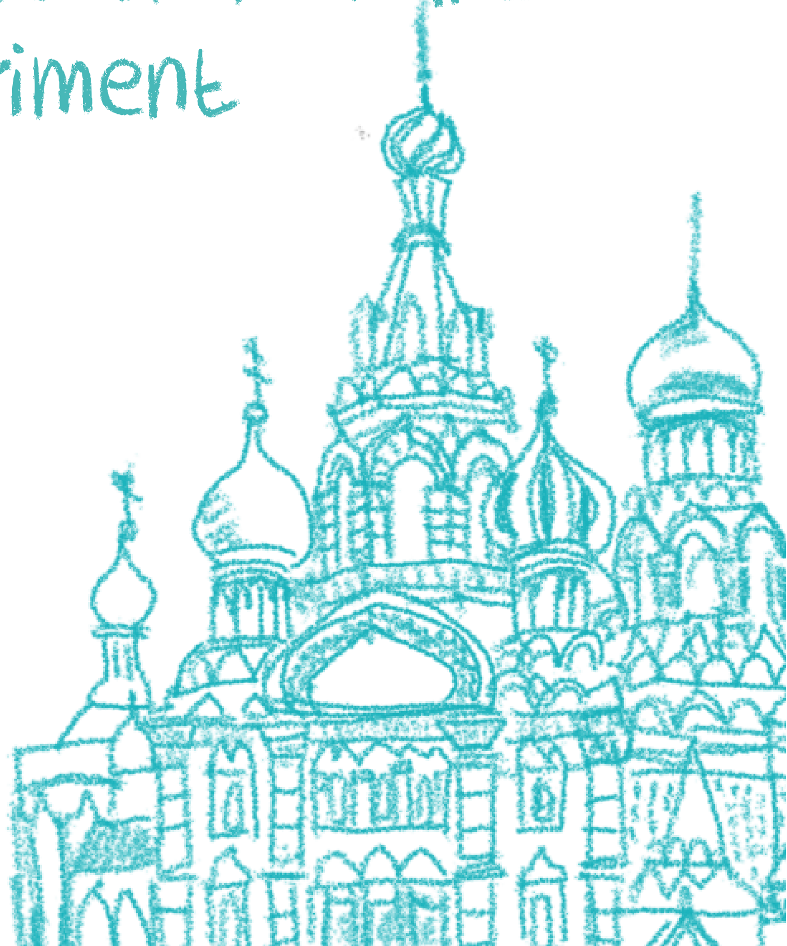
Search for new physics in dijet resonant signatures and recent results from Run2 with the CMS experiment



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On behalf of the CMS collaboration

LHCP2015
St. Petersburg - 01/09/2015

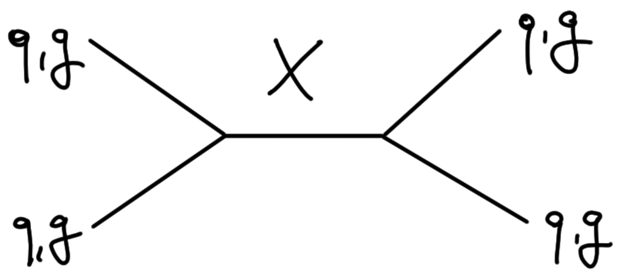
Outline

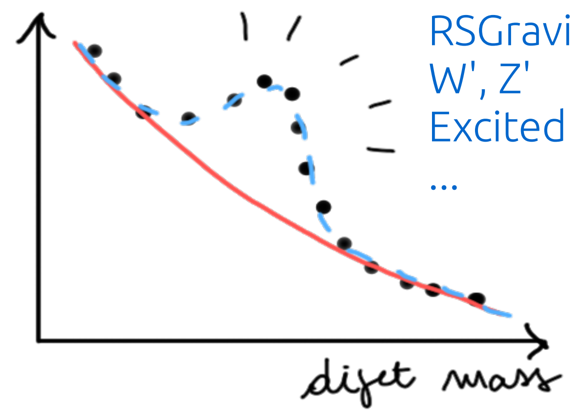
- **Focused on Run 2 analysis and results**
  → just released a public result CMS-PAS-EXO-15-001
- Introduction and motivation
- Jet reconstruction
- Trigger and selection
- Signal shapes
- Background fit and comparison with Run 1
- Upper limits and comparison with Run1
- Conclusions

NEW!

Dijet resonance search

- Narrow resonances X decaying in 2 jets → bump in the dijet mass spectrum

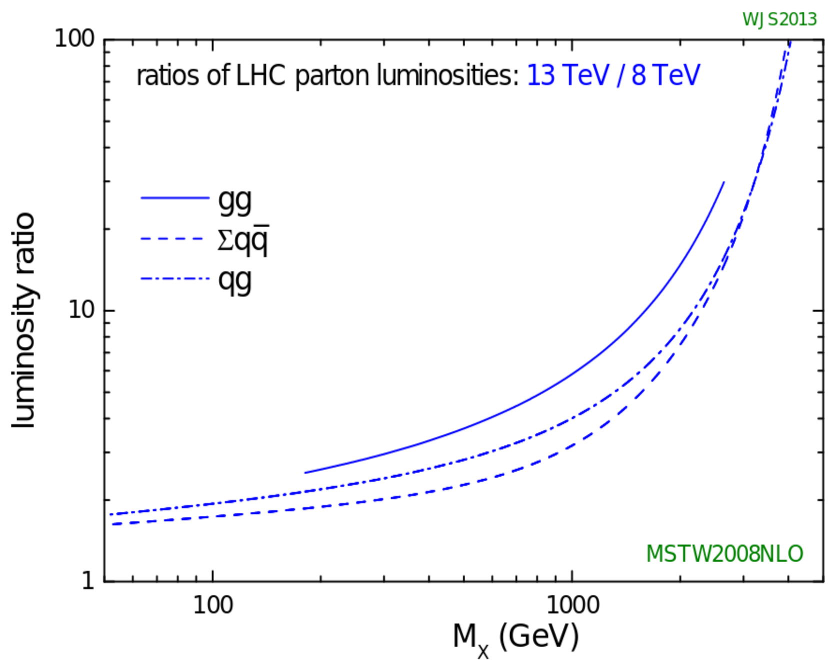


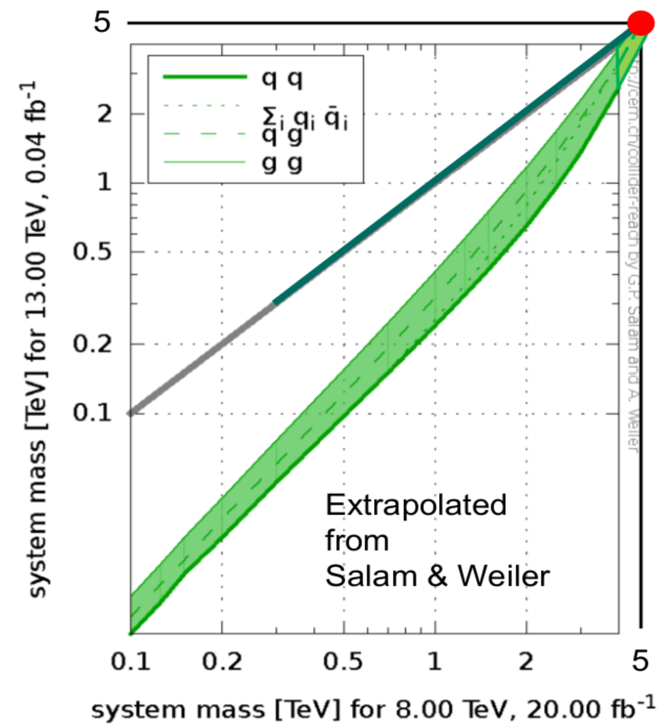


- Simple and striking signature → sensitive to any resonance coupling to quarks/gluons
- **LHC collides pp @13 TeV → dijet resonance factory at new energy scale!**
- **20 fb^{-1} of luminosity collected in Run 1 at $\sqrt{s}$ = 8 TeV**
- **42 pb^{-1} of luminosity in Run 2 at $\sqrt{s}$ =13 TeV for the results presented in this talk.**

Run 2 vs Run 1 sensitivity

- Parton luminosity ratio increase rapidly at high masses
- With much smaller integrated luminosity than Run1 → 13 TeV data same sensitivity as 8 TeV



