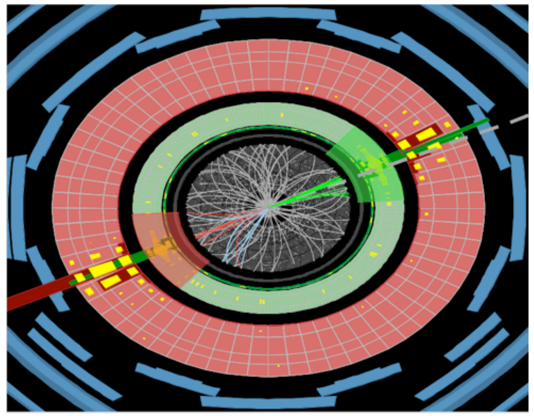
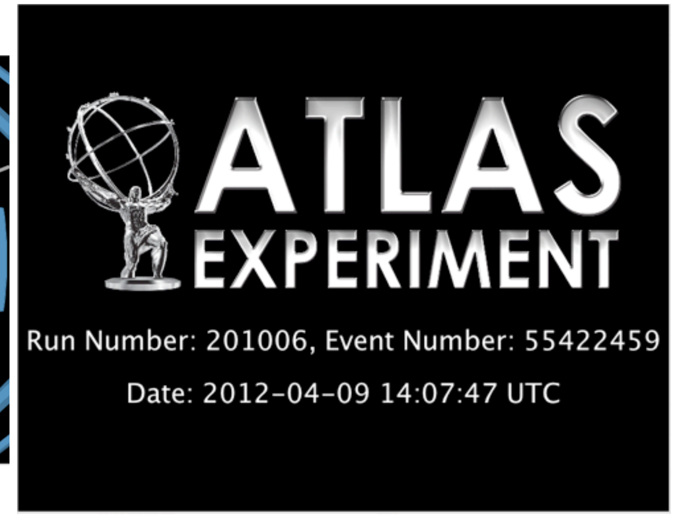
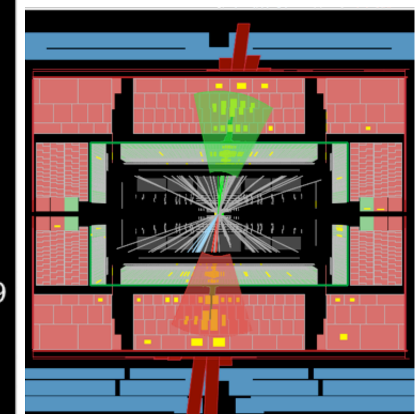






Jets, **Jet Substructure** and **ATLAS di-Boson analysis**

Attilio Picazio
University of Geneva

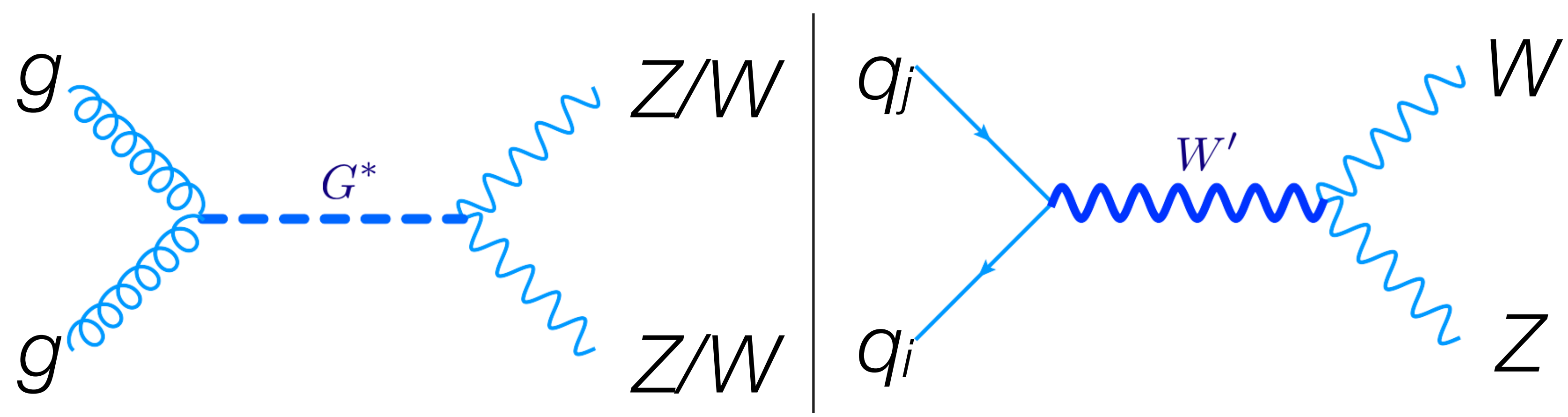
with many contributions from A. Davidson, E. Kajomovitz and G. Salam

UNIVERSITÉ DE GENÈVE
CERN
ATLAS EXPERIMENT http://atlas.ch

The Search - **di-Boson Analysis**

Searching for **heavy resonances** decaying in **WZ**,**ZZ** and **WW**

The results are interpreted in terms of bulk **Randall-Sundrum** graviton decaying in **WW/ZZ** and sequential Standard Model (**SSM**) W' boson decaying in **WZ**



s-channel production of **G* and W' at the LHC**

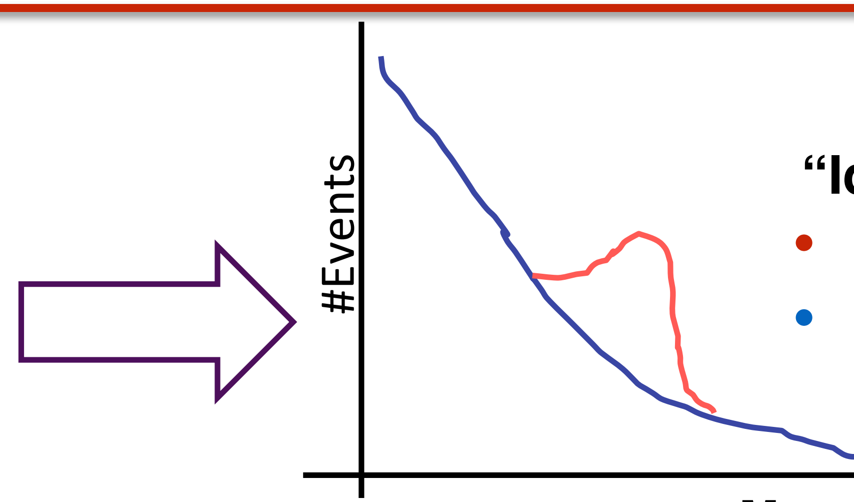
	W	Z
$l\nu$, ll	22%	7%
$\tau\nu$, $\tau\tau$	11%	3%
$\nu\nu$	-	20%
qq	67%	70%
Boson decay fractions		

➡ BR(W→qq)=3xBR(W→ln), No MET
➡ BR(Z→qq)=10xBR(Z→ll)

Exploring the edge of LHC energy - from 1 to 3 TeV

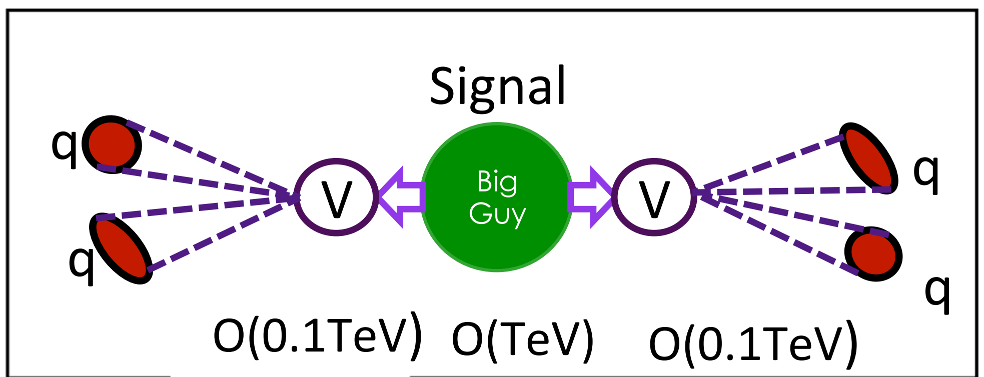
Strategy:

Bump-Hunting di-boson invariant mass spectrum



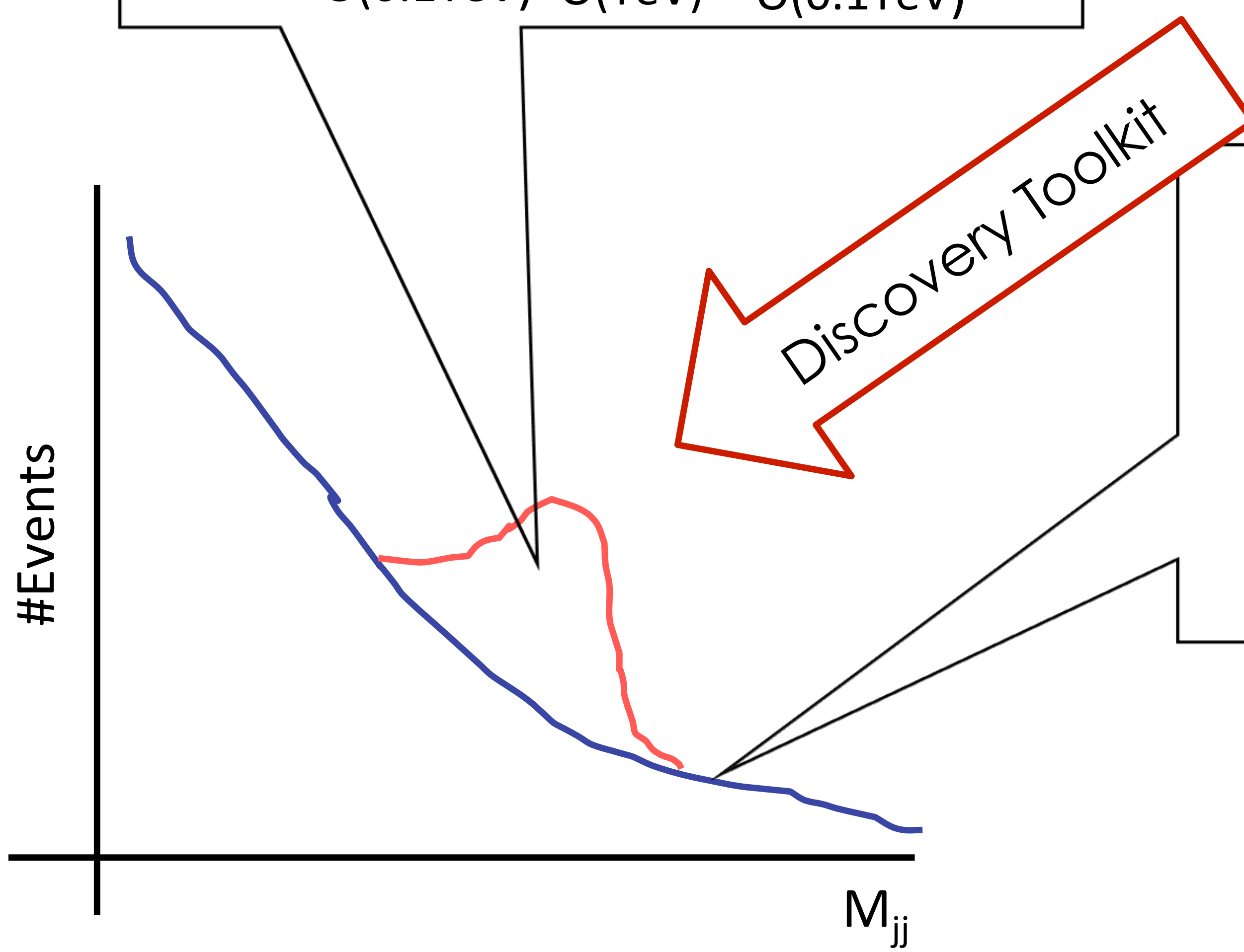
"Ideal" Invariant Mass spectrum
- Signal
- Backgroung

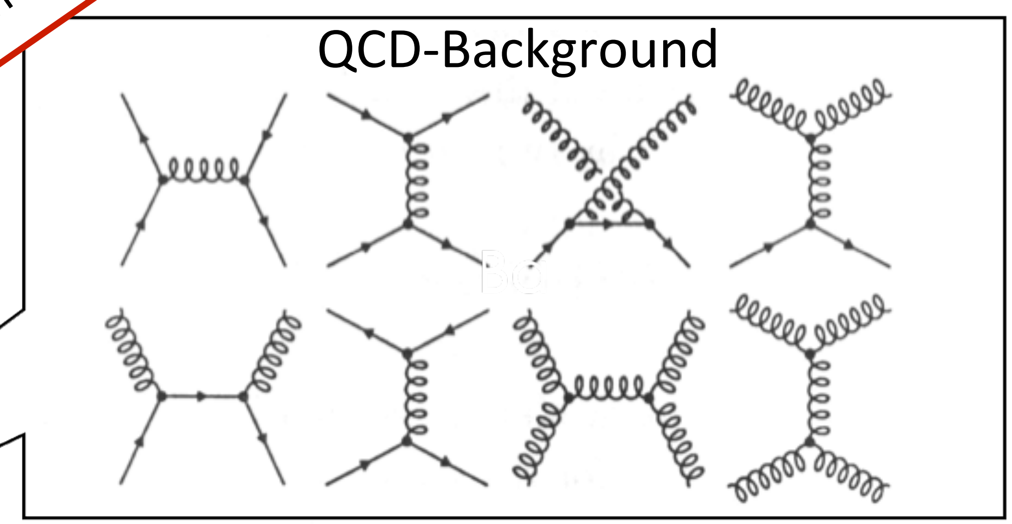
The **challenge** - **“A needle in a haystack”**



dσ/pT x BR (Orders of magnitude)*

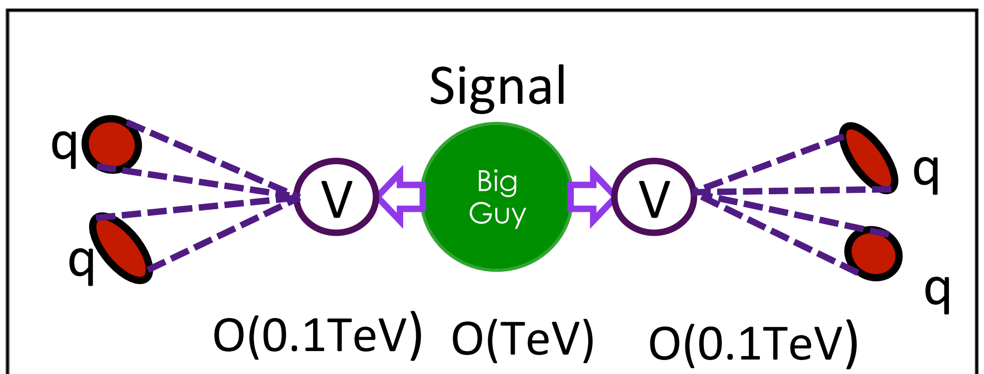
Leading Jet [GeV]	QCD [fb/GeV]	W’* [fb/GeV]
0.5 TeV (1.2 TeV W’)	10^3	10^{-1}
1.0 TeV (2 TeV W’)	10	10^{-3}





from E. Kajomovitz talk

The **challenge** - **“A needle in a haystack”**



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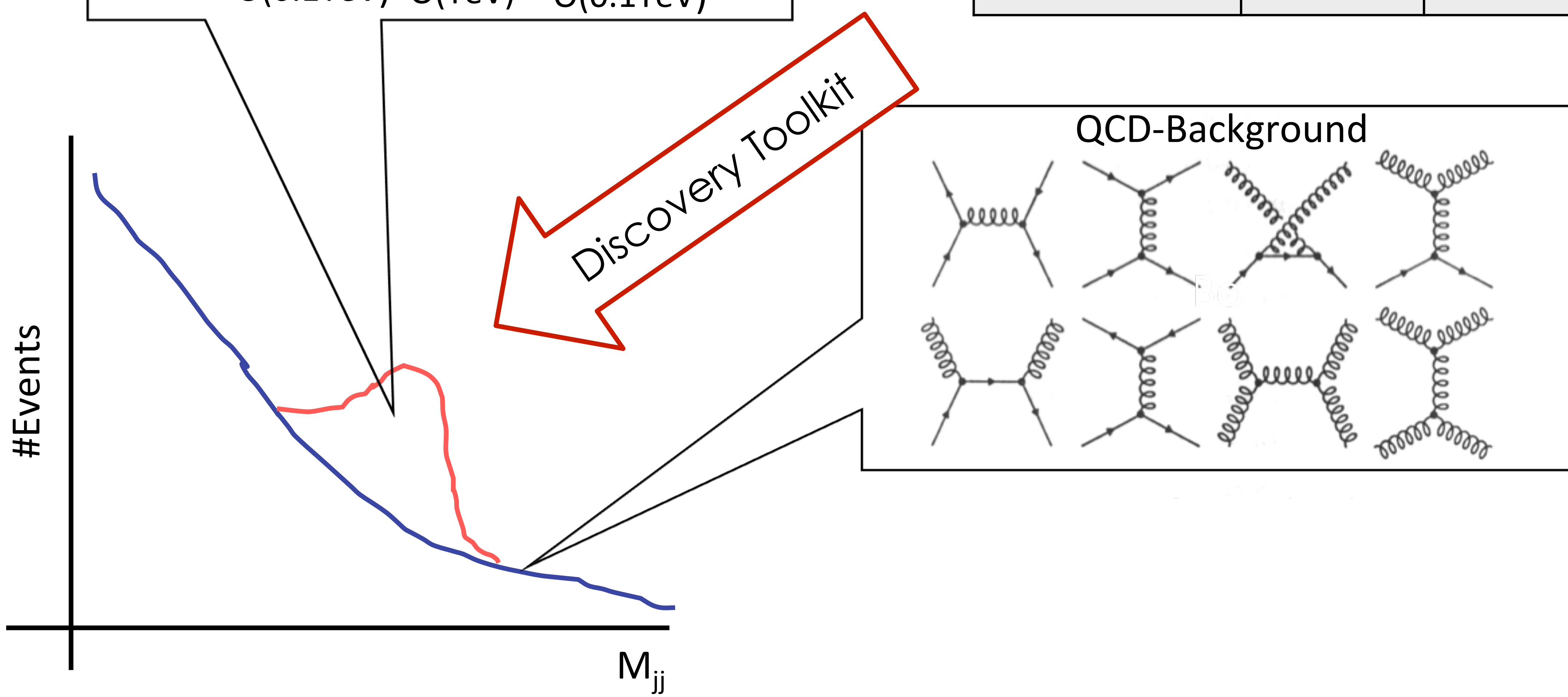
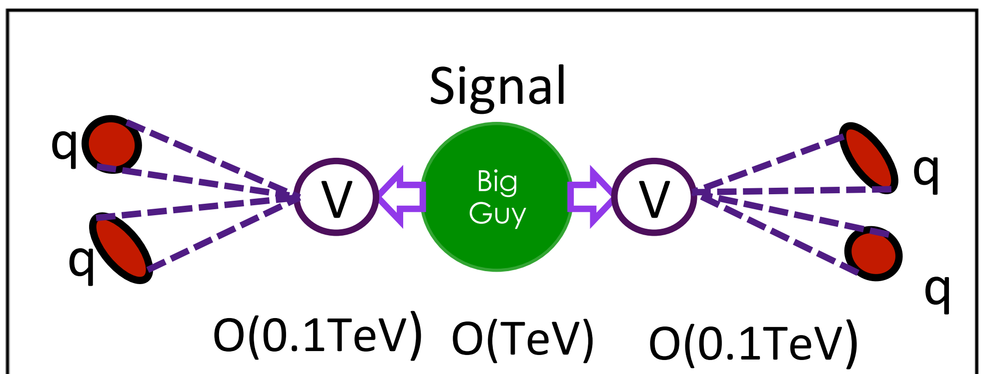


from E. Kajomovitz talk

The **challenge** - **"A needle in a haystack"**



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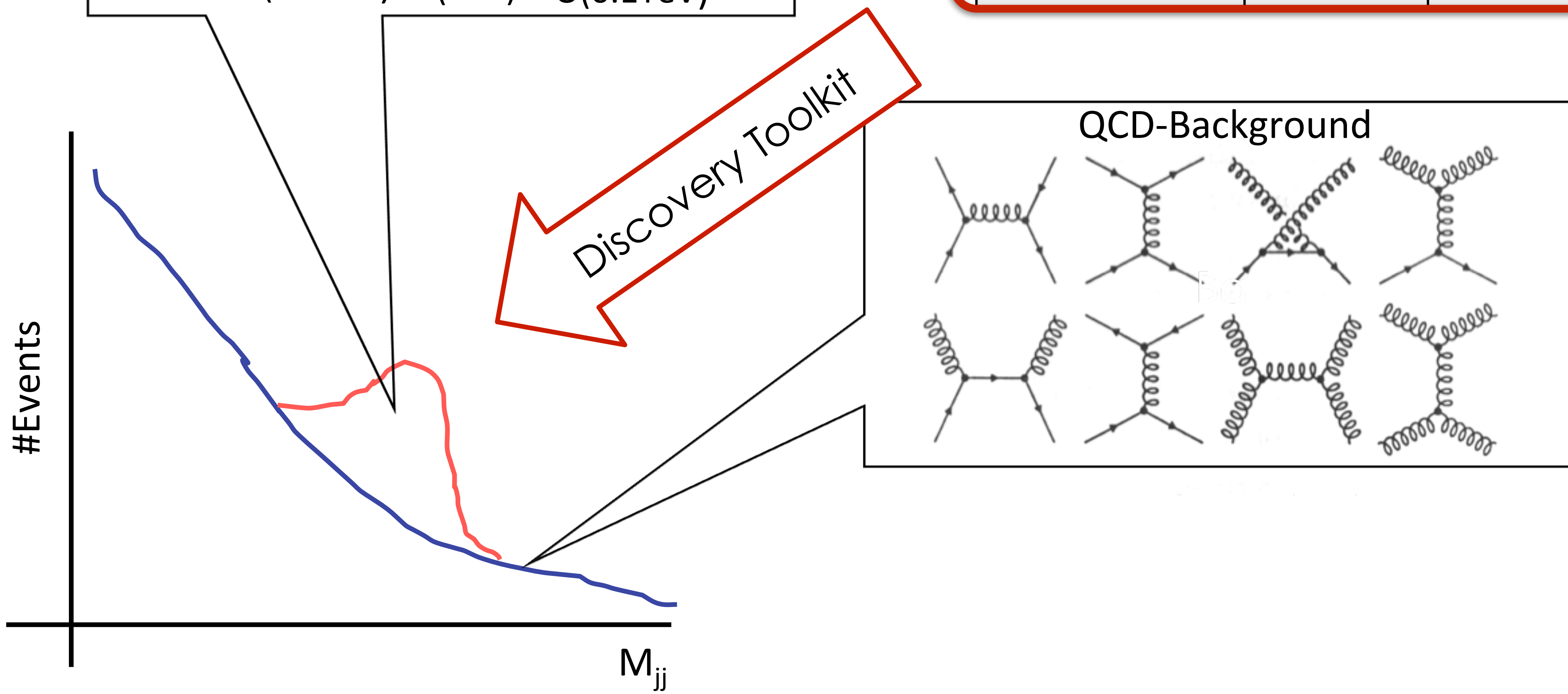
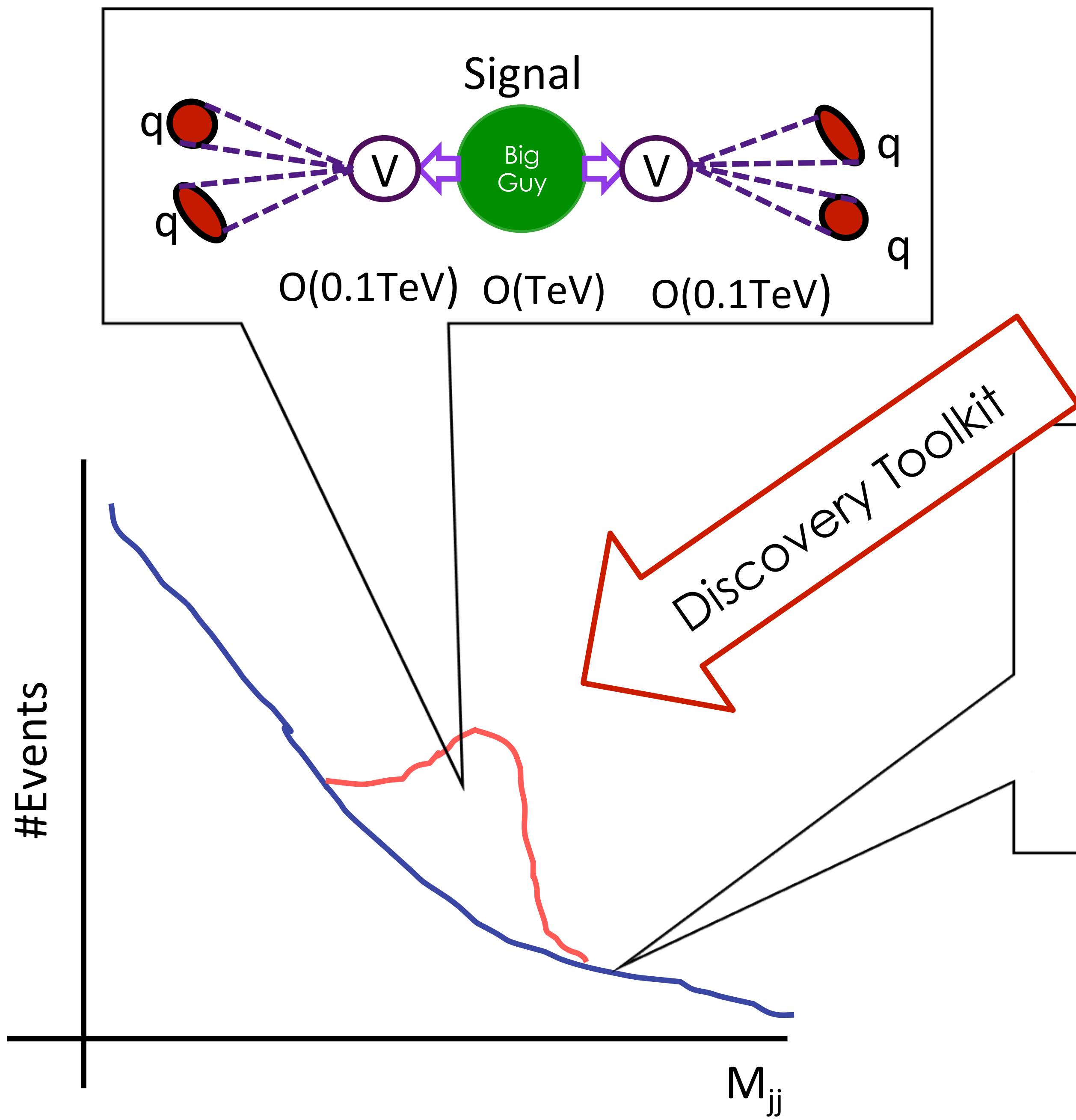


from E. Kajomovitz talk

The **challenge** - **“A needle in a haystack”**



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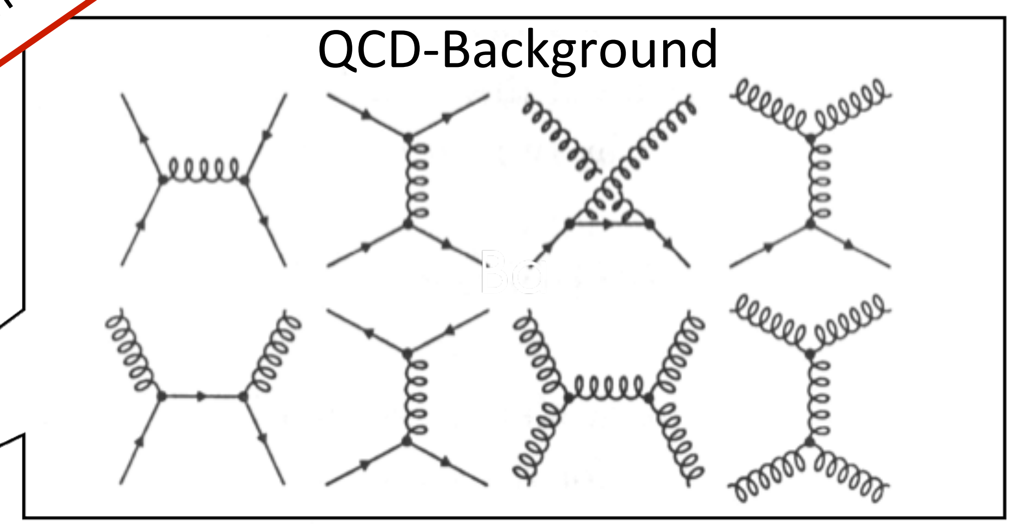
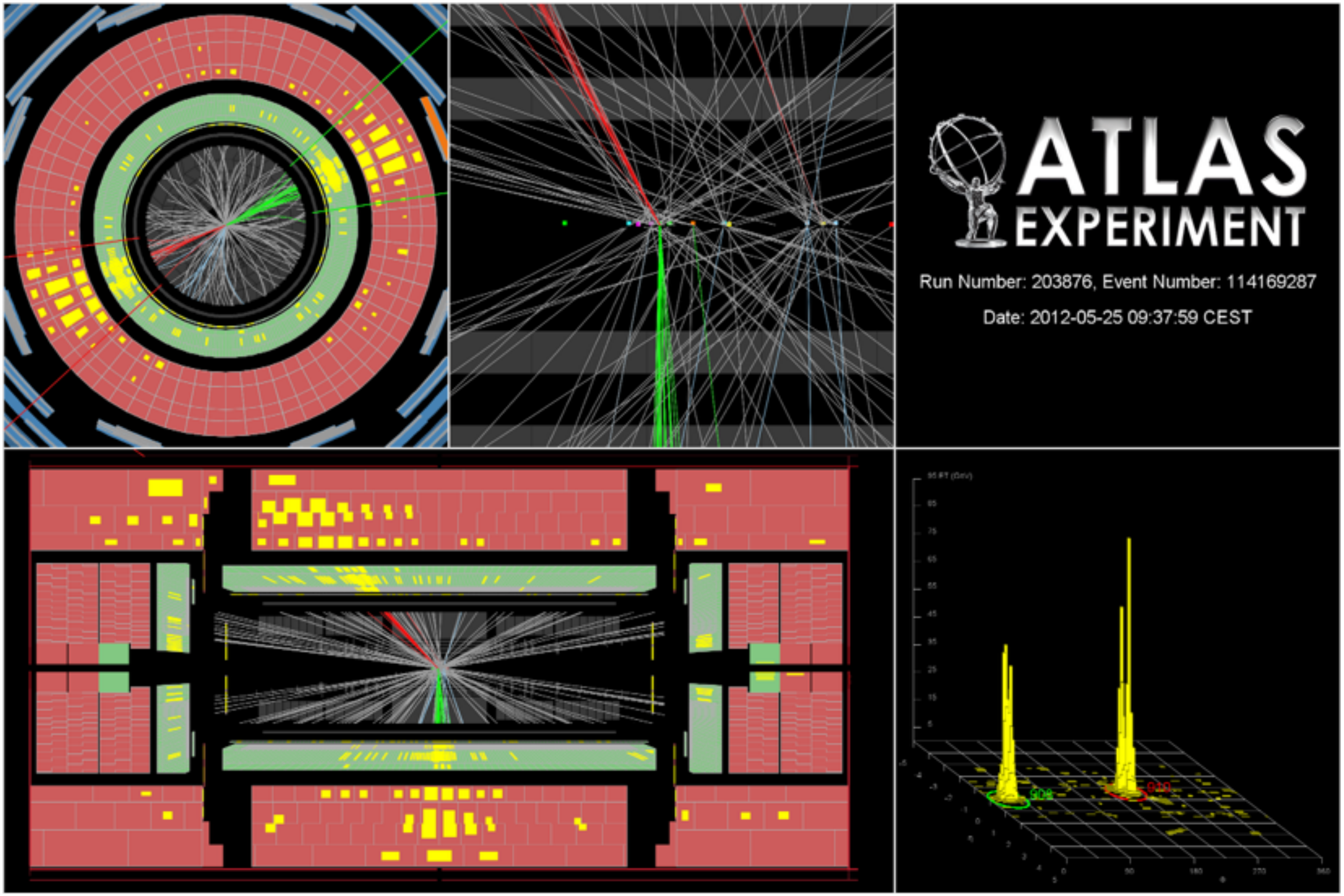


…but we are physicists!

from E. Kajomovitz talk

Let's start - **A di-jet event display**



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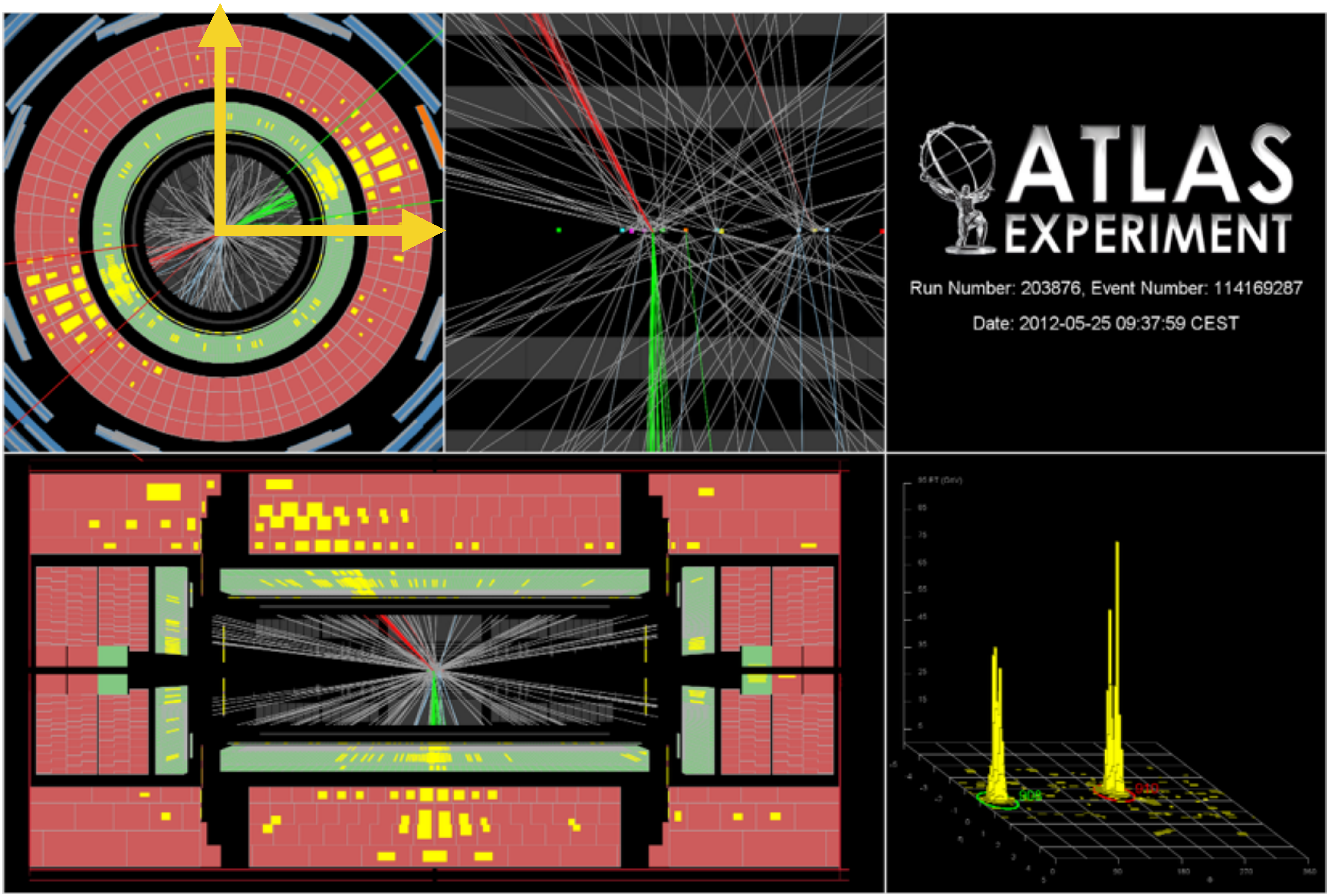

