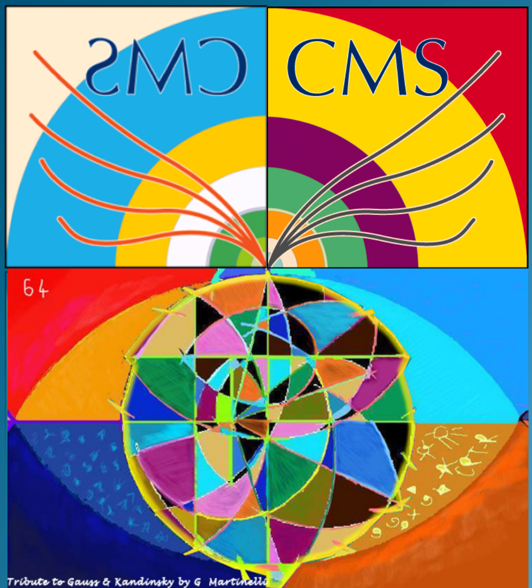
First Results of Searches for New Physics at √s=7TeV with the CMS detector



Paolo Azzurri

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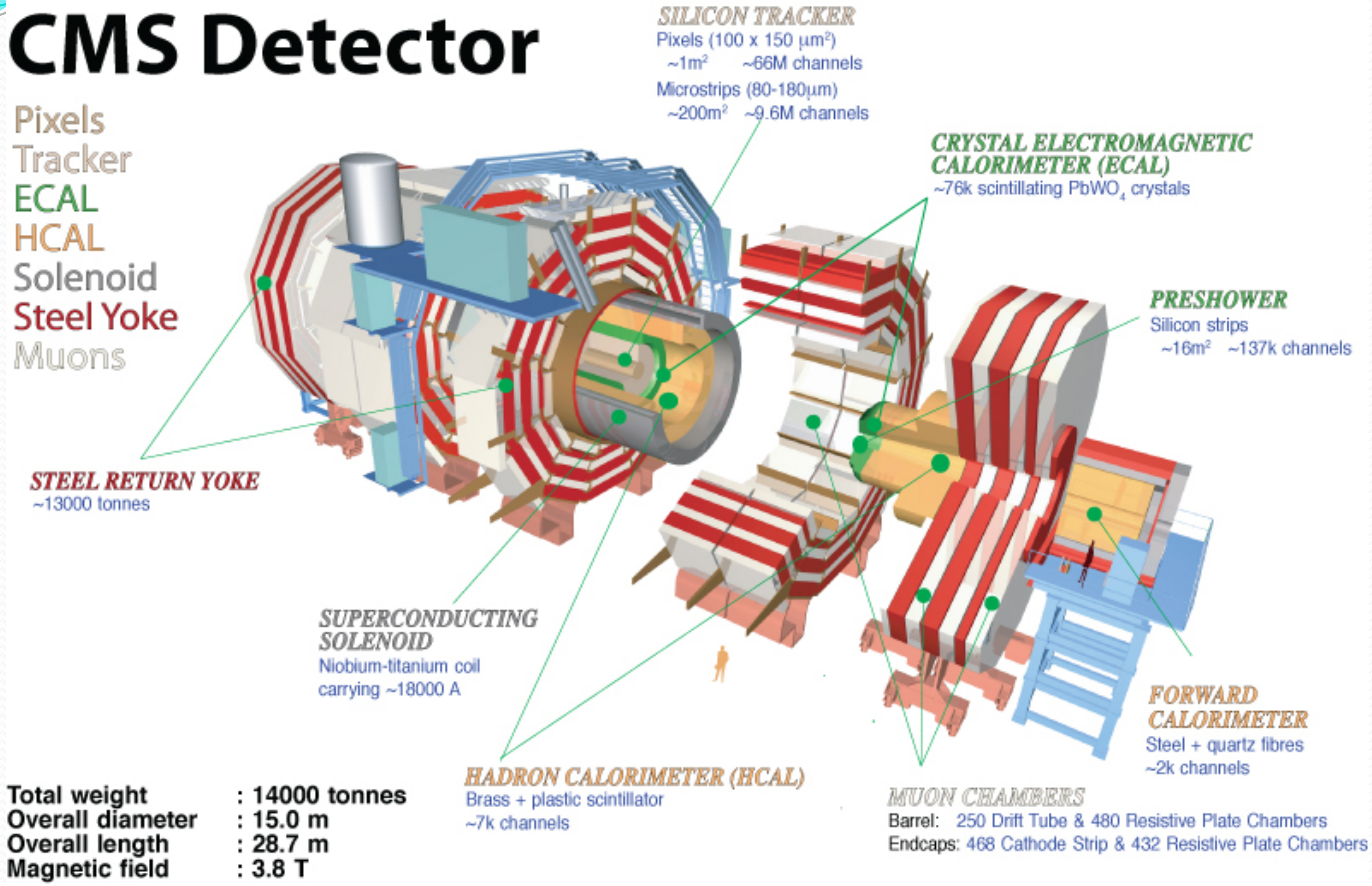
DISCRETE 2010 – Rome December 10, 2010

Outline

- Di-jet resonances
- Di-jet centrality ratio
- Heavy Stable Charged Particles
- Stopped Gluinos out of time decays