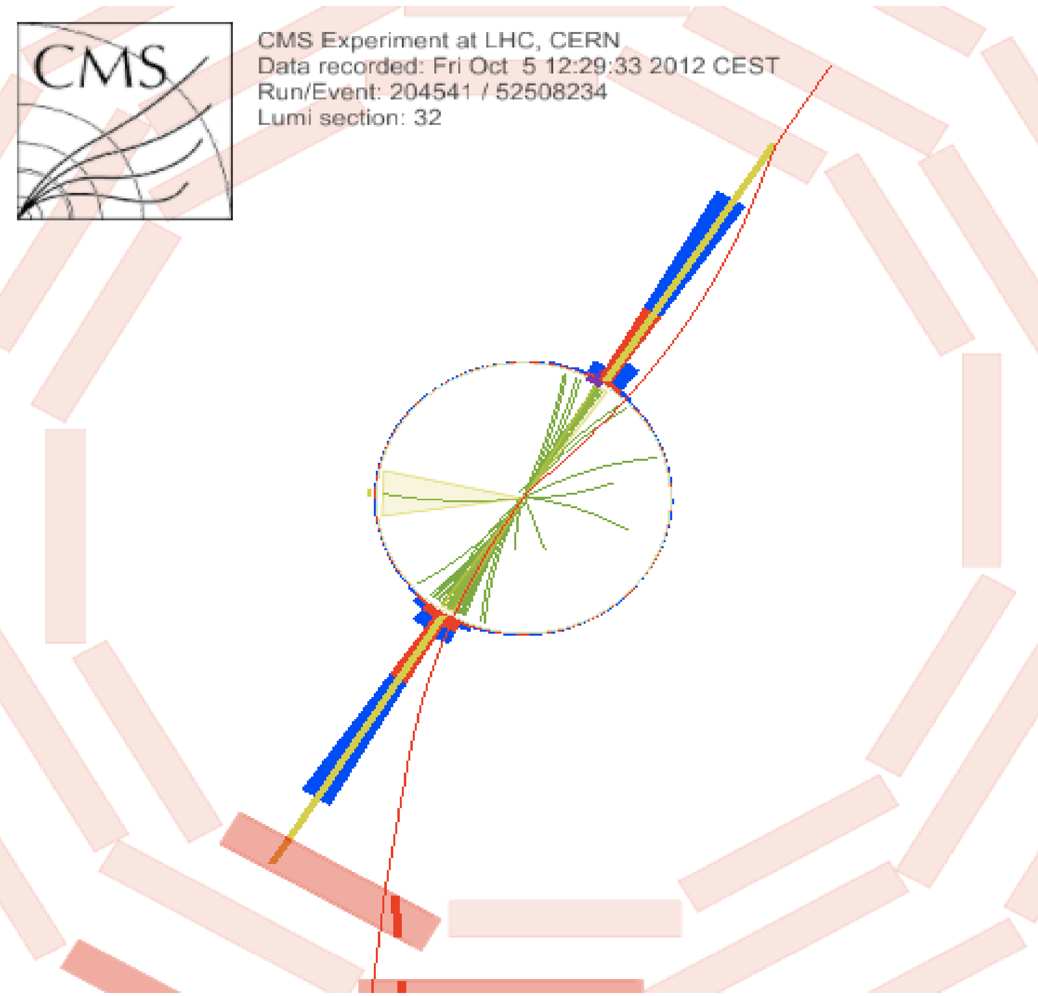


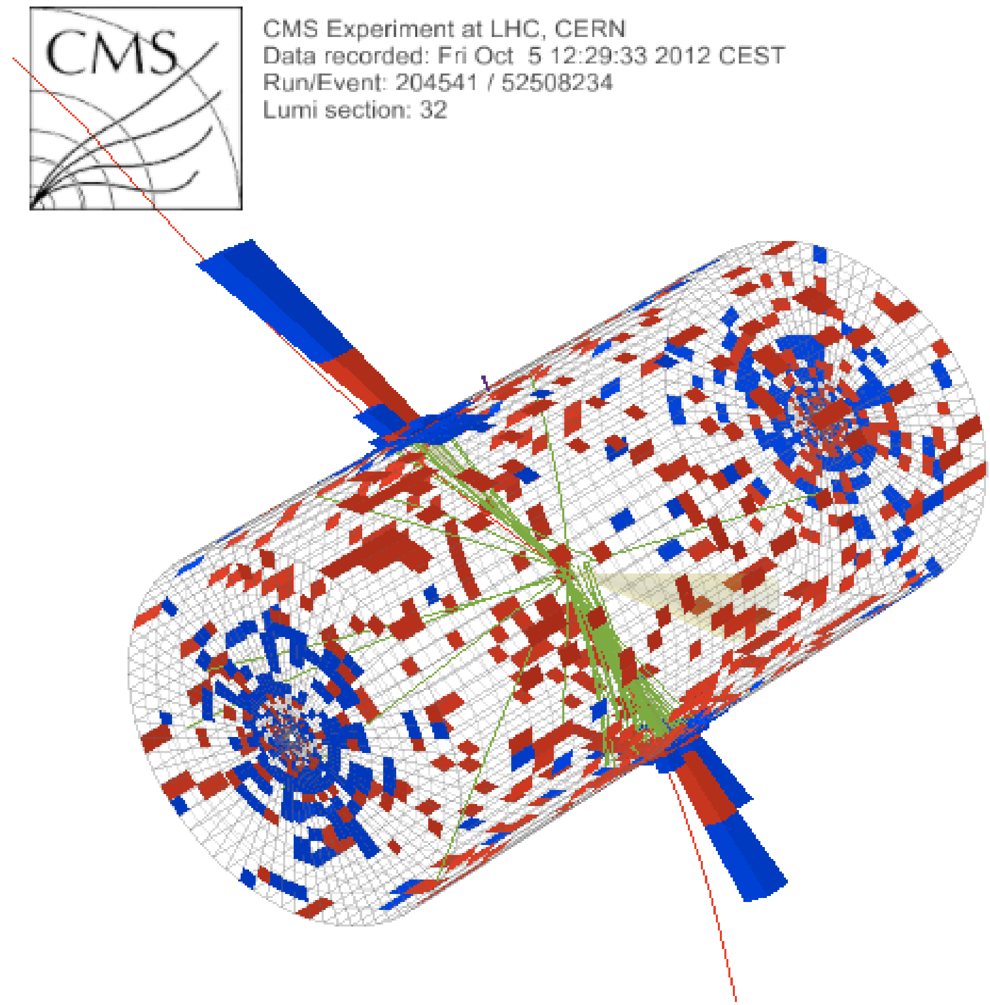
http://www.hep.ph.ic.ac.uk/~wstirlin/plots/plots.html http://collider-reach.web.cern.ch/collider-reach/

- From parton luminosity ratio → **present dataset @13 TeV more sensitive than Run 1 for masses > 5 TeV**