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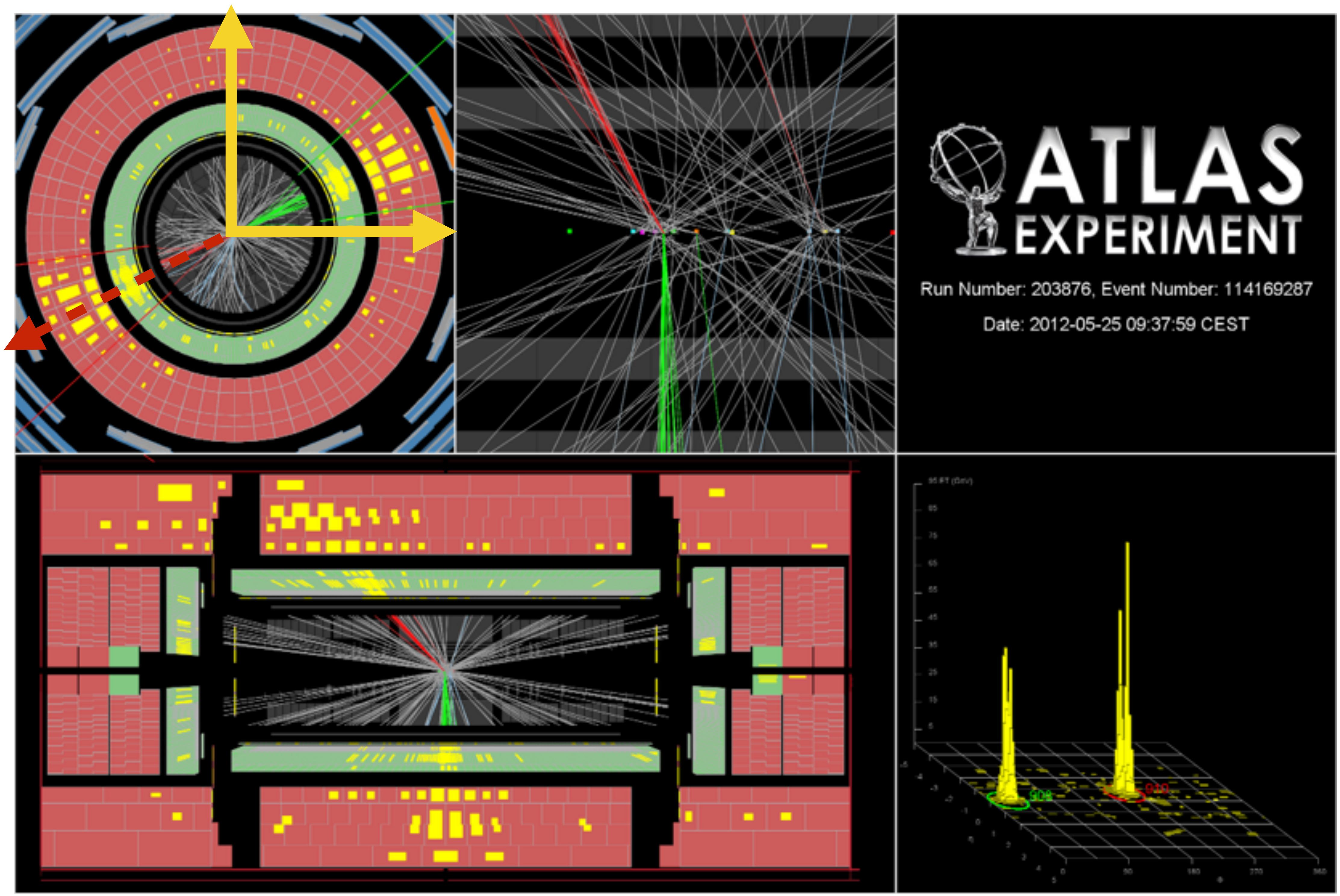

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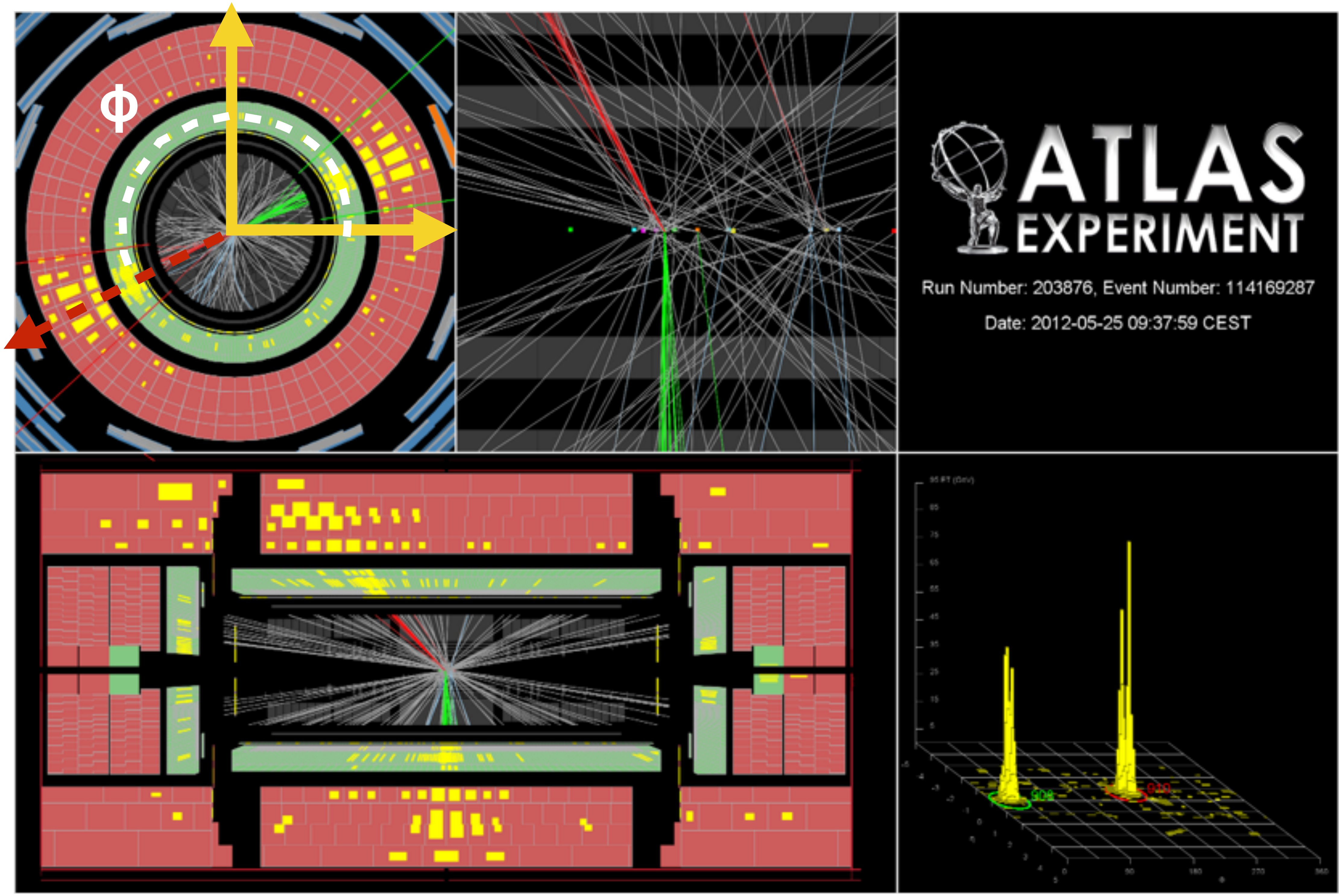

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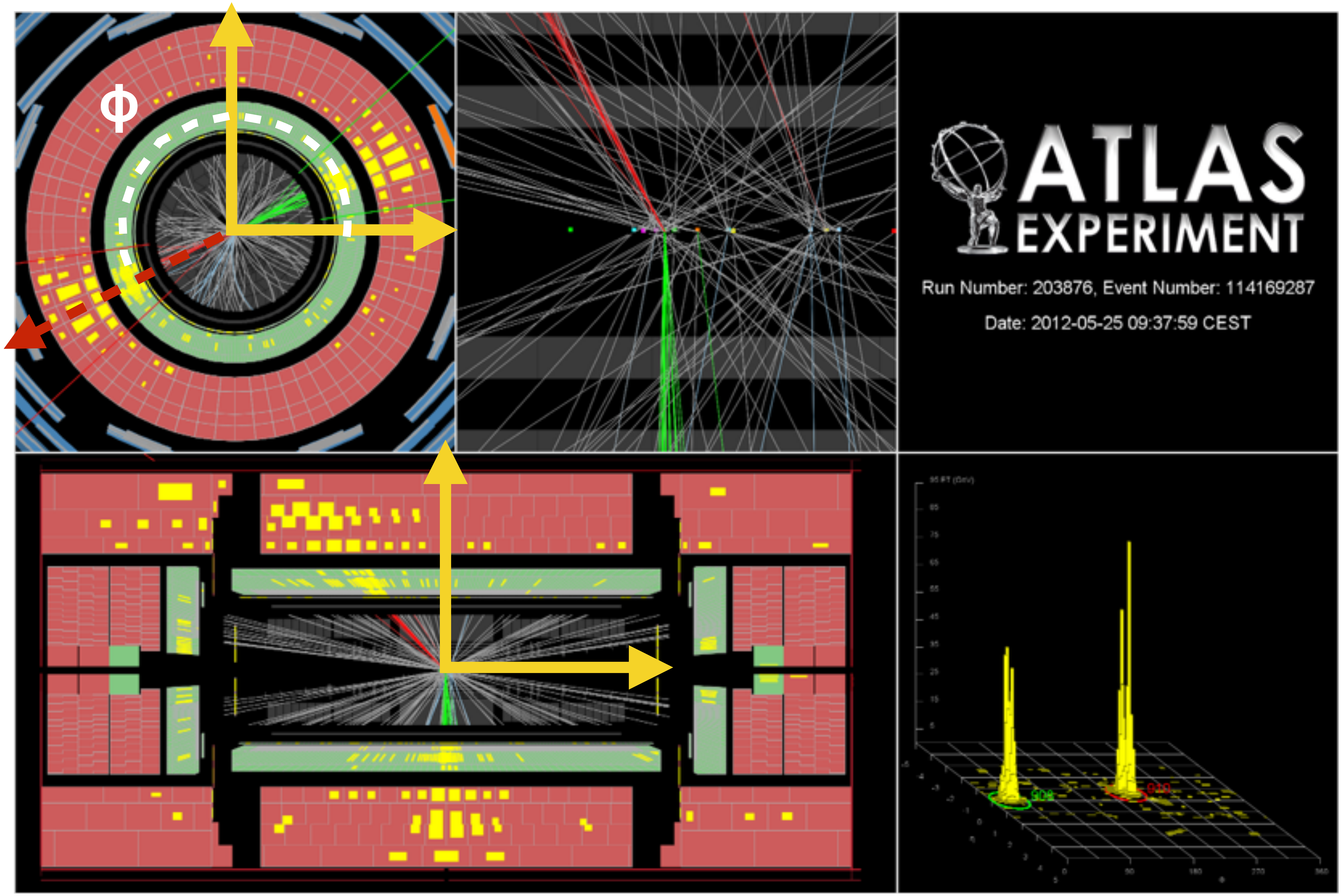

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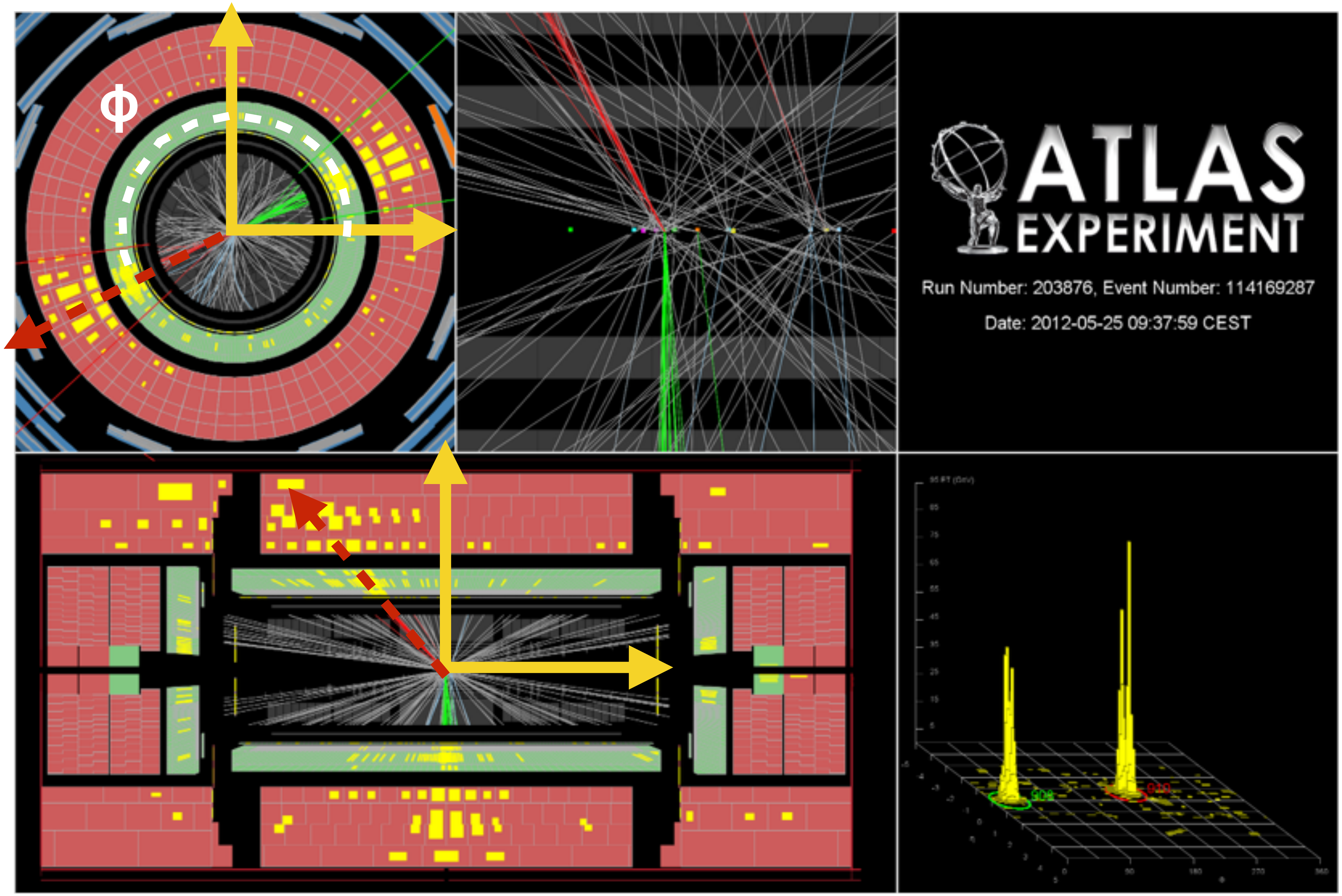

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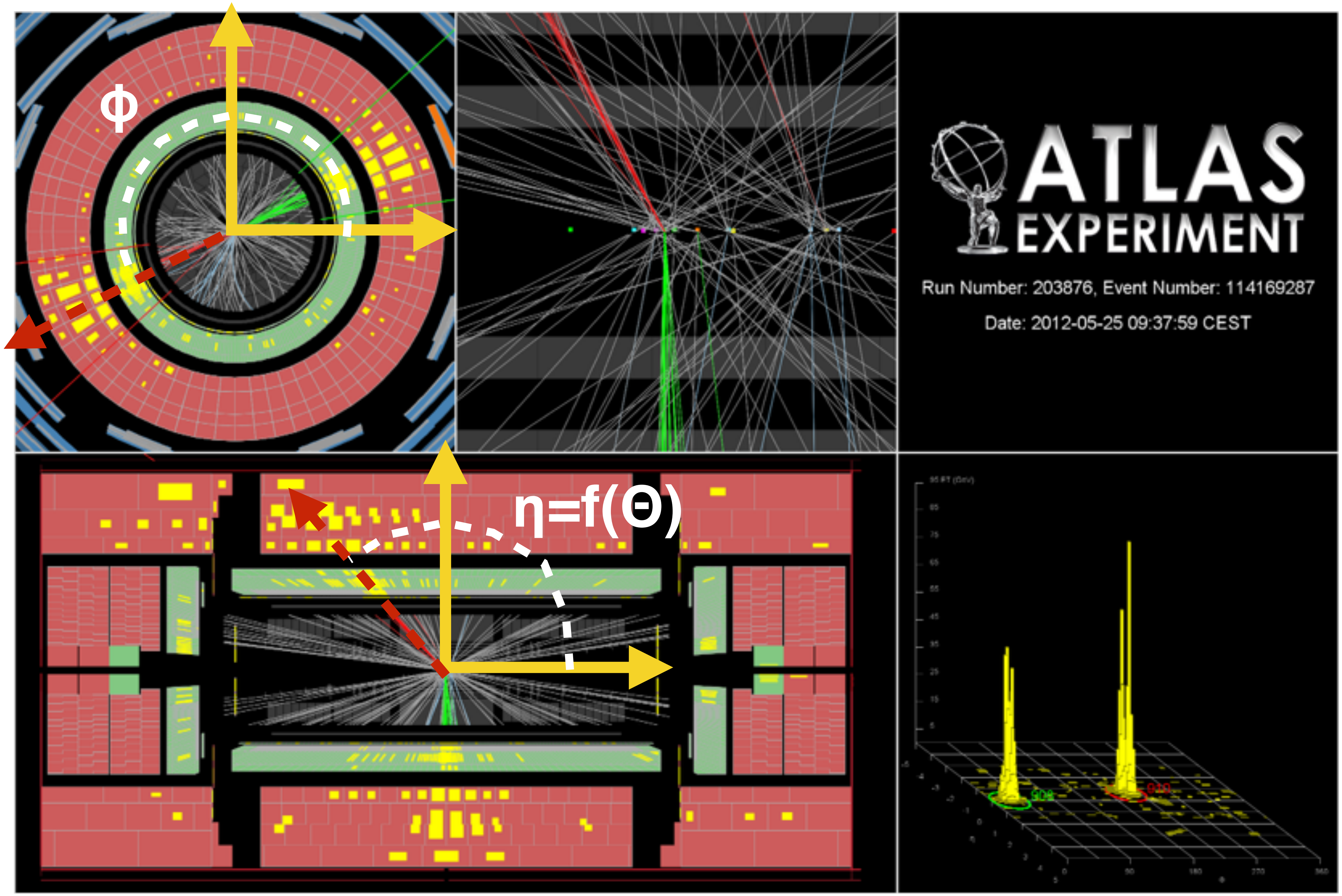
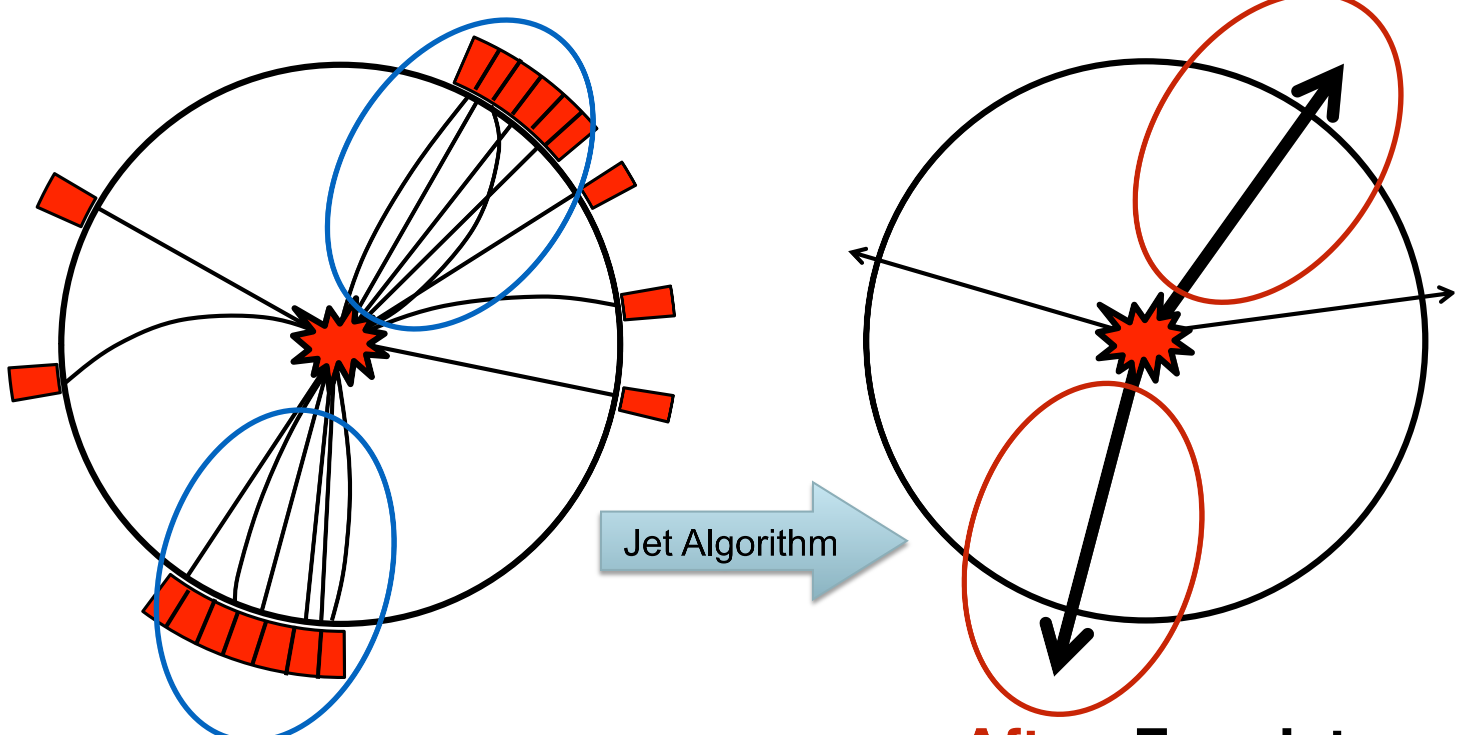


What is a “Jet”? - Some **schematic views**

Before: many particles in the events

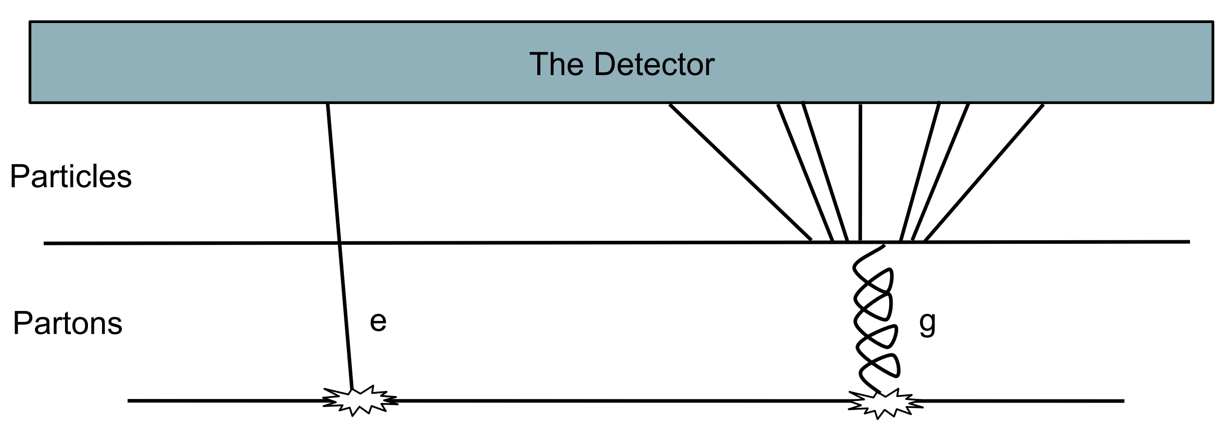
from A. Davidson talk



After: Few Jets

Very easy to identify the **di-jet topology**

…but life is never so easy

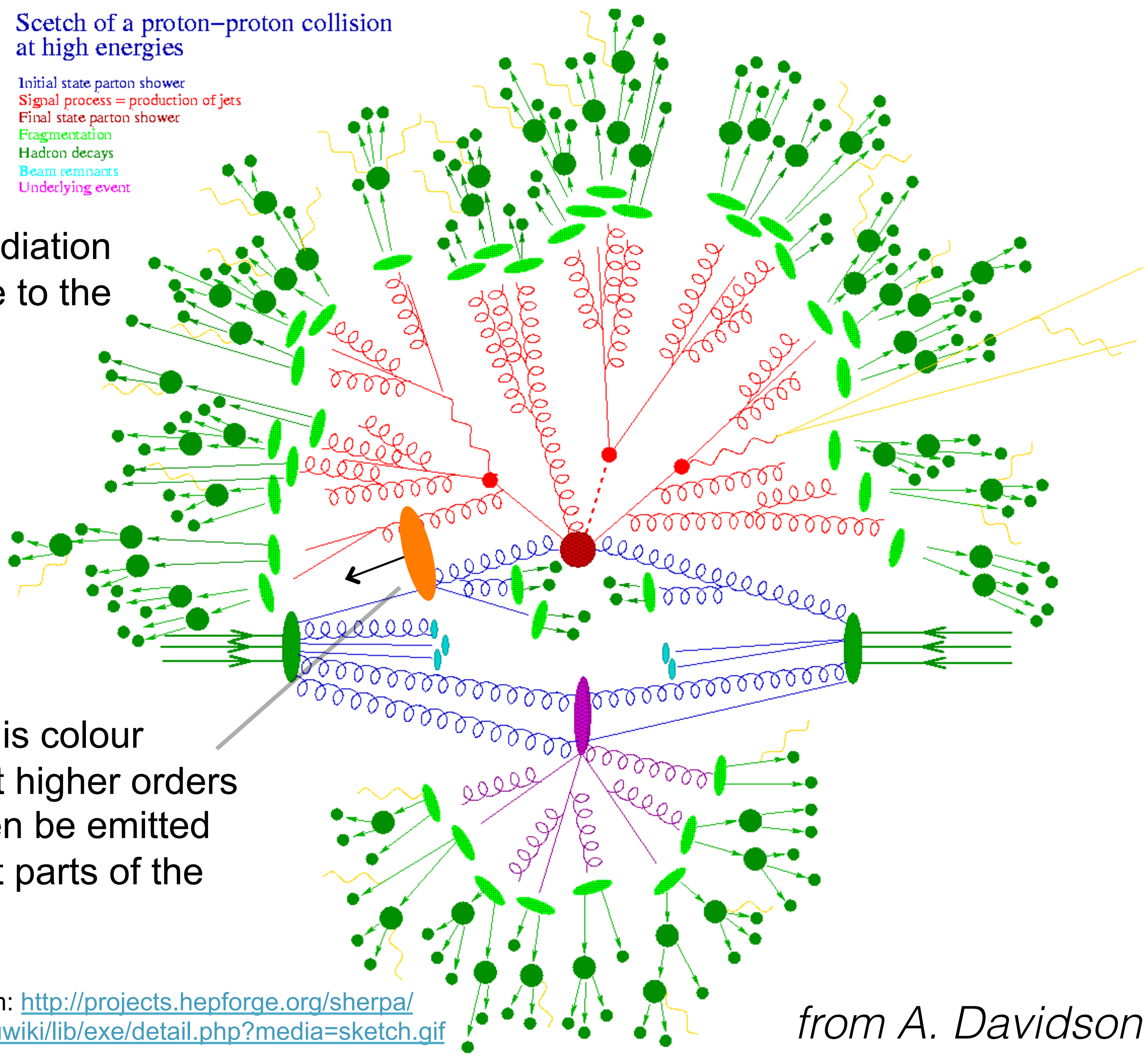


Where does a jet come from?

Quark and **gluon** production leads to **high particle multiplicities**

…indeed the life is not so easy - **proton-proton interaction**

Many sources of radiation all indistinguishable to the calorimeter



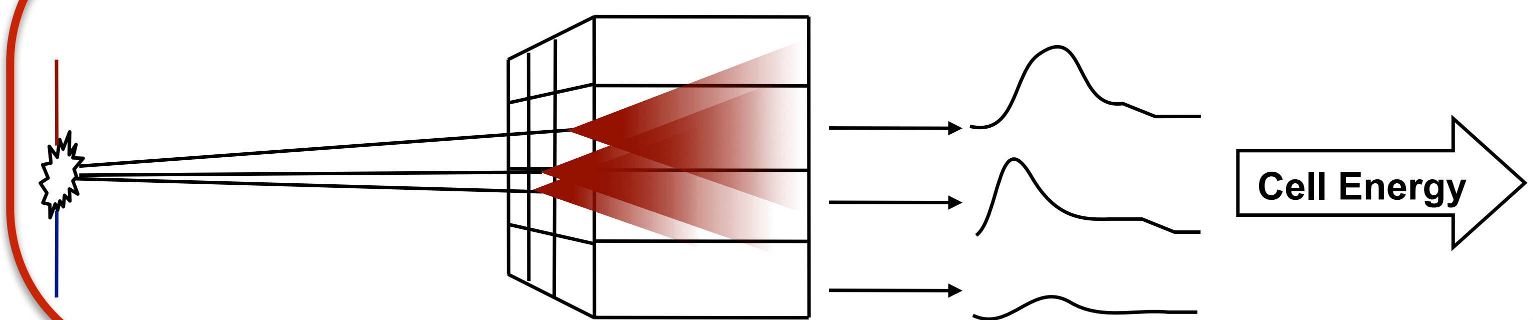
The whole event is colour connected and at higher orders radiation can even be emitted between different parts of the event

From: http://projects.hepforge.org/sherpa/dokuwiki/lib/exe/detail.php?media=sketch.gif

from A. Davidson talk

…indeed the life is not so easy - **physics inside our detector**

from A. Davidson talk



- Calorimeter cannot identify individual particles
- Has finite resolution
- Gaps, cracks for services and supports…
- Dead material scatter/absorbs particles

Where do we go from here?

