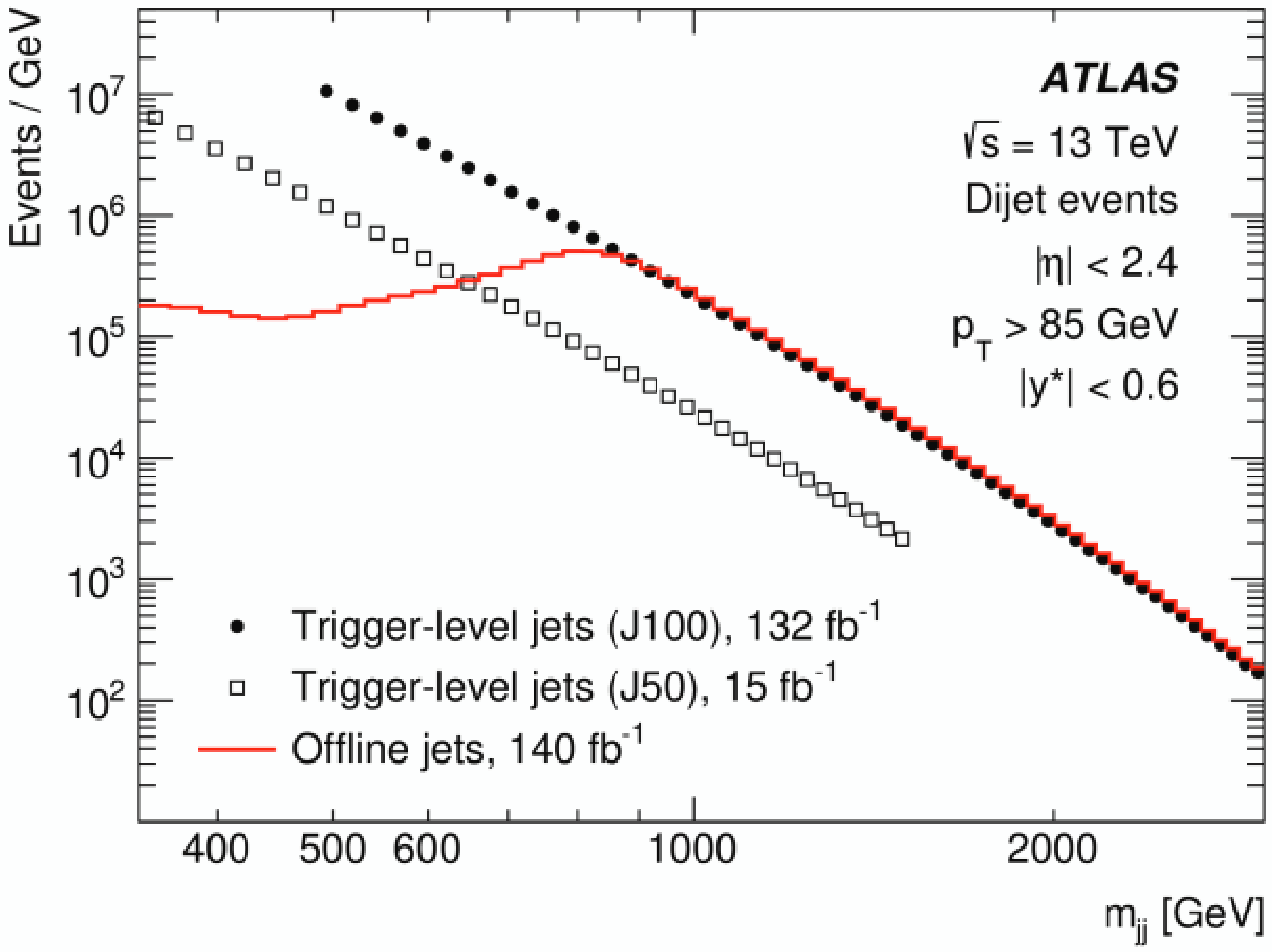


Low cost, high gain… **x20 Event rate, only 10% more data stored**

but

Information loss… if there is a mistake, **raw** is **unrecoverable**, event is **lost**

Trigger Level Analysis, a new paradigm



- **Not all signals were made the same!**
  - ✓Must have good quality online reconstruction