Highest* dijet mass event in Run 1

Dijet mass = 5.2 TeV





* for $|\Delta\eta| < 1.3$

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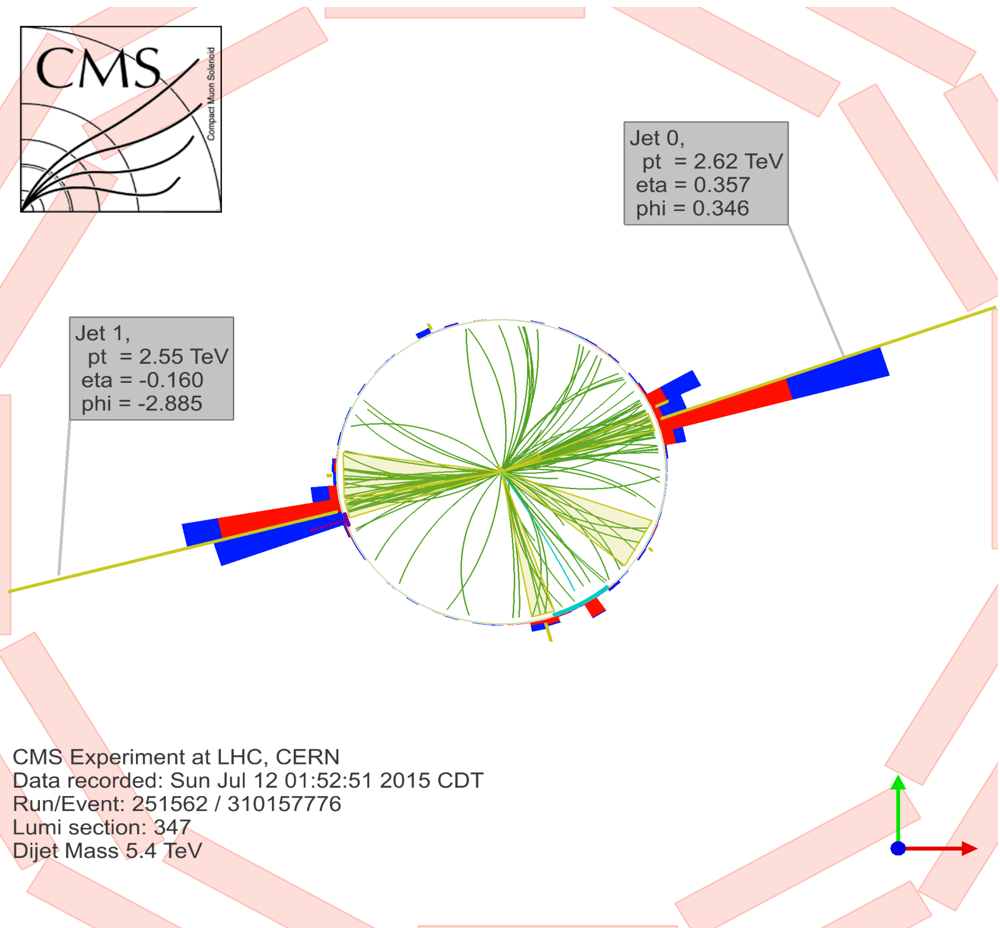
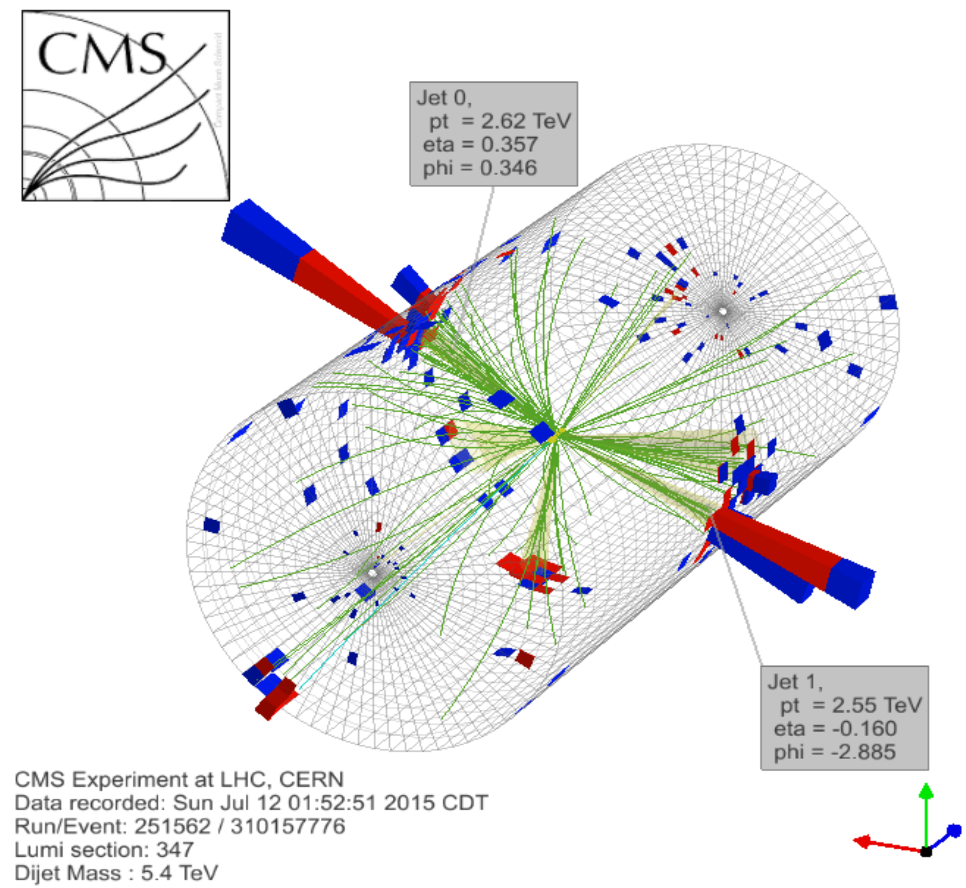
Highest* dijet mass event in Run 2

Dijet mass = 5.4 TeV
Run 2 highest mass event already greater than Run 1

NEW!





* for $|\Delta\eta| < 1.3$

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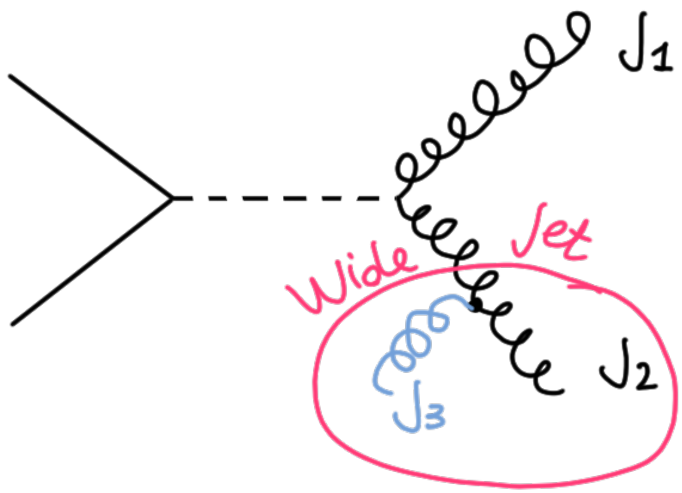
Wide jet reconstruction

- Wide jets improve dijet mass resolution → include FSR
  - clusters of **PF anti-KT jets** with cone **R=0.5 (Run 1)** or **R=0.4 (Run2)**
  - **Wide jet cone R=1.1**
- Jet identification criteria based on jet energy fractions
- Fiducial region → **$|\eta|<2.5$**
- Do not use very soft jets → **p_T>30 GeV**

Jet energy corrections from MC + data driven residual correction provided centrally from CMS JetMET group

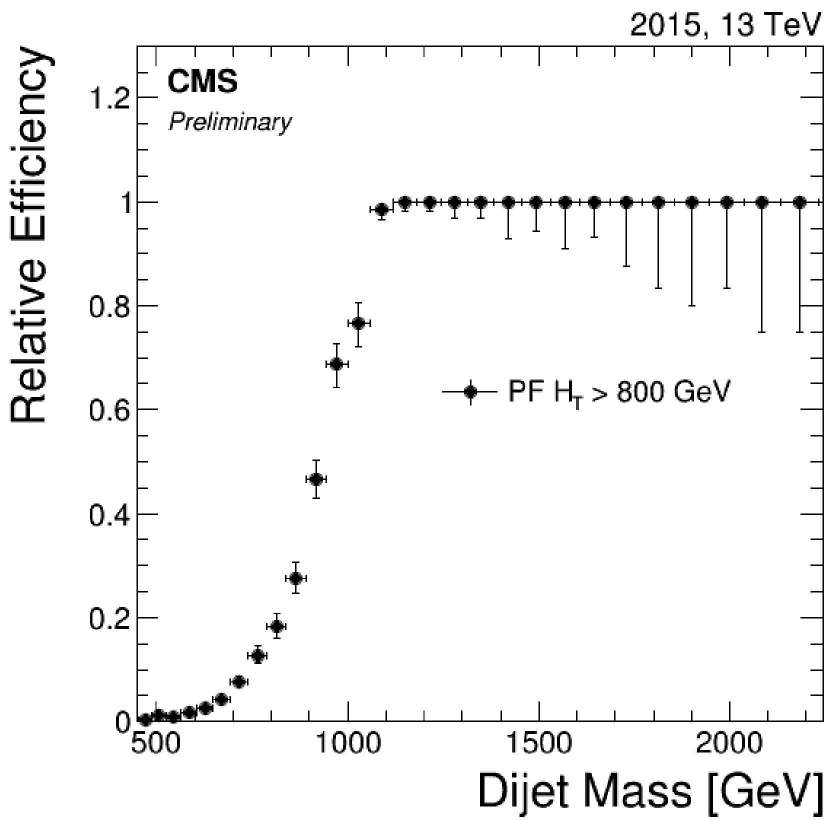


(wide jet cone R=1.1 is optimal for both 8 and 13 TeV)

Trigger

- Trigger based on the scalar sum of transverse momentum of all jets in the event
  - **HT > 650 GeV (Run1)**
  - **HT > 800 GeV (Run2)**

Run 2



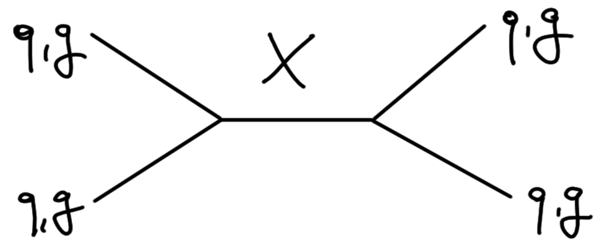
Relative efficiency vs. dijet mass
- Reference trigger HT > 475 GeV
- Reference trigger prescaled by a factor of 100