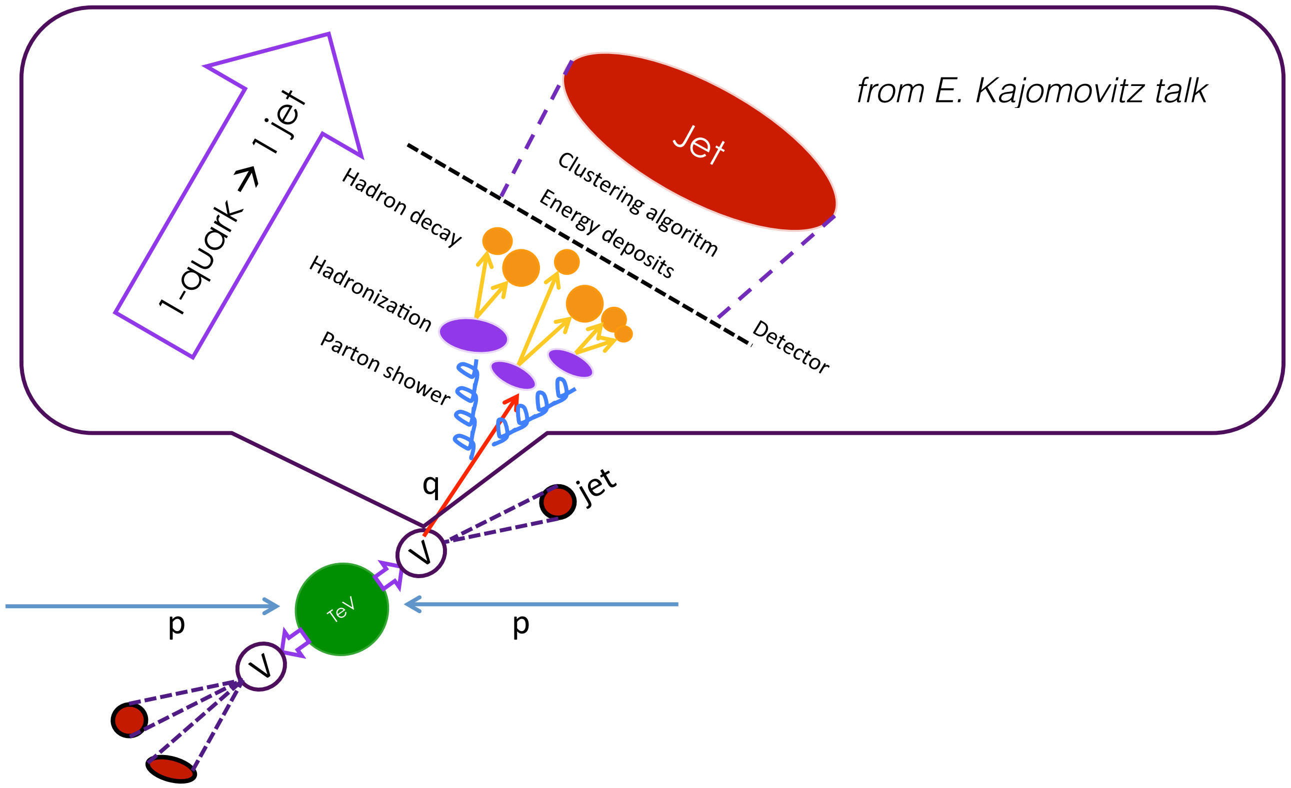
- **Parton level** isn't well defined or observable
- **Hadron level** is the only well-defined $\Longrightarrow$ **OBSERVABLES**
- **Detector causes even more problems**

At the end of the day we still want to measure hard processes involving jet-like hadron production

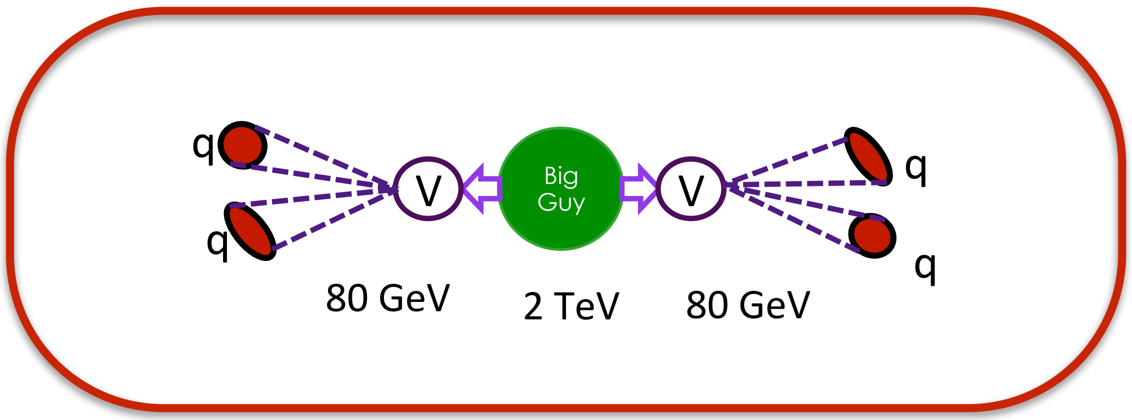
In our case we are interested in jets originated by the hadronic decay of the vector bosons

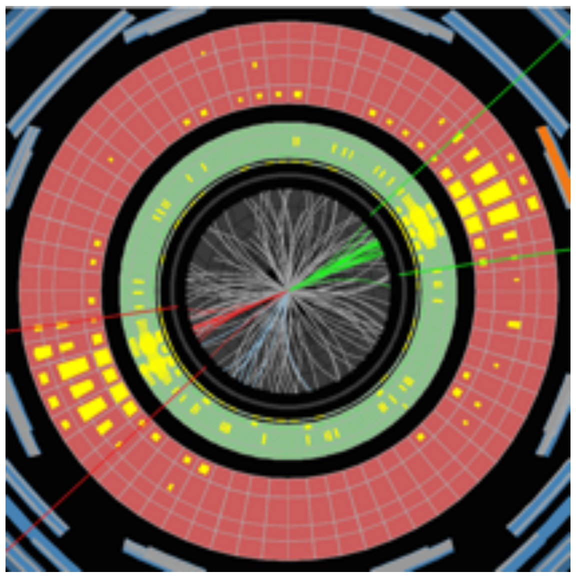
From **di-jet to di-Boson** topology

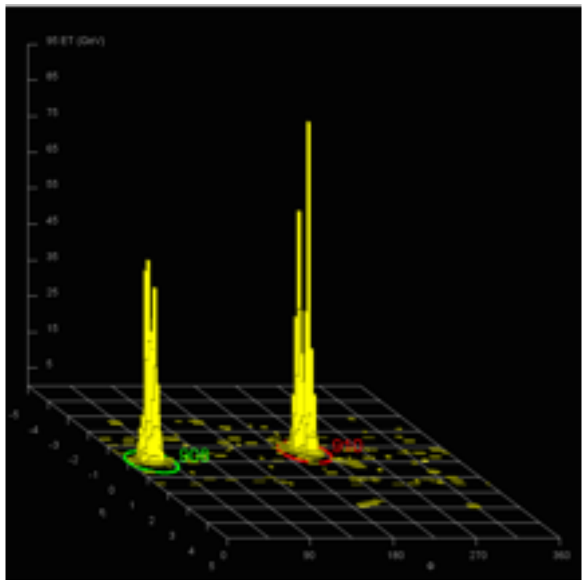
- **Vector bosons** have **masses of O(100 GeV)**
- **"New physics" particles** expected with **masses of O(TeV) - 1 to 3 TeV in 2012**



In this kind of final state the two bosons will have a momentum of O(TeV)

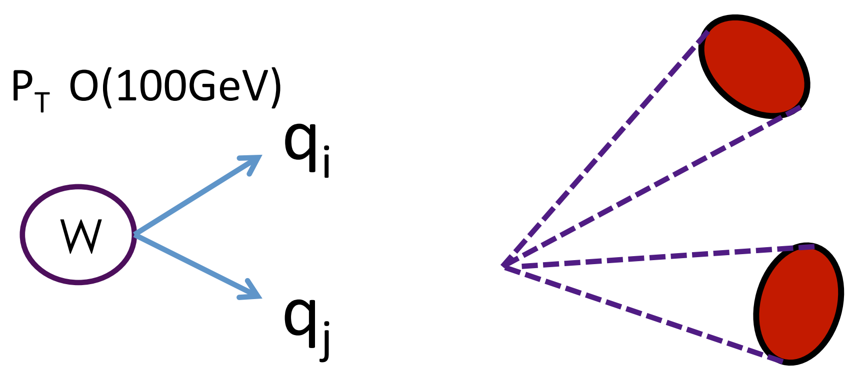






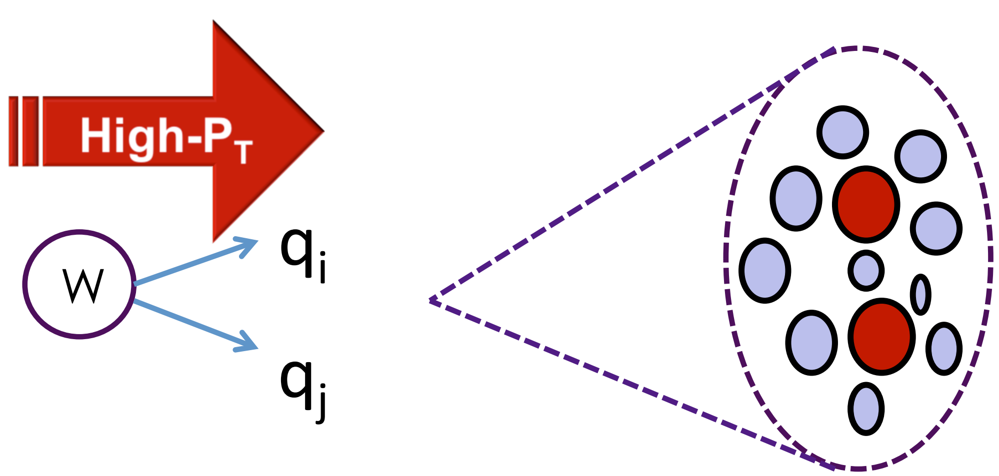
The **“boosted”** topology

“Normal” *angular separation* $\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2} \approx \frac{2m}{p_T}$



Resolved regime

- **Boson with relative low momentum in LF**
- One jet for each quark



Boosted regime

- **Boson with relative high momentum in LF - O(TeV)**
- The decay products are all merged into a single jet

The "idea" - **Jet Substructure**

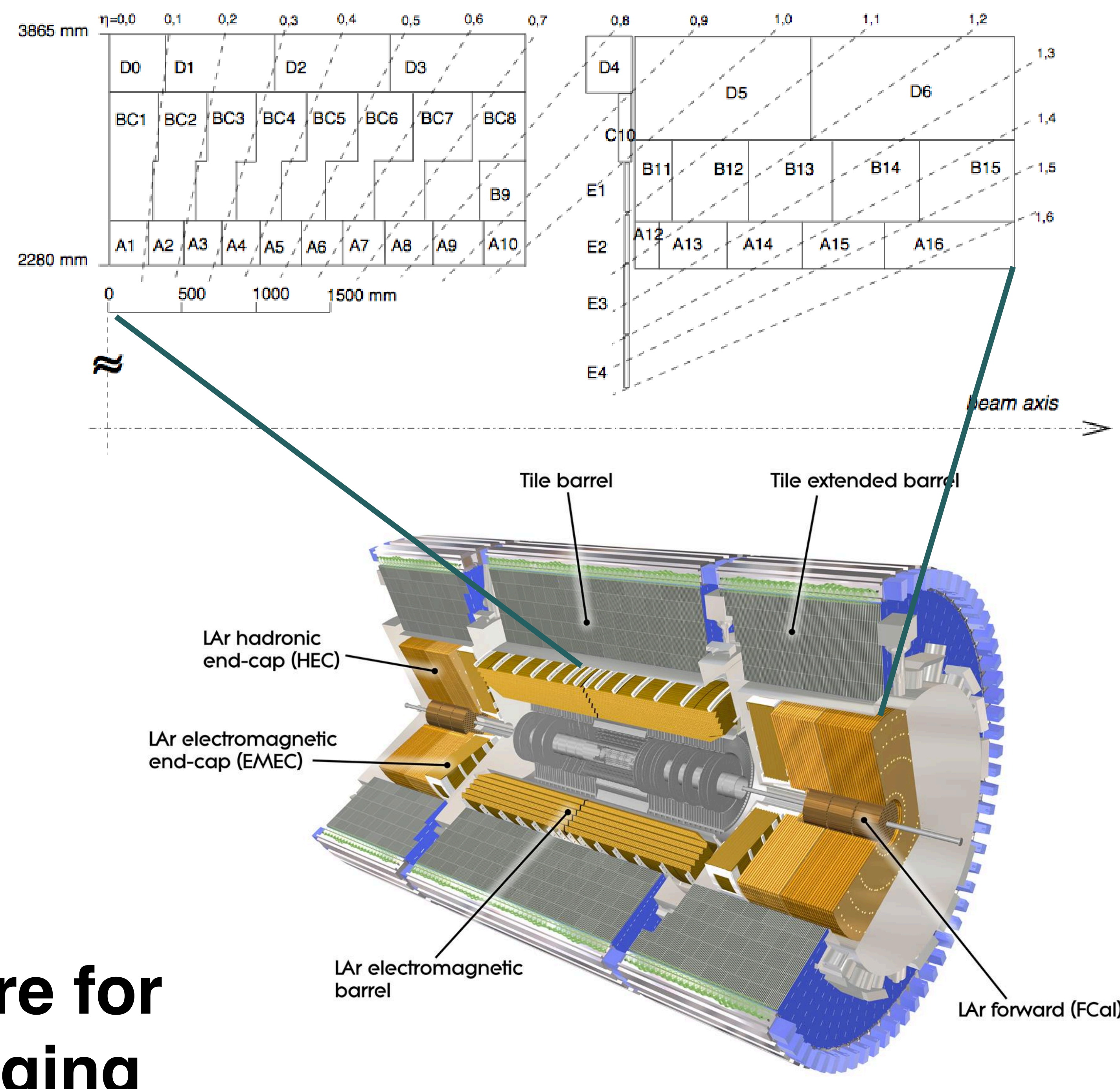
Reminder

Jet reconstruction compacts a very complicated picture into a small set of 4-vectors

ATLAS Calorimeter has a very high granularity (ΔR ~ 0.1)

We can take advantage of all the informations coming from the detector and look inside the jet structure

Jet Substructure for Boson Jet Tagging

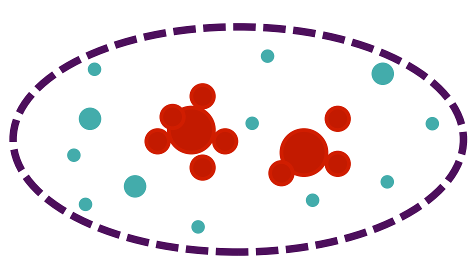


Boson Jet vs **QCD Jet**

What do we expect?

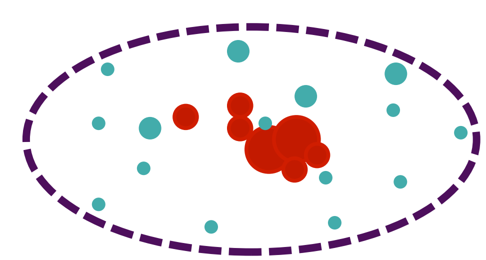
Boson Jet

- **2 regions with high energy density**
- **Each of the quarks carries comparable fraction of the boson momentum in LF**
- **Mass of the jet close to the boson mass**



QCD Jet

- **Narrow region with high energy density**
- **Most of the energy of the jet is contained in this region**
- **Mass of the jet comes from the spread of energy of the originating parton**



How does the technique work?

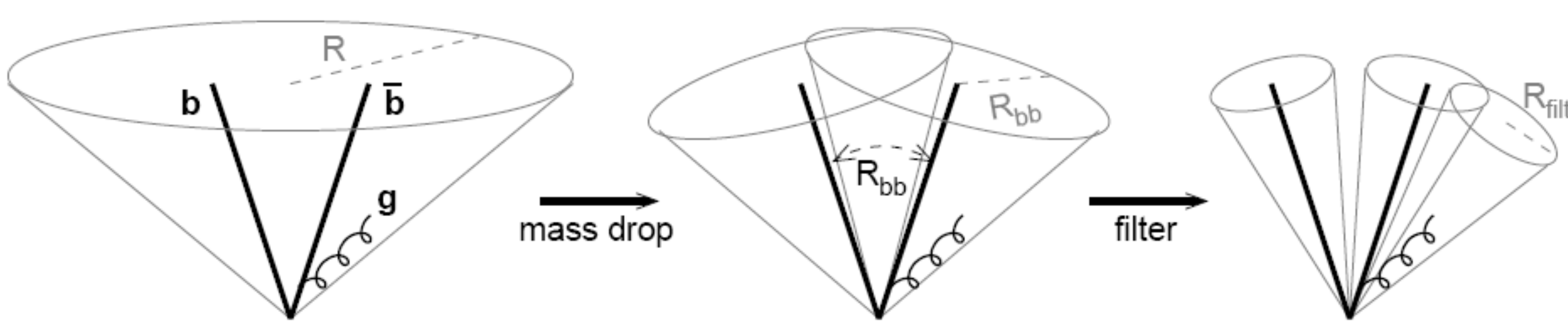
"Goal": identify a boson jet*

Using Cambridge/Aachen Jet algorithm

- Recombines closest pair of objects in the event up to R (distance parameter)
- Fat-Jets are used (R=1.2), in order to keep the analysis scale invariant

When finding a jet that passes a p_T cut (transverse momentum)

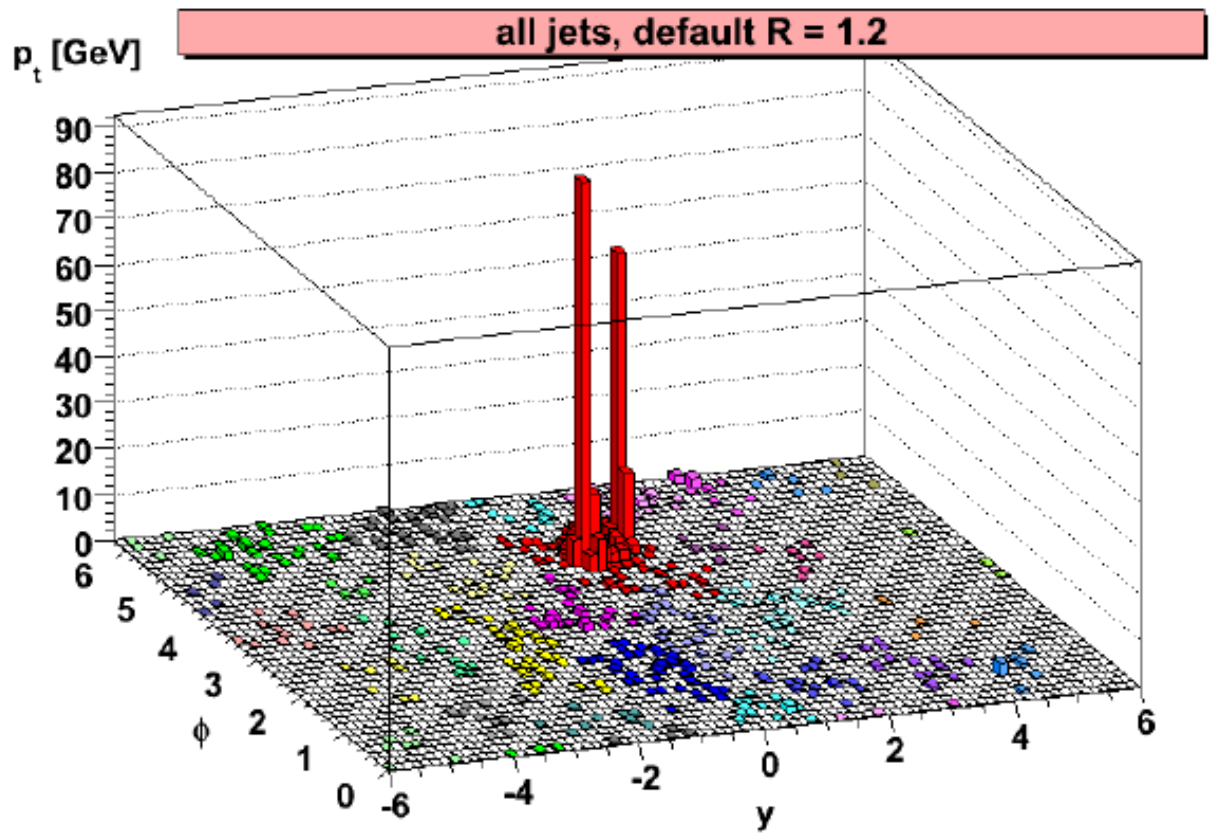
- Clustering can be undone one step at the a time
- Reverse clustering until a large drop in mass is observed
- Check this splitting is not too asymmetric
- Recluster remaining constituents with smaller R



**** the technique has been applied also to Higgs boson tagging***

Jet Substructure Cartoon - For H→bb Analysis

From G. Salam talk

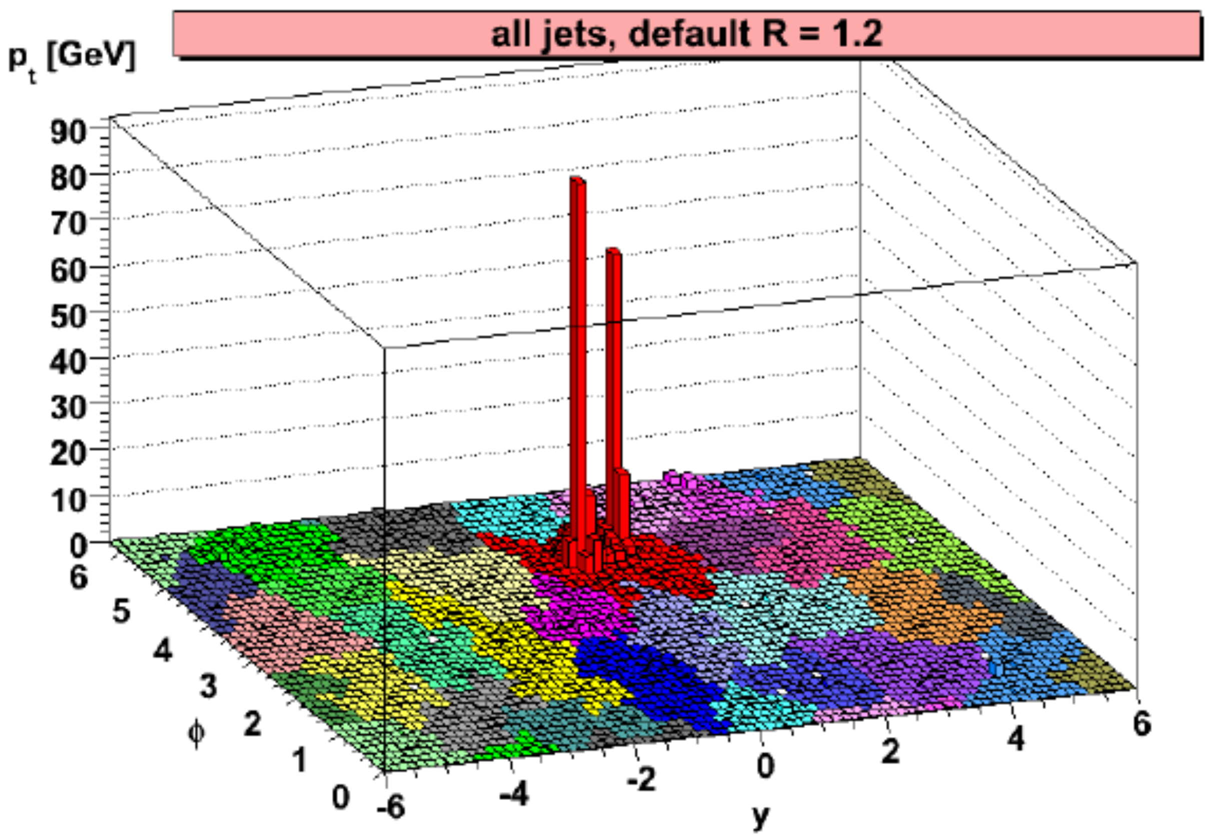


Cluster event, C/A, R=1.2

H boson test mass 115 GeV

Jet Substructure Cartoon - For H→bb Analysis

From G. Salam talk

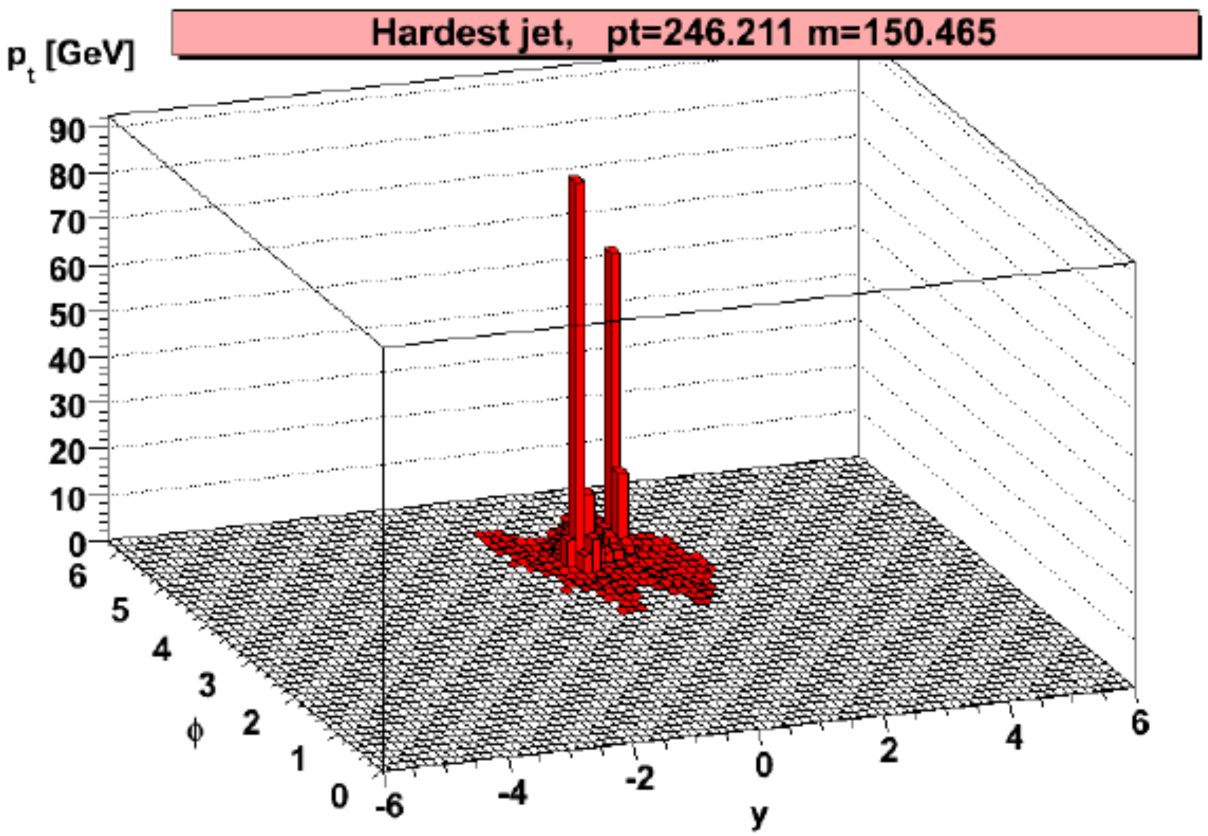


Fill it in, → show jets more clearly

H boson test mass 115 GeV

Jet Substructure Cartoon - For H→bb Analysis

From G. Salam talk

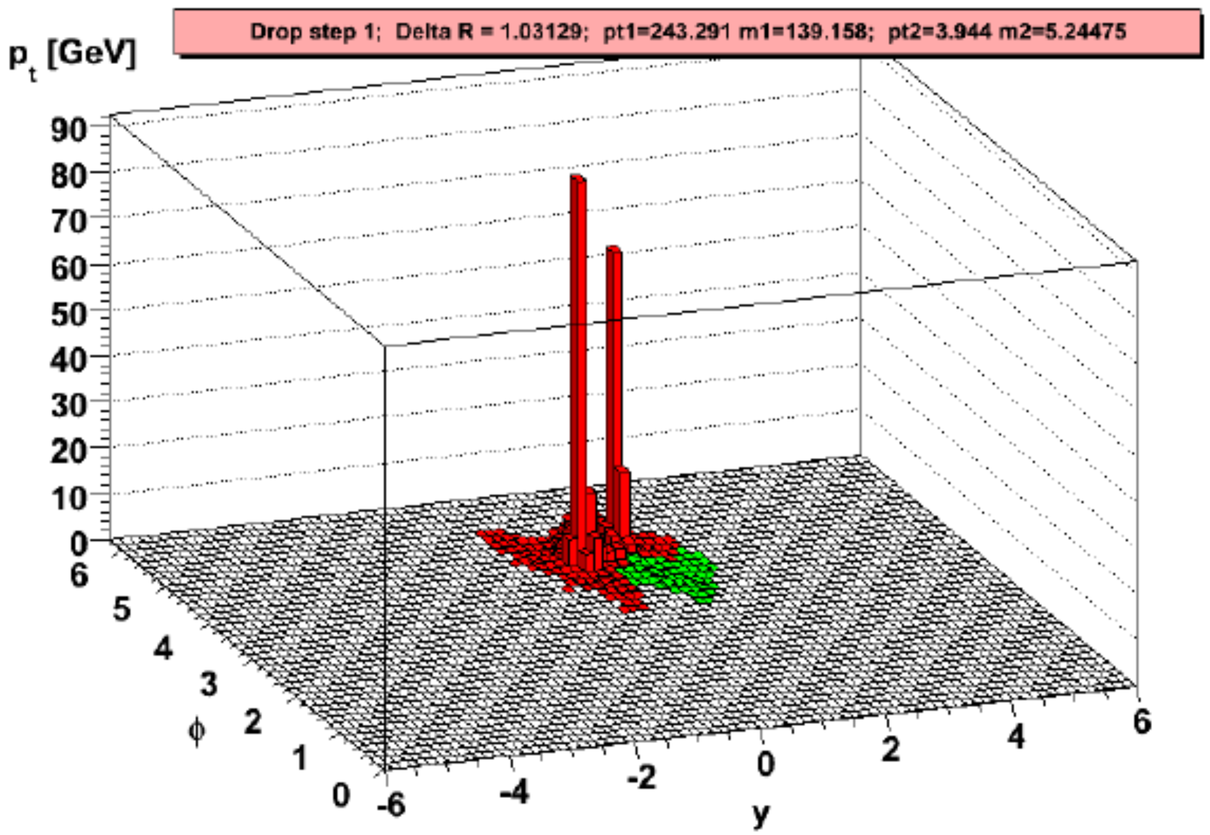


Consider hardest jet, $m = 150$ GeV

H boson test mass 115 GeV

Jet Substructure Cartoon - For H→bb Analysis

From G. Salam talk

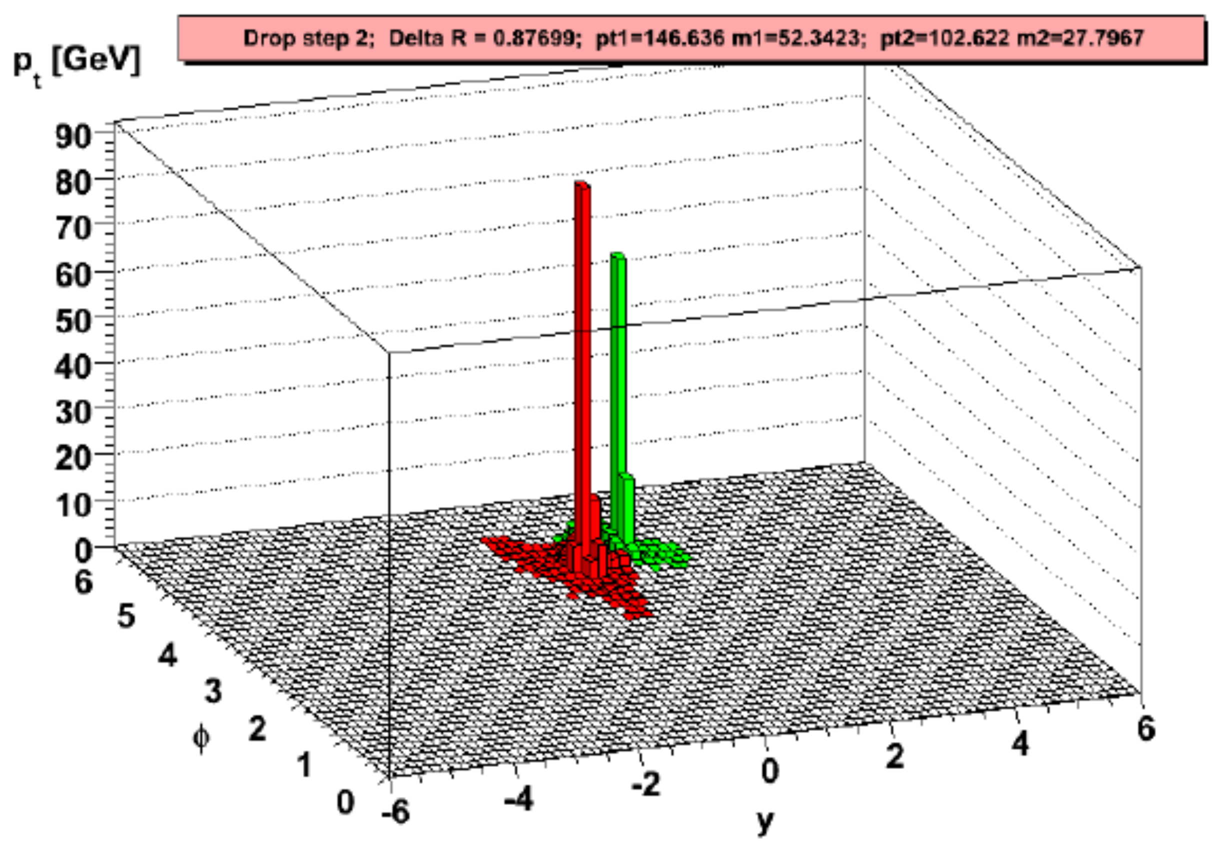


split: $m = 150$ GeV, $\frac{\max(m_1, m2)}{m} = 0.92 \rightarrow$ repeat

H boson test mass 115 GeV

Jet Substructure Cartoon - For H→bb Analysis

From G. Salam talk

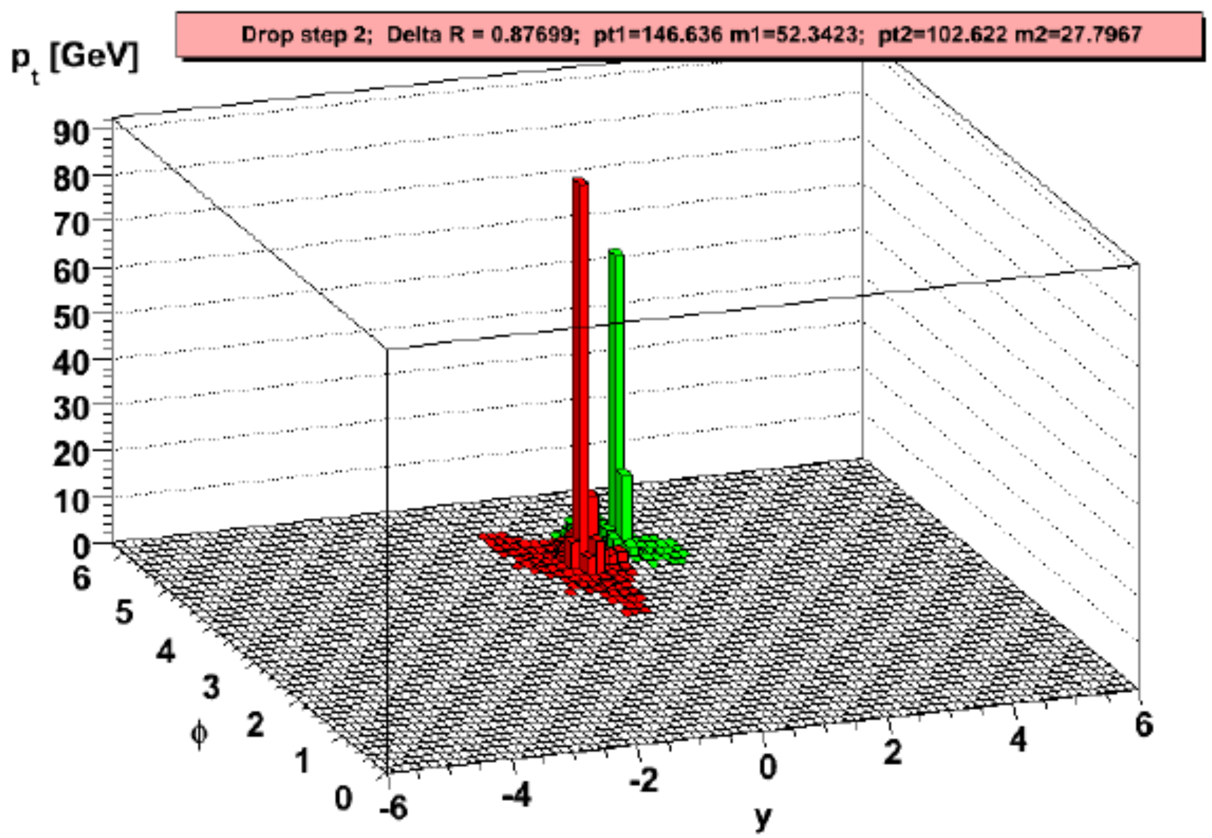


split: $m = 139$ GeV, $\frac{\max(m_1, m2)}{m} = 0.37 \rightarrow$ mass drop

H boson test mass 115 GeV

Jet Substructure Cartoon - For H→bb Analysis

From G. Salam talk

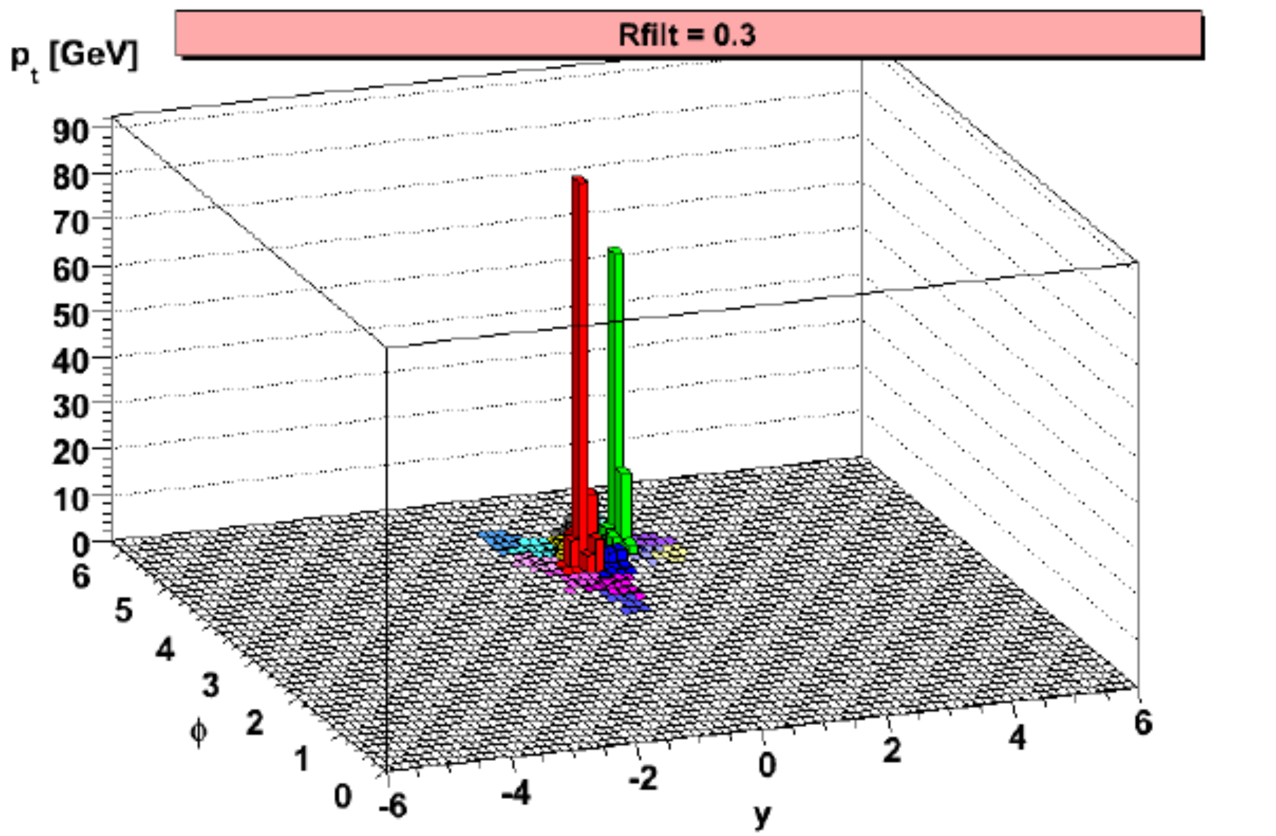


check: $y_{12} \simeq \frac{p_{t2}}{p_{t1}} \simeq 0.7 \longrightarrow \text{OK} + 2\ b\text{-tags (anti-QCD)}$