→ Lower thresholds

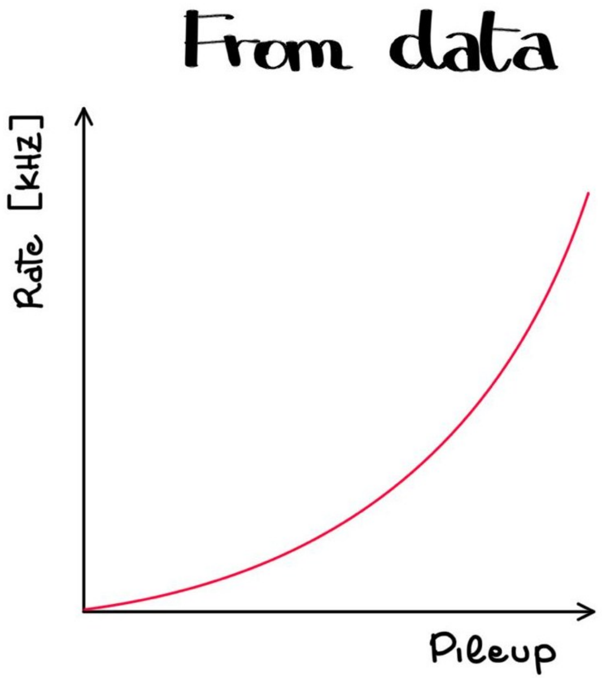
→ Higher acceptance

→ More statistics

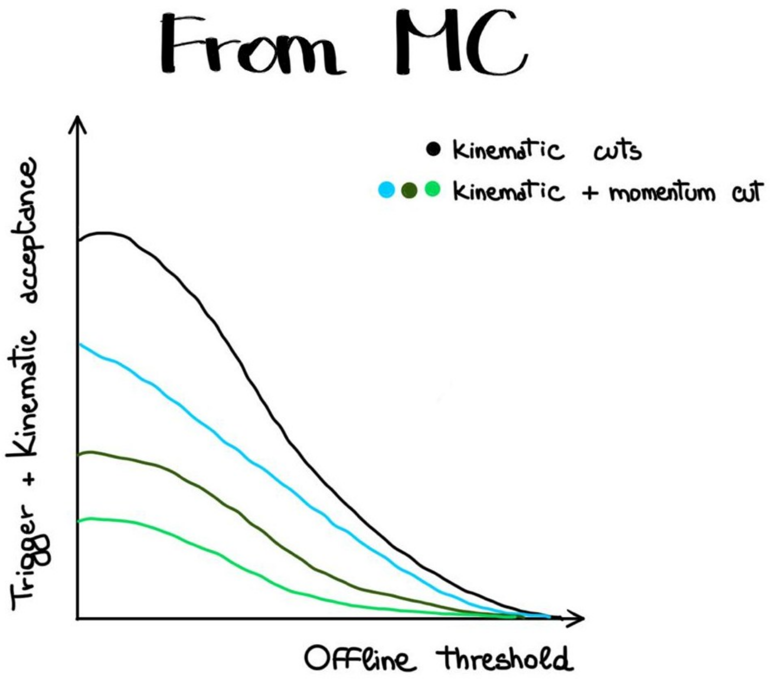
→ More discovery potential

PhD Project: Jets TLA

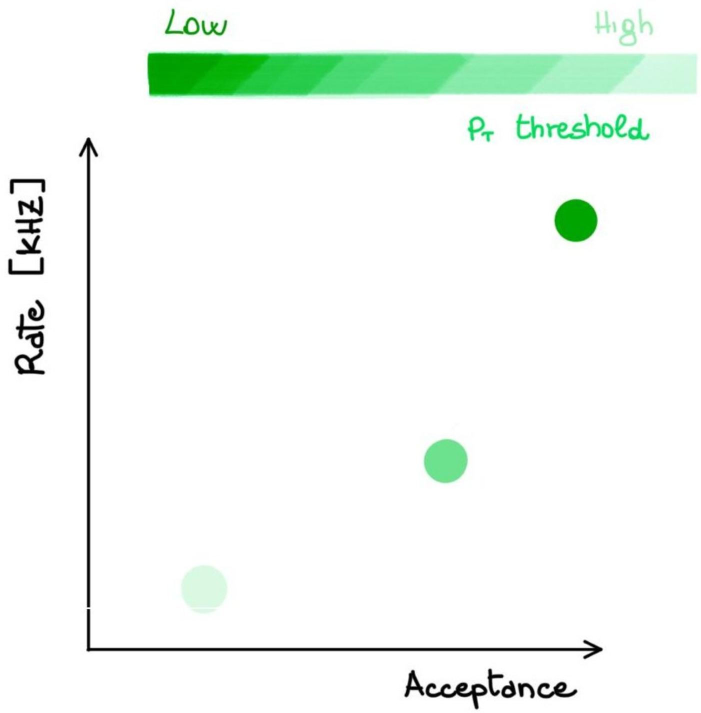
PhD focus are jets signatures:



Rate estimation for Run 4



Signal sample acceptance

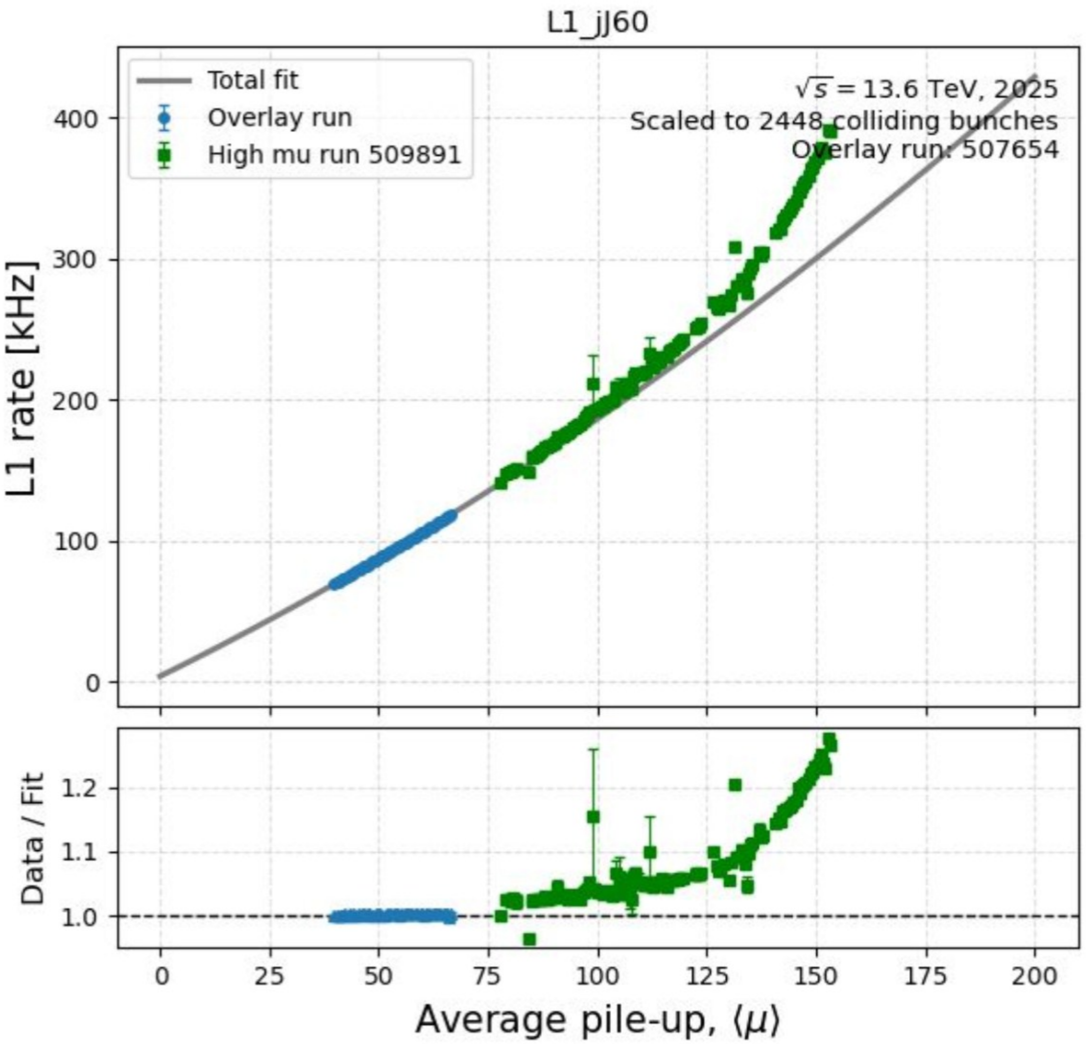


Rate vs acceptance for proposed trigger

PhD Project: Jets TLA, status

Model evaluation showed discrepancies:

- Proposed models underestimate rate scaling
- Run 4 condition are difficult on the current hardware
- Difference could be pileup driven noise around the forward region