Trigger is turned-on completely for dijet masses >1.1 TeV

EXO-15-001_TwikiPlots

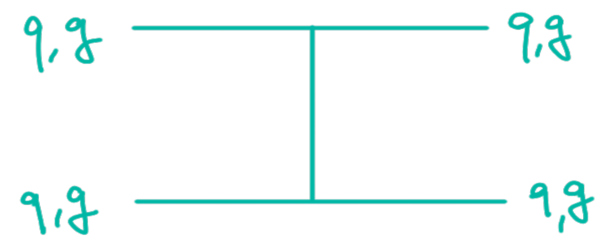
Signal

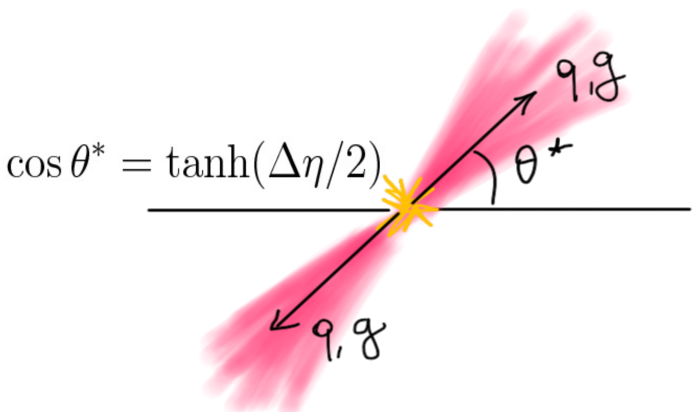
- Dijet resonance produced in S-channel



Background

- QCD produced in T-channel





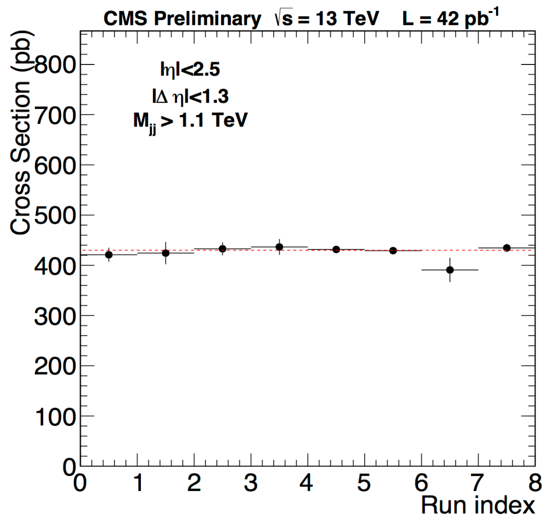
- **QCD** cos θ* peaks at 1, forward jets
- **Dijet resonance** cos θ* depends on the spin, but more flat

Selection

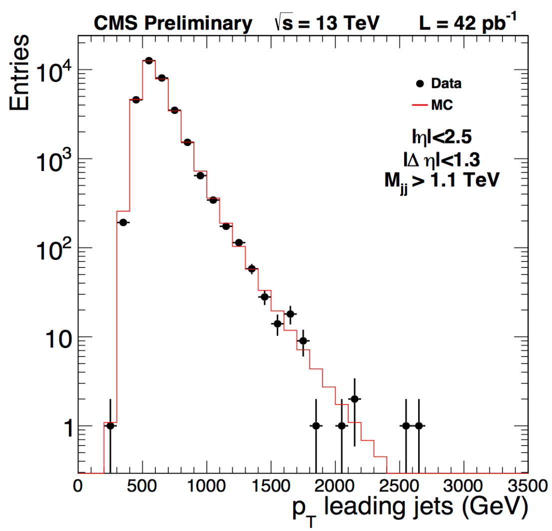
- Suppress QCD (t-channel) and enhance signal (s-channel)
  - **$|\Delta\eta|$ < 1.3 (corresponds to cos θ*<0.57)**
- Avoid bias from trigger inefficiency
  - **M_{jj} > 890 GeV (Run1)**
  - **M_{jj} > 1.1 TeV (Run2)**

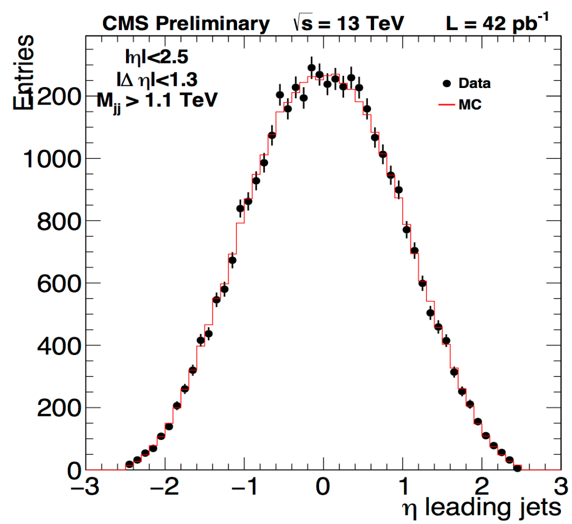
NEW!