CMS Detector



pp $\sqrt{s}$=900GeV recorded
L ≅ 0.3nb^{-1}

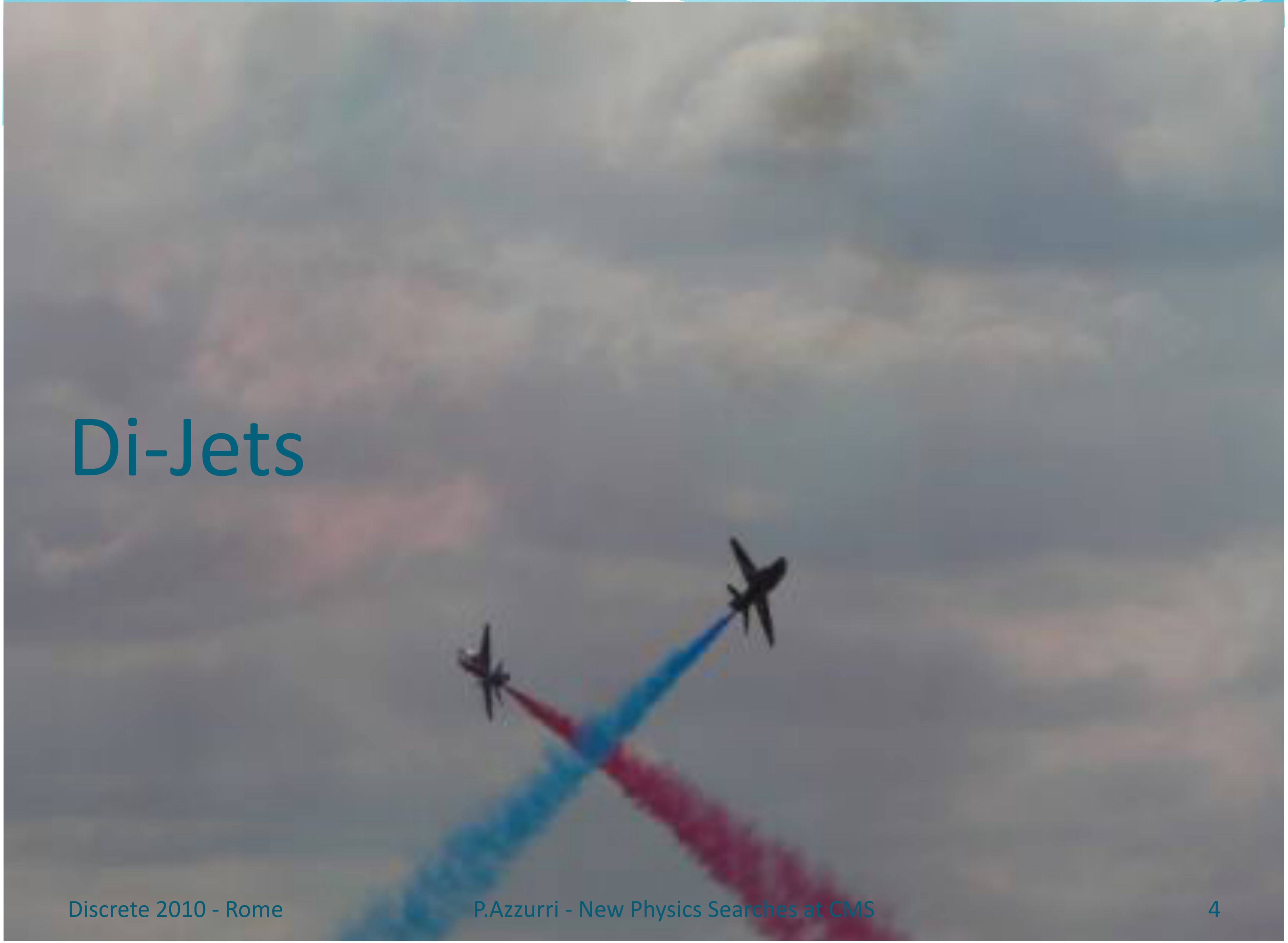
pp $\sqrt{s}$=2.36TeV recorded
L ≅ 0.4μb^{-1}

pp $\sqrt{s}$=7TeV recorded
L ≅ 43 pb^{-1}

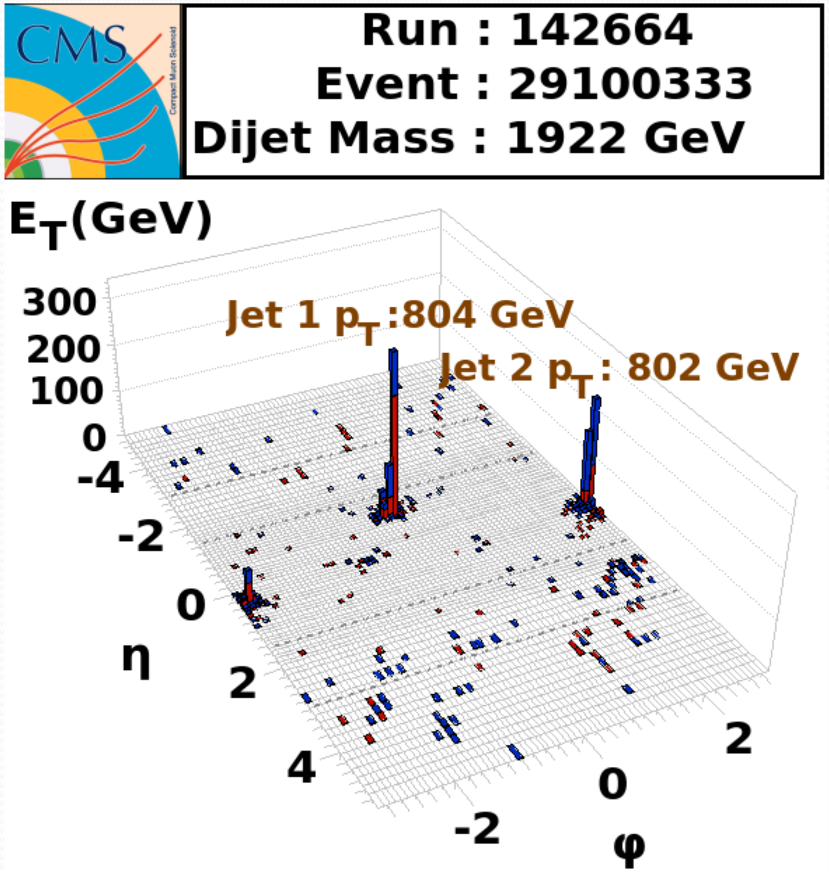
PbPb $\sqrt{s}$=574TeV recorded ($\sqrt{s_{NN}}$=2.7 TeV)
L ≈ 8μb^{-1}