H boson test mass 115 GeV

Jet Substructure Cartoon - For H→bb Analysis

From G. Salam talk

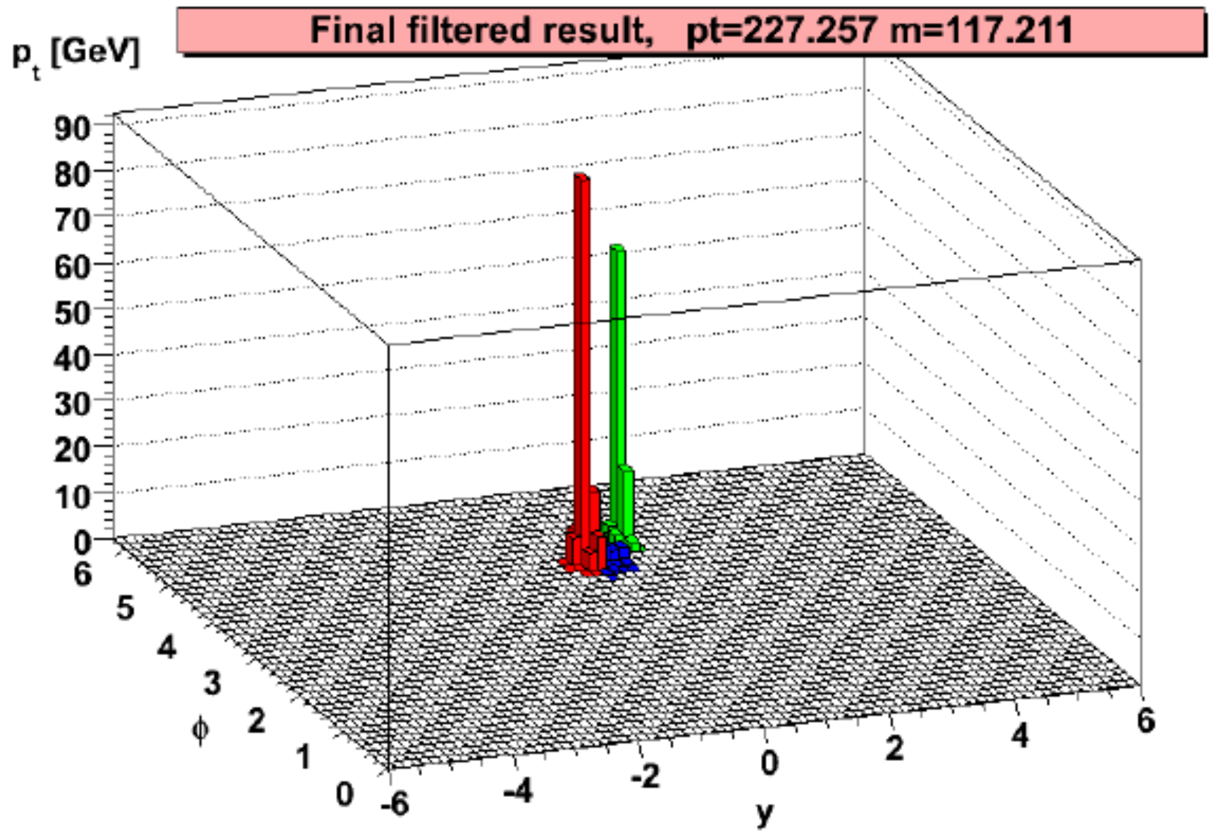


$R_{filt} = 0.3$

H boson test mass 115 GeV

Jet Substructure Cartoon - For H→bb Analysis

From G. Salam talk

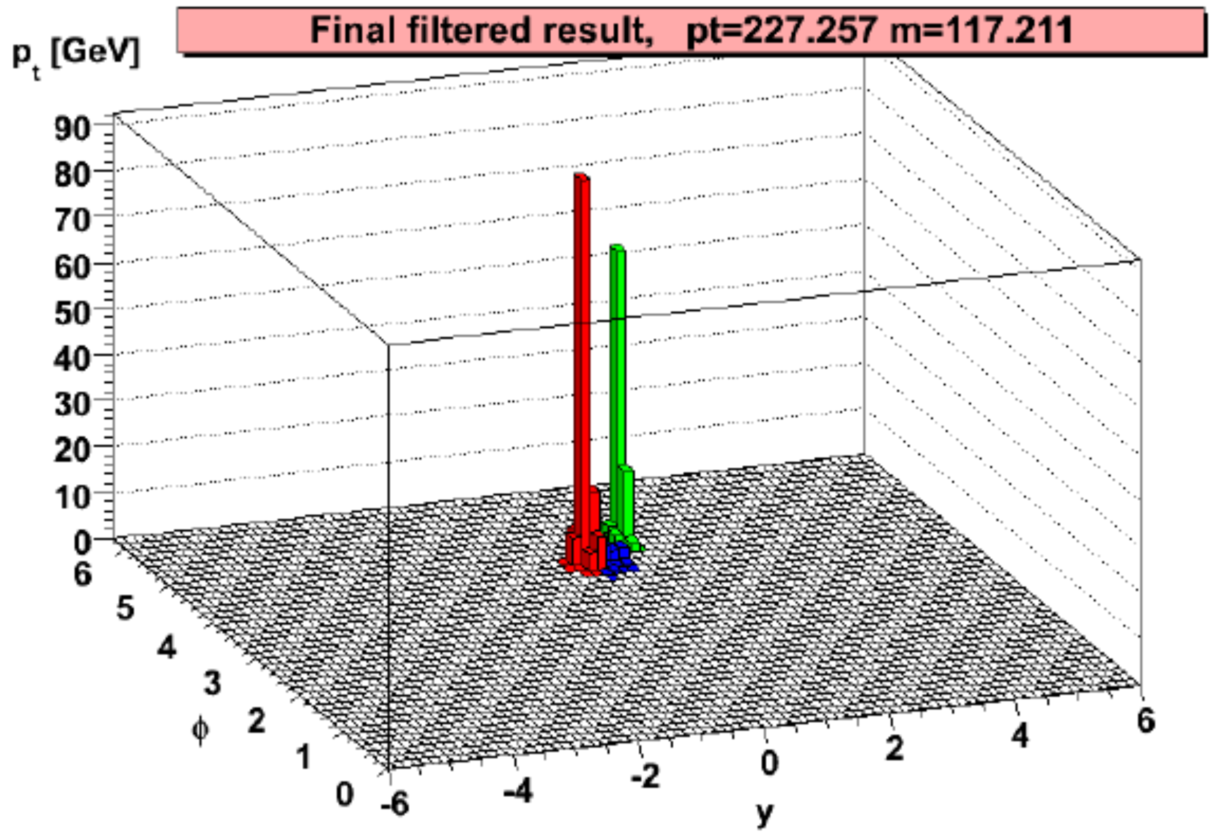


$R_{filt} = 0.3$: take 3 hardest, **m = 117 GeV**

H boson test mass 115 GeV

Jet Substructure Cartoon - For H→bb Analysis

From G. Salam talk



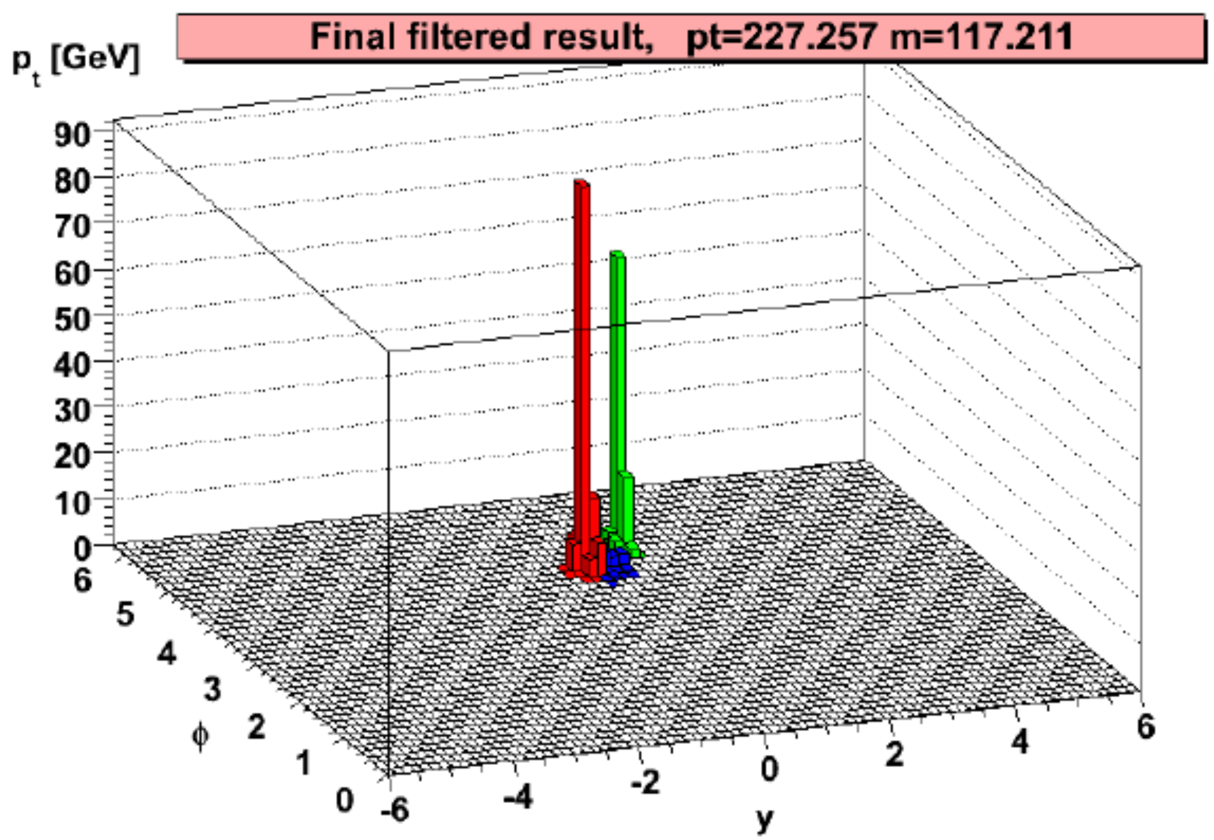
$R_{filt} = 0.3$: take 3 hardest, $m = 117$ GeV

Results:

H boson test mass 115 GeV

Jet Substructure Cartoon - For H→bb Analysis

From G. Salam talk



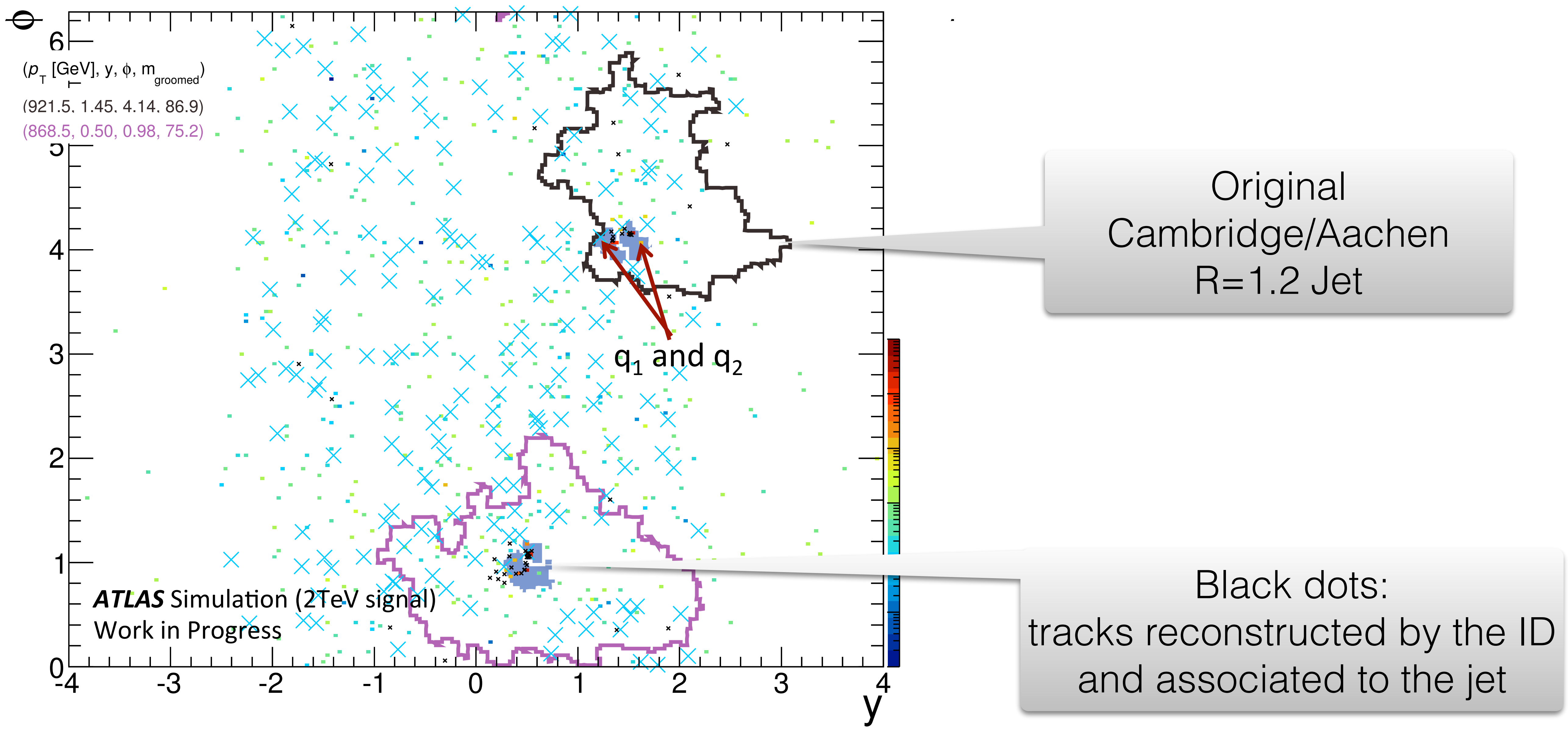
$R_{filt} = 0.3$: take 3 hardest, $m = 117$ GeV

H boson test mass 115 GeV

Results:

- Size of the initial jet reduces to accomodate the hard substructure
- Jet mass resolution improved
- Reclustered jet less affected by pile-up dependence

Jet Substructure - Reclustered W' 2 TeV event



New **observables** to **discriminate Signal** and **Background**

What does reclustering do?

- **Redefines the jet shape and size**
- **Investigating the jet substructure, provides new observables**
  - ➡ Momentum balance ($\sqrt{y_f}$)
  - ➡ NSubjettines
  - ➡ …and many others

Boson Tagging

Jet Mass

- For boson jets jet mass peaks at the nominal boson mass
- QCD mostly falling mass distribution

Momentum balance

- For boson jets the subjets have comparable momenta at the stopping point
- For QCD jets one of the subjets will have most of the momentum

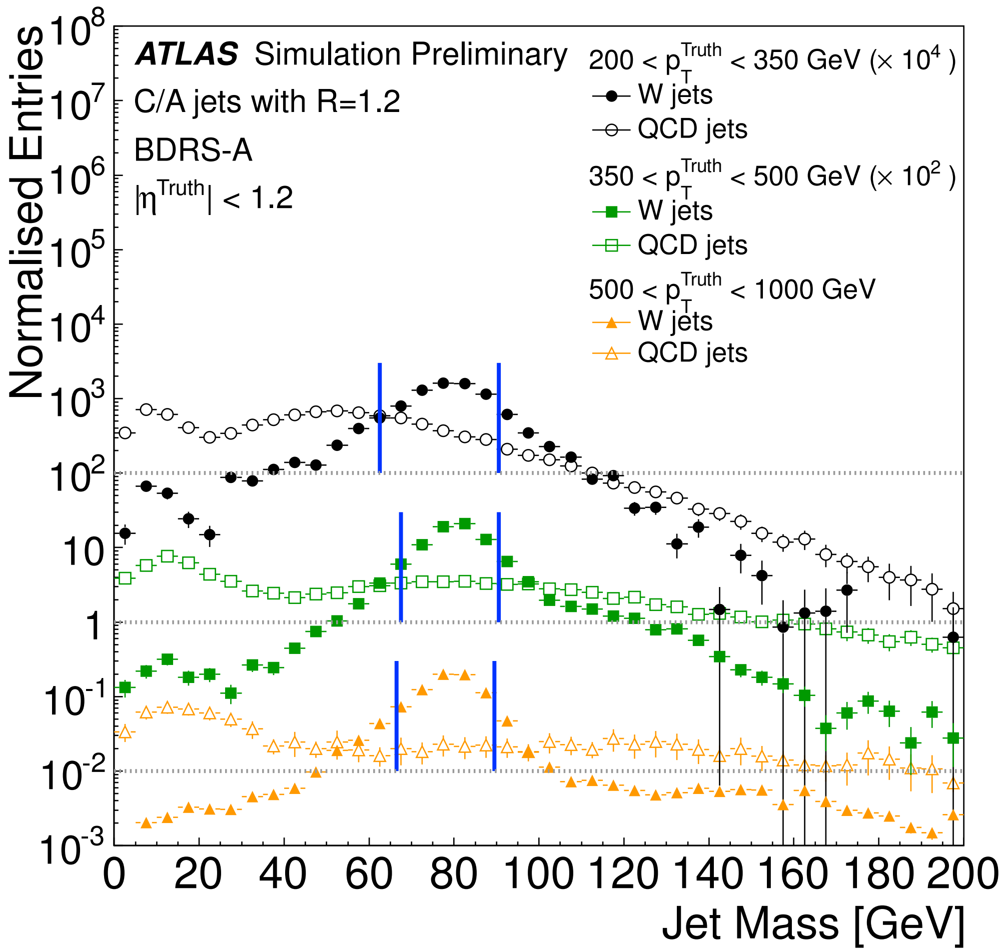
Hadronic Activity

- Increased hadronic activity in QCD jets

Performance of **Jet Mass**

Jet Mass

- ➡ For boson jets jet mass peaks at the nominal boson mass
- ➡ QCD mostly falling mass distribution



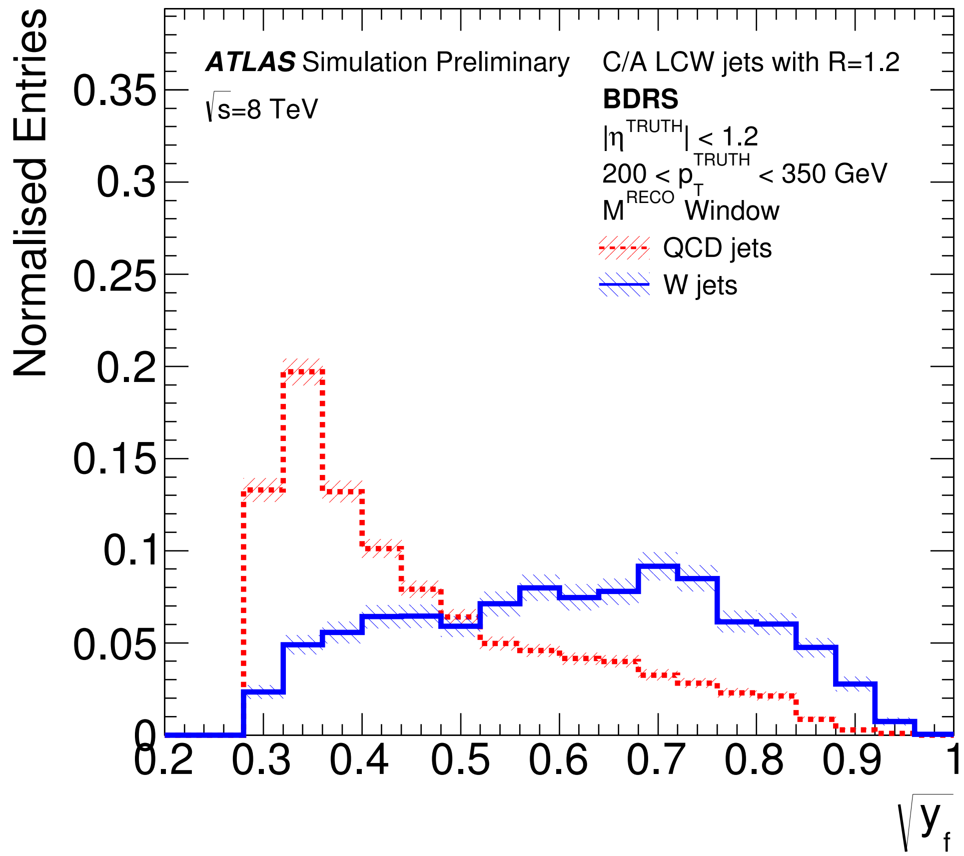
(c) C/A, R = 1.2 BRDS-A jet mass.

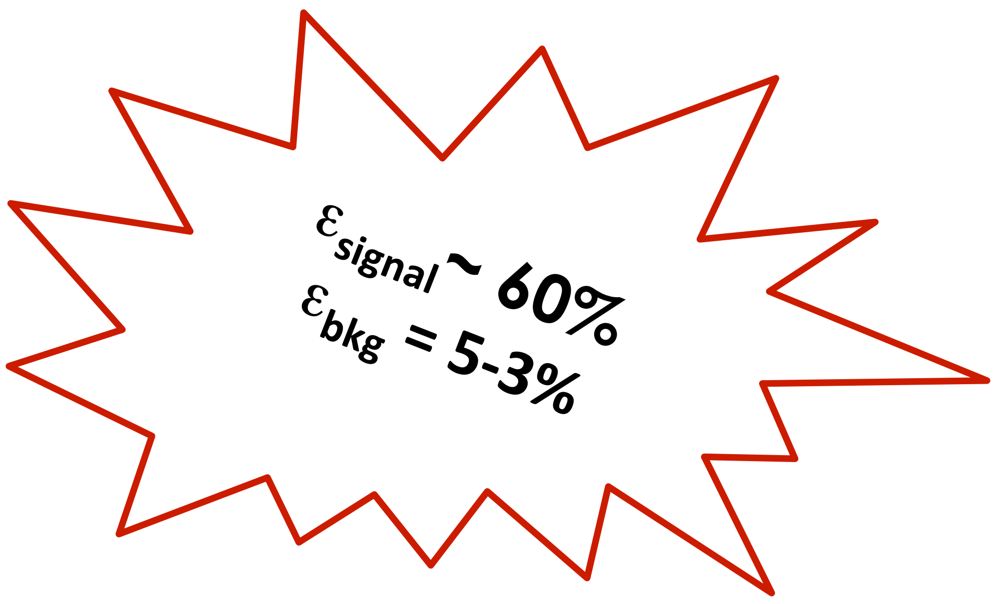
* Optimized cuts

Performance of **Jet Momentum Balance**

Momentum balance

- ➡ For boson jets the subjets have comparable momenta at the stopping point
- ➡ For QCD jets one of the subjets will have most of the momentum

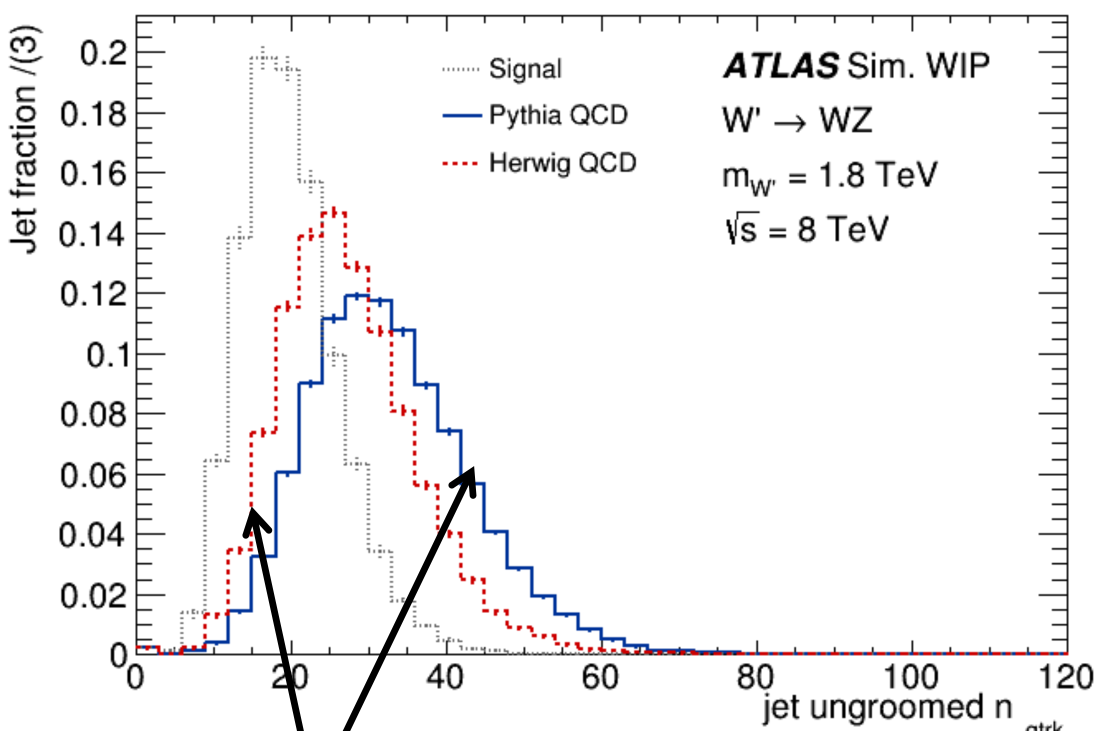




Performance of **Jet Hadronic Activity**

After applying the two previous selections most of the background is QCD jets with a hard gluon splitting

- ➡ Expect hadronic activity proportional to parton charge (3 gluon, 4/3 quark)
- ➡ Use #Trk as a proxy for hadronic activity



There seems to be discrimination power but the variable is not well modeled in MC… what can we do?

Systematic uncertainties

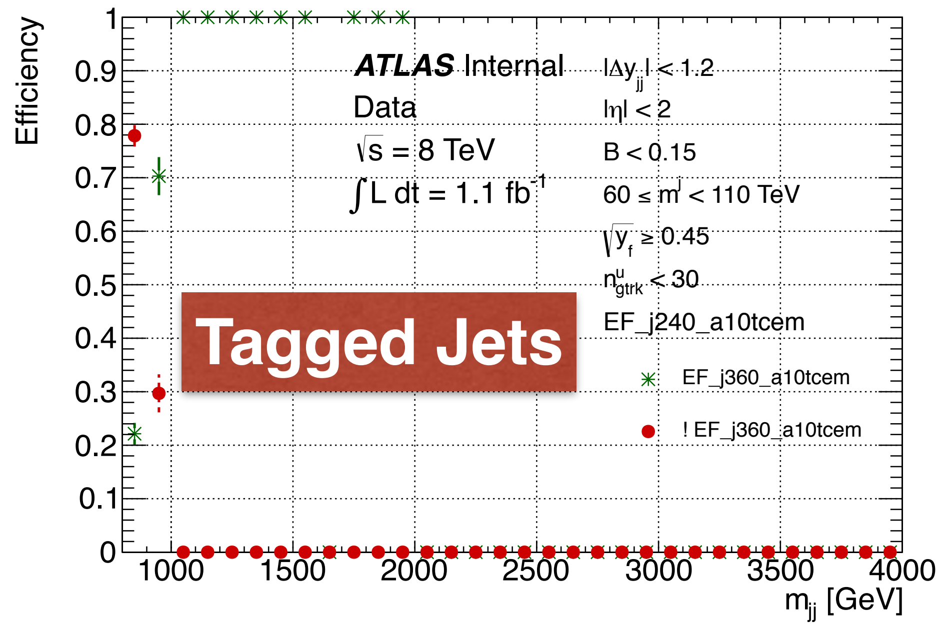
…After defining the tagging - **Full event selection for VV→JJ analysis**

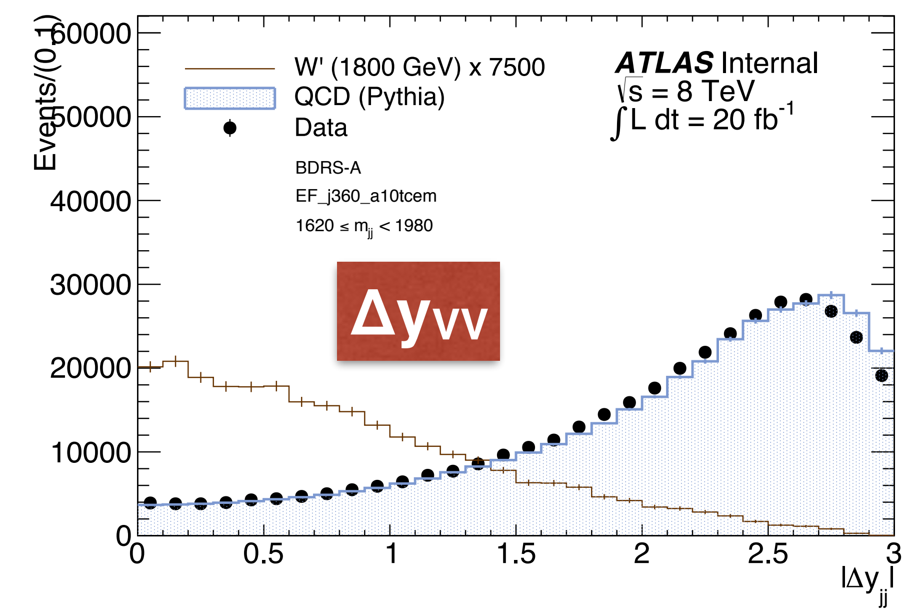
The **goal of the event selection** is to **maximize the sensitivity** of the **dijet mass spectrum** to the observation of **W'→WZ or other narrow VV resonances**.

1. **Trigger Selection**: events acquired with EF_j360_a10tcem trigger (lowest unprescaled jet trigger for 2012)
2. **Filtering** with **BDRS-A**
3. **Mass of dijet-system** is required to be **above 1.0 TeV,** in order to avoid region with trigger inefficiency
4. **Rapidity gap between the two leading jets $|\Delta y_{12}| < 1.2$**, to reject QCD t-channel dijet production
5. **p_T asymmetry**, **A < 0.15**, between two leading jet, to select balanced events

$$A = \frac{P_{T,jet1} - P_{T,jet2}}{P_{T,jet1} + P_{T,jet2}} < 0.15$$

6. **$|\eta_{jet}| < 2,$** to ensure good overlap with the inner detector
7. **Special Jet Cleaning** to avoid wrong **BCH_CORR_CELL**
8. **Boson Tagging Criteria**





Background Parametrization - Data drive approach

QCD Background not completely understood.
Data driven approach much more reliable

BG described with 3-parameter function:

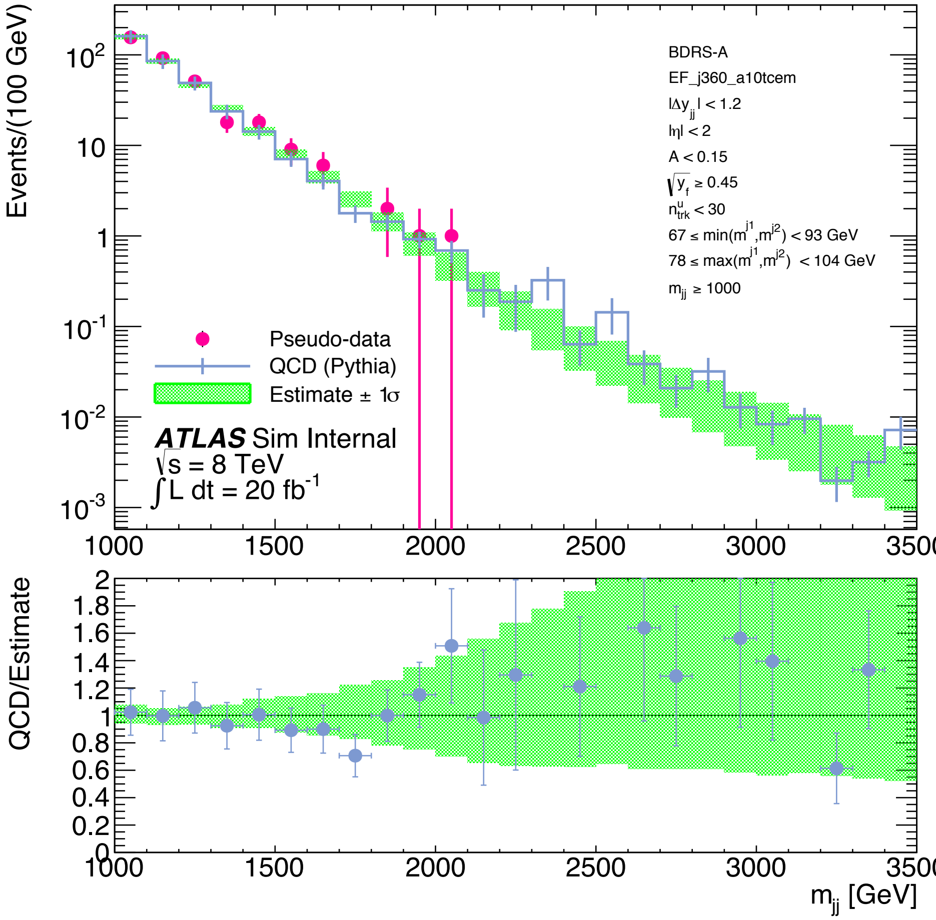
- $\frac{dN}{dx} = C(1-x)^{p_2+p_9 p_3} x^{p_3}$
- Classic dijet function with $p_4 = 0$
  - Shown in 2011 to be sufficient with greater statistics

$x = m_{jj}/p_5$

$p_5 = 8$ TeV

Backgroeund fit performed with **Bayesian analysis with a Poisson likelihood**

- Flat prior with exponential tails probability distributions for $\mathbf{p_1}$, $\mathbf{p_2}$, $\mathbf{p_3}$



Last ingredient - **Statistical Analysis**

For counting experiment the likelihood is: $\mathcal{L}(\mathbf{n}_{\text{obs}}|\mathbf{n}_{\text{exp}}) = \prod_i P_{\text{pois}}(n^i_{\text{exp}}, n^i_{\text{obs}})$

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$$P_{\rm pois}(\lambda, n) = \frac{\lambda^n e^{-\lambda}}{n!}$$

n : $n_{\rm observed}$ counts

λ : $n_{\rm expected}$

→ In our case the number of counts are the entries in each bin of the observed histogram

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→ In our case the number of counts are the entries in each bin of the observed histogram

$$n_{exp}=n_{bkg}+\mu n_{sig} \rightarrow n_{exp}=f(\mu,B_{NP},S_{NP})$$

➡ **B_{NP}** : Background parameters - p1, p2, p3

➡ **S_{NP}** : Signal parameters, included systematics

Last ingredient - **Statistical Analysis**

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$$n_{exp} = n_{bkg} + \mu n_{sig} \quad \Rightarrow \quad n_{exp} = f(\mu, B_{NP}, S_{NP})$$

- ➡ B_{NP} : Background parameters - p1, p2, p3
- ➡ S_{NP} : Signal parameters, included systematics