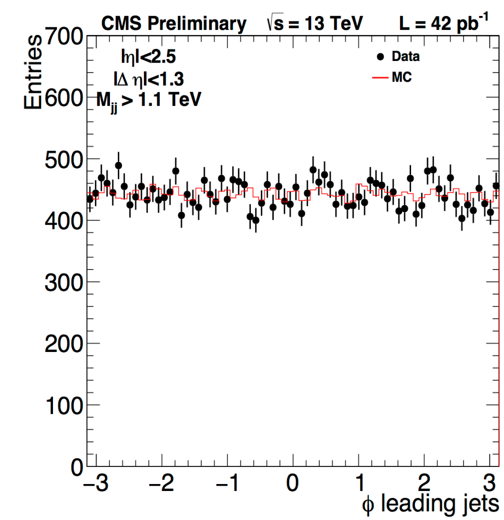
Data-MC comparisons and stability



The measured cross section is stable vs time
→ good data quality



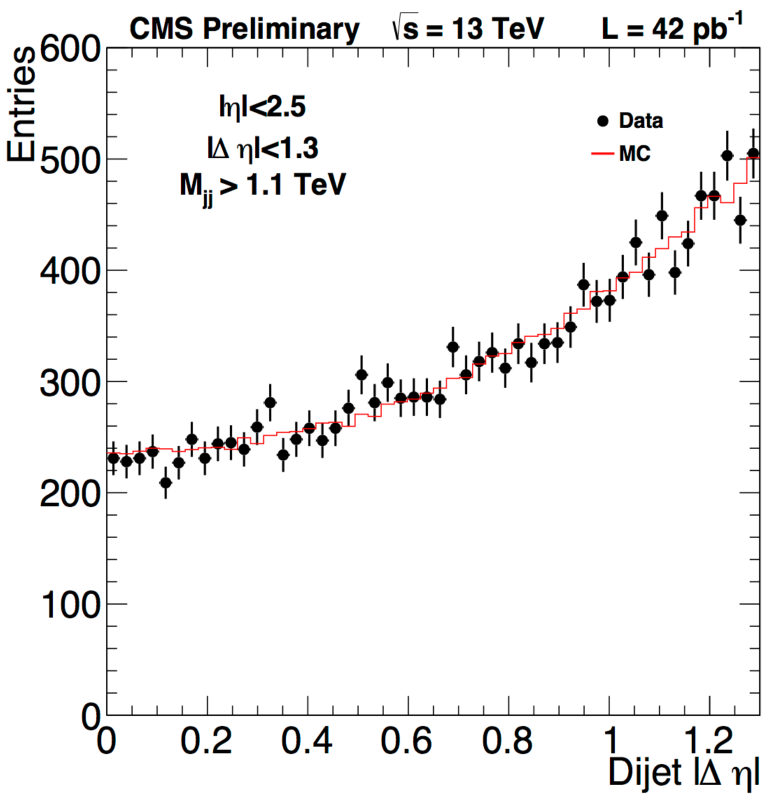


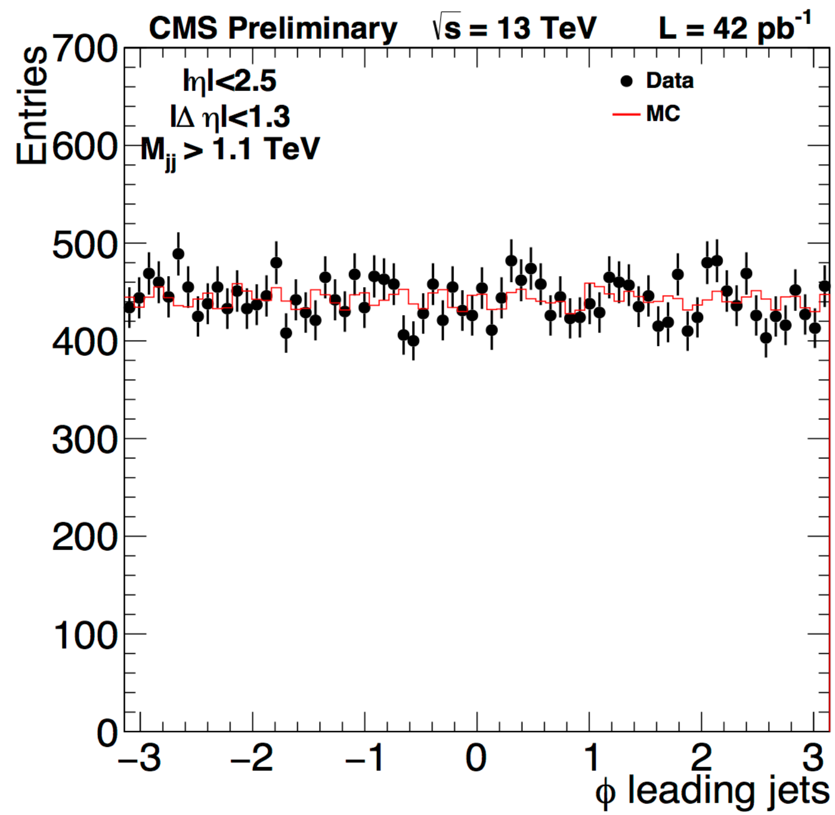


- Agreement in shape between data and simulation
- MC normalized to data

EXO-15-001_TwikiPlots

Dijet event topology





- Angular distribution typical of clean dijet events

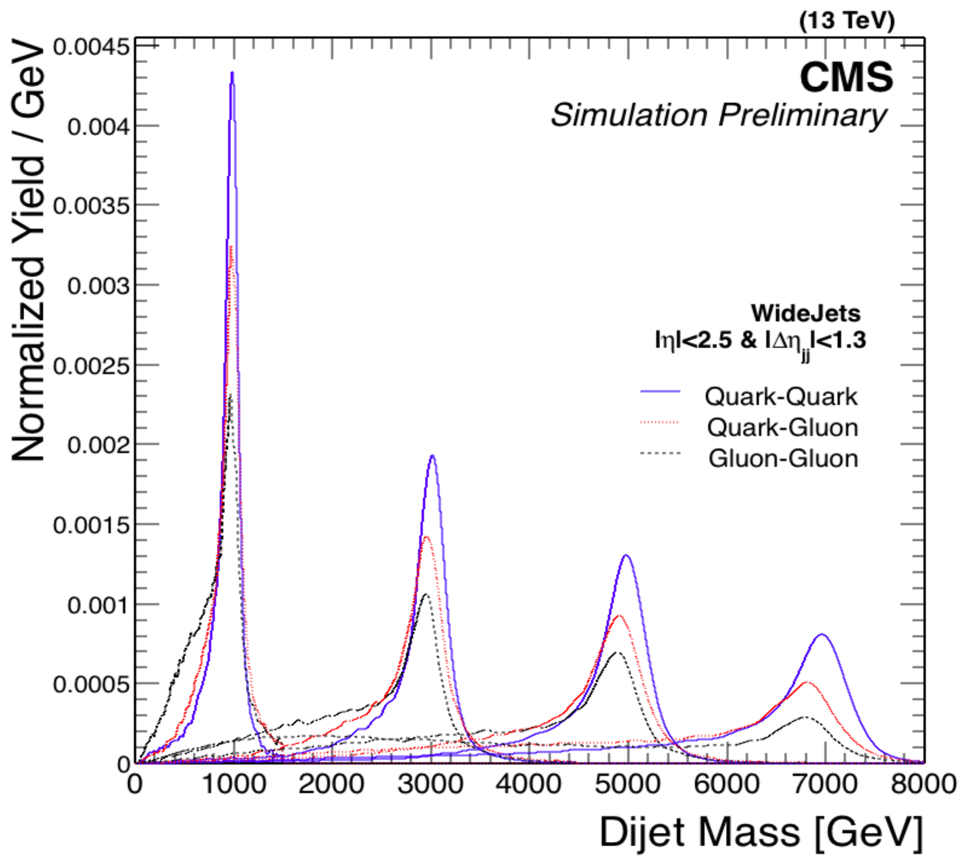
EXO-15-001_TwikiPlots

Signal modeling

- Narrow resonance shapes from simulations of RSGravitons and excited quarks, as in Run 1
  - quark-quark (qq→G→qq)
  - quark-gluon (qg→q*→qg)
  - gluon-gluon (gg→G→gg)

- Resonance masses up to 7 TeV

- Left tail mostly from FSR for low masses
- Some tail from PDFs at high masses, especially when gluons in final state



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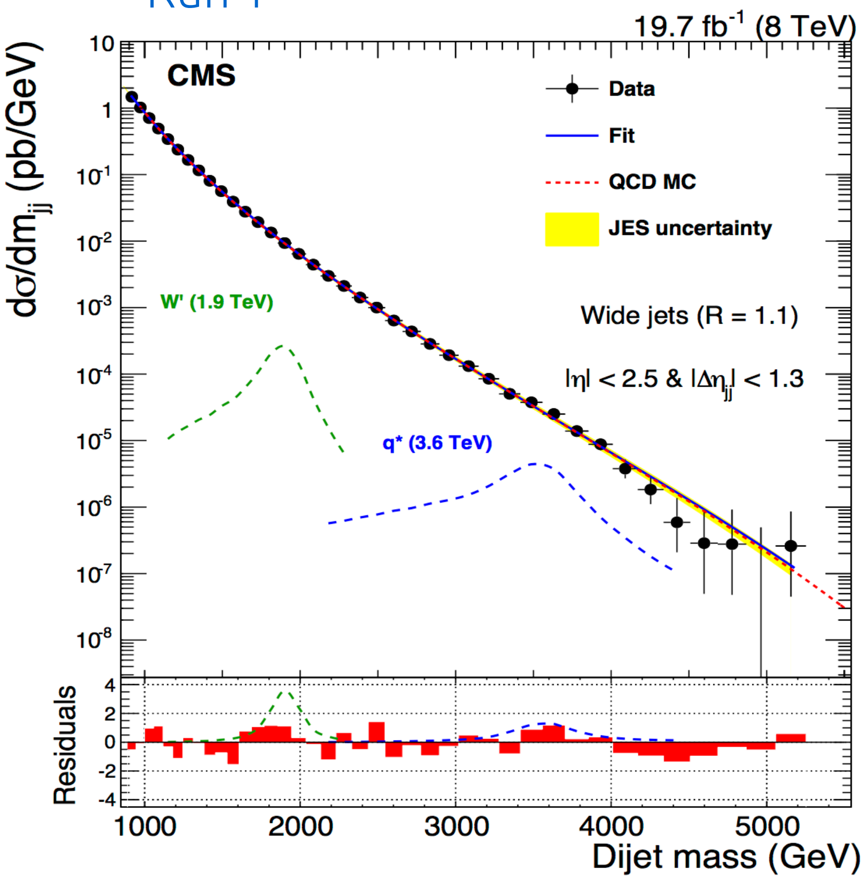
Background fit in Run 1

Data are fit with the parametrization

$$\frac{d\sigma}{dm_{jj}} = \frac{p_0(1-x)^{p_1}}{x^{p_2 + p_3 \ln(x)}} \qquad x = \frac{m_J}{8000}\,\text{GeV}$$

Run 1



- No evidence of dijet resonances: data agree with background fit function

- "excesses" @1.8TeV and @3.6 TeV (<~ 2 σ)
- Run 2 analysis still not as sensitive as Run 1
  - Need ~400 pb^{-1} for 3.6 TeV
  - Need ~3 fb^{-1} for 1.8 TeV

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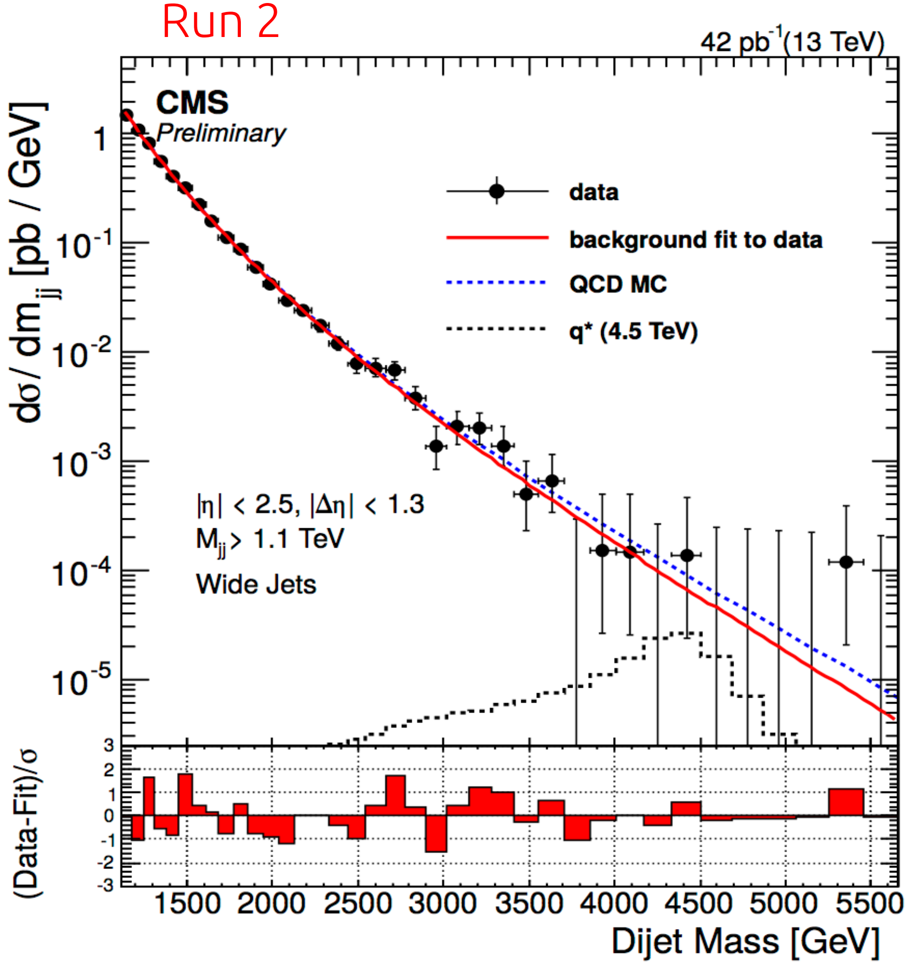
Background fit in Run 2