Results shown today with up to 10pb^{-1} of pp $\sqrt{s}$=7TeV

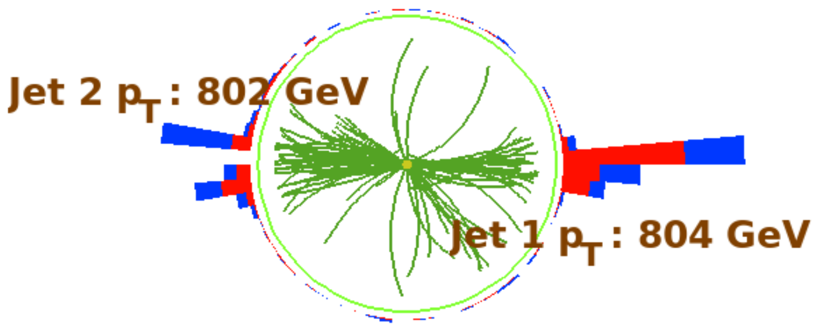
Di-Jets



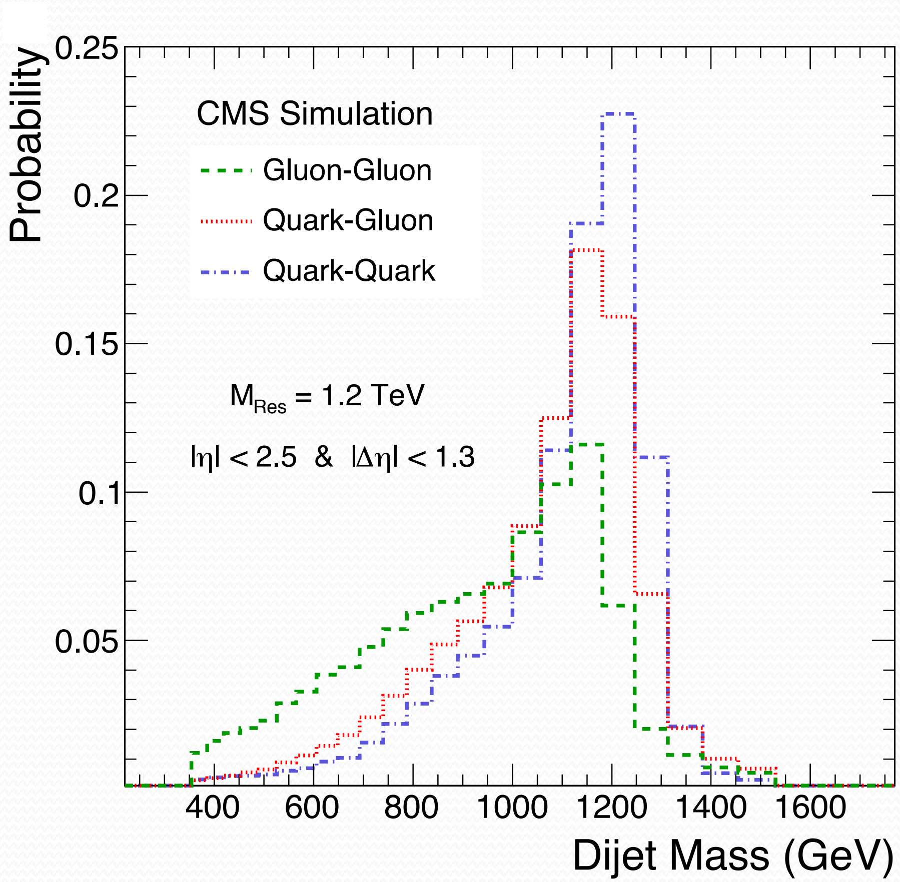
Di-jet resonances



single jet trigger E_T>50GeV
ε>99.5% for m_{jj}>220GeV/c^2
Primary Vertex with |z|<24cm
offline anti-kT calorimeter jets (R=0.7)
Two leading jets |η|<2.5 |Δη|<1.3
jet energy corrections +(40-15%)



Di-jet resonance simulation



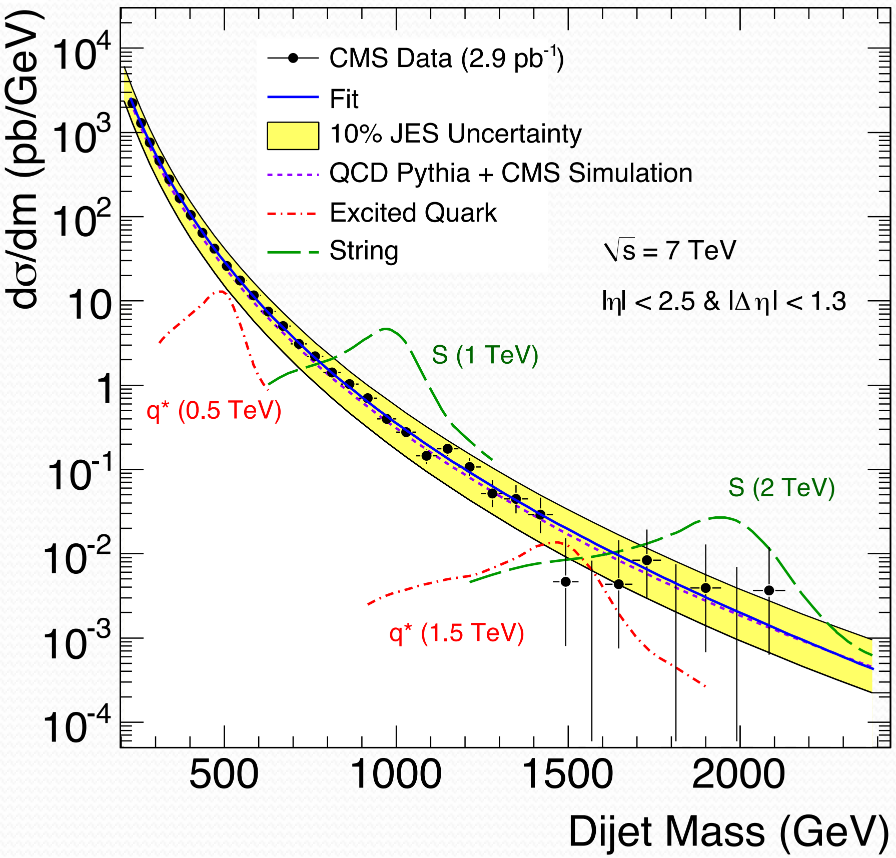
1.2 TeV

Searching for resonances with a narrow natural width (<< CMS di-jet mass resolution)