Full set of parameters with their probability density functions

Param.	pdf	Meaning
μ	flat	Signal strength relative to SSM
p_1, p_2, p_3	flat	Background parameters
S_{L}	$G(S_{\text{L}}\,\|\,1, 0.028)$	Integrated luminosity SF
α	$G(\alpha\,\|\,1, 0.02)$	Jet p_{T} (m_{jj}) scale
σ_E	$G(\sigma_E\|0, 0.0t \times \sqrt{1.2^2 - 1})$	Jet p_{T} resolution (additional smearing)
α_m	$G(\alpha_m\,\|\,1, 0.03)$	Jet mass scale
σ_m	$G(\sigma_m\|0, 0.075 \times \sqrt{1.2^2 - 1})$	Jet mass resolution (additional smearing)
α_y	$G(\alpha_y\,\|\,1, 0.02)$	Jet momentum balance ($\sqrt{y_{\text{f}}}$) scale
σ_y	$G(\sigma_y\|0, 0.16 \times \sqrt{1.2^2 - 1})$	Momentum balance resolution (additional smearing)
S_{t}	$G_{\text{t}}(S_{\text{t}}\|0.89, 0.095, 1.07)$	Track multiplicity SF
S_{ps}	$G(1.0, 0.05)$	Parton Showering uncertainty SF

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S_{ps}	$G(1.0, 0.05)$	Parton Showering uncertainty SF

$n_{sig} = \mu n_{SSM}$ assuming **model hypothesis (MH)** signal strength

μ = 1 : MH prediction
μ = 0 : SM prediction

Last ingredient - **Bayesian Fit**

Full set of parameters with their probability density functions

Param.	pdf	Meaning
μ	flat	Signal strength relative to SSM
p_1, p_2, p_3	flat	Background parameters
S_{L}	$G(S_{\mathrm{L}} \,\vert\, 1, 0.028)$	Integrated luminosity SF
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Applying the Bayes theorem

$$P_{post}(T) = \mathscr{L}(n_{obs} \vert T) P_{prior}(T)$$

The systematics are included in the priors for the Nuisance Parameters

$$T = \{\mu, B_{NP}, S_{NP}\}$$

Last ingredient - **Bayesian Fit**

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Full set of parameters with their probability density functions

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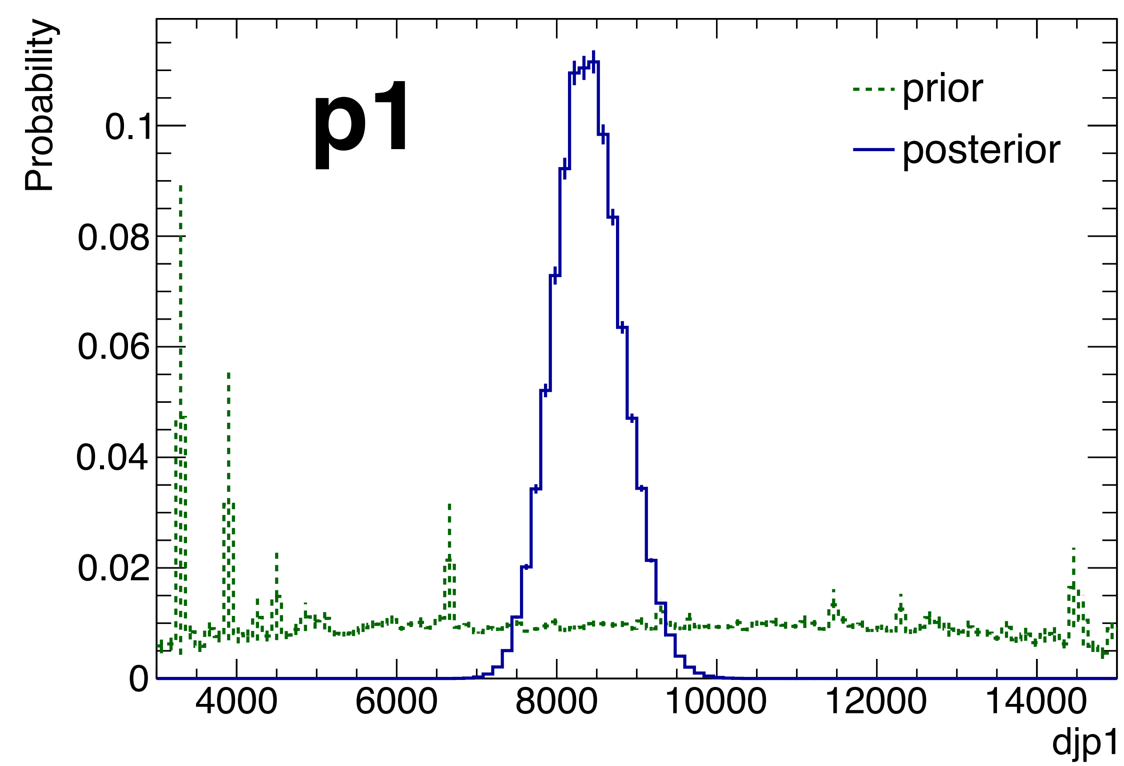

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p_1, p_2, p_3	flat	Background parameters
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Full set of parameters with their probability density functions

Applying the Bayes theorem

$$P_{post}(T) = \mathscr{L}(n_{obs} \mid T) P_{prior}(T)$$

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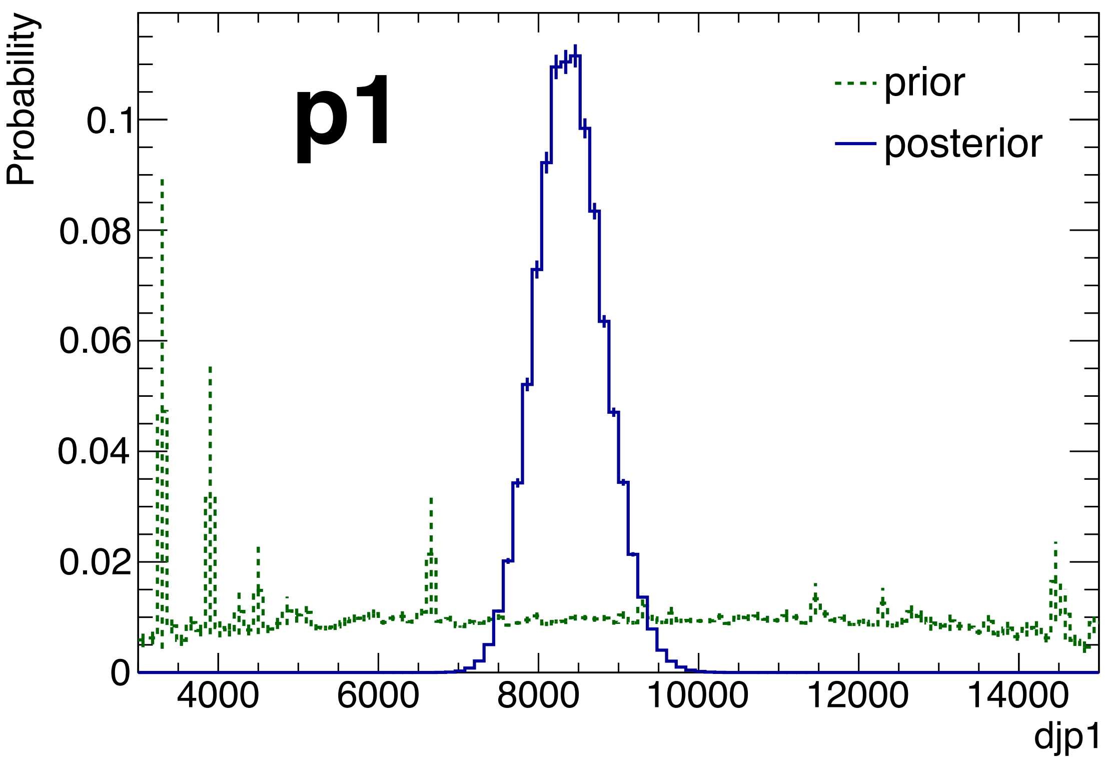
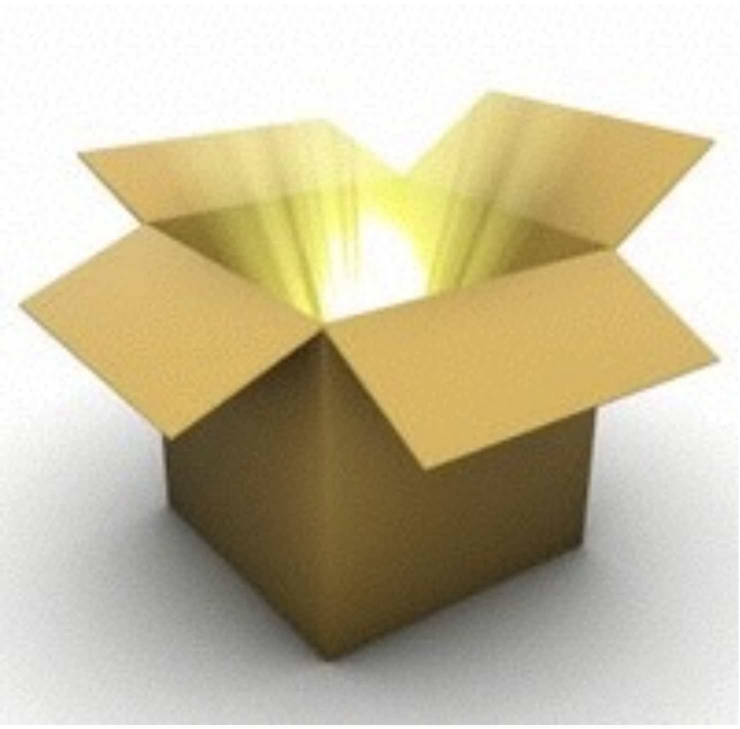


Expected limits are obtained from a serie of **pseudo-experiments**, **fluctuating the background only histogram** according to a Poisson distribution

…and opening the box

…and opening the box

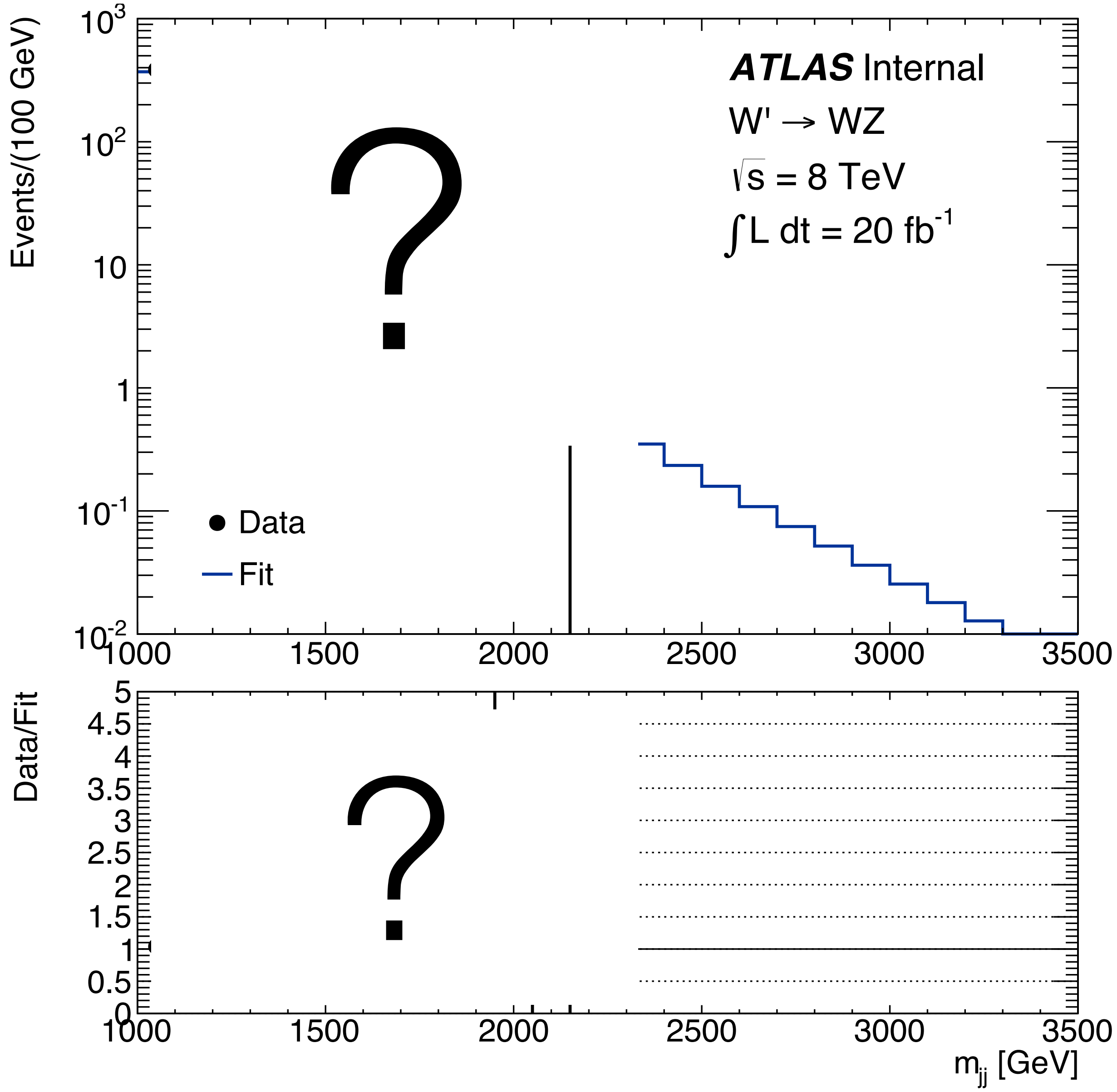


…and opening the box

Background only fit for WZ selection

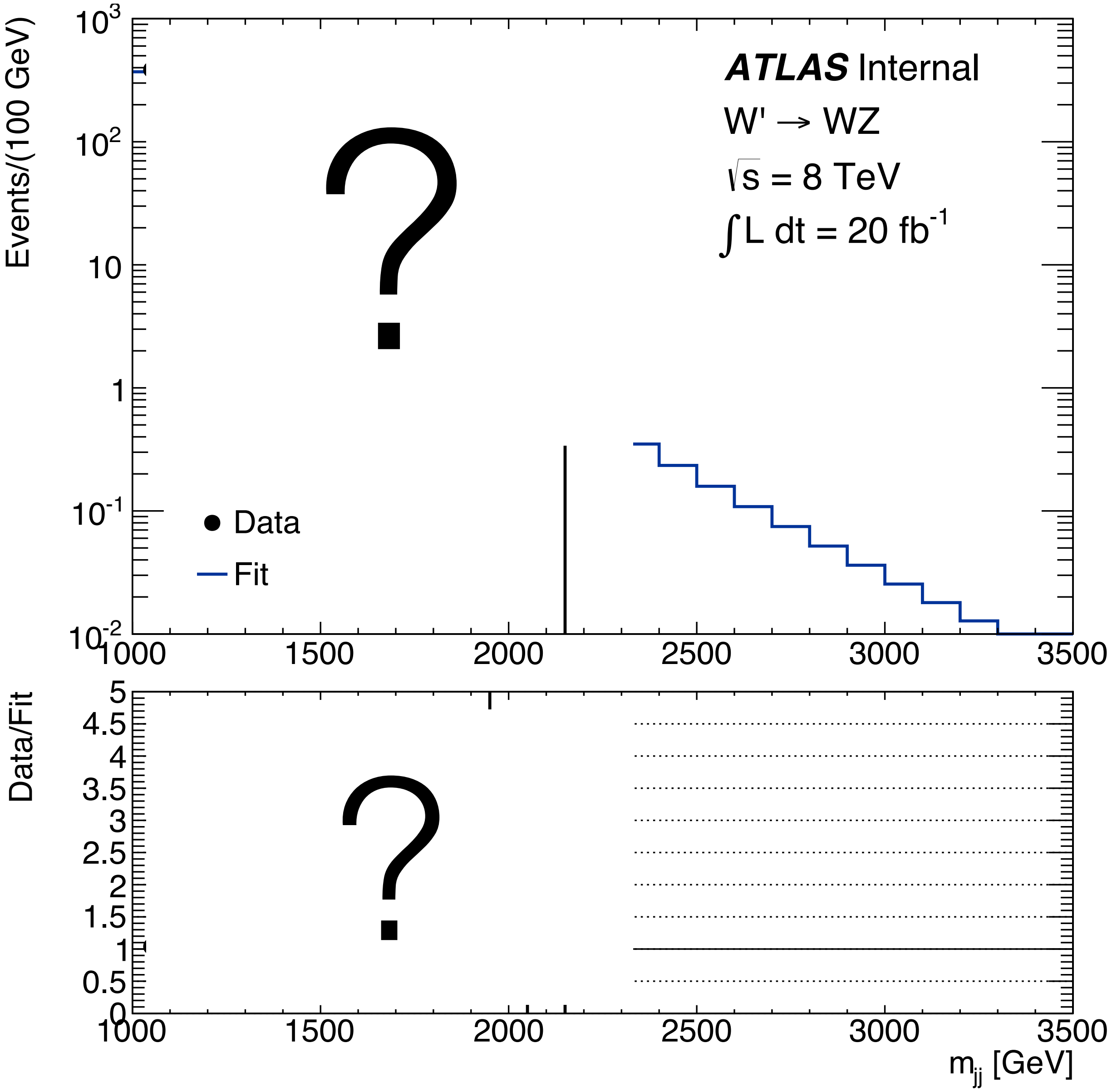
…and opening the box

Background only fit for WZ selection



…and opening the box

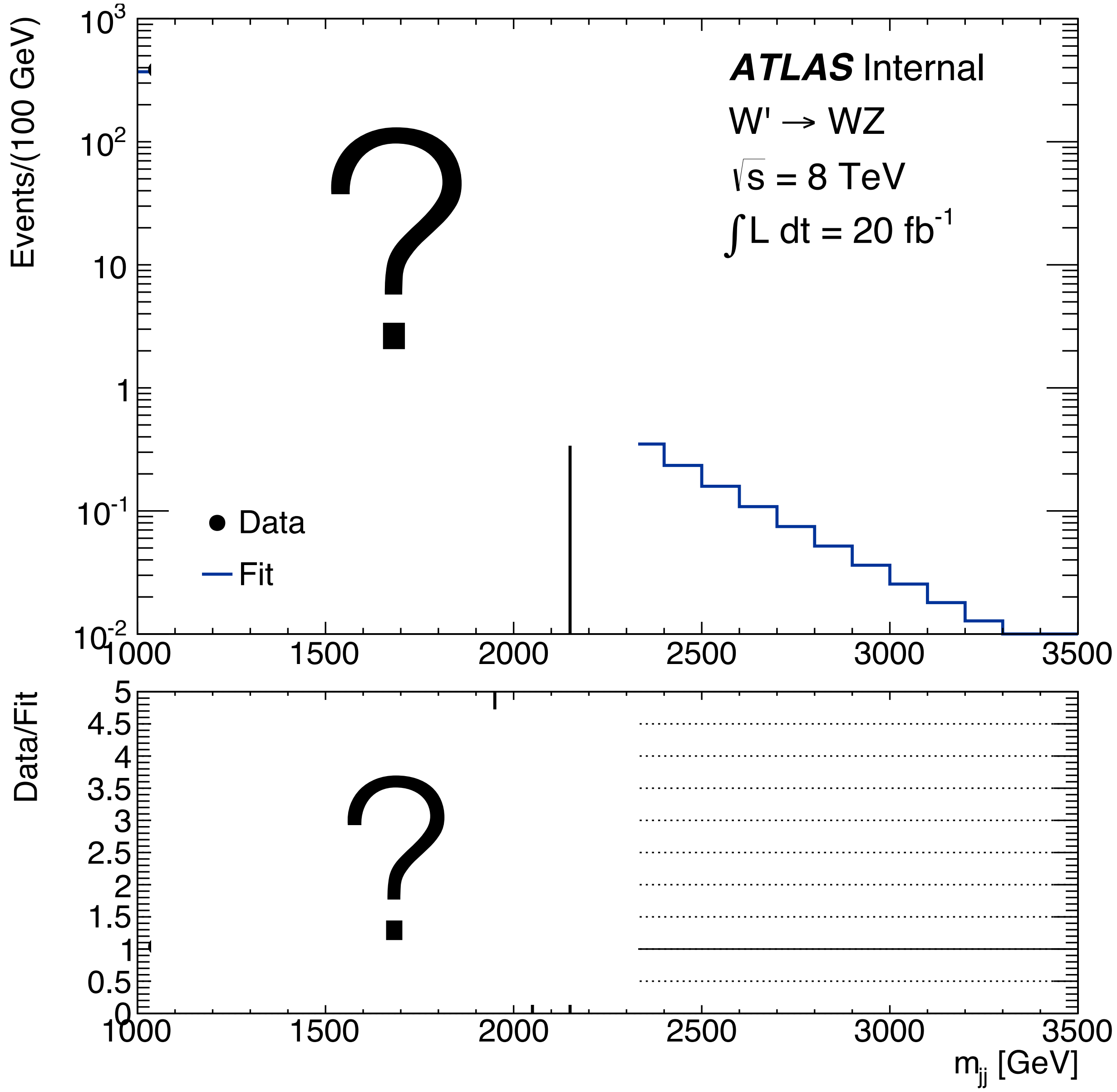
Background only fit for WZ selection



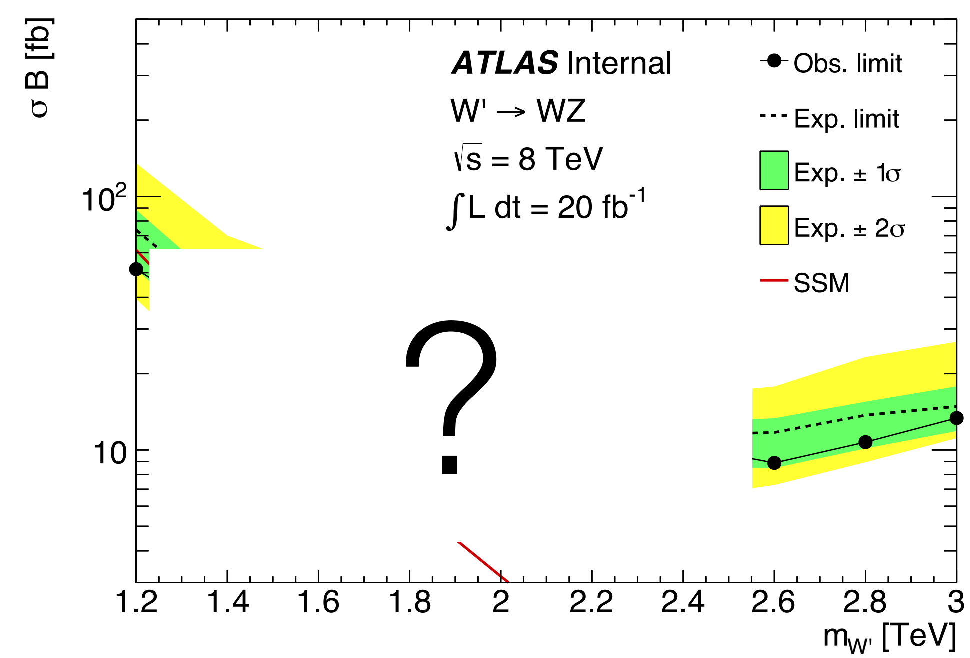
Observed limits on W'→WZ hypotesis

…and opening the box

Background only fit for WZ selection



Observed limits on W'→WZ hypotesis



Conclusions

- ➡ **LHC is a very powerful tool to investigate a new energy frontier**
- ➡ The research of **heavy resonances decaying in W/Z bosons** is a fundamental part of the ATLAS and LHC physics program
- ➡ **Full hadronic final states** are characterized by **large Branching Ratios**, but this signatures are **overwhelmed by the large QCD background**
- ➡ In the last few years the development of **jet substructure techniques significantly increased the discovery potential** of this kind of searches
- ➡ **Jet Substructure is the key of the ATLAS di-boson search in hadronic channels**
- ➡ A **very active community** of theoreticians and experimentalists is providing **new ideas and new tagging strategies**

CERN and the LHC experiments are writing part of the exciting and never-ending story of knowledge, thanks to the passion and effort of many curious scientists

Thanks a lot for your attention and again welcome to CERN

Bonus slides

Systematic Uncertainties

Systematics related to the background expectation are evaluated directly **by the background estimation procedure** using the **fit errors as uncertainties**

Luminosity Scale

Norm. Syst.

P = Probability
S = Scale Factor

$S_L = L_{int}/(20\ fb^{-1})$

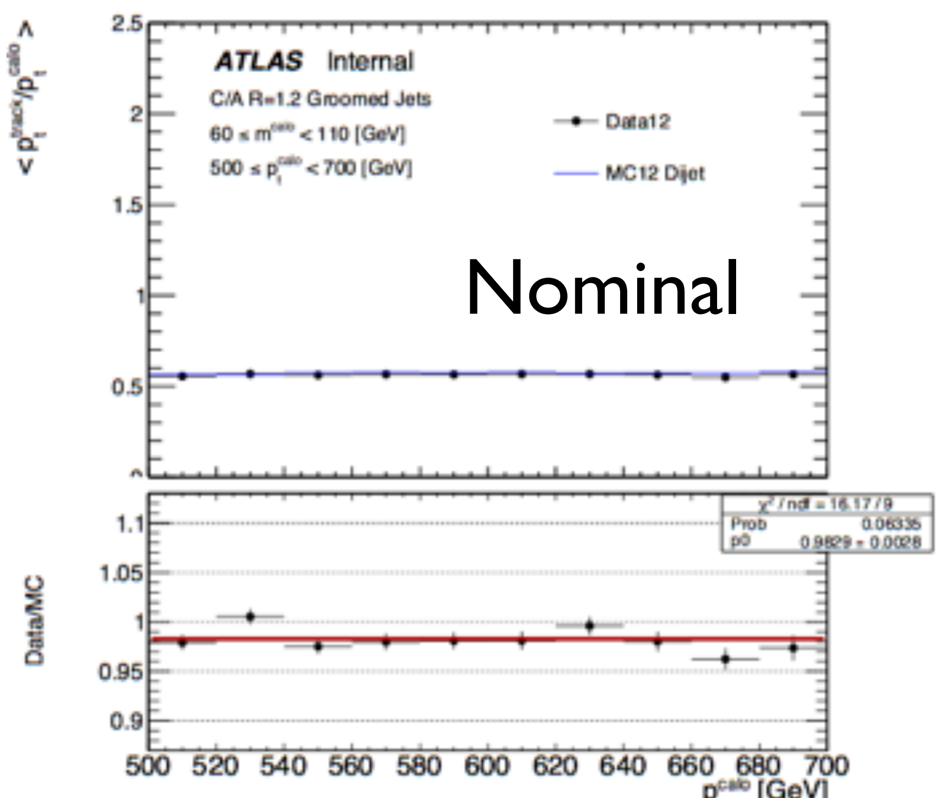
$P(S_{int}) = 1.015\ G(L_{int}|1,0.028)$

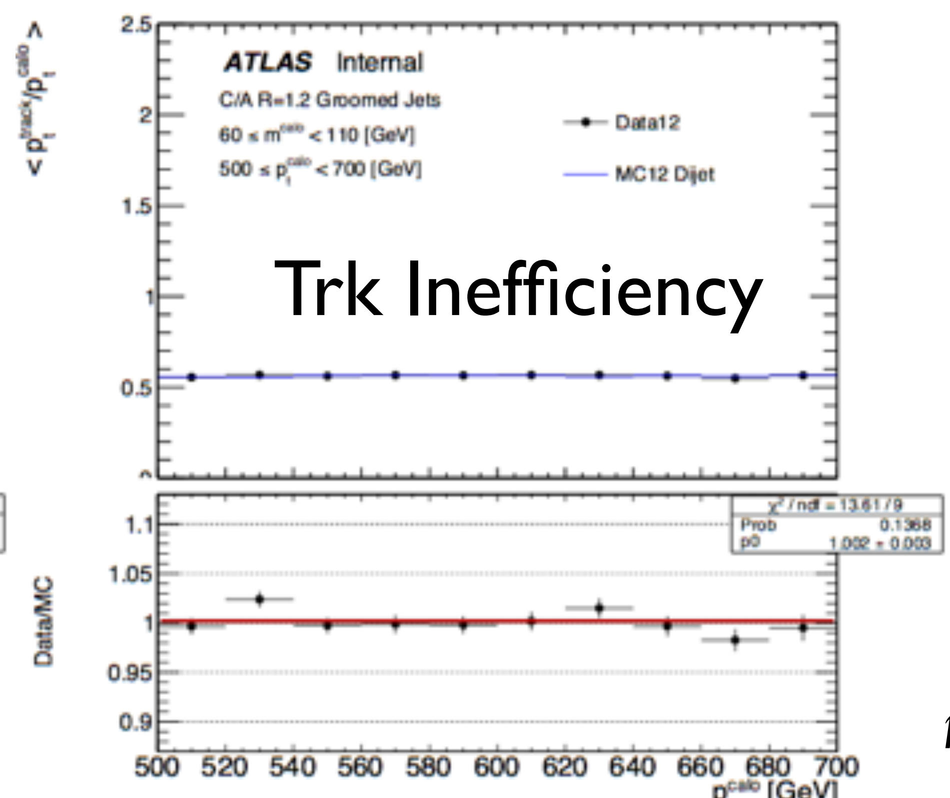
Jet Energy Scale

Important because a change in that scale moves the signal peak on a background which is rapidly falling with dijet mass

assuming that the uncertainty in jet direction is negligible

$p_t^{Data} = \alpha p_t^{MC} \rightarrow m_{jj}^{Data} = \alpha m_{jj}^{MC}$





Shape Syst.

2 % uncertainty

$P(\alpha) = G(\alpha|1,0.02)$

Calo-Track Double Ratio

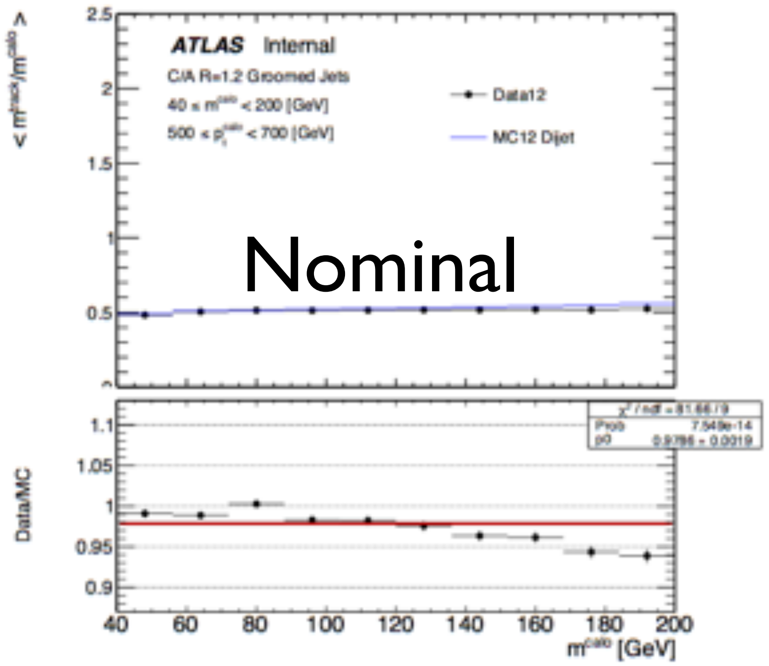
Inner detector and calorimeter have uncorrelated uncertainties

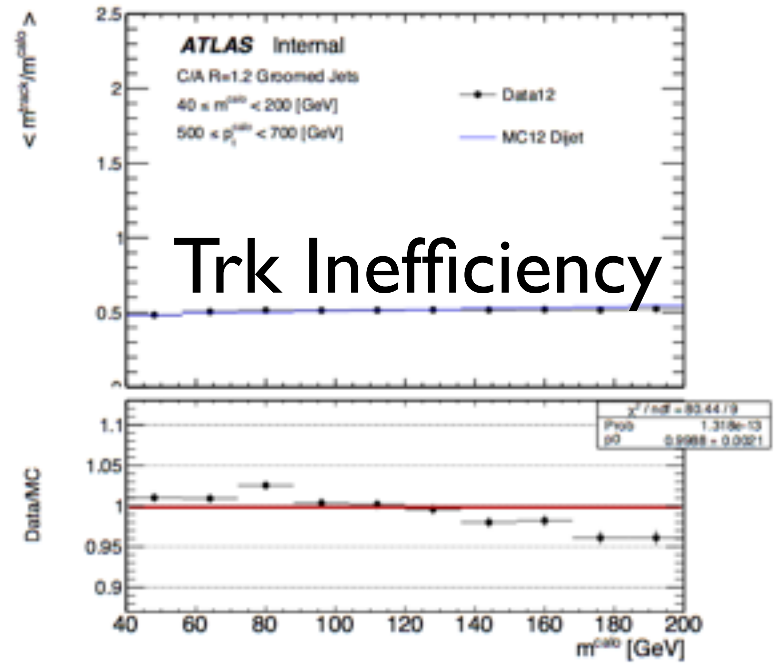
probe detector modeling effects in Data and MC

Systematic Uncertainties (2)

Jet Mass Scale

Calo-Track double ratio used also in this case





$m_j^{Data} = \alpha_m m_j^{MC}$

Shape+Norm. Syst.

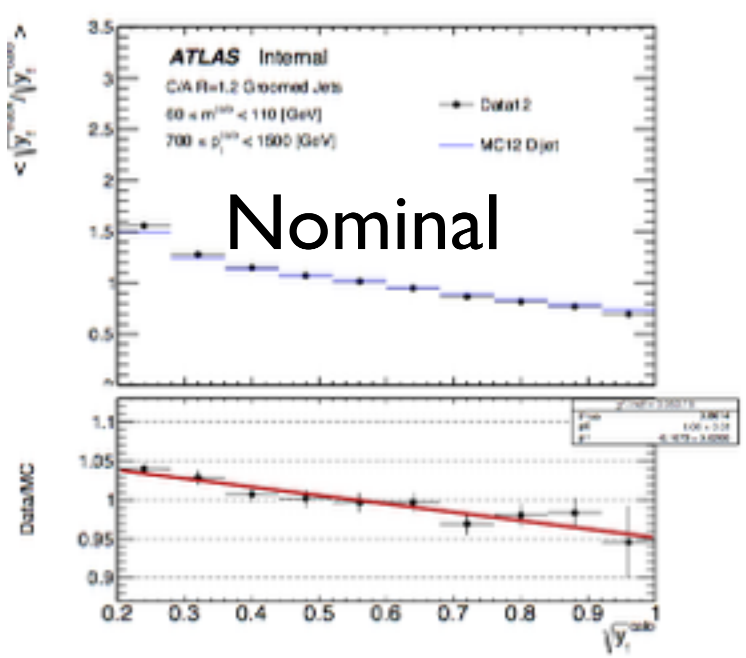
3 % uncertainty

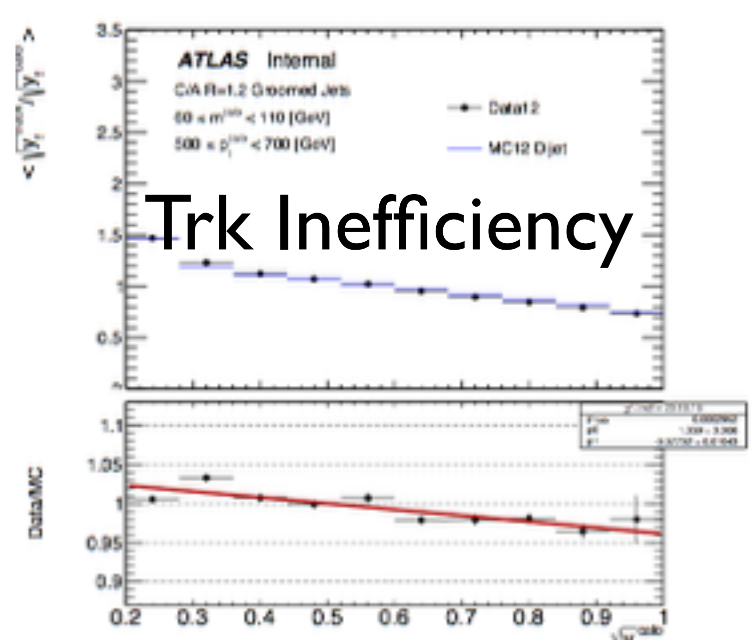
$P(\alpha_m) = G(\alpha_m | 1, 0.03)$

Also checked in V+Jet sample

Jet Momentum Balance Scale ($\sqrt{y_f}$)

Calo-Track double ratio used also in this case





$\sqrt{y_f}^{Data} = \alpha_y \sqrt{y_f}^{MC}$

Norm. Syst.