Data are fitted with the parametrization

$$\frac{d\sigma}{dm_{jj}} = \frac{p_0(1-x)^{p_1}}{x^{p_2 + \cancel{p_3 \ln(x)}}} \qquad x = \frac{m_{jj}}{13000}\ \text{GeV}$$

→ proved with Fisher test that p3 not needed to fit Run 2 dataset

Run 2



- Data well described by the background parametrization
  - $\chi^2/ndf=25/34$ (with empty bins)
  - $\chi^2/ndf=24/27$ (excluding empty bins)
- q* resonance signal with mass=4.5 TeV superimposed for illustration

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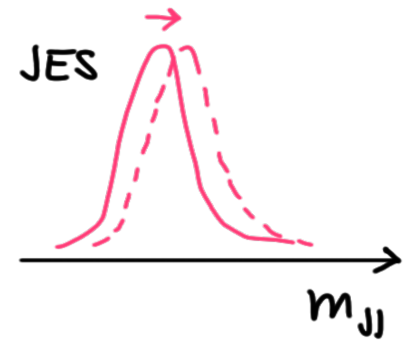
Systematic uncertainties

Sources of uncertainty are the same as in Run 1, more conservative values used for Run 2

- **Jet energy scale (JES)**

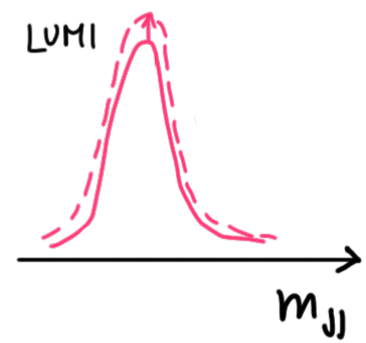
  conservative value 5%

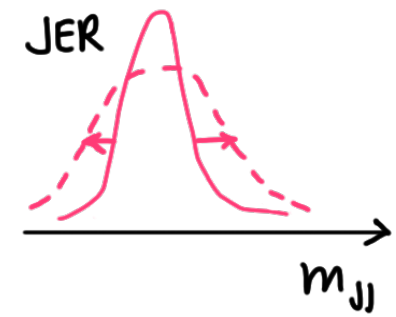
  → propagated to the search by shifting the dijet resonance shapes by ±5%



- **Jet energy resolution (JER)**

  same value as in Run 1 of 10%.
  → propagated to the search by changing the width of the dijet resonance shapes by ±10%



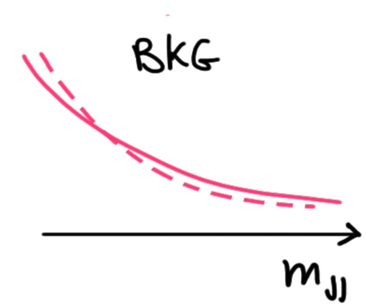


- **Integrated luminosity**

  estimated at 12%

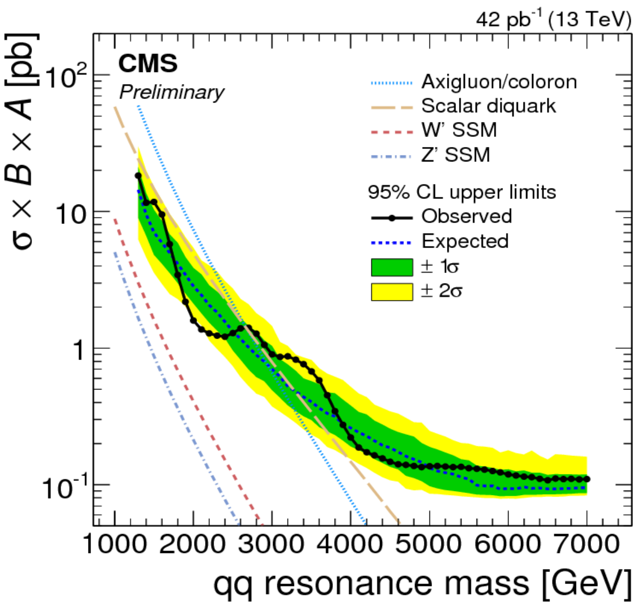
- **Choice of background parameterization**

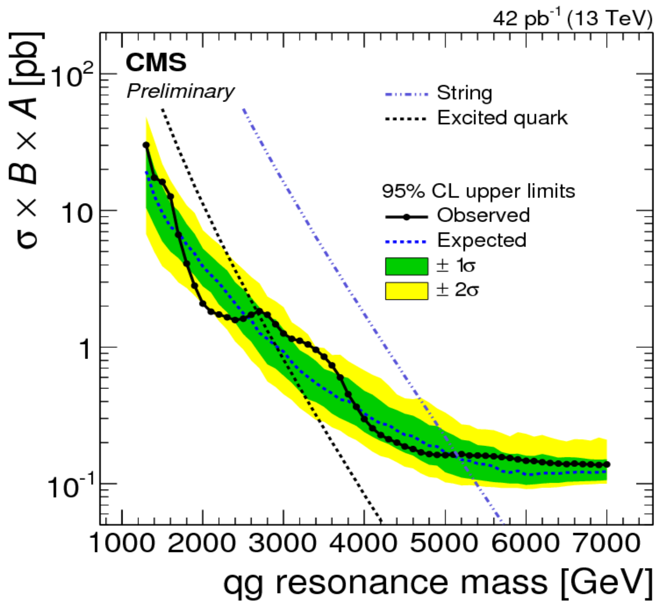
  All 3 background parameters are varied in a correlated fashion along the 3 eigenvectors of the covariance matrix.

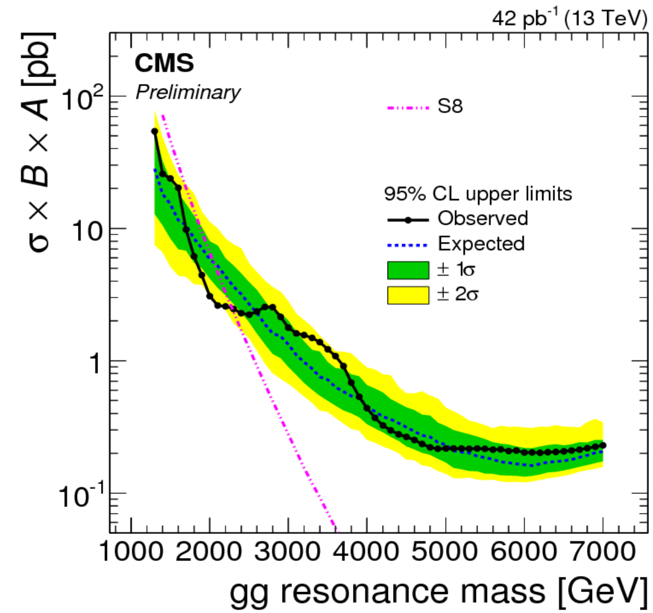


Run 2 exclusion

- Upper limits @95% CL on the cross section of **qq**, **qg**, and **gg** resonances
- Comparison to calculations of model cross sections







- Gives the following mass limits on models of dijet resonances

Model	Final State	Obs. Mass Limit [TeV]	Exp. Mass Limit [TeV]
String Resonance (S)	qg	5.1	5.2
Excited Quark (q^*)	qg	2.7	2.9
Scalar Diquark (D)	qq	2.7	3.3
Axigluon (A)/Coloron (C)	$q\bar{q}$	2.7	2.9
Color Octet Scalar (s8)	gg	2.3	2.0

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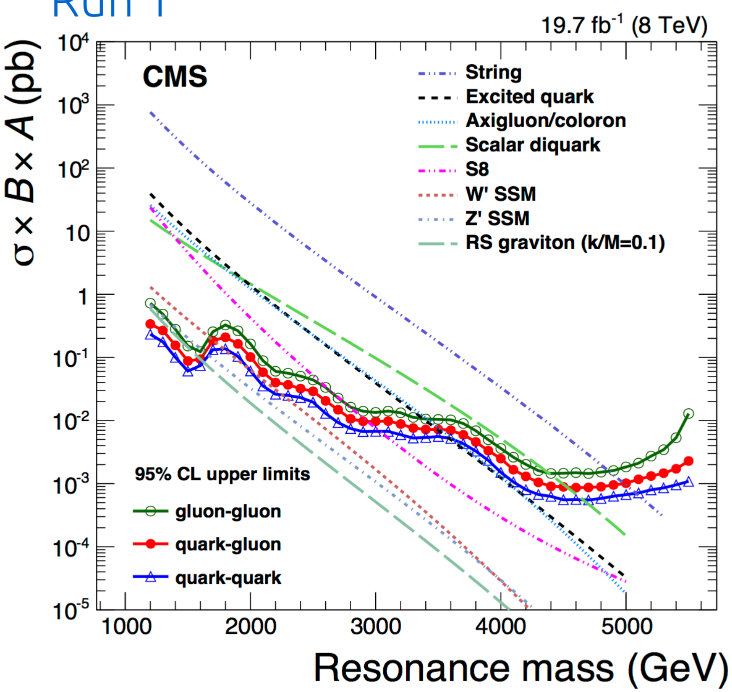
Limits summary