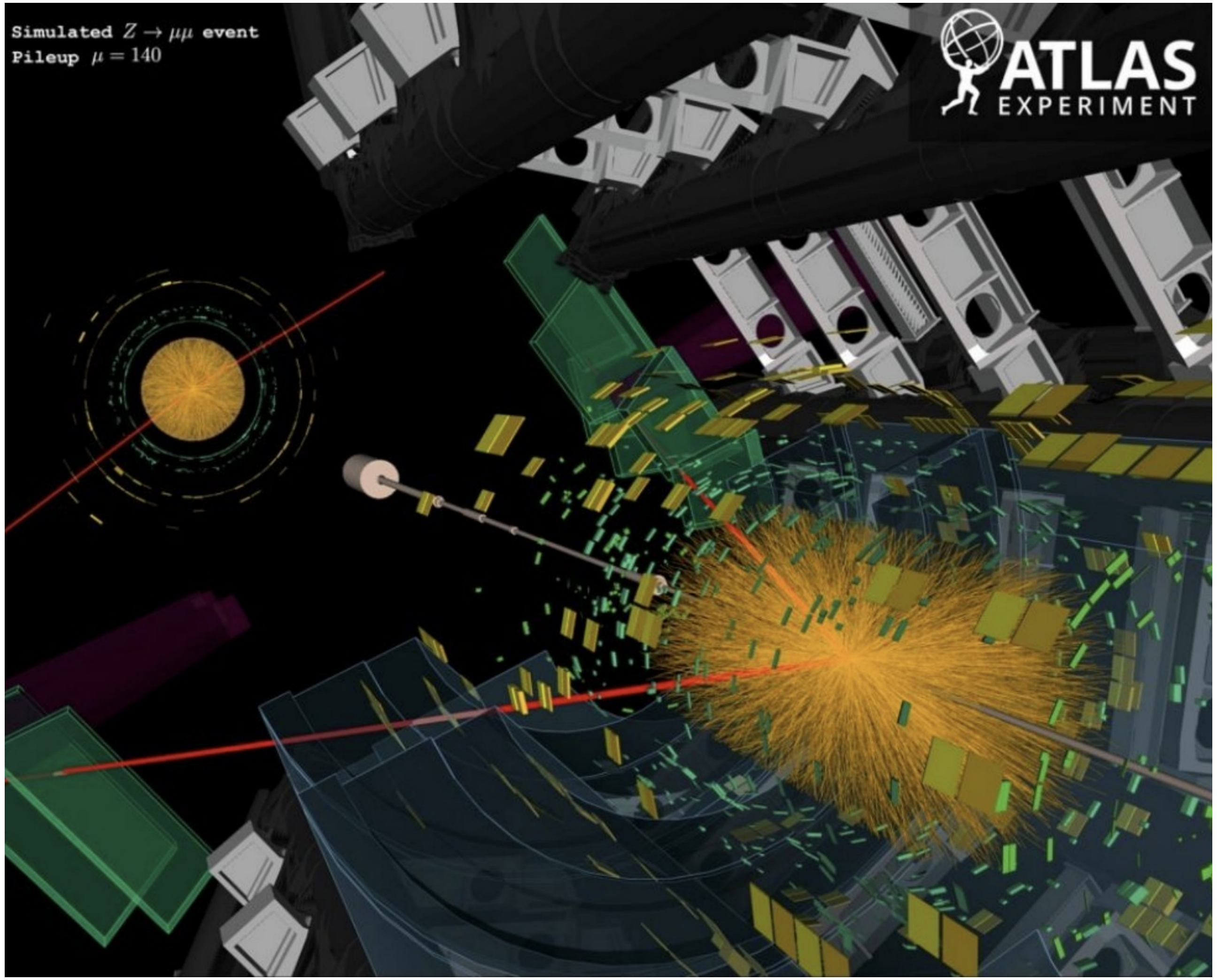
PhD Project: Jets TLA, status

Work in progress:

- Monte Carlo simulation to identify noise regions
- Better fit to confirm rate models

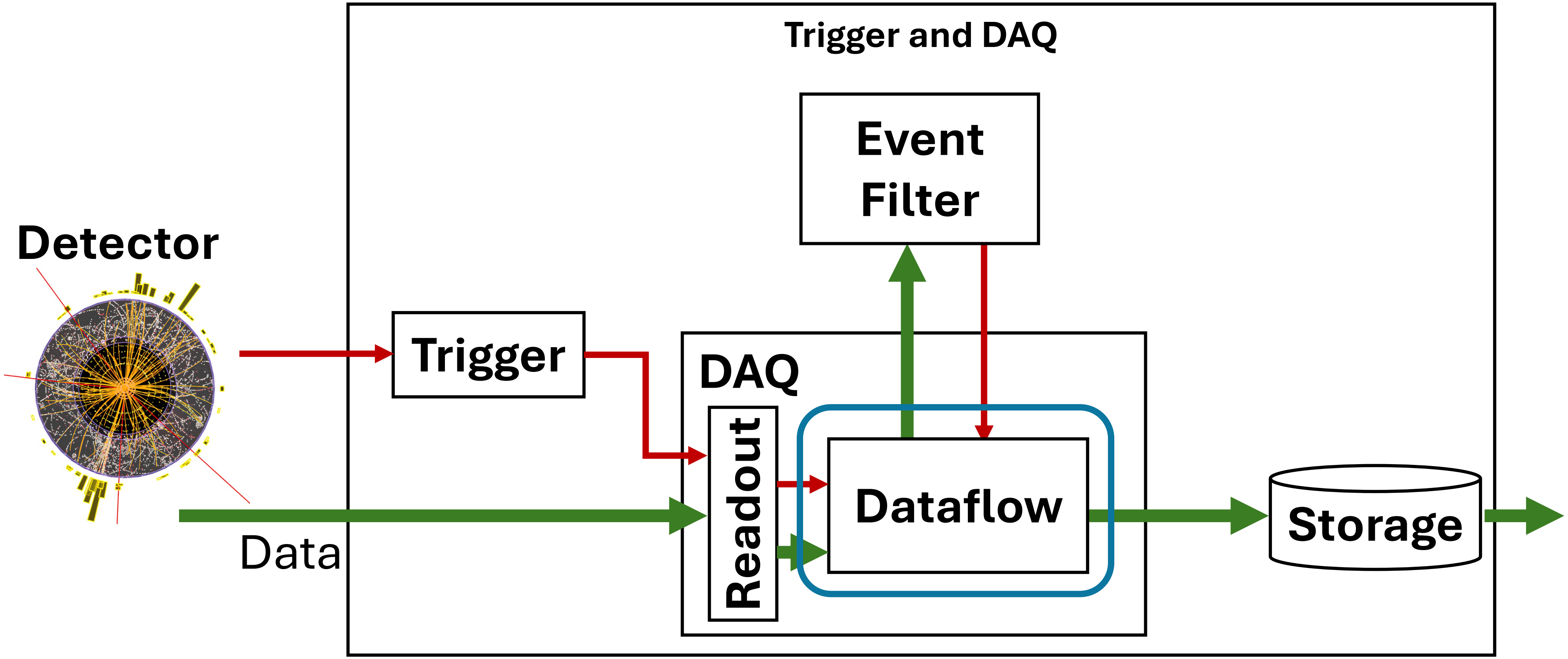
Thesis goals:

- Acceptance plot using new, updated models
- Full TLA cost-benefit evaluation for jets



The other side: Dataflow

At the center of DAQ is the **Dataflow** system.



- Reconstruction
- Analysis
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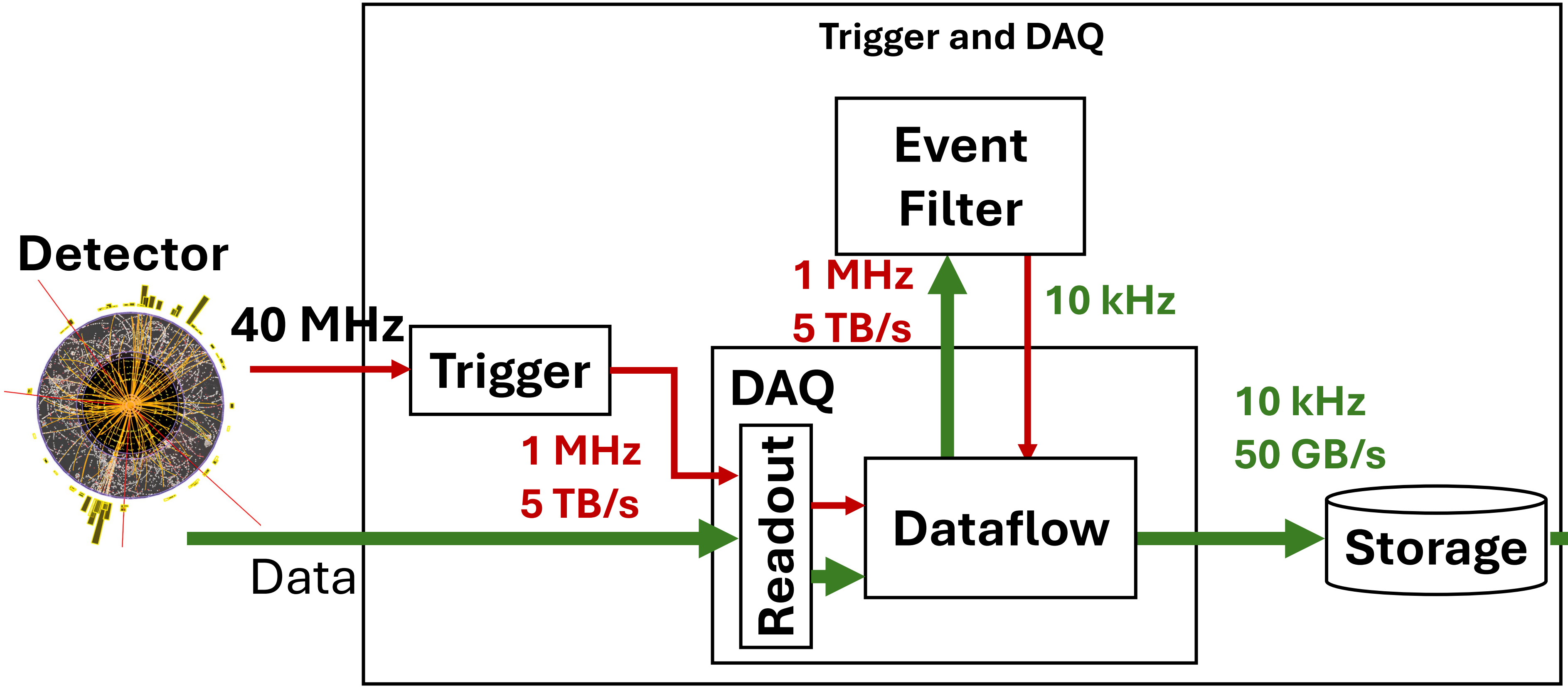
The other side: Dataflow

At the center of DAQ is the **Dataflow** system.