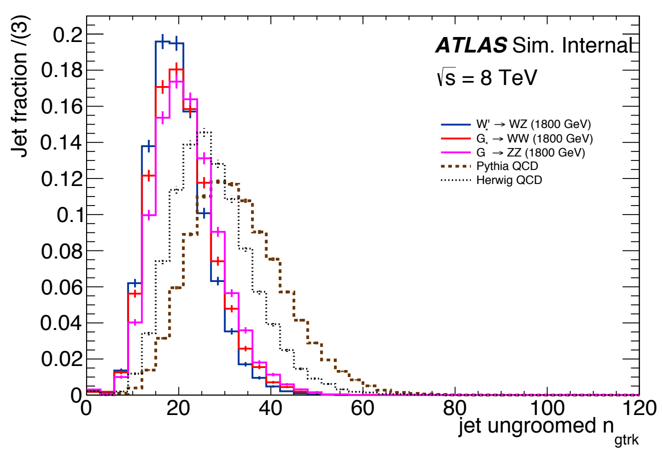
2 % uncertainty

$P(\alpha_y) = G(\alpha_y | 1, 0.02)$

Systematic Uncertainties (3)

Norm. Syst.

Track-multiplicity efficiency

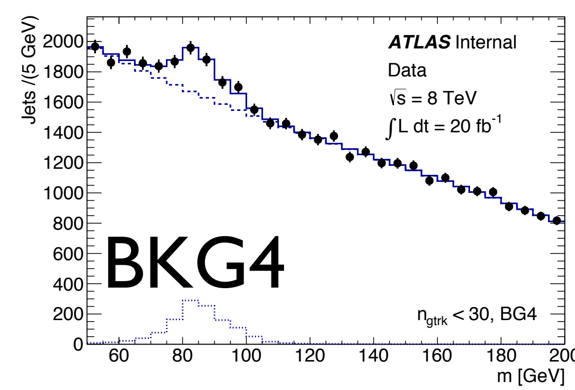


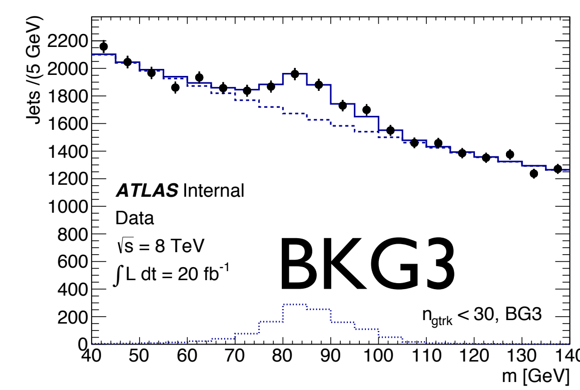
Unfortunately there is **big discrepancy in the predictions for different generators**, especially for the background

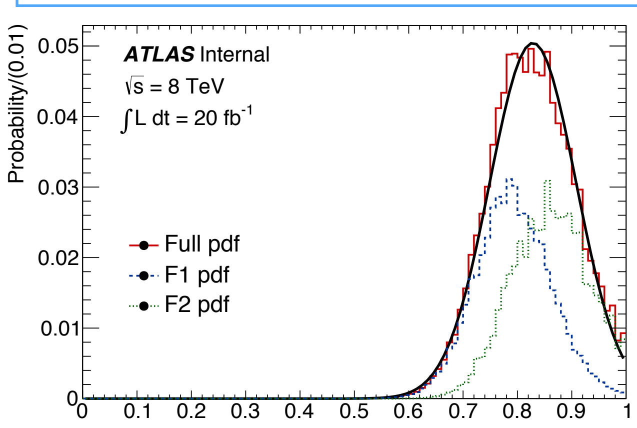
V+Jets data samples to evaluate this efficiency

Signal + Bkg bayesian fits to get the **signal strength posterior** and then the efficiency of the cut

2 bkg models







Efficiency distributions for n_{trk}<30

$P(S_T)=G_t(0.89,0.095,1.07)$ from V+Jets

$G_t(\mu, \sigma, x_{max})$ is Gaussian with mean μ and RMS σ truncated at 0 and x_{max}

Summary of Systematics

Systematics on Resolutions

- **Jet Energy Resolution**: 20 % uncertainty over the nominal JER (recommended by Jet Substructure for large-R jets). Nominal 5 % JER derived based on the width of energy response for MC signal after tagging.
- **Jet Mass Resolution**: 20 % uncertainty over the nominal JMR (recommended by Jet Substructure for large-R jets). Nominal 7.5 % JMR extracted from the width of W/Z mass shape in a control sample.
- **Subjet Momentum Balance ($\sqrt{y_f}$) Resolution**: 20 % uncertainty over the nominal $\sqrt{y_f}$ Resolution. Nominal 16 % $\sqrt{y_f}$ Resolution extracted from response of momentum balance in MC for signal jets.

All the systematics uncertainties and their models

Systematic	pdf
Luminosity	$G(S_{\rm L}\,|\,1, 0.028)$
Jet energy scale	$G(\alpha\,|\,1, 0.02)$
Jet energy resolution (additional smearing)	$G(\sigma_E|\,0, 0.05\times\sqrt{1.2^2-1^2})$
Jet mass scale	$G(\alpha_m\,|\,1, 0.03)$
Jet mass resolution (additional smearing)	$G(\sigma_m|\,0, 0.075\times\sqrt{1.2^2-1^2})$
Momentum balance scale	$G(\alpha_y\,|\,1, 0.02)$
Momentum balance resolution (additional smearing)	$G(\sigma_y,|\,0, 0.16\times\sqrt{1.2^2-1^2})$
Track-multiplicity efficiency	$G_{\rm t}(S_{\rm t}|\,0.89, 0.095, 1.07)$
Parton shower	$G(1.0, 0.05)$

Uncertainty on **parton showering model** is evaluated **comparing the signal efficiencies after the full event selection (excluding n_{trk})** obtained using **Pythia** and **Herwig** samples

Systematics Evaluation with double-ratio technique

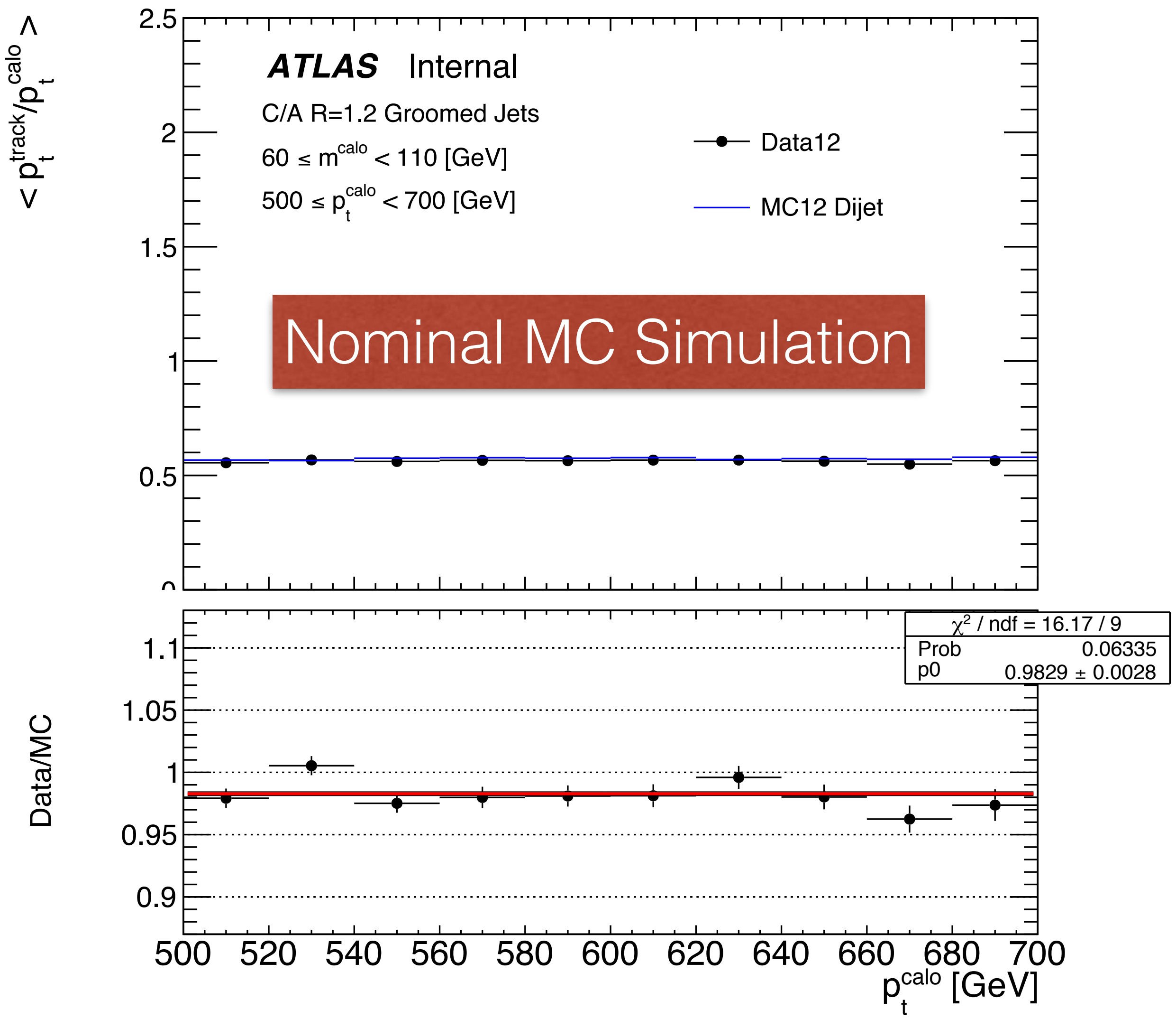
For both **Data** and **MC**

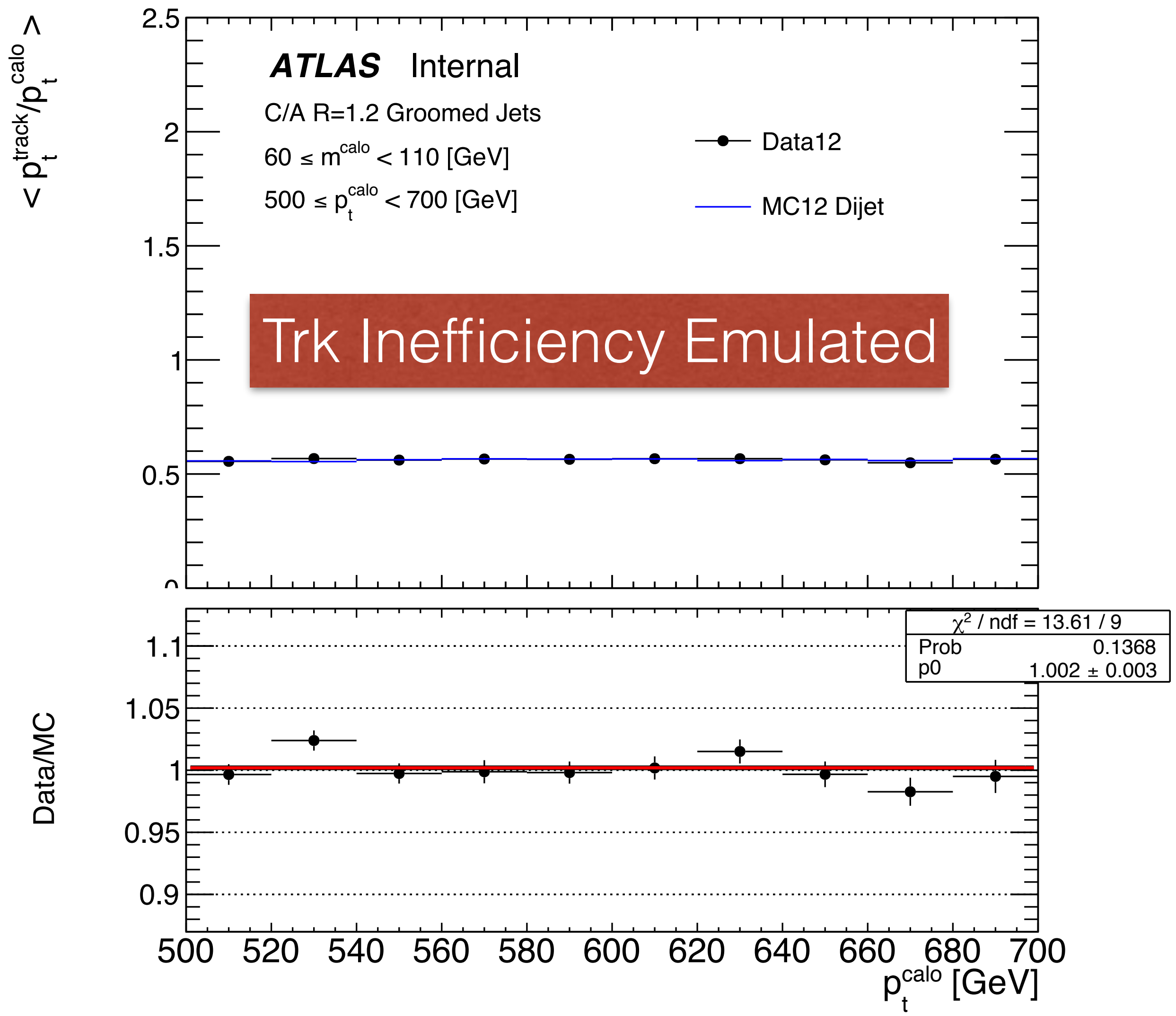
- Divide the **phase-space in bins of p_T,η,m and $\sqrt{y_f}$**
- **In each bin of the phases-pace** and for each leading reconstructed **calorimeter jet**, ask for a **matching ($\Delta R<0.3$ and $|dr12_{calo}-dr12_{Trk}|<0.1$)** with a reconstructed **track jet**
- For each variable X (i.e. p_T,mass and $\sqrt{y_f}$) produce the binned distribution of X_{trk}/X_{calo}
- **Get the mean of the distribution**

$$\frac{\left\langle \frac{X_{trk}}{X_{calo}} \right\rangle_{Data}}{\left\langle \frac{X_{trk}}{X_{calo}} \right\rangle_{MC}}$$

*If a **detector effect** has **not** been correctly taken into account **in the MC simulation**, it can produce a **deviation from one of the double-ratio***

Systematics Evaluation with double ratio technique - In VV→JJ Analysis





An average ***2 % inefficiency in the ID-track reconstruction*** *was observed but* ***not included in the MC simulation***

- **Definition of our Boson-Tagging Cuts relies on Pythia MC simulation**
- **If the tracking inefficiency is correctly taken into account the double-ratio deviation from one is recovered**

Deviation from "one" observed using the nominal MC simulation is considered as systematic uncertainty

Last ingredient - **Statistical Analysis**

For counting experiment the likelihood is: $\mathcal{L}(\mathbf{n}_{\text{obs}}|\mathbf{n}_{\text{exp}}) = \prod_i P_{\text{pois}}(n^i_{\text{exp}}, n^i_{\text{obs}})$

$$P_{\text{pois}}(\lambda, n) = \frac{\lambda^n e^{-\lambda}}{n!}$$

n : n_{observed} counts
λ : n_{expected}

→ $\mathbf{n}_{\text{exp}} = \mathbf{n}_{\text{sig}} + \mathbf{n}_{\text{bg}}$

$\mathbf{n}_{\text{observed}}$ function of dijet bkg parameters $\mathbf{B}_{\text{NP}}$=$\{\mathbf{p}_1,\mathbf{p}_2,\mathbf{p}_3\}$ → $\mathbf{n}_{\text{exp}}$

$\mathbf{n}_{\text{sig}} = \boldsymbol{\mu} \mathbf{n}_{\text{SSM}}$ assuming model hypothesis (MH) signal strength → **μ = 1** : MH prediction; **μ = 0** : SM prediction

we can replace $\mathbf{n}_{\text{exp}}$ with the full set of parameters **T={μ,B$_{\text{NP}}$,S$_{\text{NP}}$}**

Applying the Bayes theorem

$$P_{\text{post}}(\mathbf{T}) = K\, \mathcal{L}(\mathbf{n}_{\text{obs}}|\mathbf{T})\, P_{\text{prior}}(\mathbf{T})$$

The systematics are included in the priors for the Nuisance Parameters

Param.	pdf	Meaning
μ	flat	Signal strength relative to SSM
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S_{L}	$G(S_{\text{L}}\,\|\,1, 0.028)$	Integrated luminosity SF
α	$G(\alpha\,\|\,1, 0.02)$	Jet p_{T} (m_{jj}) scale
σ_E	$G(\sigma_E\|0, 0.0t \times \sqrt{1.2^2 - 1})$	Jet p_{T} resolution (additional smearing)
α_m	$G(\alpha_m\,\|\,1, 0.03)$	Jet mass scale
σ_m	$G(\sigma_m\|0, 0.075 \times \sqrt{1.2^2 - 1})$	Jet mass resolution (additional smearing)
α_y	$G(\alpha_y\,\|\,1, 0.02)$	Jet momentum balance ($\sqrt{y_{\text{f}}}$) scale
σ_y	$G(\sigma_y\|0, 0.16 \times \sqrt{1.2^2 - 1})$	Momentum balance resolution (additional smearing)
S_{t}	$G_{\text{t}}(S_{\text{t}}\|0.89, 0.095, 1.07)$	Track multiplicity SF
S_{ps}	$G(1.0, 0.05)$	Parton Showering uncertainty SF

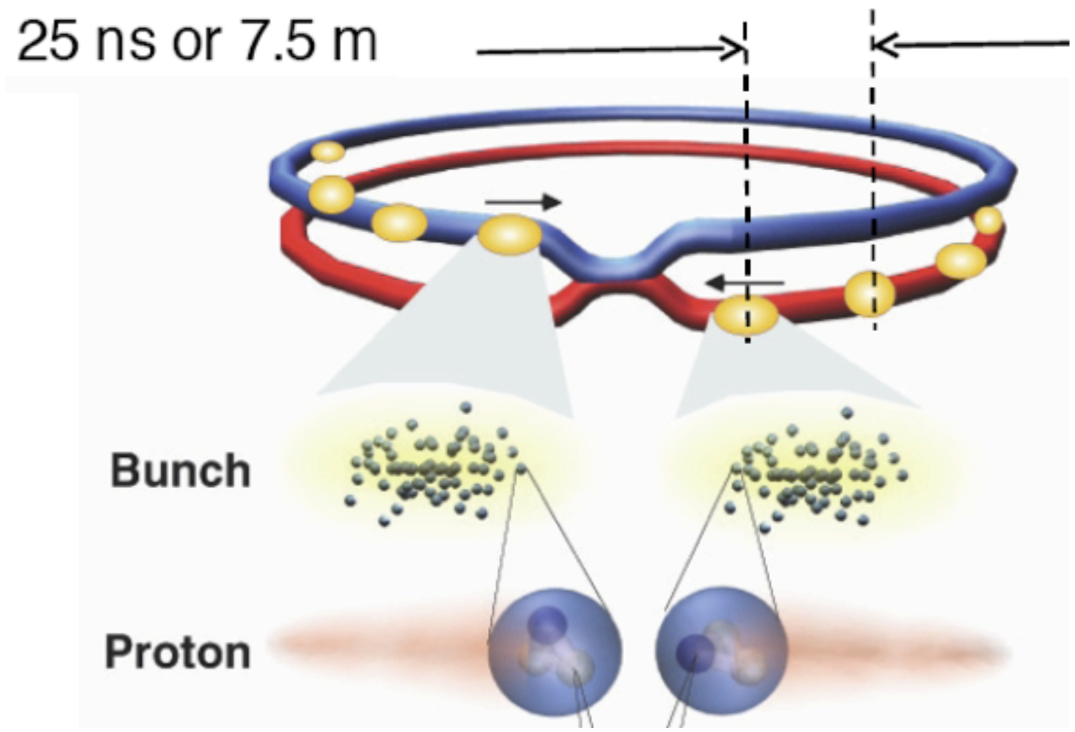
Expected limits are obtained from a serie of **pseudo-experiments**, **fluctuating the background only histogram** according to a Poisson distribution

Background parameters

- Constrains on prior to avoid unphysical scenarios: $\mathbf{p_2+p_9p_3>0}$, $\mathbf{p_3<0}$
- Parameter **C** is a function of **p1** and $\mathbf{p_9}$ is adjusted by hand to minimize the posterior correlations and then increase the sampling efficiency

The LHC Collider

The LHC Collider



Design Performances

- Proton-Proton ☛ 2808 bunch/beam
- Centre of Mass Energy ☛ 14 TeV
- Instantaneous Luminosity ☛ 10^{34} cm^{-2} s^{-1}
- Crossing rate ☛ 40 MHz

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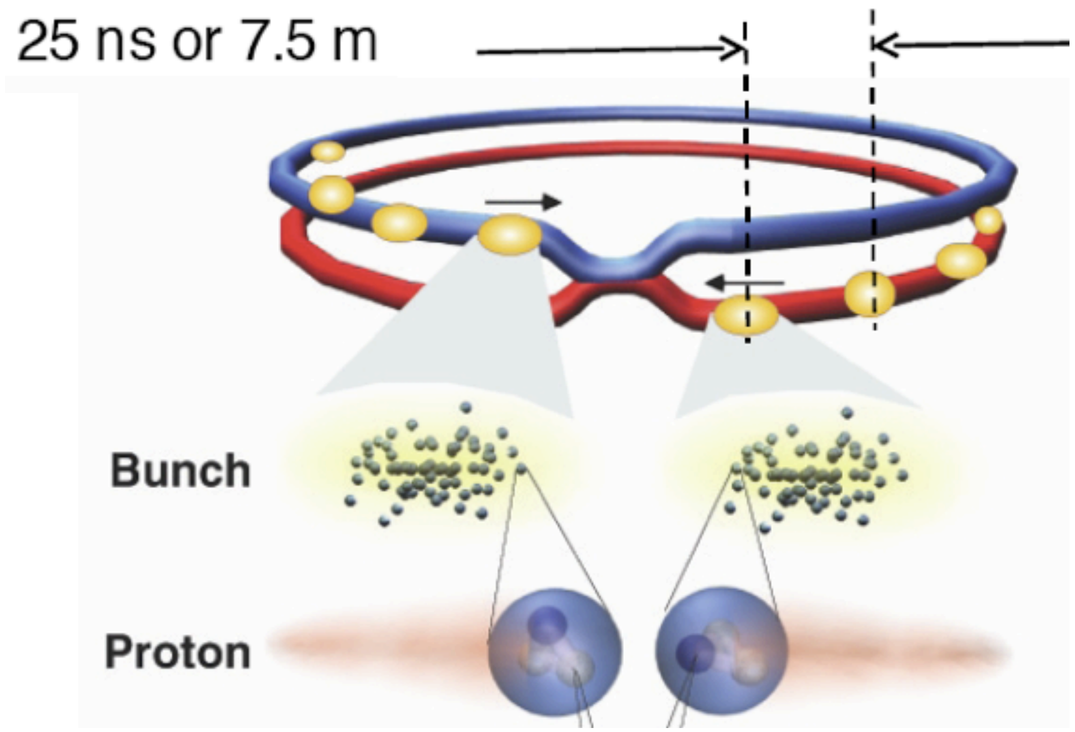

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From 30 of March 2010 -> 7 TeV P-P Collisions

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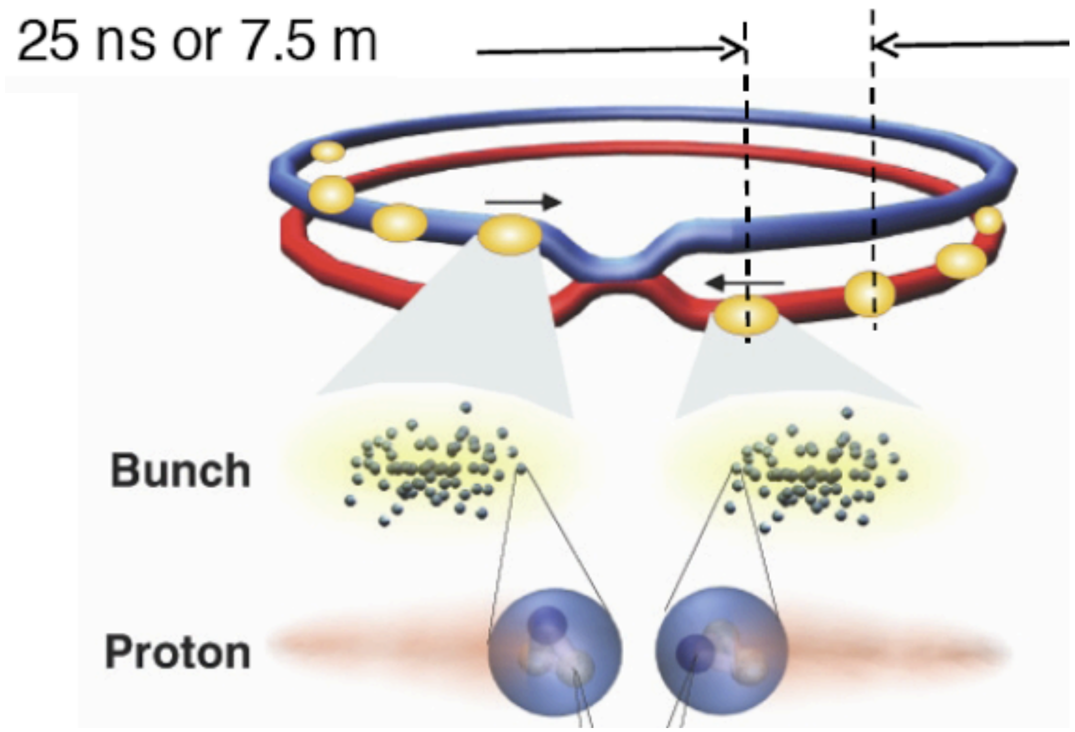

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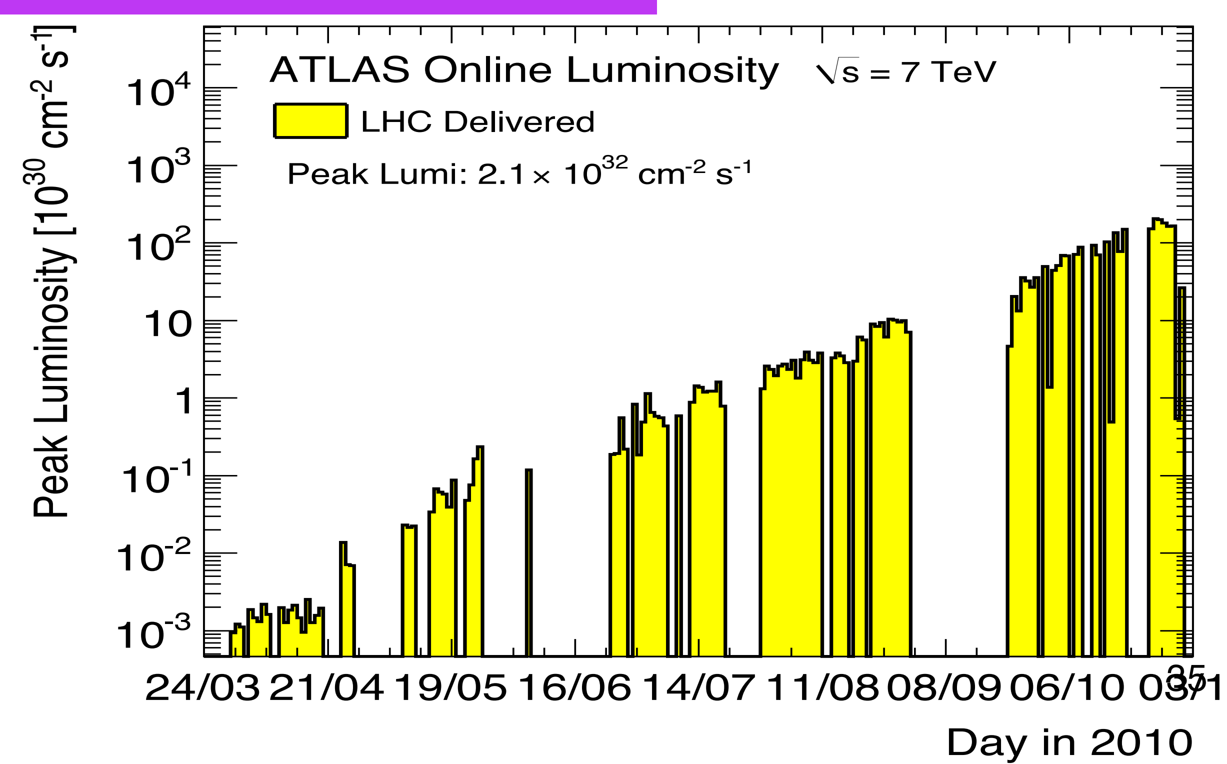
From 30 of March 2010 -> 7 TeV P-P Collisions

Actual Perfomance (Goal 2010!)

- Centre of Mass Energy ☛ 7 TeV
- Instantaneous Luminosity ☛ 2.1 x 10^{32} cm^{-2} s^{-1}



The ATLAS Physics Goals

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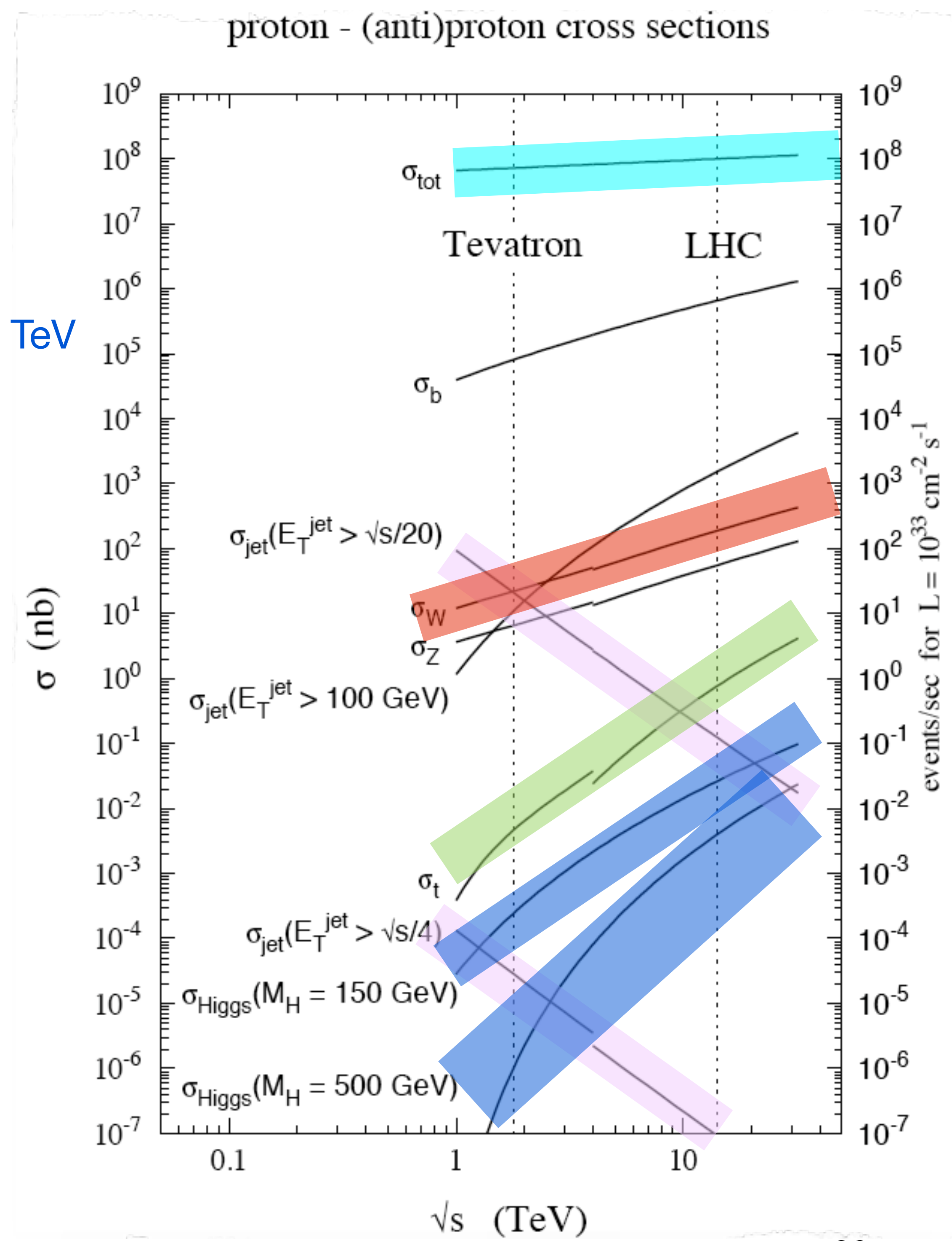
Precise SM measurements:

- QCD jet cross sections and α_s
- W mass
- Top quark (factory!): mass, couplings and decay properties
- Search for Standard Model Higgs boson in the range ≈ 115 GeV ≤ m_H ≤ 1 TeV



$\sigma_{pp} \approx 100$ mb

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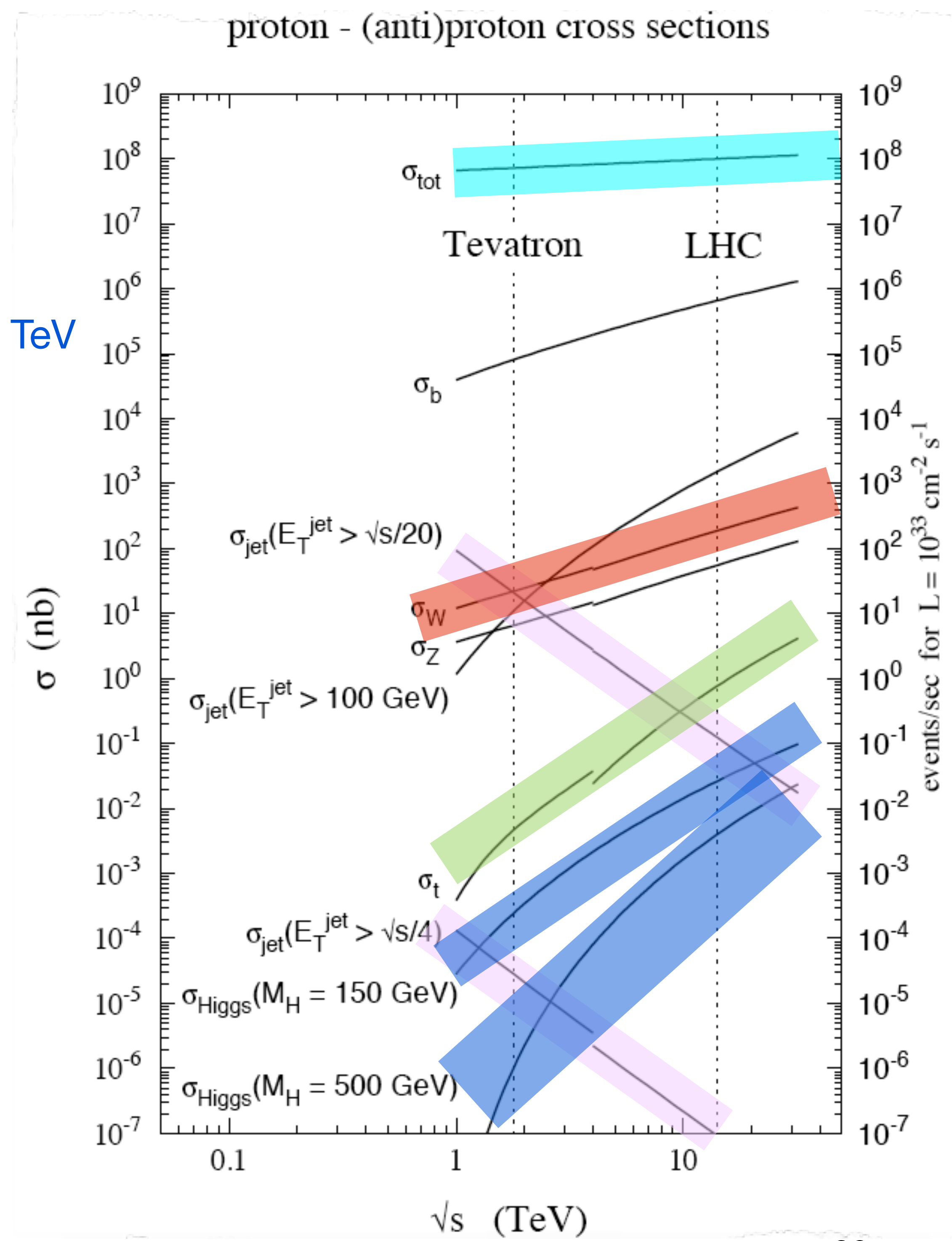

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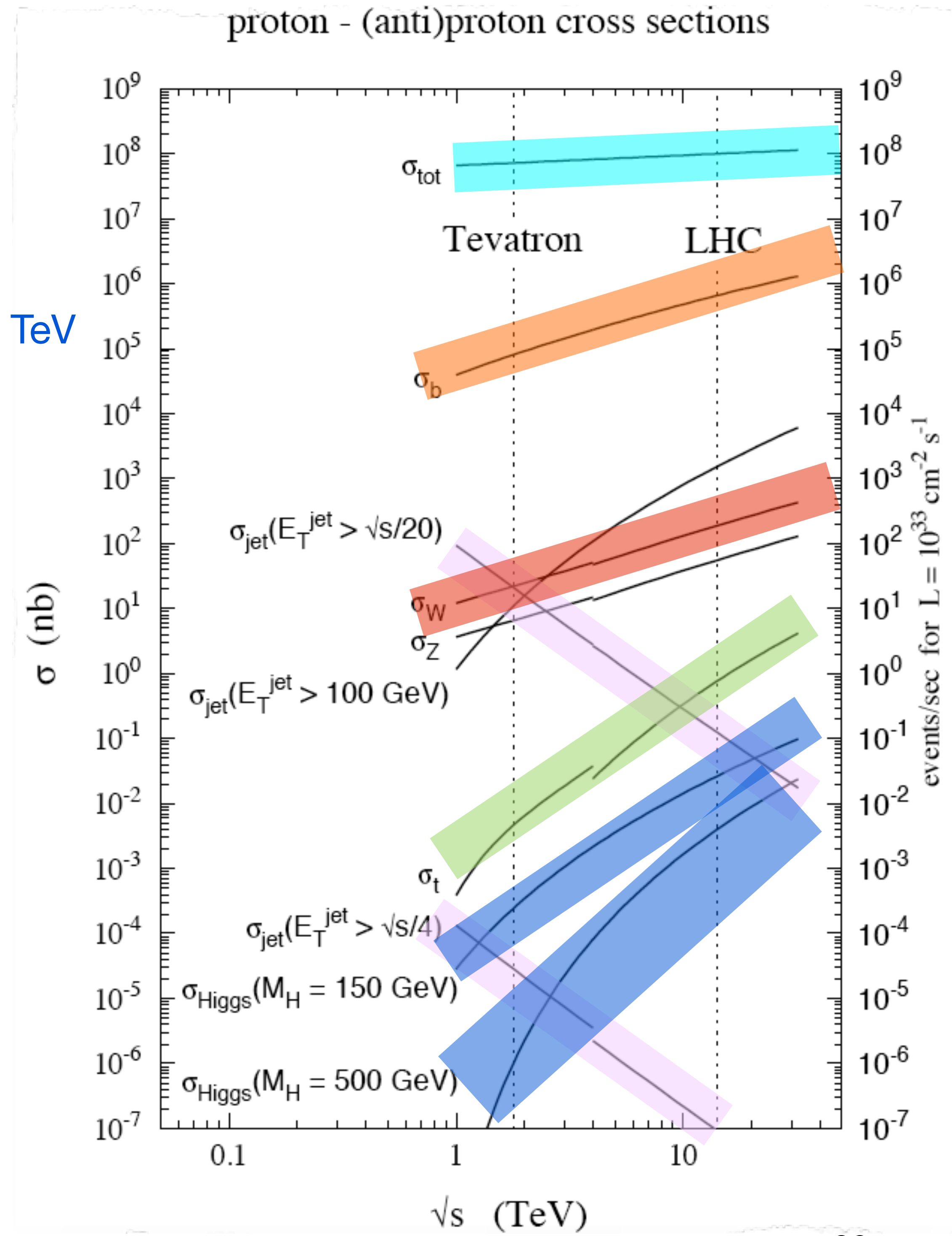
- Explore the highly-motivated TeV-scale (SUSY, Extra-dimensions, W'/Z',...)