Summary of observed limits, model cross sections, and mass limits

Run 1



Model	Final state	Observed mass exclusion (TeV)	Expected mass exclusion (TeV)
Inclusive search			
String resonance (S)	qg	[1.2,5.0]	[1.2,4.9]
Excited quark (q^*)	qg	[1.2,3.5]	[1.2,3.7]
E_6 diquark (D)	qq	[1.2,4.7]	[1.2,4.4]
W′ boson (W′)	$q\bar{q}$	[1.2,1.9] + [2.0,2.2]	[1.2,2.2]
Z′ boson (Z′)	$q\bar{q}$	[1.2,1.7]	[1.2,1.8]
RS graviton (G), $k/\overline{M}_{Pl} = 0.1$	$q\bar{q}$ + gg	[1.2,1.6]	[1.2,1.3]
b-enriched search			
Excited b quark (b^*)	bg	[1.2,1.6]	
Wide resonance search			
Axigluon (A)/coloron (C)	$q\bar{q}$	[1.3,3.6]	
Color-octet scalar (S8)	gg	[1.3,2.5]	

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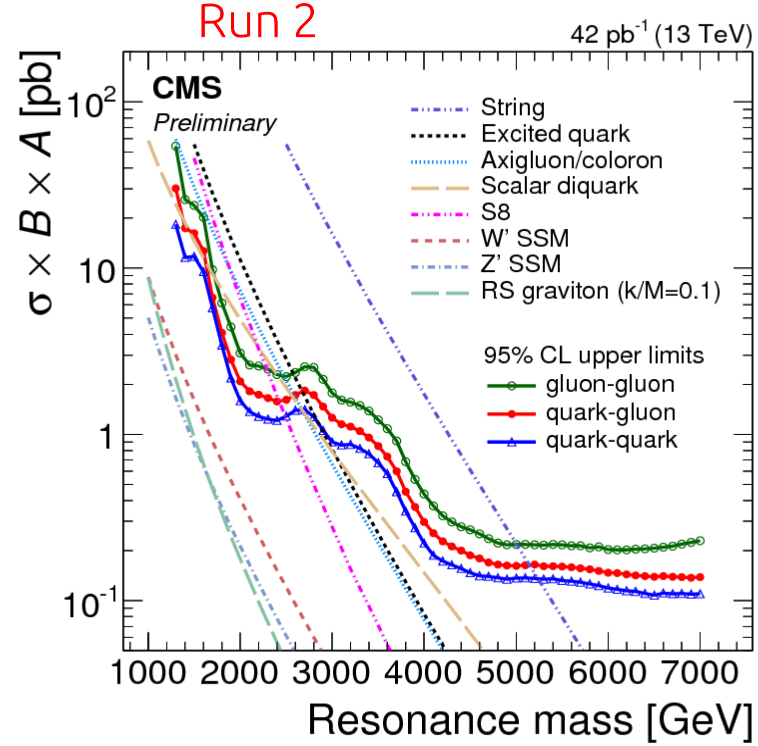
Run 2



Model	Final State	Obs. Mass Limit [TeV]	Exp. Mass Limit [TeV]
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Color Octet Scalar (s8)	gg	2.3	2.0

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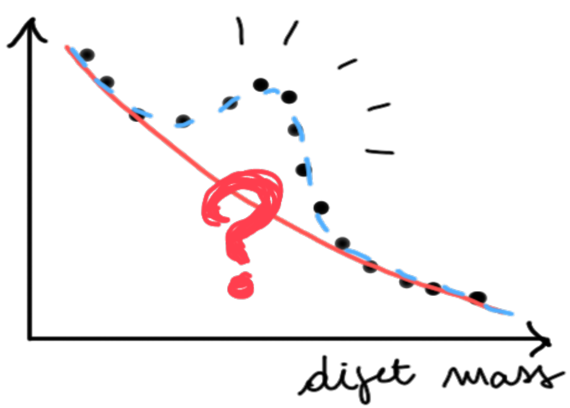
Conclusions

NEW!

- Presented **first results at $\sqrt{s}$ = 13 TeV** and comparison with Run 1
- Dijet mass distribution well modeled by the background parameterization
  - **No evidence of dijet resonances... yet**

- New mass limit on string resonances at 5.1 TeV exceeds previous limit of 5.0 TeV
- **CMS now more sensitive to new physics than Run 1 for M > 5 TeV**
- Still not as sensitive as Run 1 to lower masses
  - Need ~400 pb^{-1} for 3.6 TeV
  - Need ~3 fb^{-1} for 1.8 TeV
- **Great potential on discovering new physics with the first few fb^{-1} of data @13 TeV !**

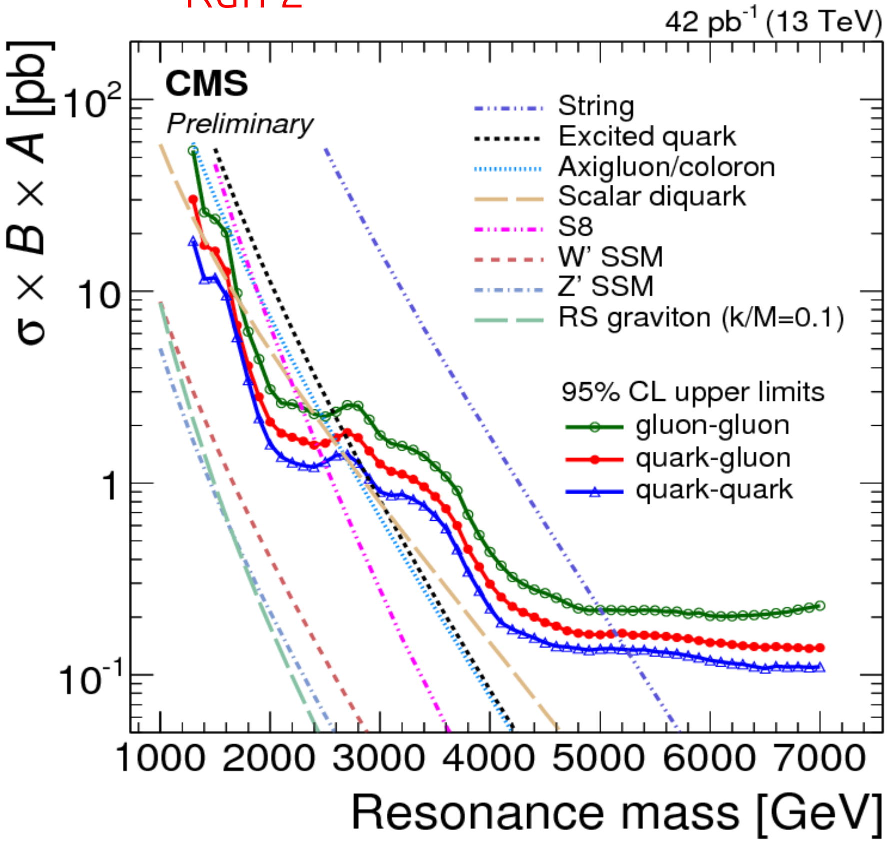


BACKUP

Limits summary

Summary of observed limits, model cross sections, and mass limits

Run 2



Comparison of exclusion limits for a narrow resonance search

Model	Mass Limits (TeV)			
	Run 1 (20 fb^{-1})		Run 2 (42 pb^{-1})	
	Observed	Expected	Observed	Expected
String Resonance (S)	5.0	4.9	5.1	5.2
Excited Quark (q*)	3.5	3.7	2.7	2.9
Axigluon (A) / Coloron (C)	3.7	3.9	2.7	2.9
Scalar Diquark (D)	4.7	4.7	2.7	3.3
Color Octet Scalar (S8)	2.7	2.6	2.3	2.0