With the upgrade, this will have to sustain:



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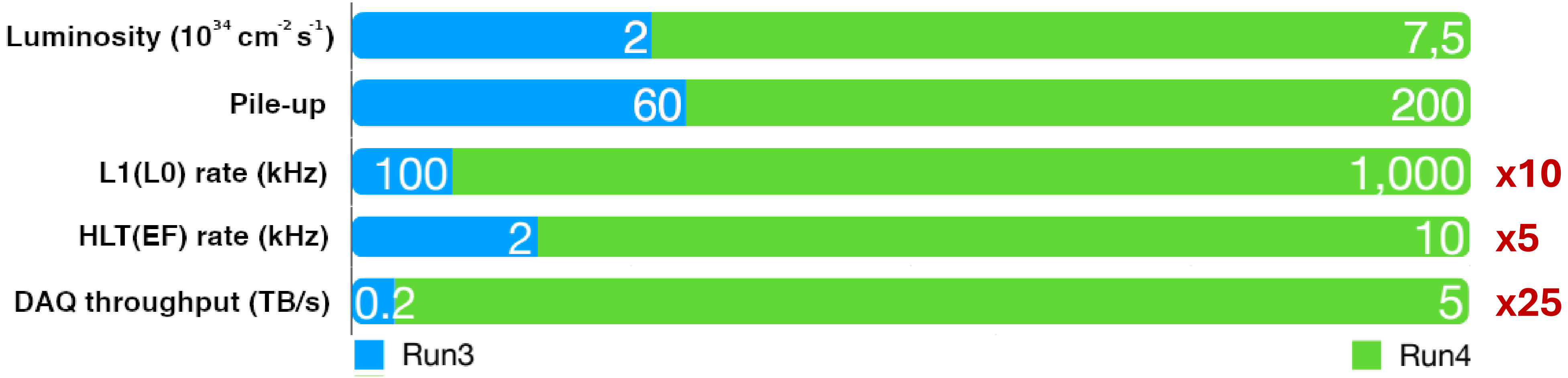
PhD project Dataflow evolution



Research focus is:

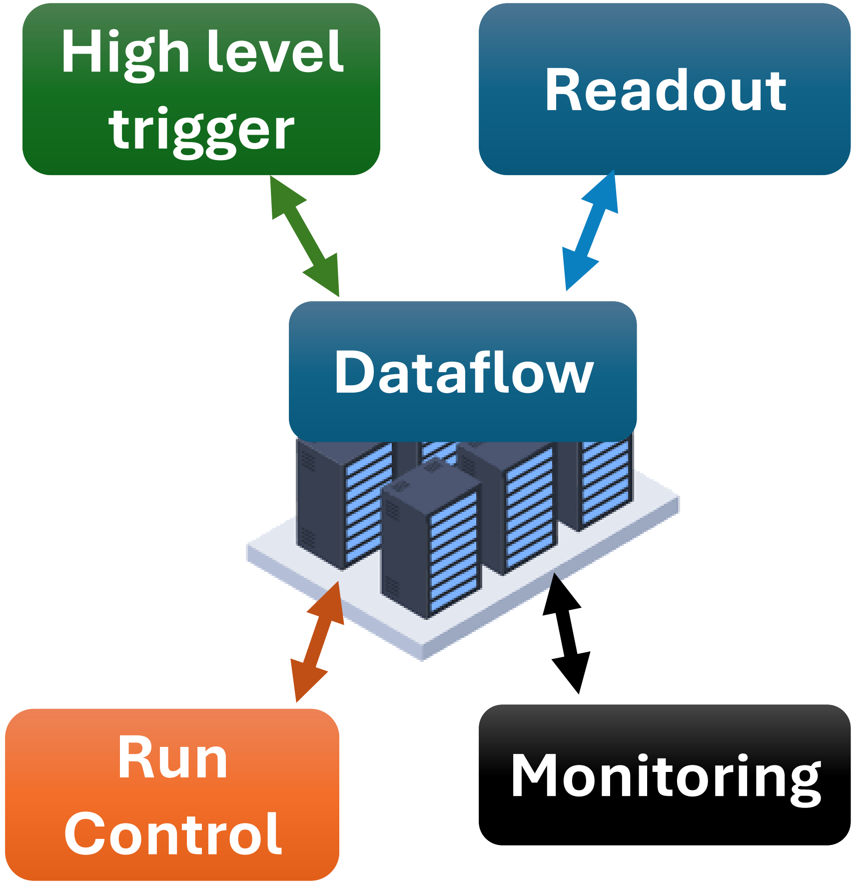
- Develop the new system to handle much **higher performance**
- **Optimize resource usage** as much as possible to **lower** upgrade **costs**
- Create a **flexible system** to accommodate new workflows (like **TLA**)

The other side: Dataflow

System integration is critical:

- Dataflow talks with almost **all DAQ systems**
- We need extensive test for **reliability** and **robustness** to ensure maximum **efficiency**