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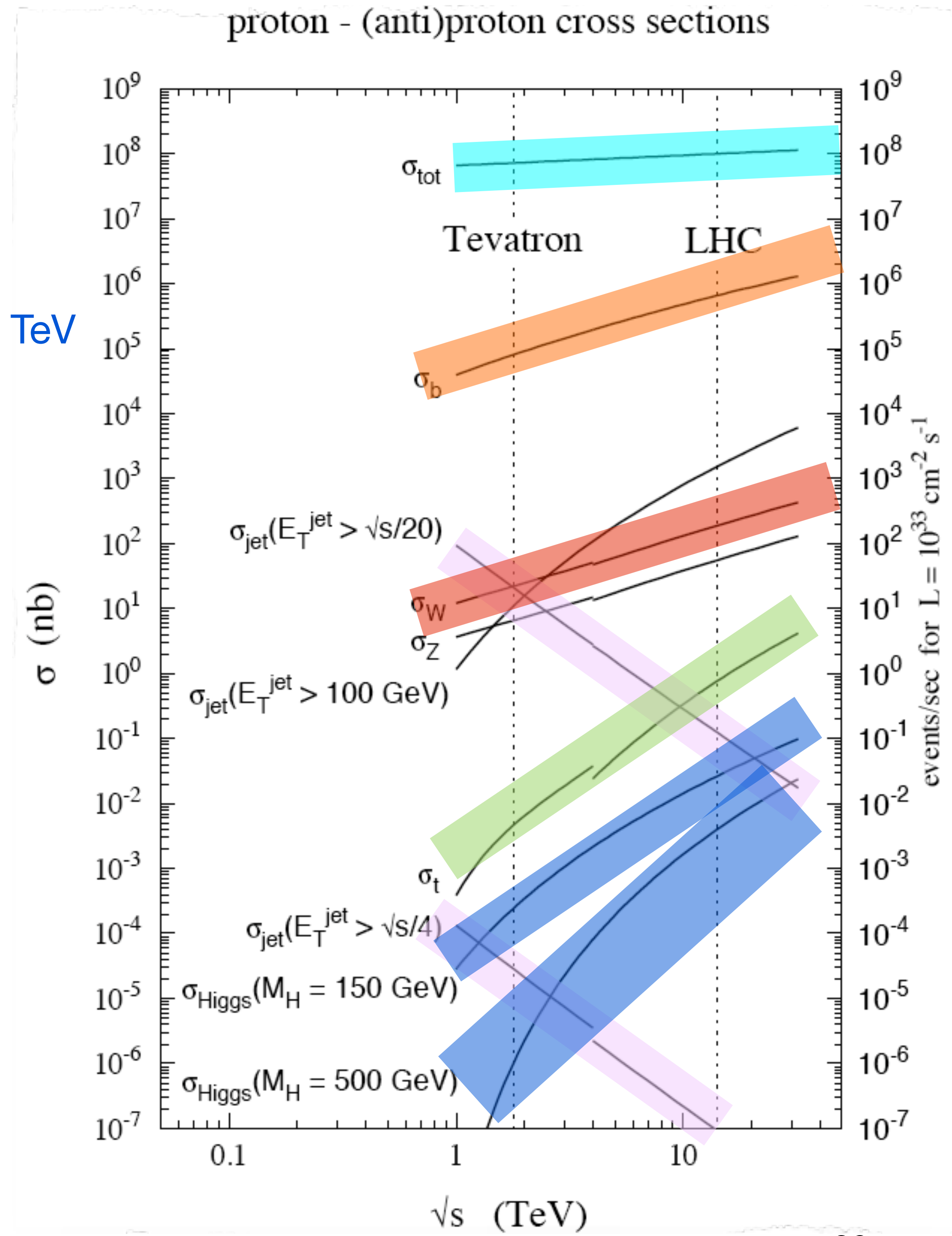
Heavy ions:

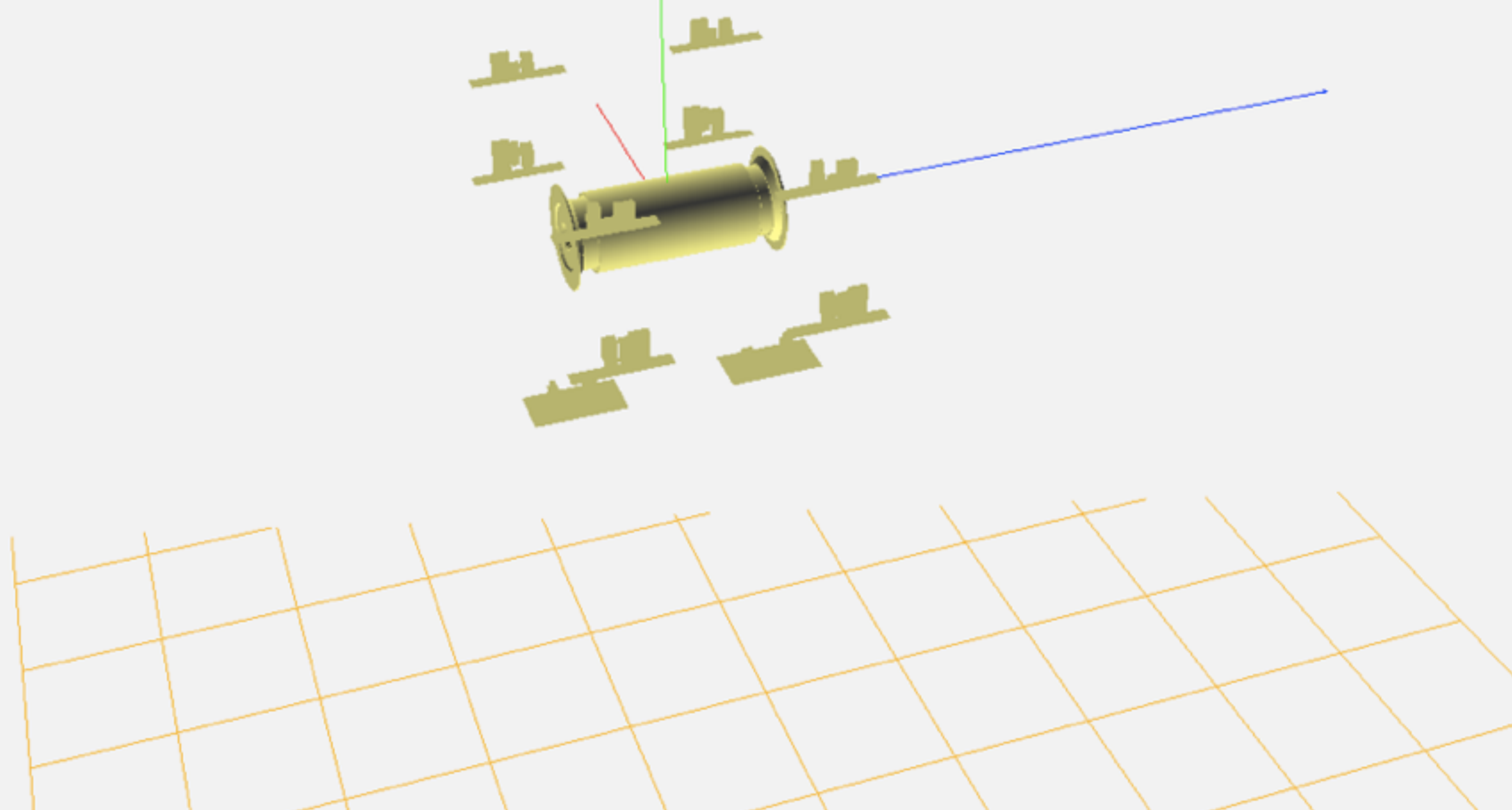
- Phase transition from hadronic matter to quark-gluon plasma

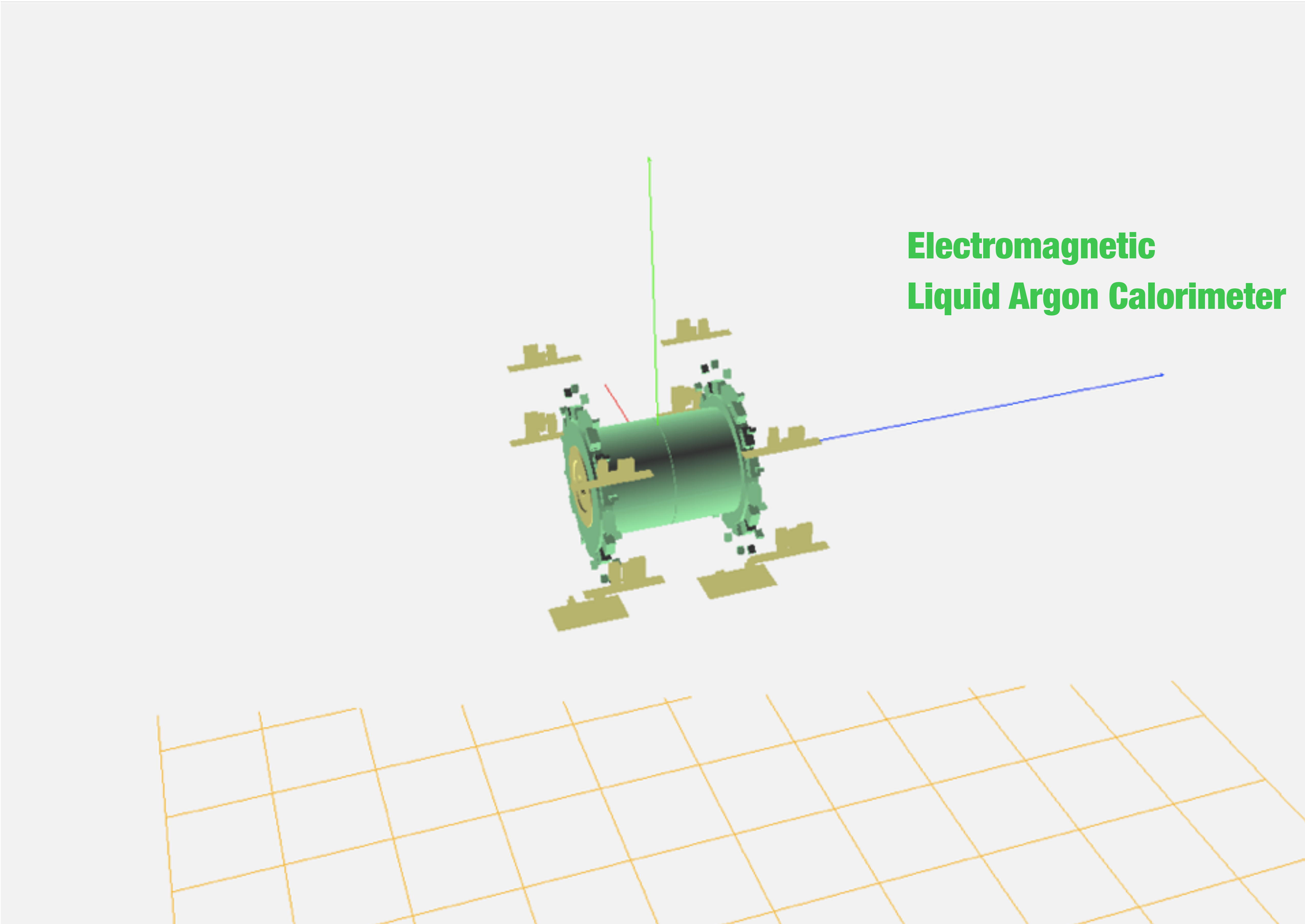
$\sigma_{pp} \approx 100$ mb

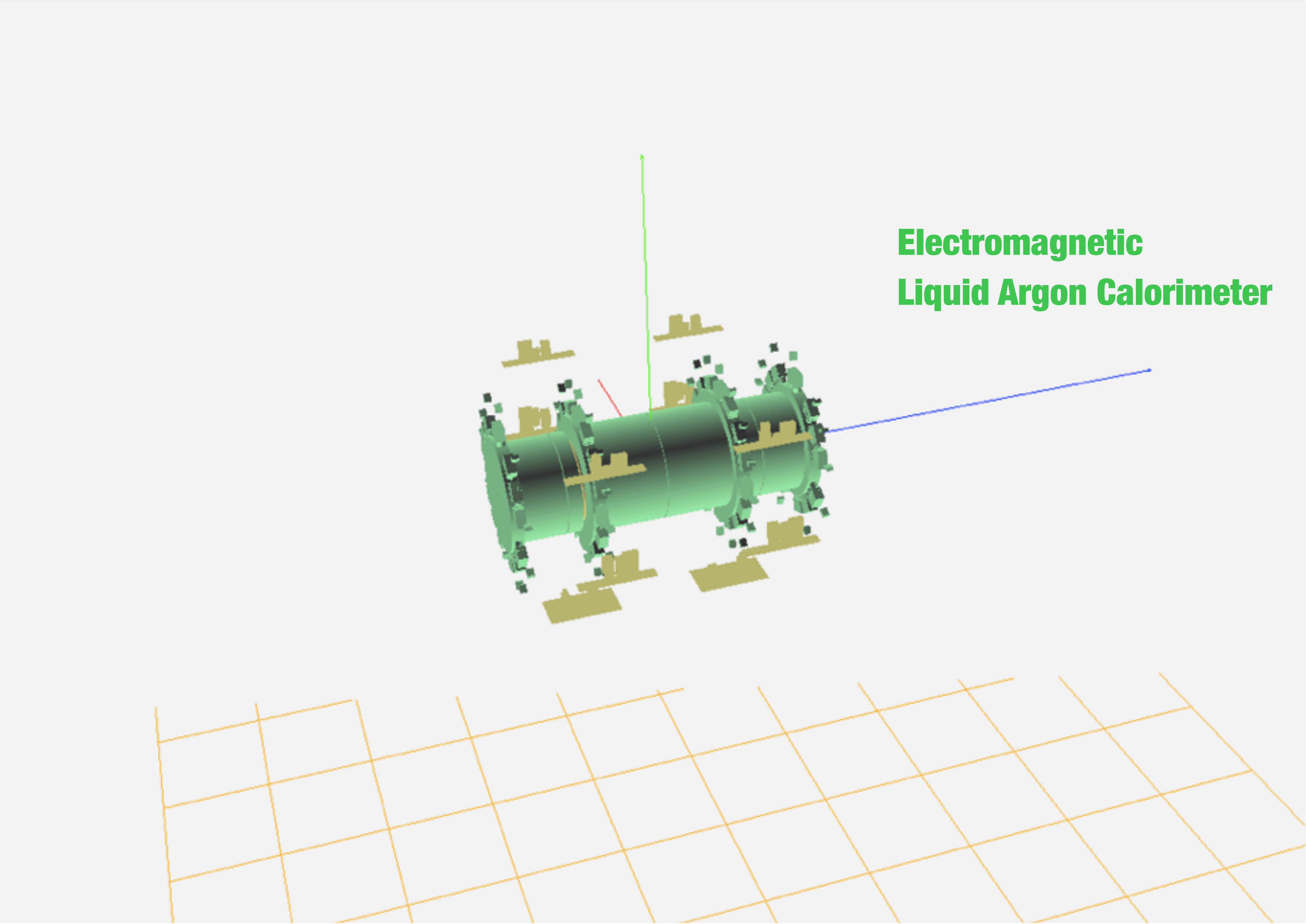


Inner Tracker 3 Detector

- *Pixel*
- *Silicon*
- *Transition radiation*




Electromagnetic
Liquid Argon Calorimeter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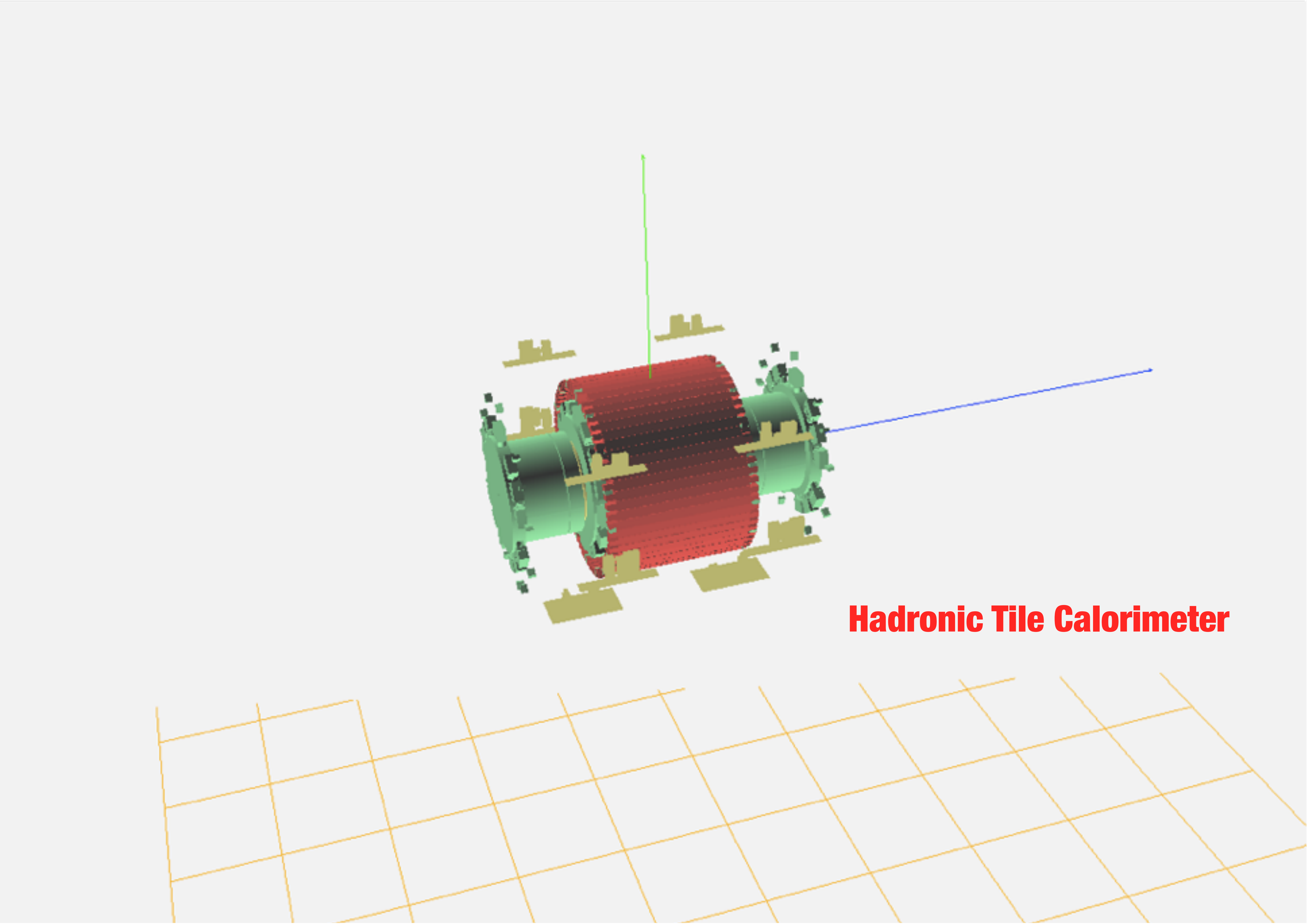
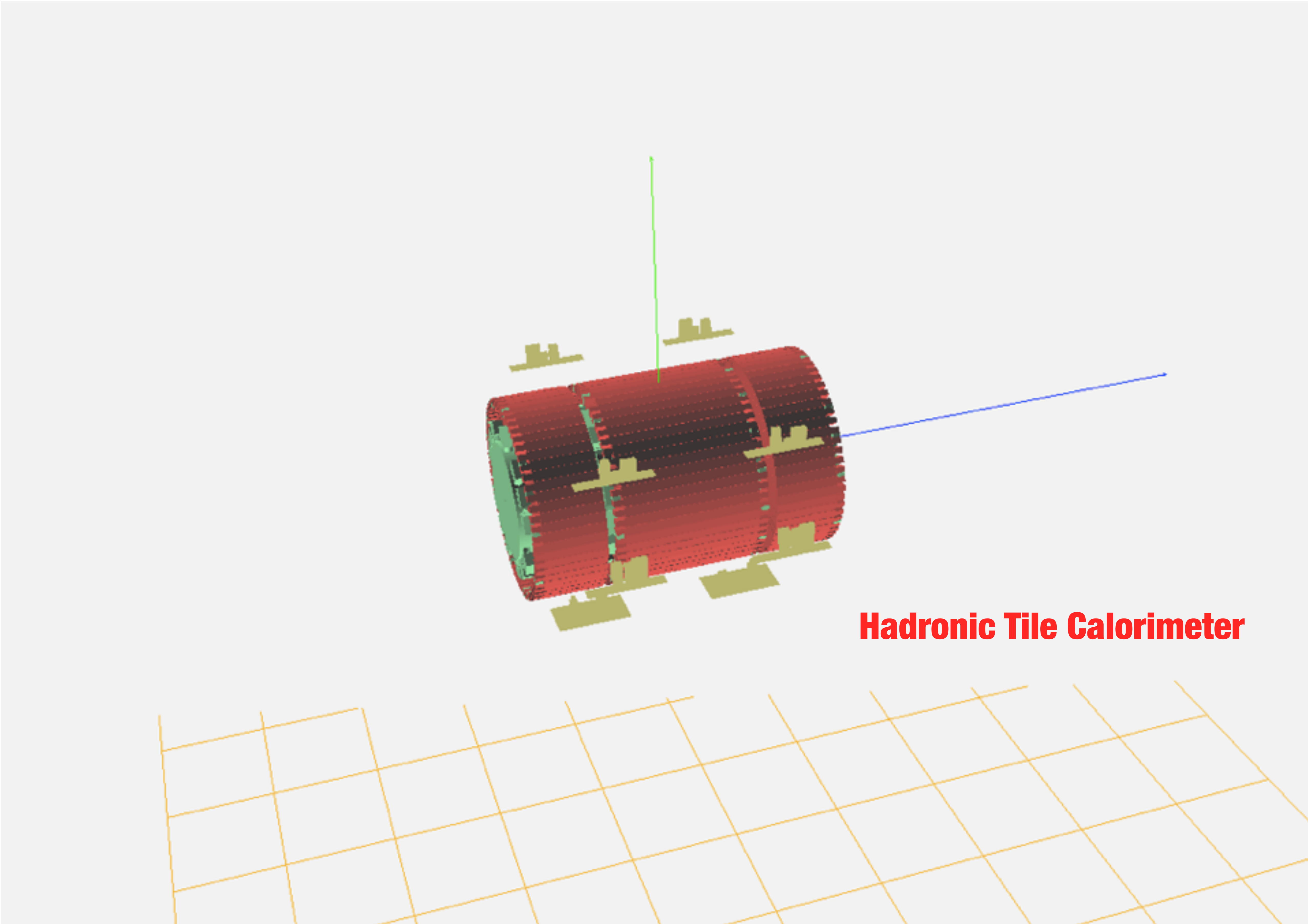