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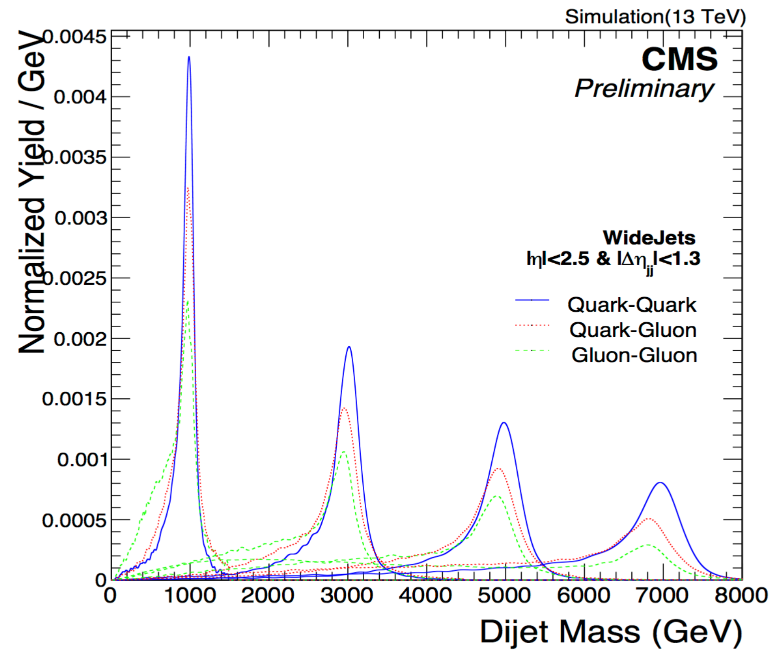
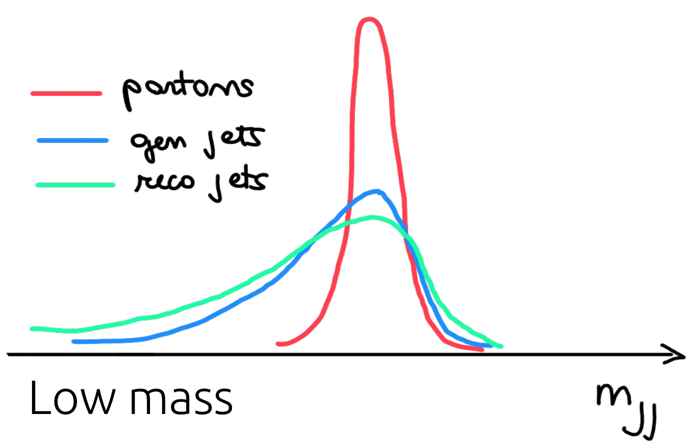
Signal modeling

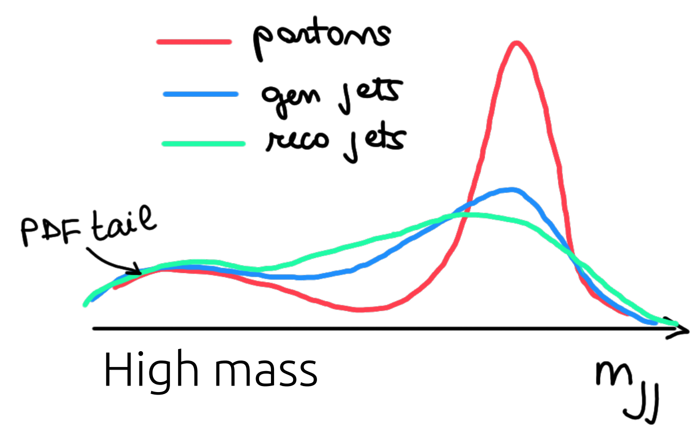
- Narrow resonance shapes from simulations of RSG gravitons and excited quarks, as in Run 1
  - quark-quark ($qq \to G \to qq$)
  - quark-gluon ($qg \to q^* \to qg$)
  - gluon-gluon ($gg \to G \to gg$)

- Resonance masses up to 7 TeV

- Left tail mostly from FSR for low masses
- Significant tail from PDFs at high masses, especially when gluons in final state







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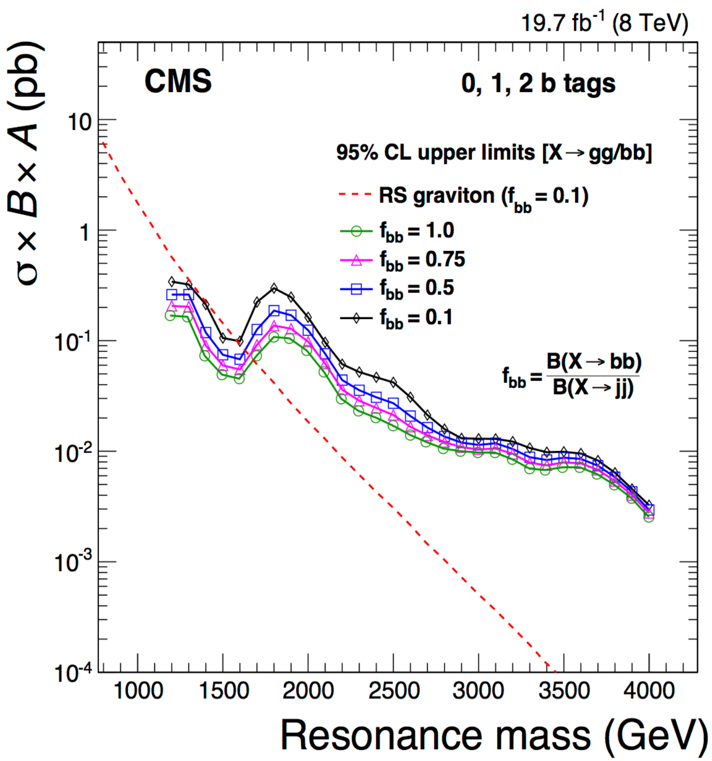
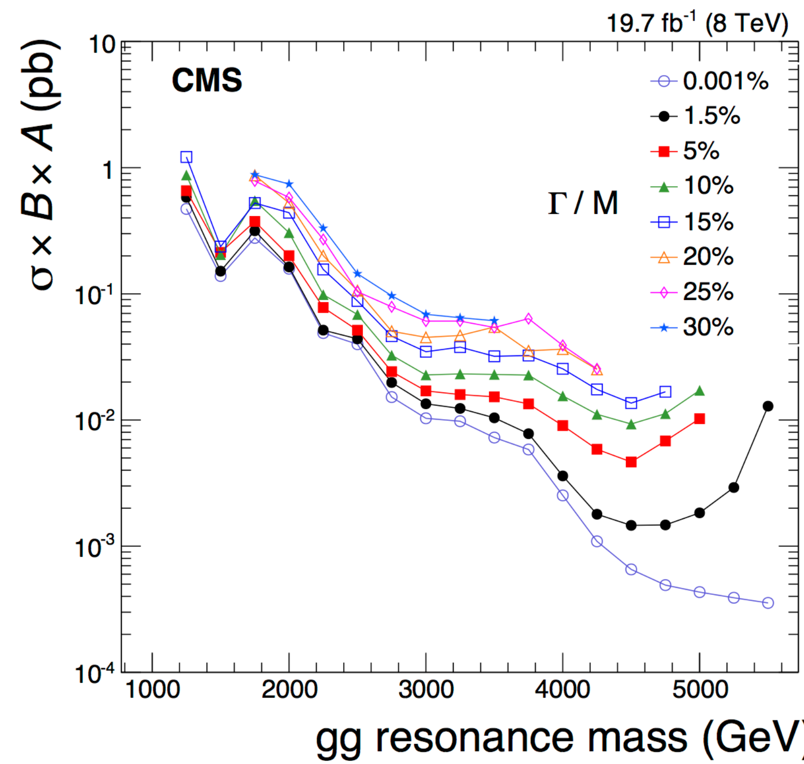
Extensions of the inclusive analysis

(Run 1)

Search in 0,1,2 b-tag categories

Wide resonances:
- analysis sensitive to resonances with width/mass ratio up to ~30%





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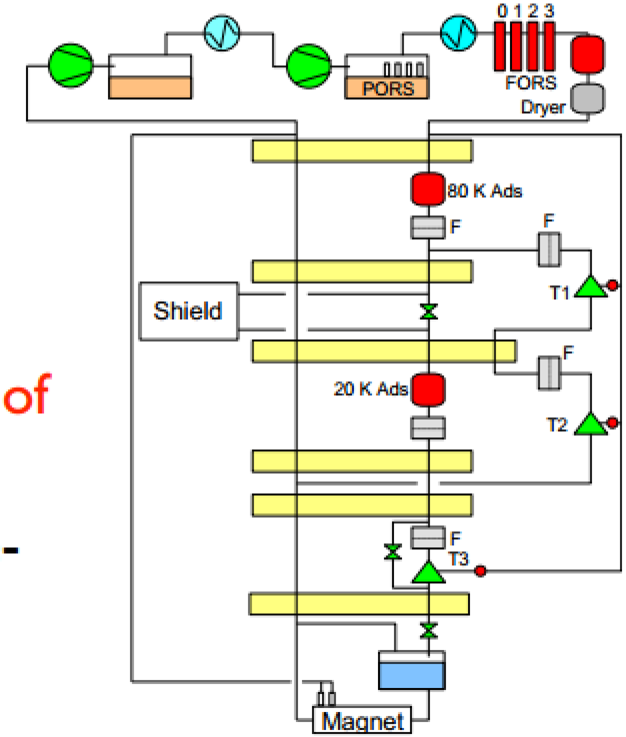
Magnet cryogenics issues



- The restart of the CMS magnet after LS1 was more complicated than anticipated due to problems with the cryogenic system in providing liquid Helium.
- Inefficiencies of the oil separation system of the compressors for the warm Helium required several interventions and delayed the start of routine operation of the cryogenic system.
- The data delivered during the first two weeks of LHC re-commissioning with beams at low luminosity have been collected with B=0
- Currently the magnet can be operated, but the continuous up-time is still limited by the performance of the cryogenic system requiring more frequent maintenance than usual.
- A comprehensive program to re-establish its nominal performance is underway. These recovery activities for the cryogenic system will be synchronized with the accelerator schedule in order to run for adequately long periods.
- A consolidation and repair program is being organized for the next short technical stops and the long TS at the end of the year.