- Integration with **monitoring** tools to provide early **problems detection**



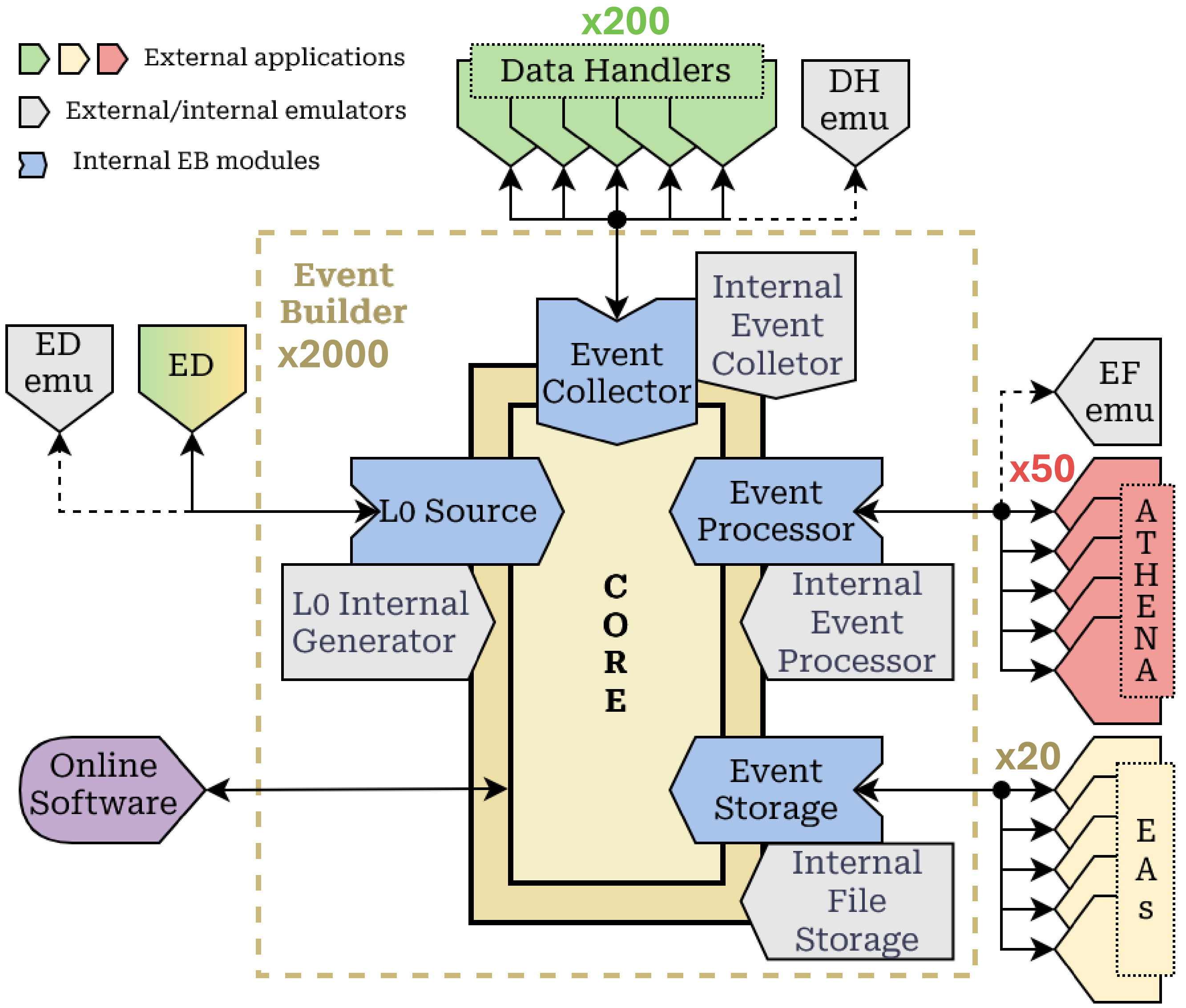
PhD Project: Jets TLA, status

Work in progress:

- Core software prototype is done
- Full system performance **tests and optimization** ongoing

Thesis goals:

- Complete **Technical Design Report** of the system
- **Working system**, integrated with the rest of DAQ

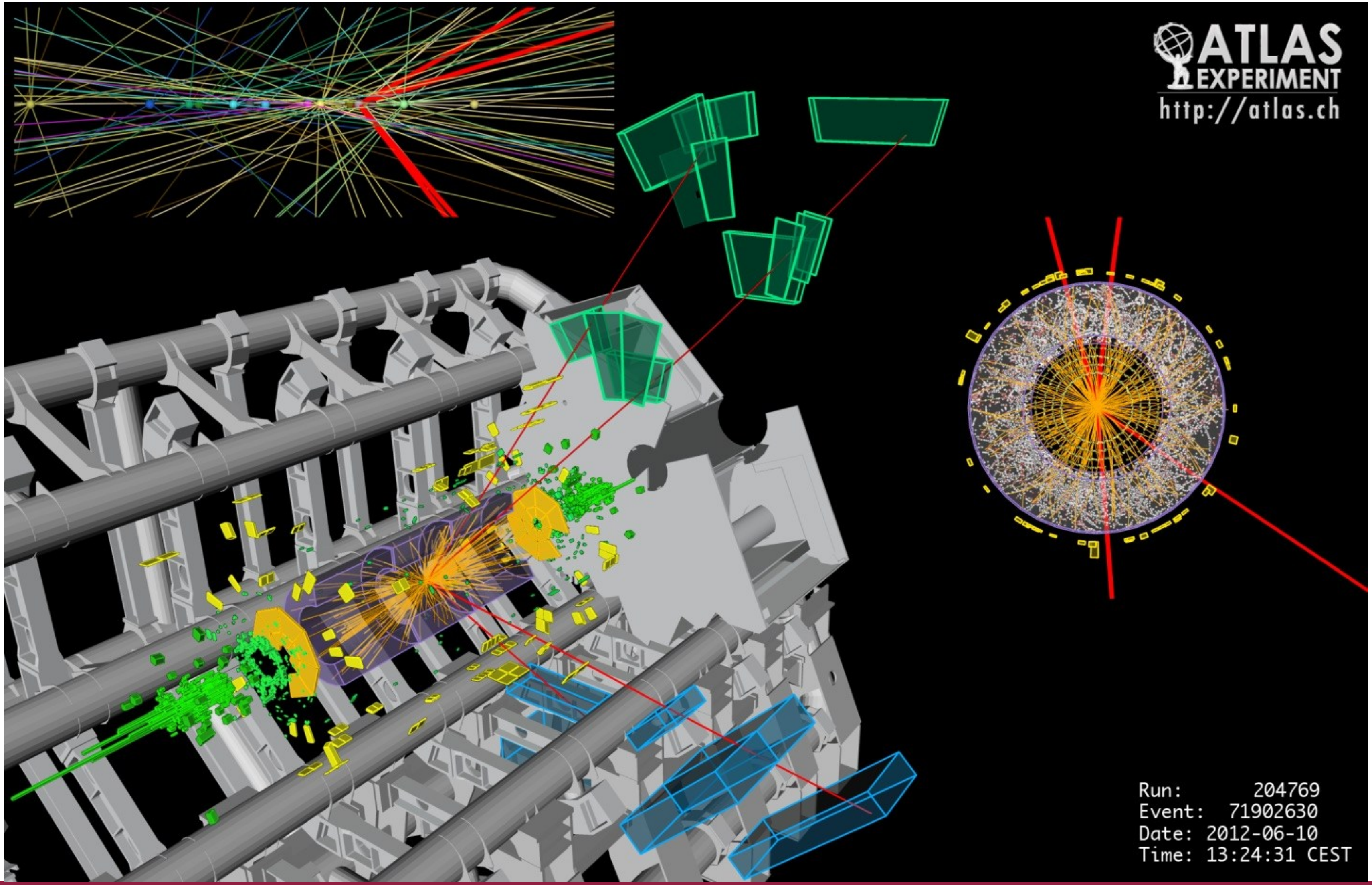


Conclusions

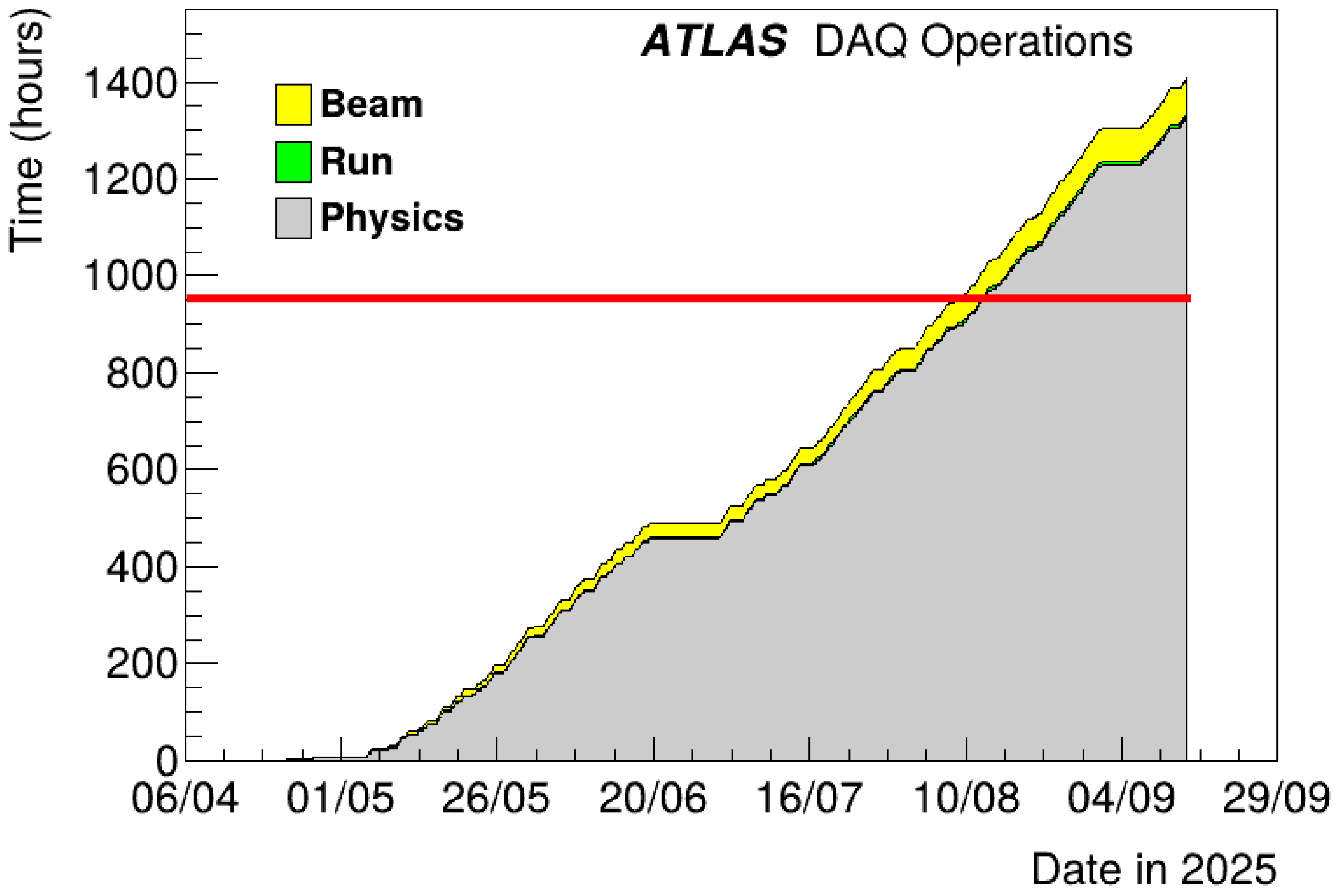
Research paths	Trigger Level Analysis	Dataflow Evolution
ATLAS Hi-Lumi upgrades: • New analysis techniques, TLA • TDAQ upgrade: Dataflow	More physics, less space! • Increasing discovery reach • Enhance data collection	Faster. Denser. Better. Cheaper. • Better DAQ performance • Peak efficiency and flexibility