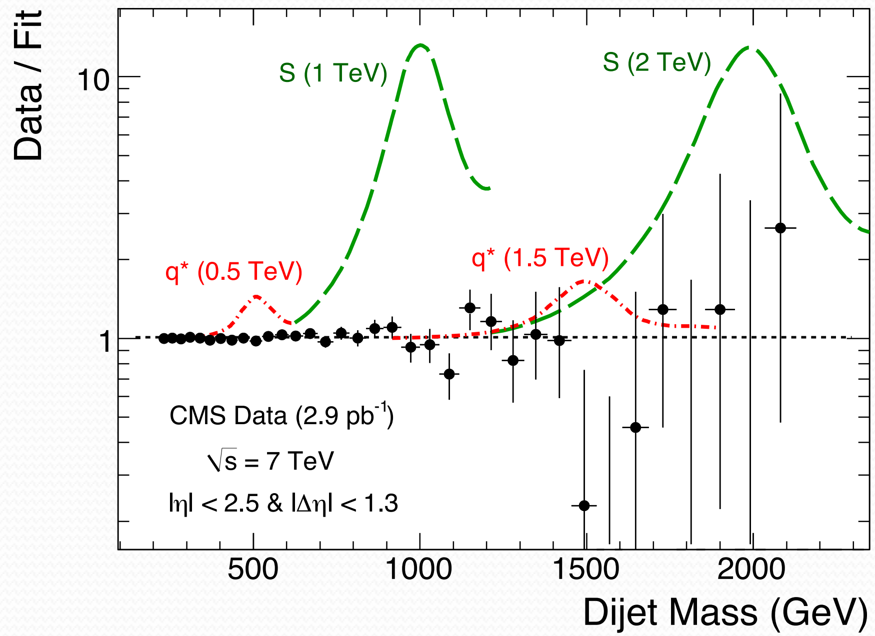
Resolution 5-16% for m_{jj}=0.5-2.5 TeV

Low mass tail and degraded resolution due to QCD radiation (larger with gluon final states)

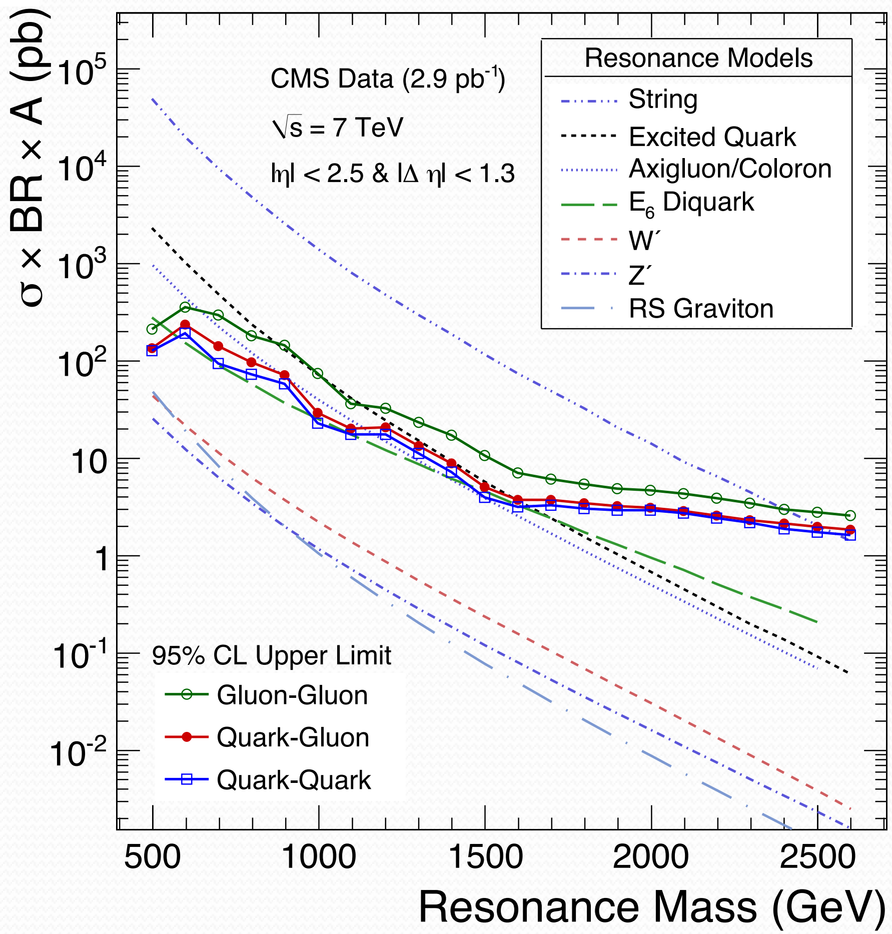
Di-jet mass cross section



$$\frac{d\sigma}{dm} = \frac{a\left(1 - m/\sqrt{s}\right)^{b}}{\left(m/\sqrt{s}\right)^{c + d\,\ln\left(m/\sqrt{s}\right)}}$$



Di-jet resonances limits



Bayesian upper limits (uniform prior)

Systematic uncertainties from
•Jet Energy Scale (10%)
•Jet Energy Resolution (10%)
•Data Luminosity (11%)
•Background Parameterization
included smearing PDF