Hadronic Tile Calorimeter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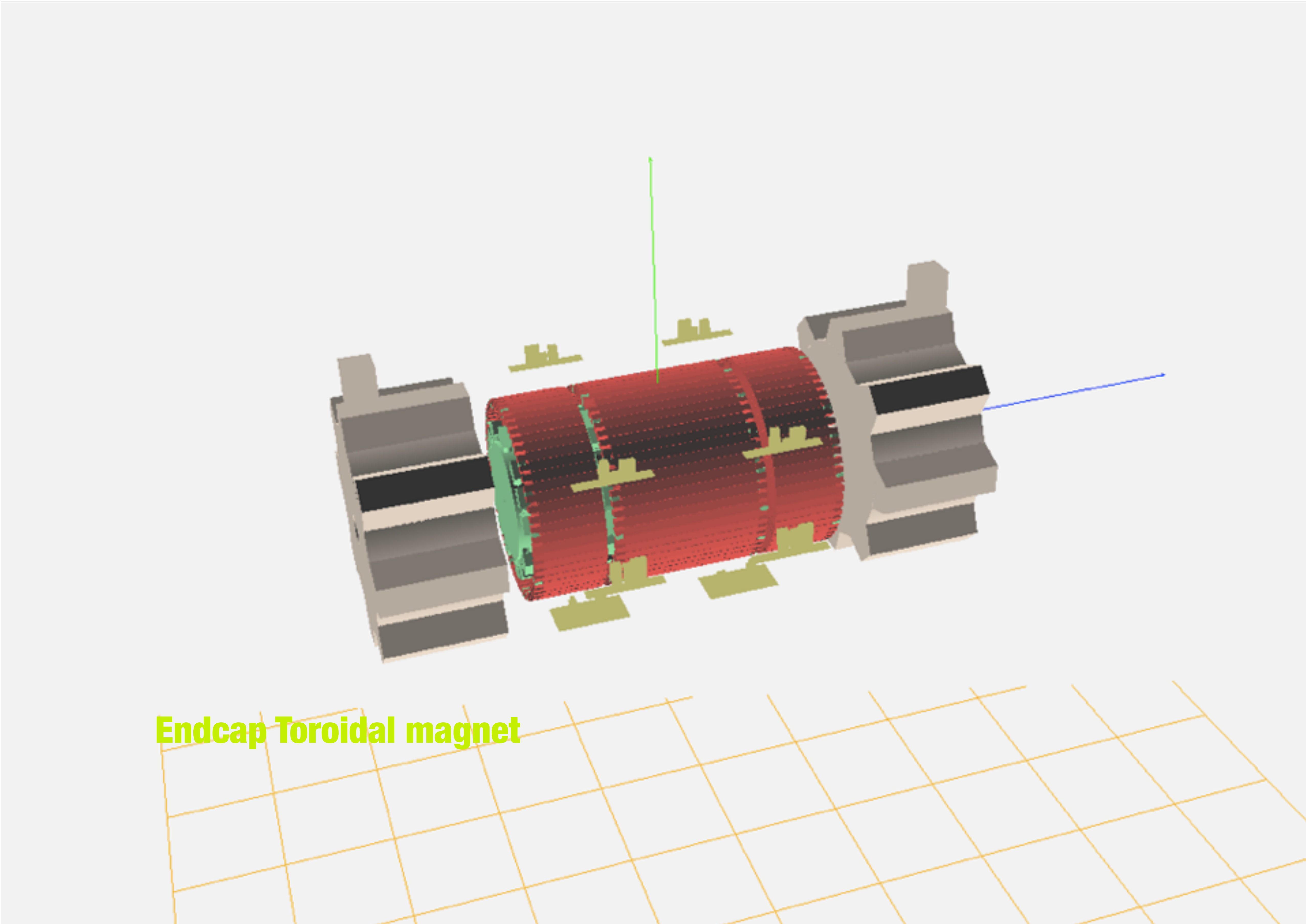
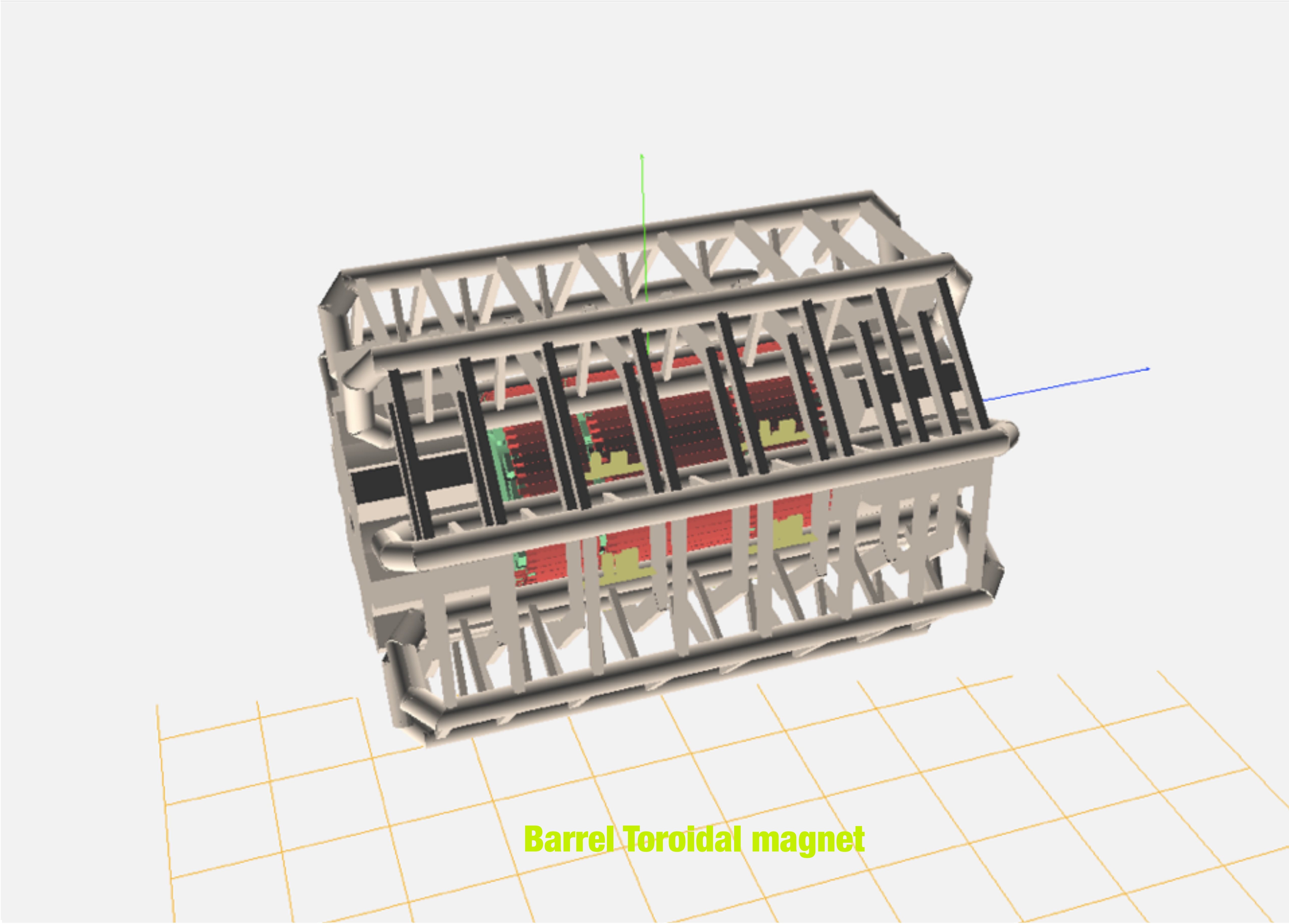
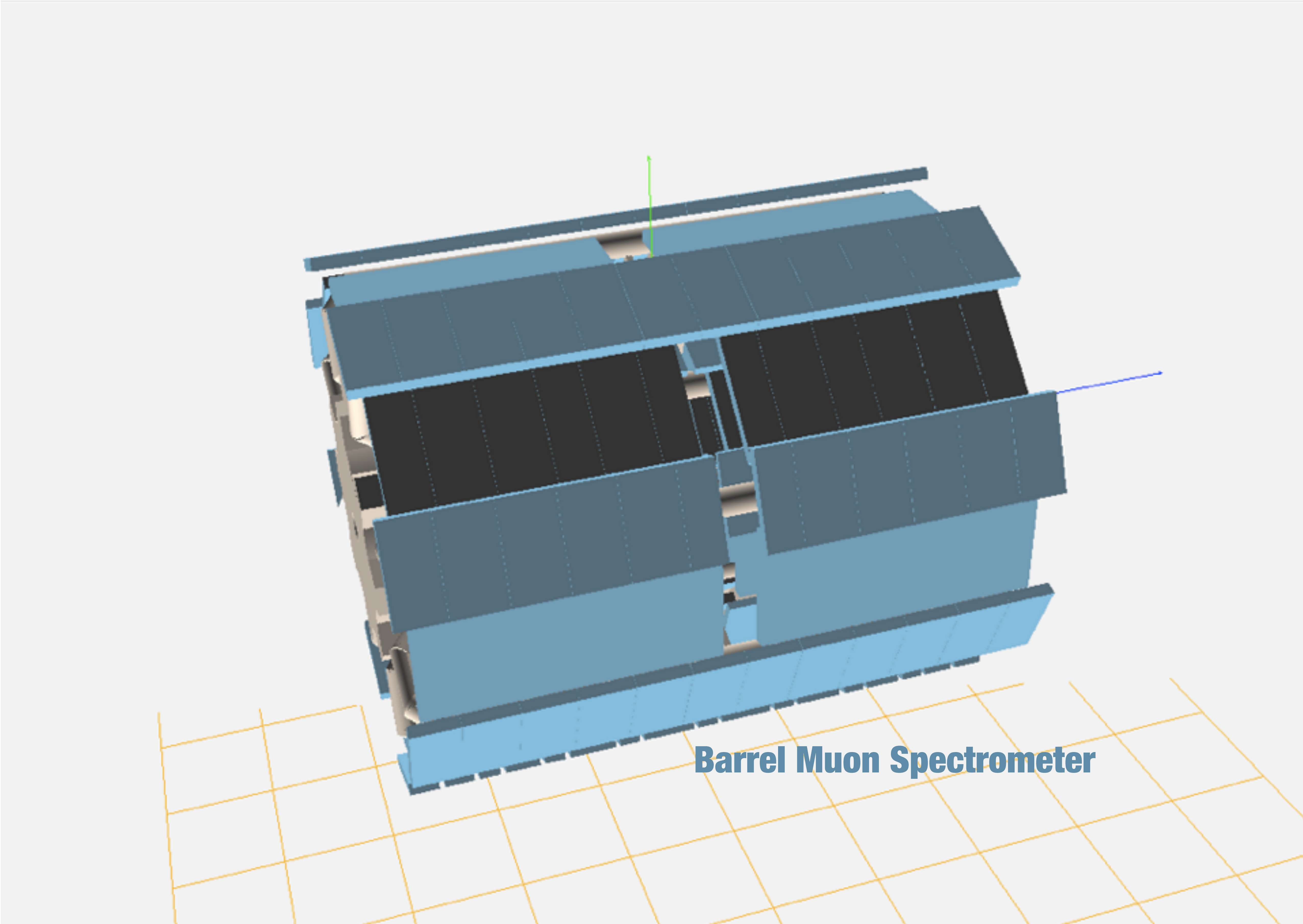
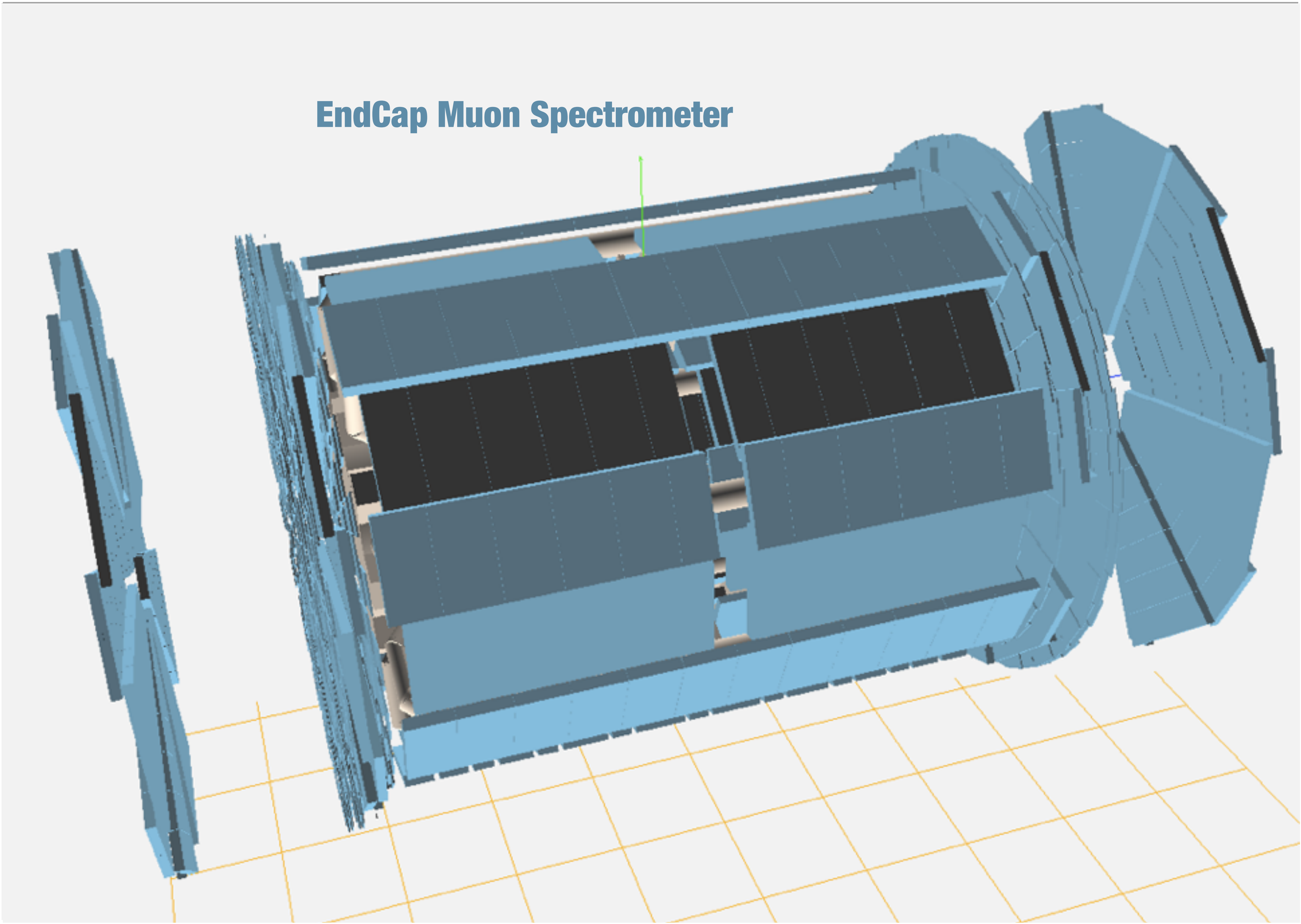
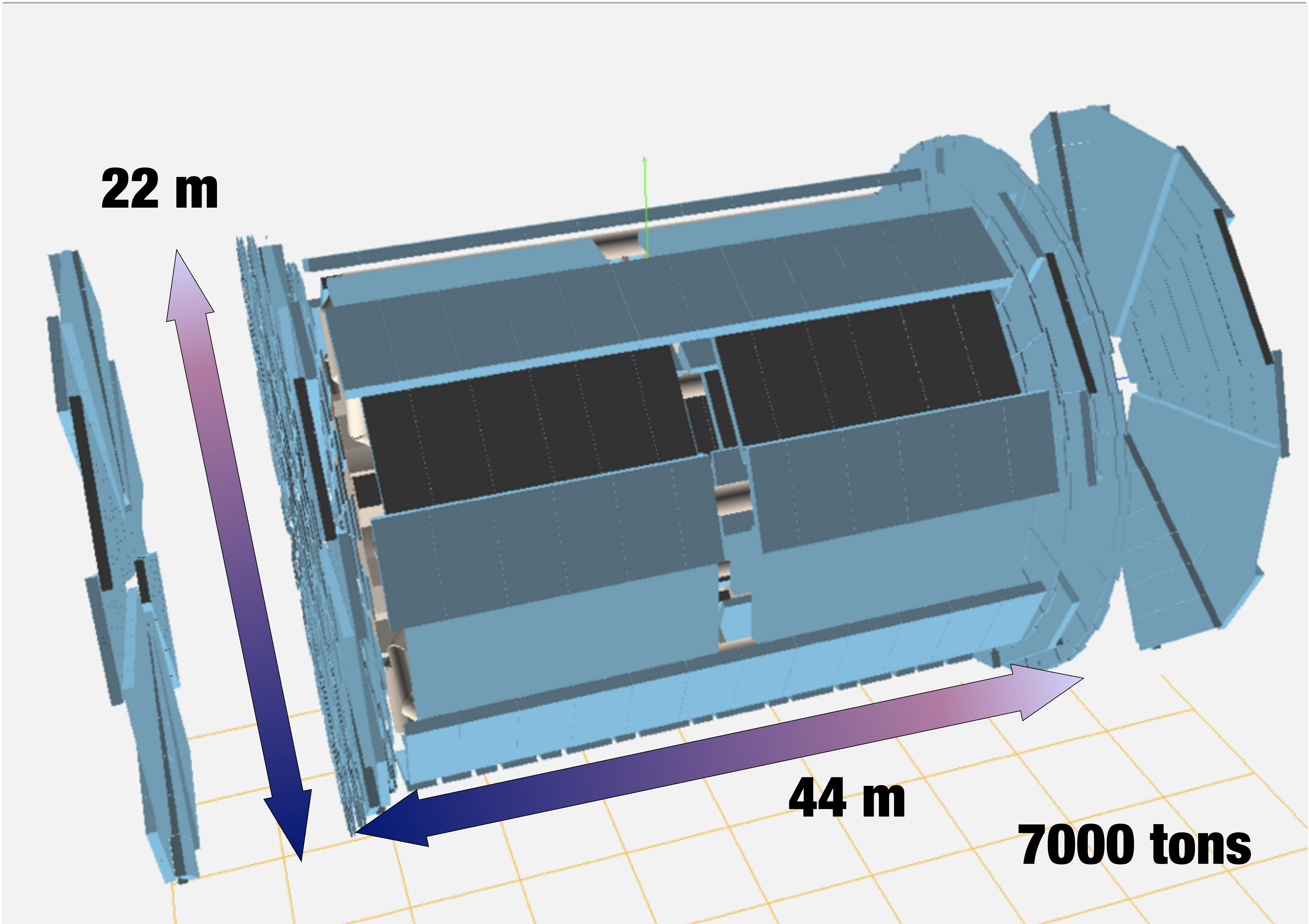

Endcap Toroidal magnet

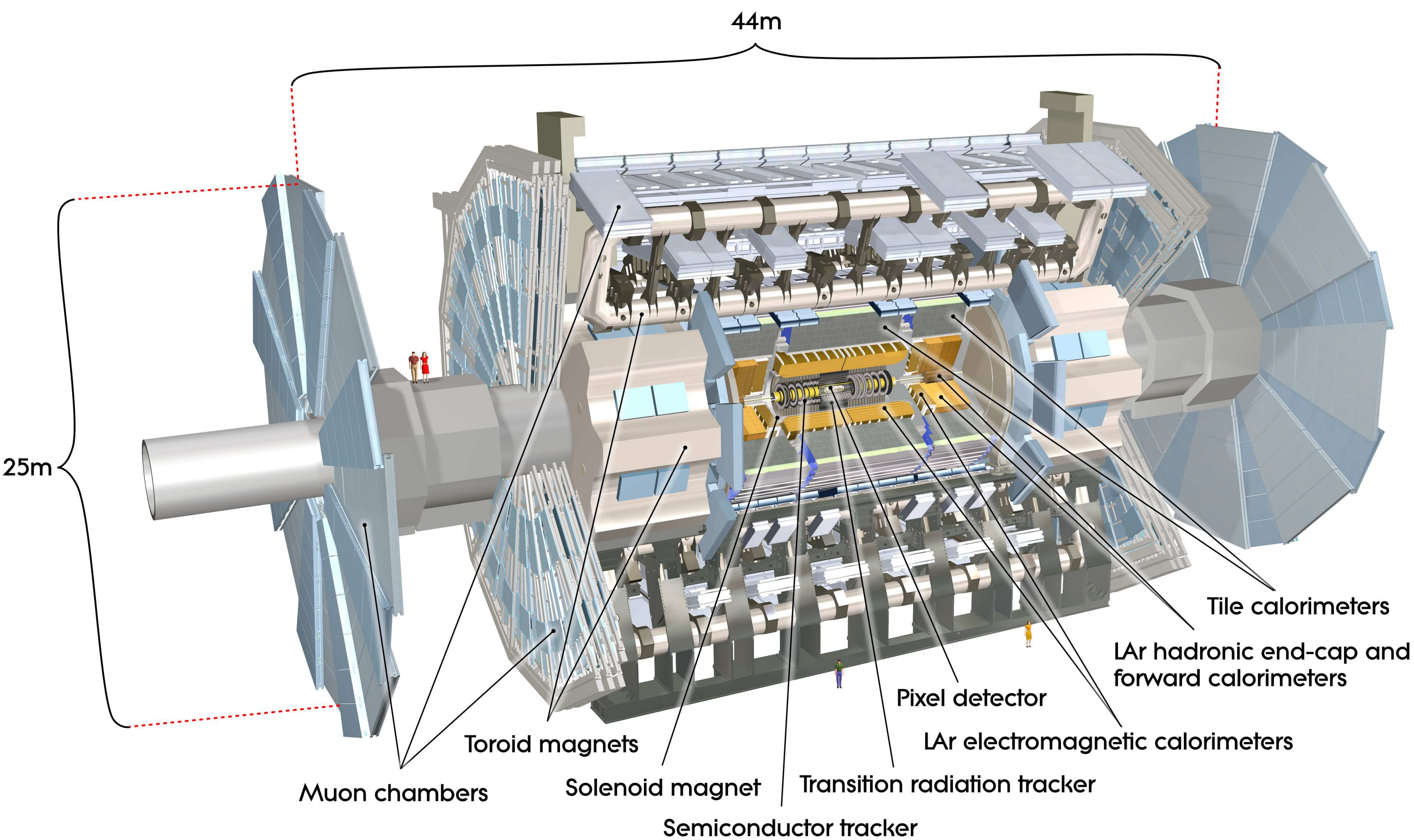

Barrel Toroidal magnet


Barrel Muon Spectrometer


EndCap Muon Spectrometer


22 m
44 m
7000 tons

The ATLAS Detector at LHC: A Toroidal LHC ApparatuS (2)



Inner detector ($|\eta| < 2.5$):

* Silicon pixel and strip, Transition Radiation Tracker (TRT) $\sigma/p_T \approx 5 \cdot 10^{-4} p_T \oplus 0.001$
* 2T Solenoidal field

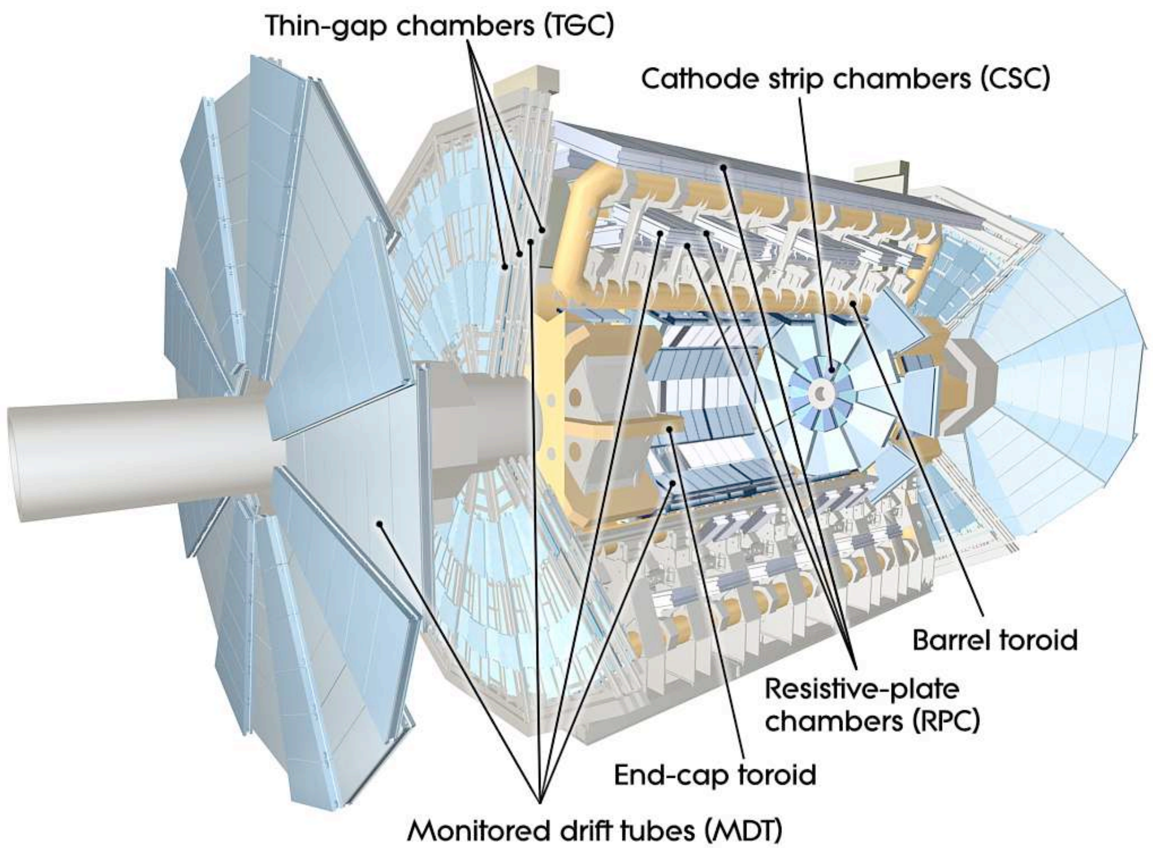
Calorimeters ($|\eta|<5$):

* EM : Pb-LAr $\sigma/E \approx 10\%/\sqrt{E(\text{GeV})} \oplus 0.7\%$
* HADRONIC: Iron Scintillator Tiles $\sigma/E \approx 50\%/\sqrt{E(\text{GeV})} \oplus 3\%$
* Forward (FCal) :$3.2<|\eta|<5$

Muon Spectrometer ($|\eta| < 2.7$):

* Trigger chambers: Resistive Plate Chambers (RPC) & Thin Gap Chambers (TGC) - $\sigma_t \sim$ ns
* 0.5 T Toroidal field
* Coordinate Measurements Chambers: Monitored Drift Tubes (MDT) & Cathode Strip Chambers (CSC) $\sigma/p_T \approx 10\%$ (for $p_T = 1$ TeV/c)

The ATLAS Detector at LHC: Muon Spectrometer



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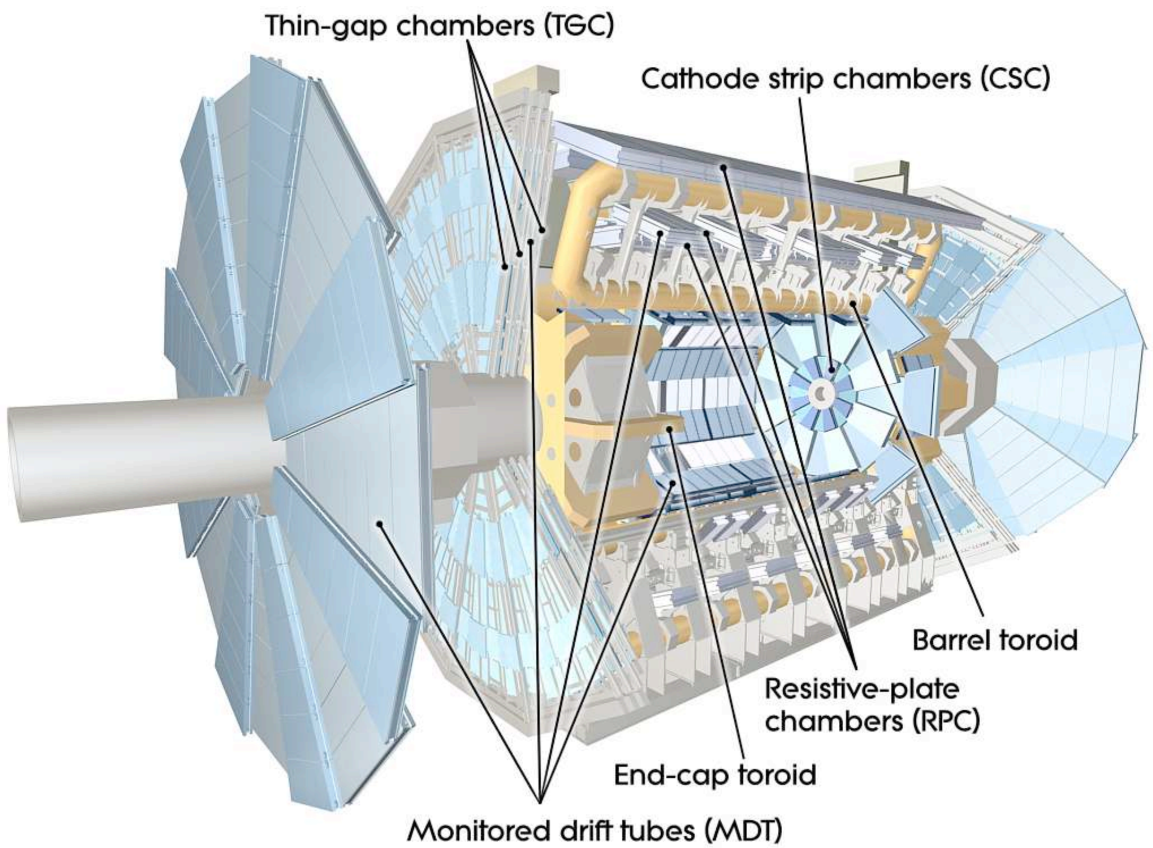

- Coverage **|η| < 2.7**
- Air core **0.5T Toroidal field** in huge area
- **MDT** chambers are used for precise measurement, with < 100 μm precision
- **CSC** chambers exist in high-η (|η| > 2.0) region of the innermost station to cope with high rate measurement
- Trigger chambers: **TGC**s (endcap) and **RPC**s (barrel)

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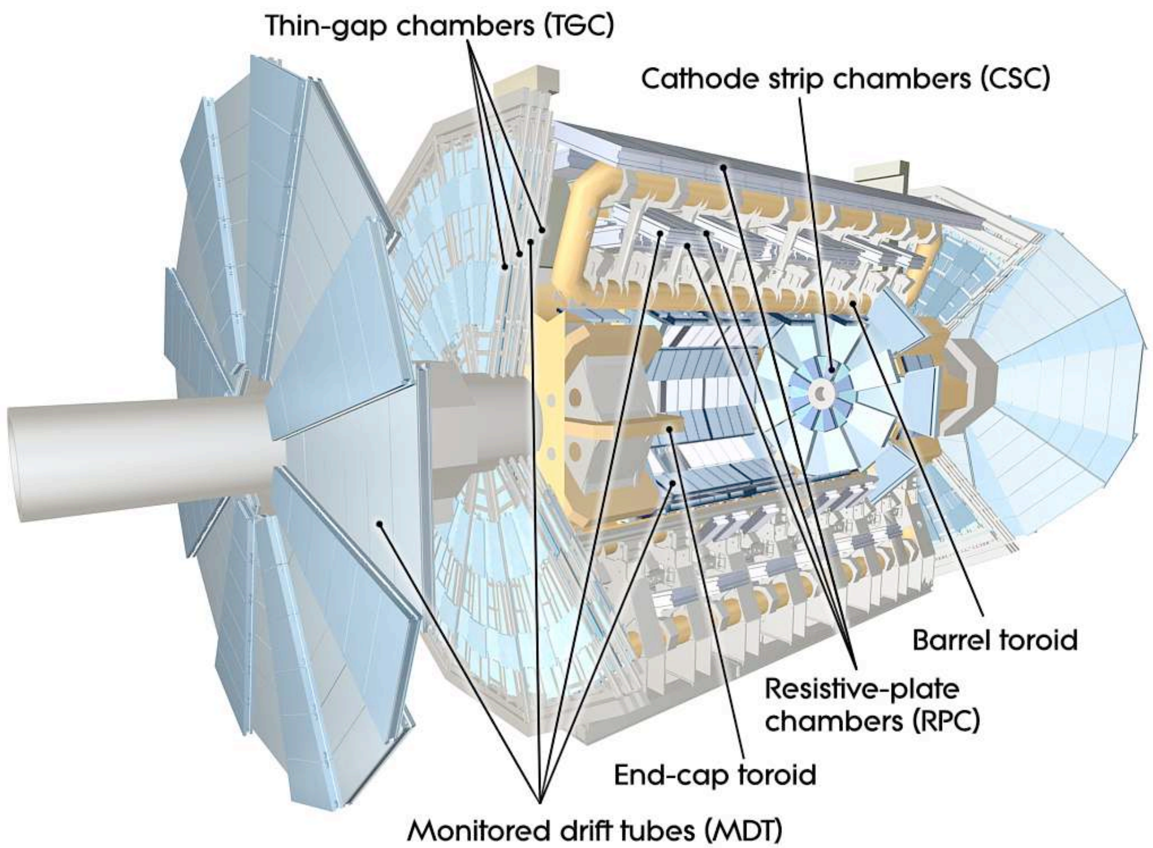

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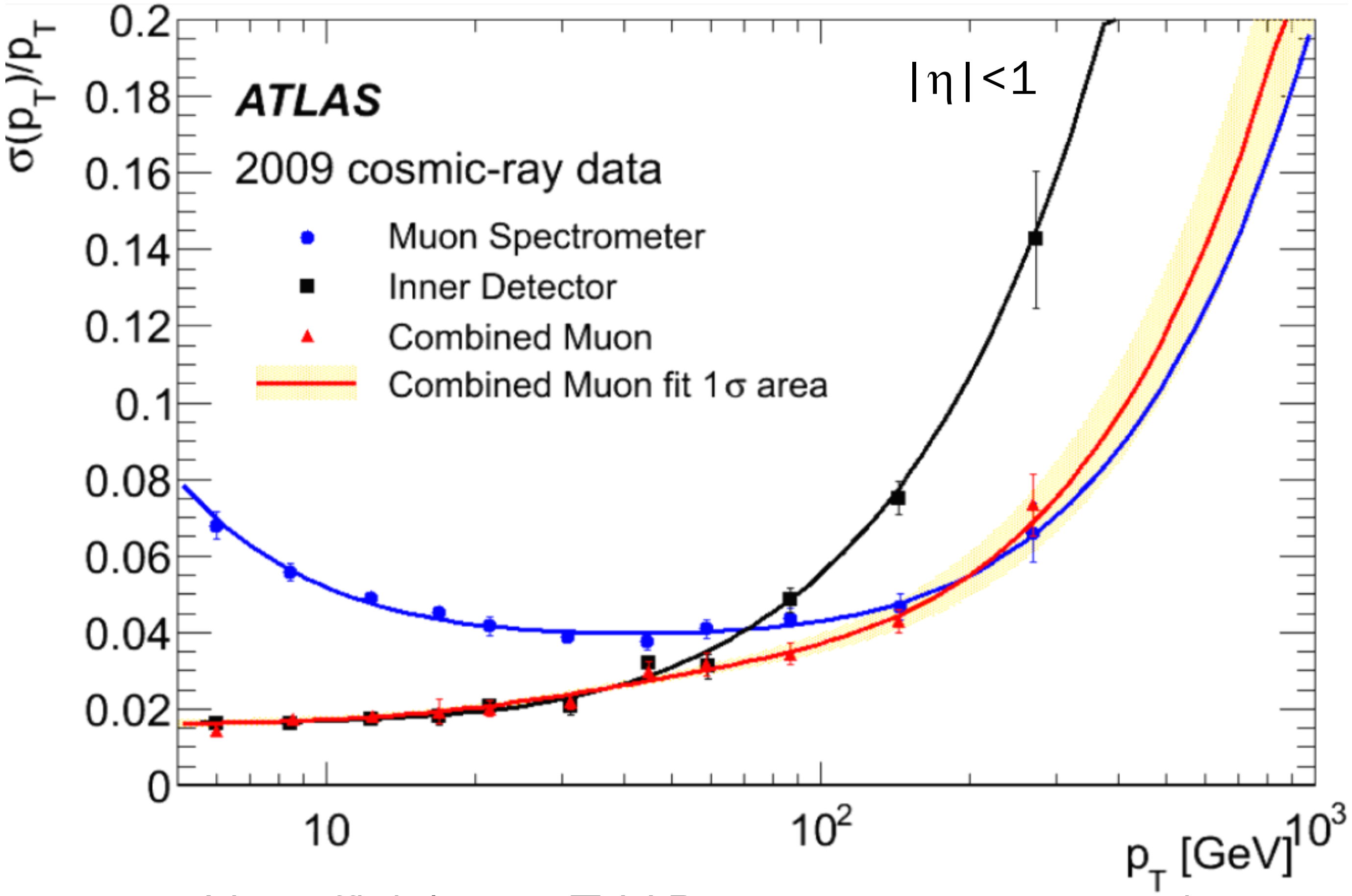
Muon Resolution

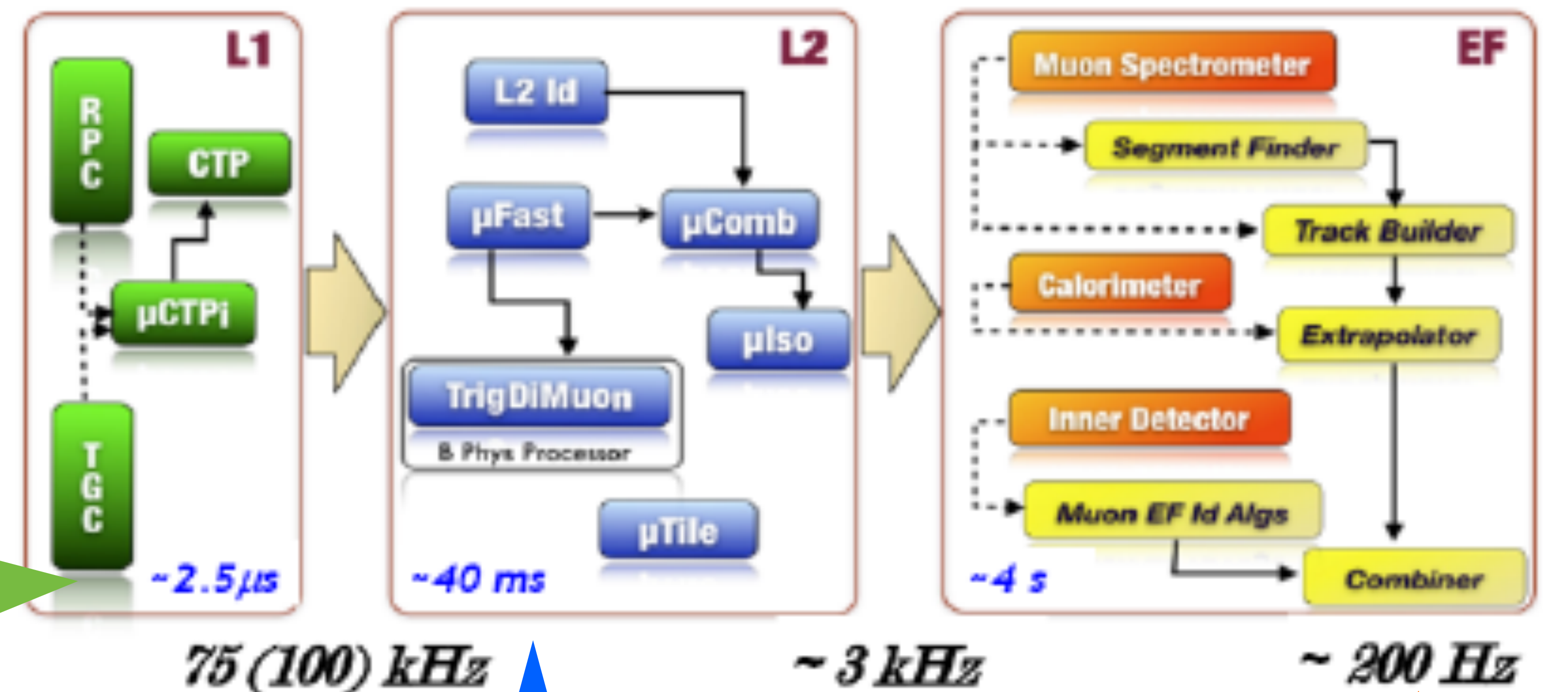


Not official pp 7 TeV Data measurement at the moment

Online muon trigger

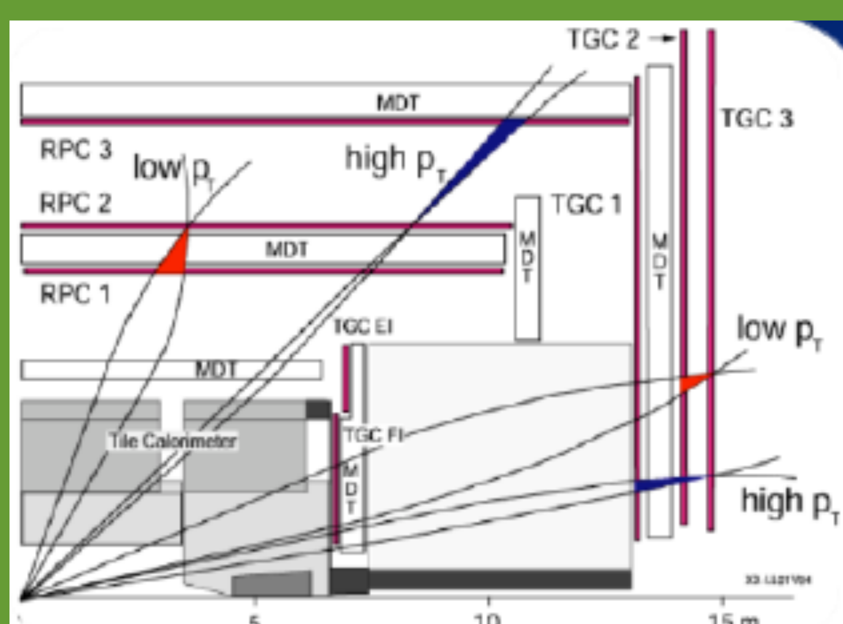
Three levels reduce LHC interaction rate of ~1 GHz to ~200Hz:

- Level1 (L1), hardware-based;
- High Level Trigger (HLT):
  Level2(L2)+Event Filter (EF),
  software based



Level 1 (L1)

- Hardware (RPC+TGC)
- 'Prompt' muons from interaction point (IP), p_T > threshold
- RoI (Region of Interest) id :p_T, η, φ



Level 2 (L2)

- RoIs in parallel,
- Several algorithms:
  1. 'Fast' Muon Spectrometer(MS), 'Stand Alone'
  2. 'Combined' reconstruction
  3. Isolation

Event Filter (EF)

- Full event data available
- 'Offline' reconstruction adapted to the 'on-line' environment
- Two main strategies:
  1. Inside-Out (MS->IP) Outside-In (ID ->MS)
  2. Combined reconstruction