Backup slides

The Higgs candidates



The ATLAS experiment TDAQ



DAQ must maximize **efficiency**.

In previous Runs:

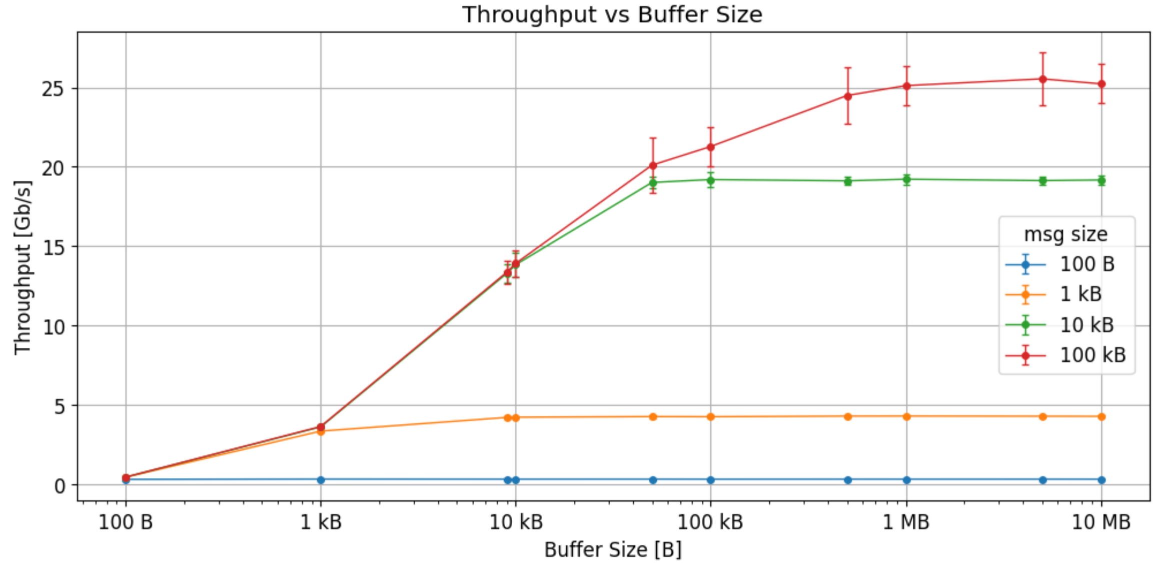
- Very small data loss from DAQ: **93%** all time avg efficiency
- Dataflow efficiency: **100%**

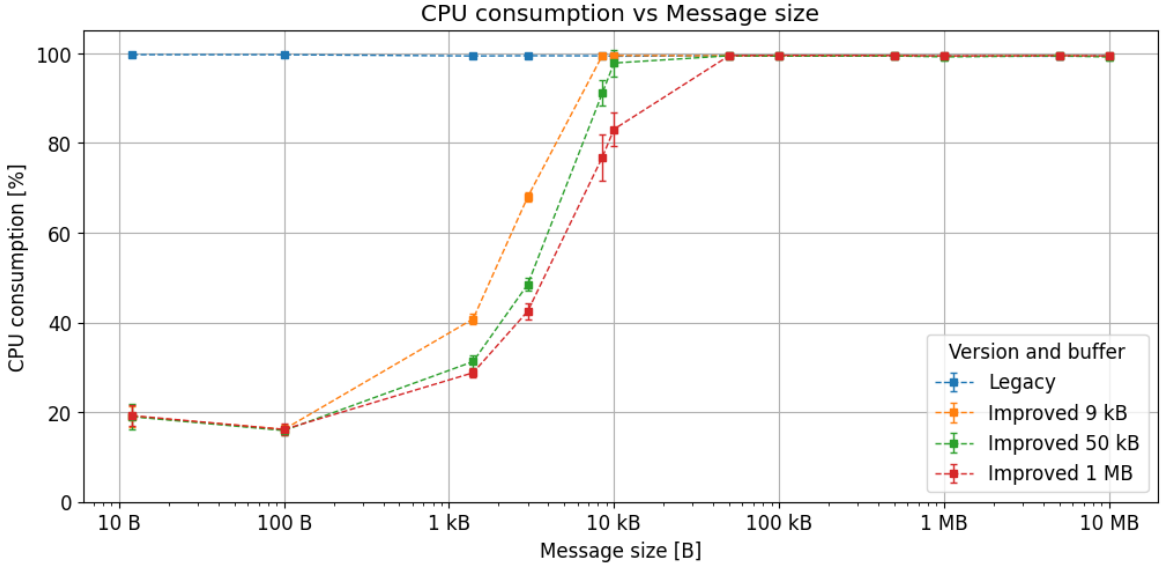
What happens if the Dataflow system fails?

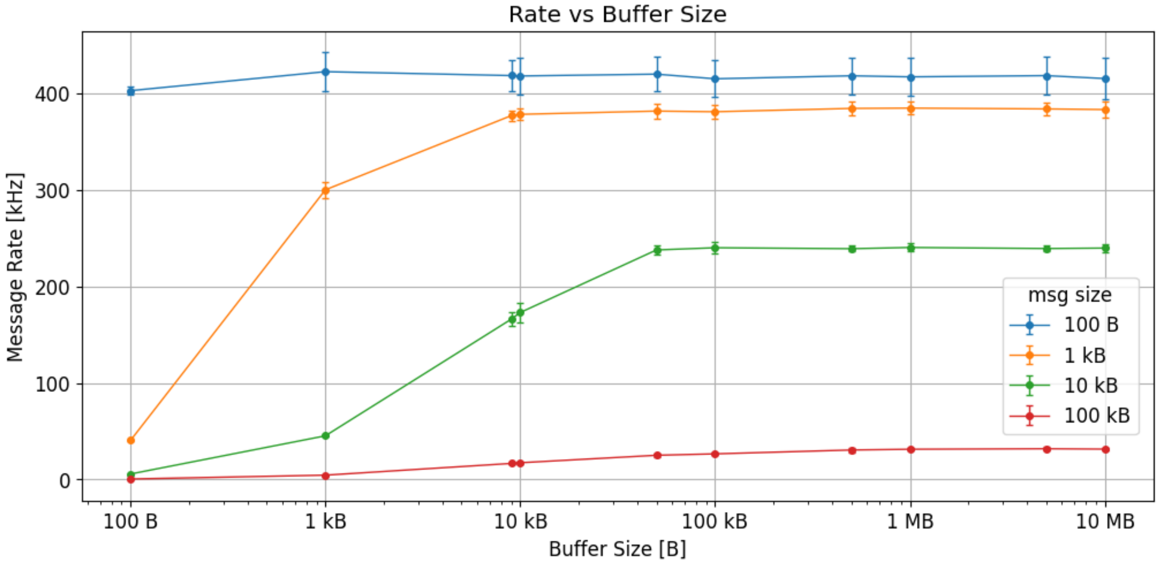
With 80% efficiency:

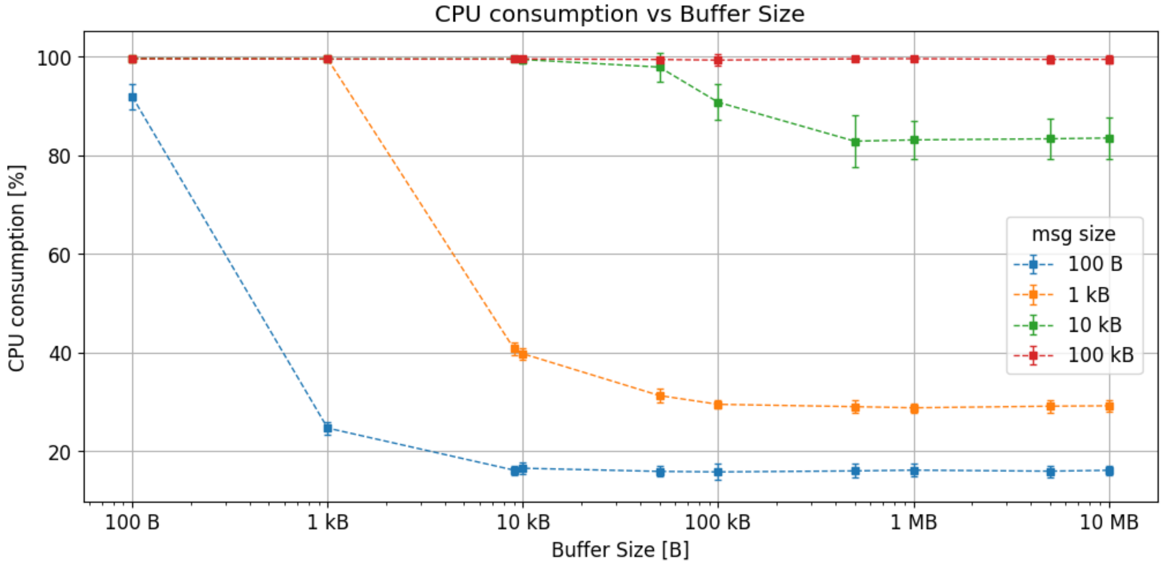
- DAQ efficiency would drop to 74,4%
- **Severe impact** on rare event detection and measurement