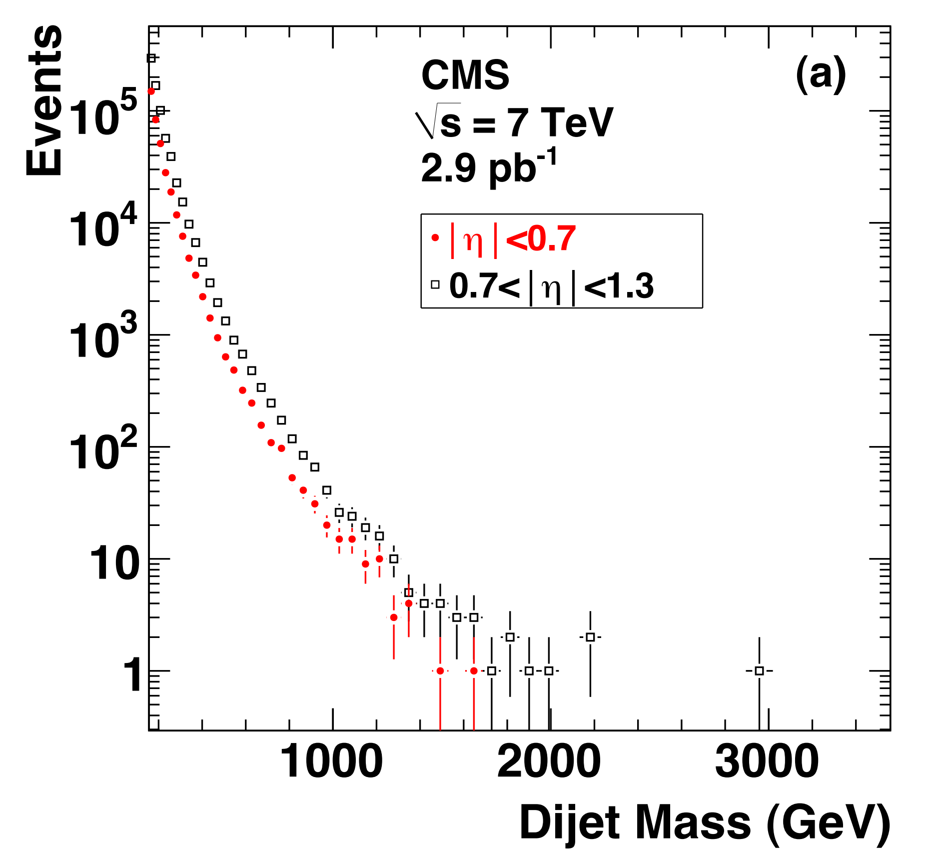
Mass lower limits in specific models (@95%CL)
m(S)>2.5 TeV (qq,qg,gg)
m(q*)>1.58 TeV (qg)
m(A,C)>1.17 TeV (qq)

no limits for W', Z' and RS gravitons

arXiv: 1010.0203 PRL **105, 211801**

TeVatron : m(S)>1.4 TeV m(q)>0.87 TeV m(A/C)>1.25 TeV*

Di-jet centrality



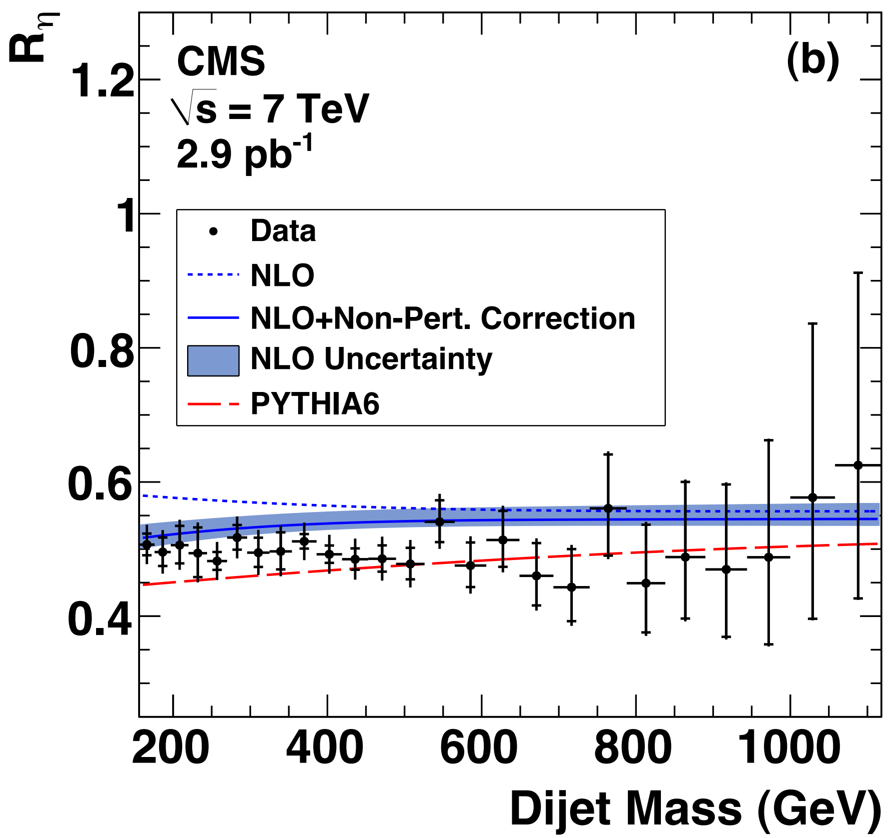
bin width ~ dijet mass resolution

Centrality Ratio among events with
- both leading jets with |η|<0.7
- both leading jets with 0.7<|η|<2.3

$$R = \frac{N(|\eta| < 0.7)}{N(0.7 < |\eta| < 1.3)}$$

Compared to the complete angular analysis, R requires less statistics to be sensitive to finer mass binning . Systematic effects cancel in the ratio. More sensitive to **contact interactions** rather then to di-jet resonances.