Buffer size evaluation





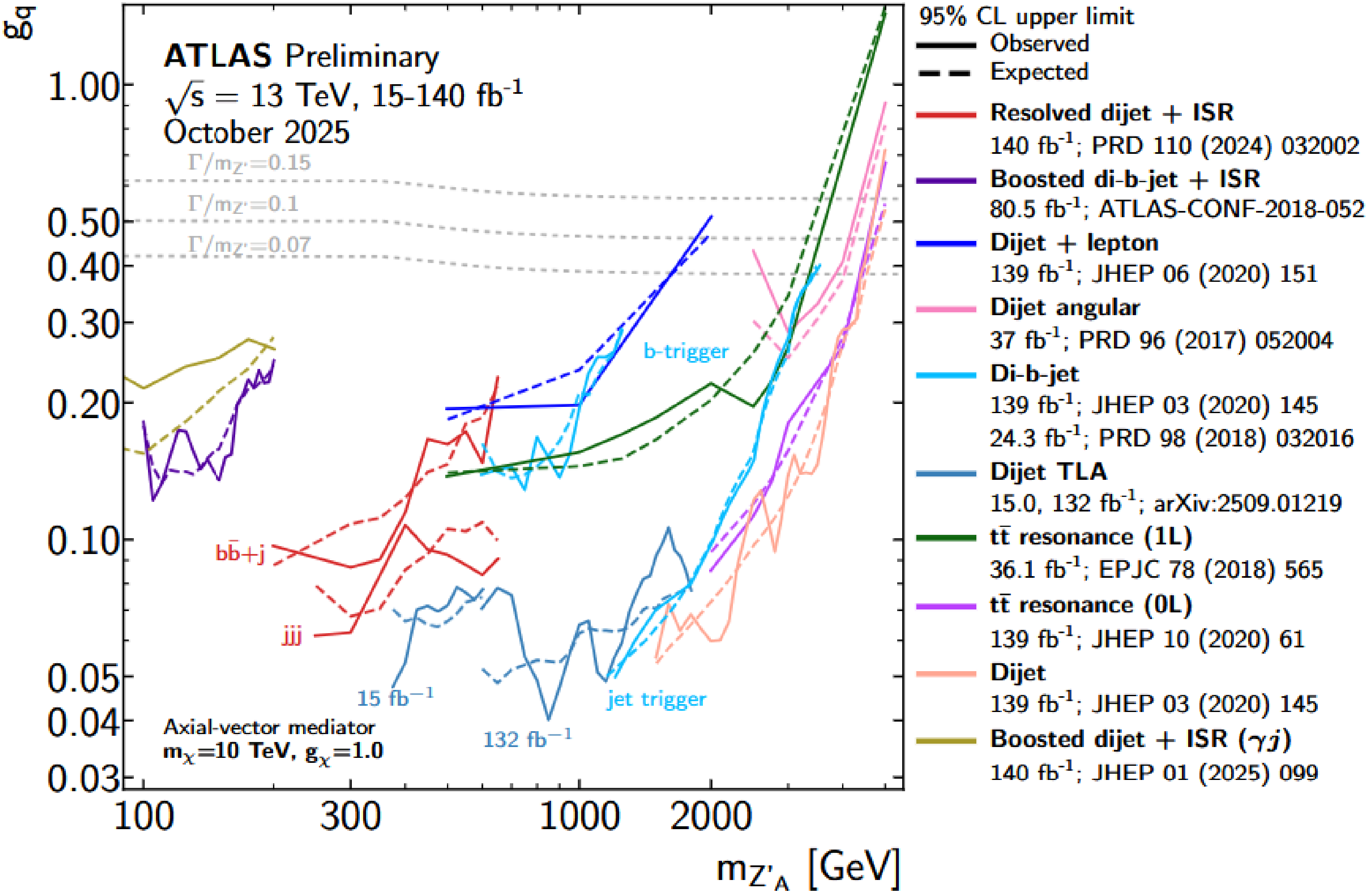




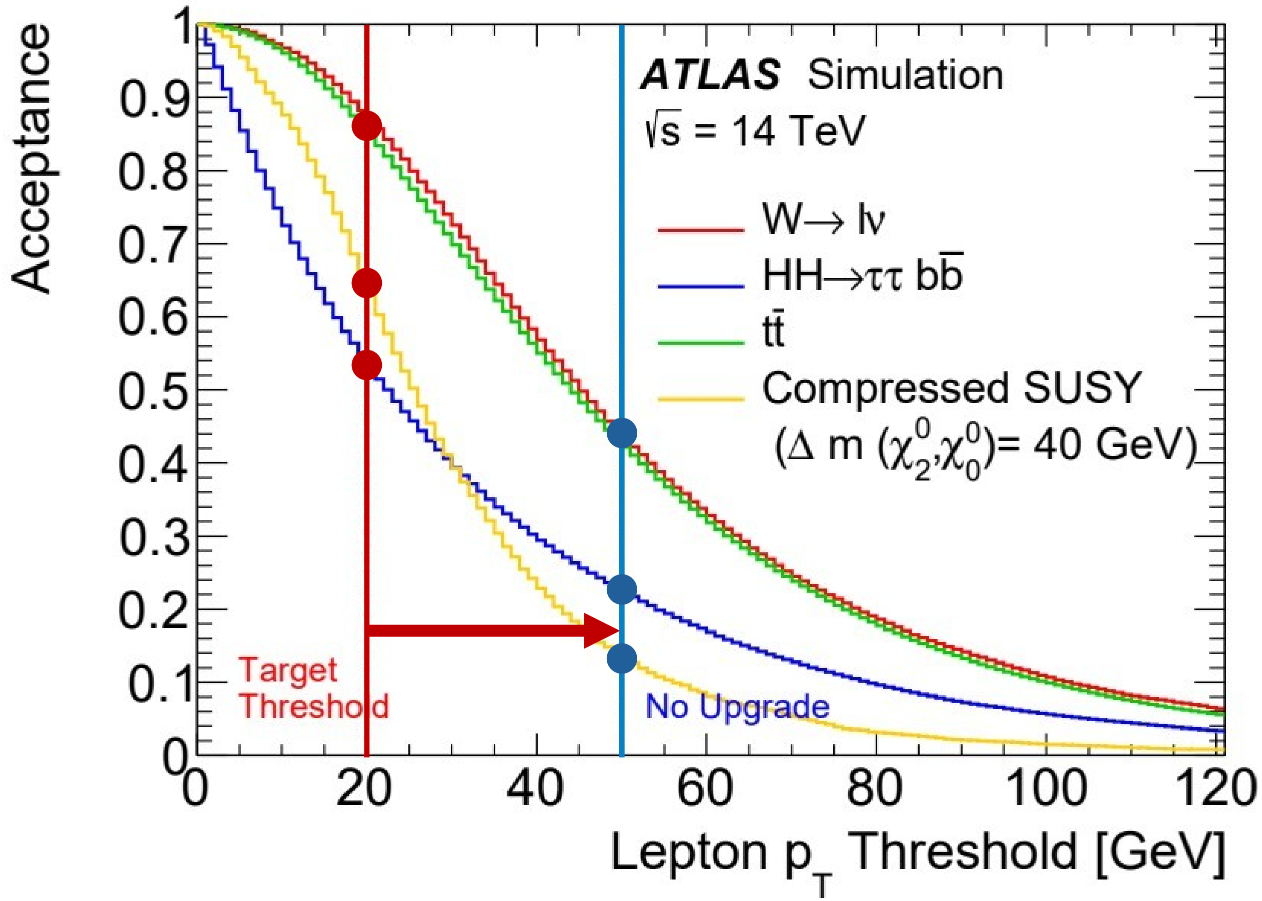
Where does TLA helps?

Dijet resonance in search for Z' mass (exclusion plot)

- Normal trigger only reaches up to ~1 TeV dijet mass
- Lower masses are prescaled (too many events)



The High Luminosity Upgrade



To solve the issue, one can raise the **thresholds, but**

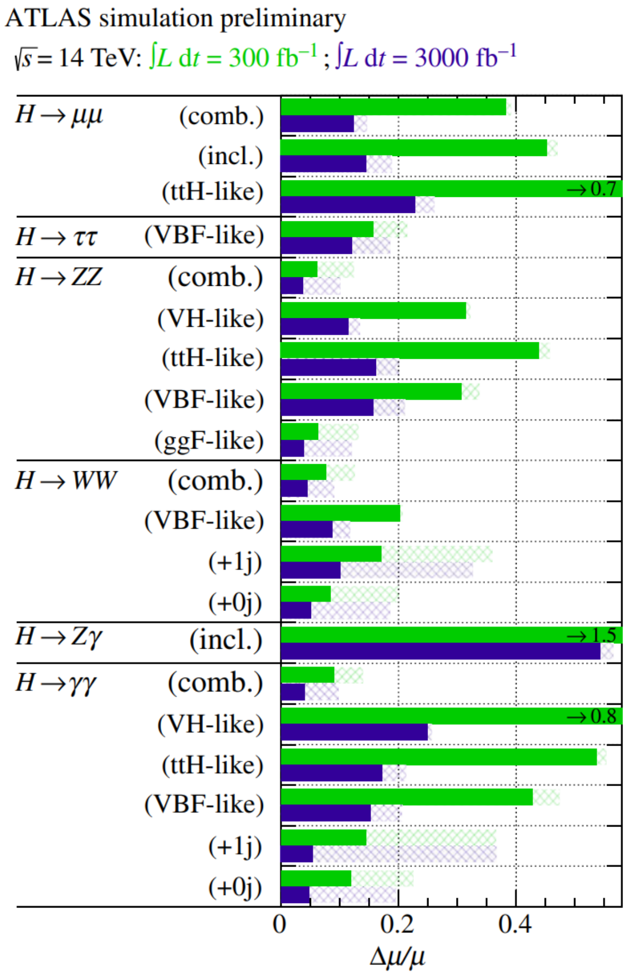
- severely reduce acceptance

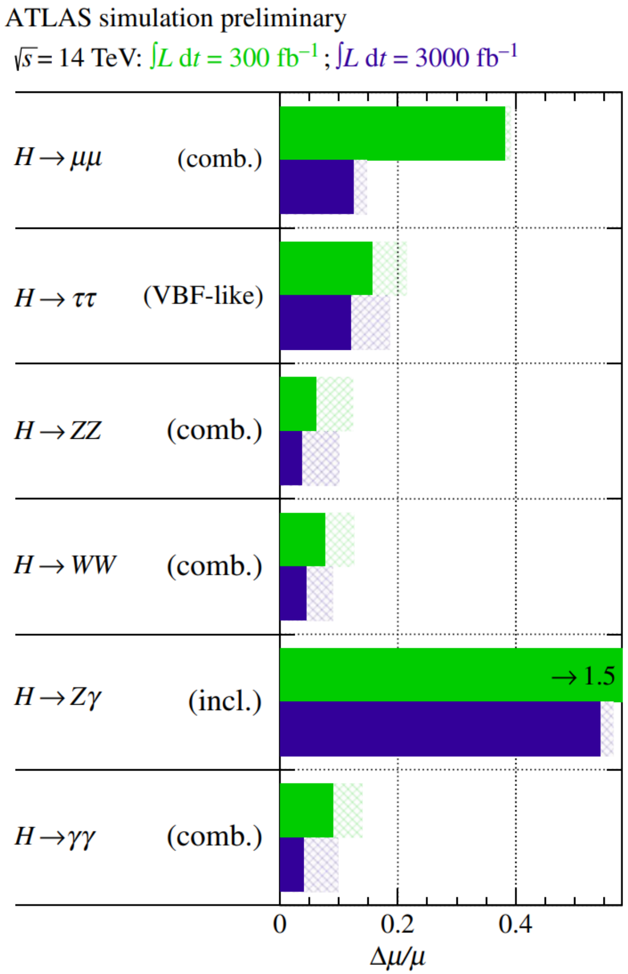
With the current detector this means

- Raising single μ, e^- thresholds from 20 GeV to 50 GeV
- Efficiency dropping by almost 50%

Trigger rate must be increased

The High Luminosity Upgrade





The **High Luminosity Upgrade** aim is:

- Switch from discovery to **precision measurements**
- **Extend** the accelerator **lifetime** collecting as much data as possible
- Significantly **improve precision** for the Higgs sector
- Observe **very rare** new phenomena