Di-jet centrality

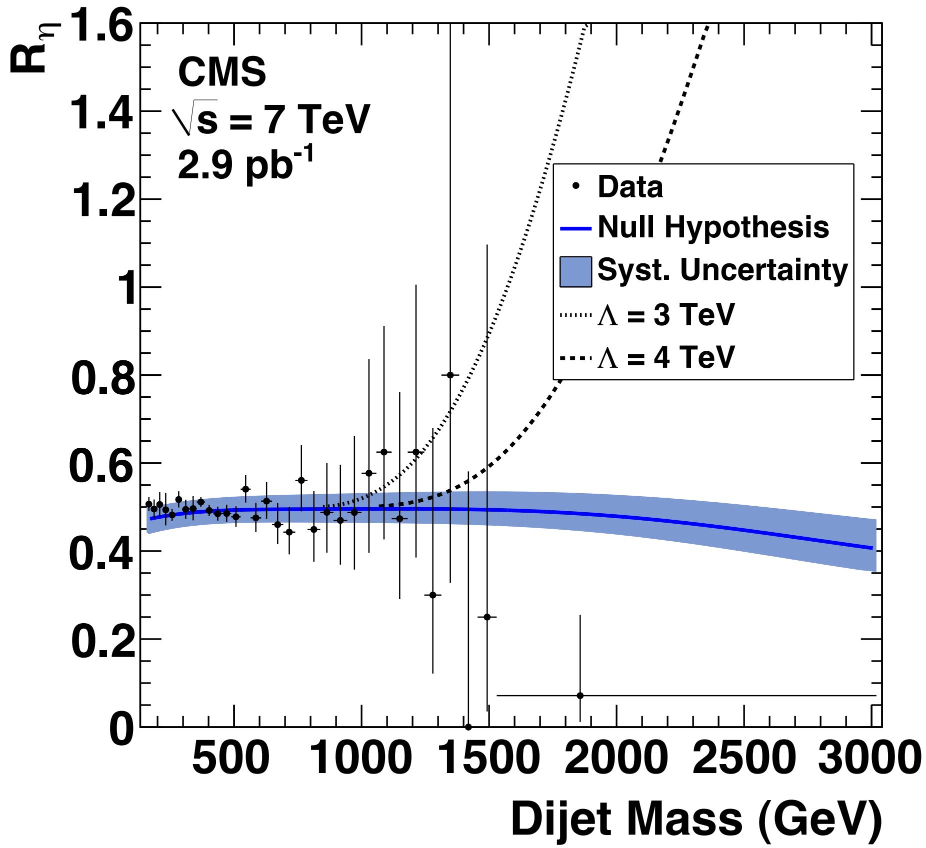


Non perturbative effects (hadronization, multiple parton interactions) evaluated with PYTHIA and HERWIG

NLO uncertainties from normalization and factorization scales choices (3-4% effect)

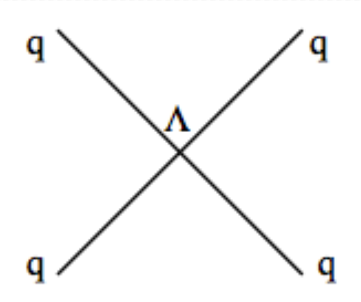
The average ratio is ~7% lower than the corrected NLO

Di-jet centrality



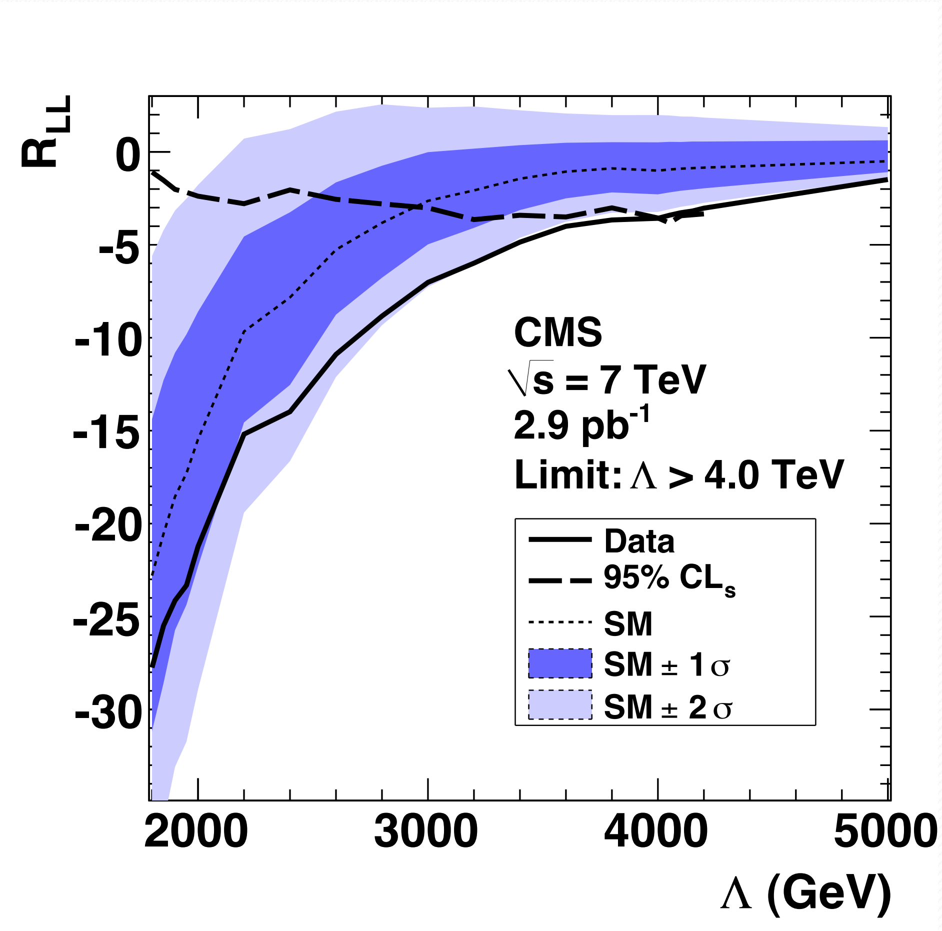
Effective low energy Contact interaction

$$L = \pm \frac{2\pi}{\Lambda^2}\left(\bar{q}\gamma_\mu q\right)\left(\bar{q}\gamma_\mu q\right)$$



enhanced production of central di-jets

Di-jet centrality limits



Log-likelihood ratio

$$R_{LL} = \log L_{QCD+\Lambda} - \log L_{QCD}$$

to test the contact interaction scale Λ

Pseudo-experiments (frequentist) approach to derive 95%CL exclusion:

Λ>4.0 TeV (expected 2.9 TeV)

Systematic effects included with Cousins –Highland method

arXiv: 1010.4439
accepted by PRL

Stable Massive Particles

HSCP searches

(Quasi) Stable Massive Particles

interact strong/e.m. and do not decay in the detector

Many new physics scenarios predict heavy long-lived particles

- Stau NLSP in GMSB, decaying via gravitational coupling only
- Light stop models with kinematically limited decays
- Split-SUSY, where gluino decay is suppressed by heavy squark masses
- Hidden valley models, GUTs

see Phys.Rep.438 (2007) 1

particular interest in cosmology

HSCP searches in CMS

Generic search based on first 200nb^{-1} of data . Triggers with :
-single-muon (p_T>3 GeV)/ di-muons
-missing E_T>45 GeV
- single jets p_T>30 GeV/c

HSCP candidate: 1) *tracker-only,* or 2) *tracker+muon*
Search for dE/dx (derive mass), eventually require muon-id

MC Signals from (quasi)-stable
-stops : 100-800 GeV
-gluinos: 200-900 GeV
- sleptons (GMSB staus benchmark)

MC Backgrounds QCD inclusive (pT>30)

HSCP Selection

select tracks with:

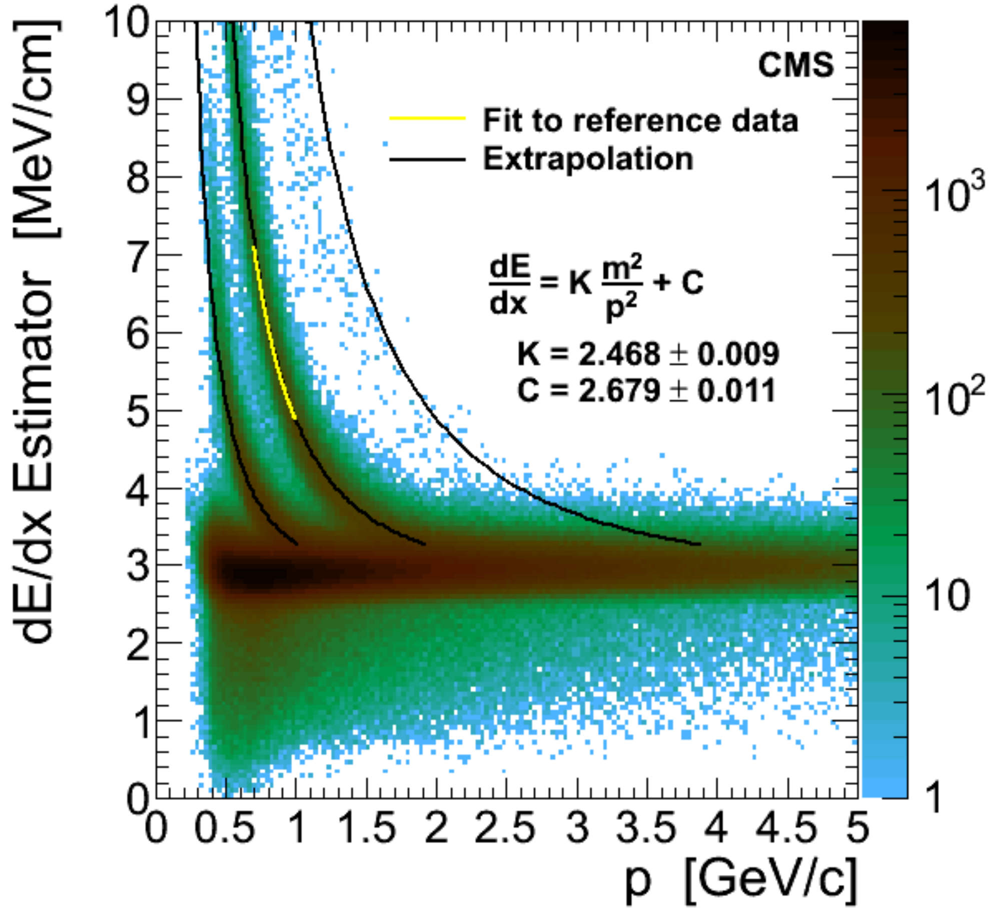
- Tracker Hits N≥12
- p_T>7.5 GeV/c $\Delta p_T/p_T$<0.15
- $|\Delta d_0|$<0.25cm
- $|\Delta z|$<2cm

Clusters are cleaned from anomalous ionization contributions :

- overlapping MIPs
- nuclear interactions
- hard δ-rays

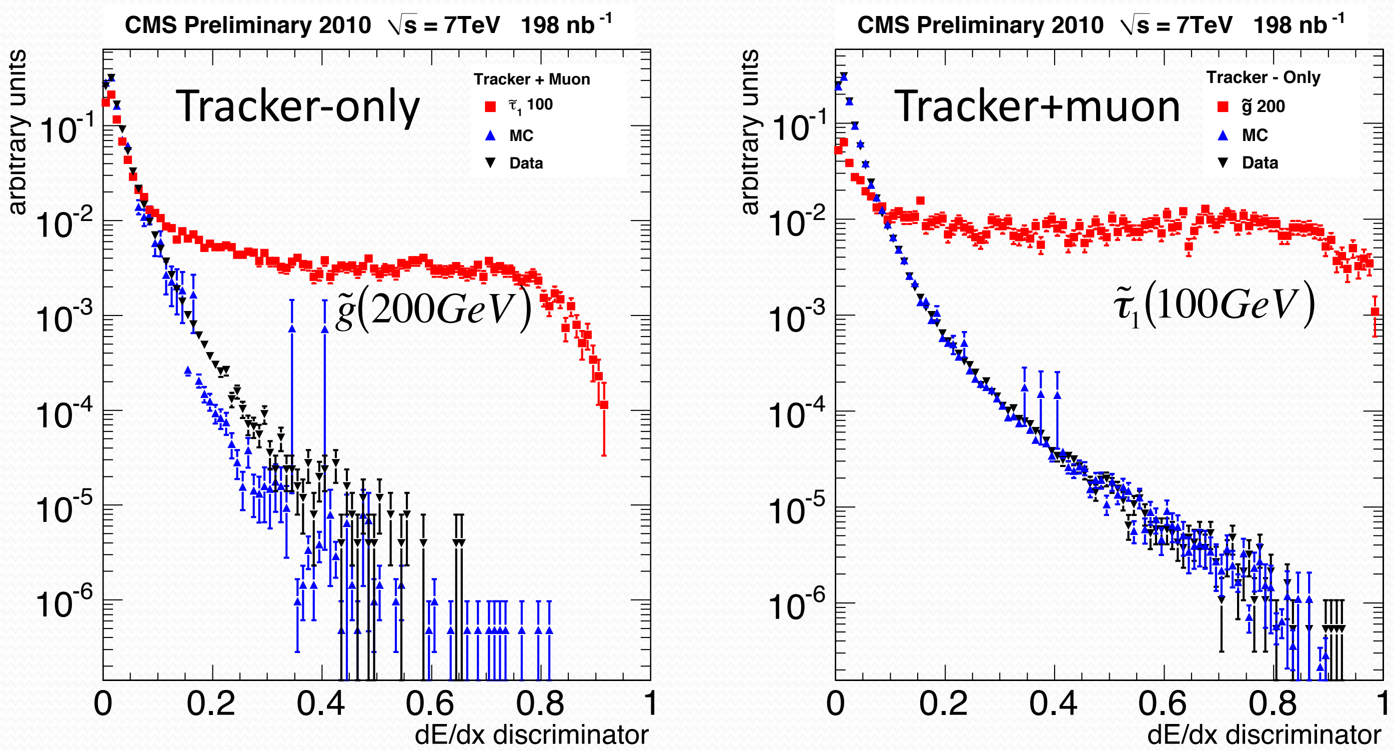
$$I_h = \frac{dE}{dx} = \left(\frac{1}{N}\sum c_i^{-2}\right)^{-1/2}$$

generalized mean of grade *k=-2*



N number of layers with c_i charge measures

dE/dx estimator of MIP hypothesis

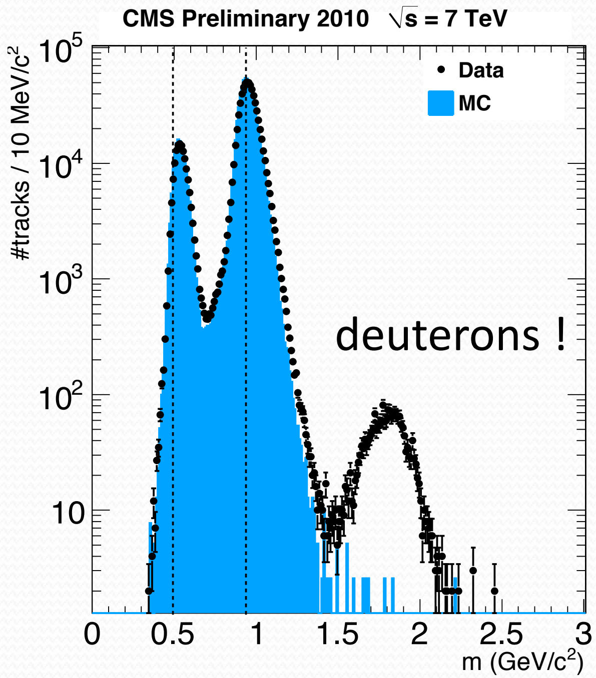


I_{as} high dE/dx compatibility estimator, based on Smirnov - Cramer – von Mises estimator

I_{as} estimator increases S/B separation by a factor 3 with respect to I_h

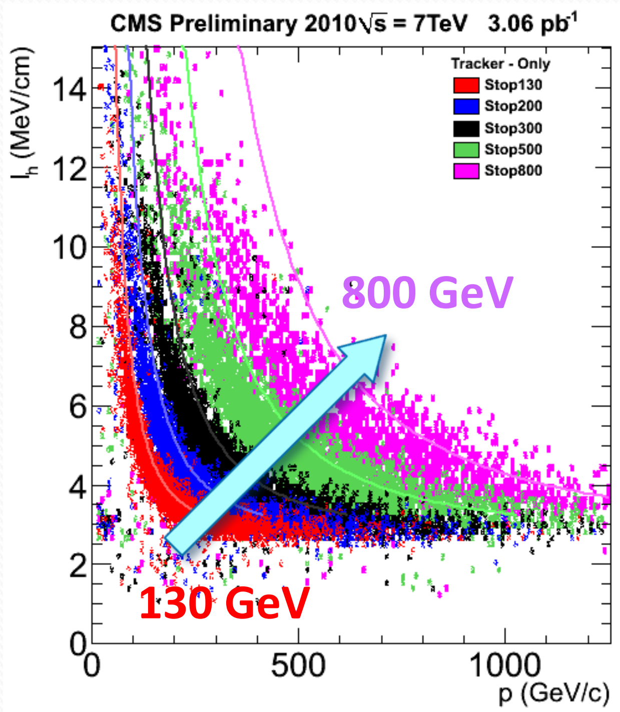
Further division in subsamples according to the number of hits (N) improves S/B by a factor 8

HSCP Mass estimator



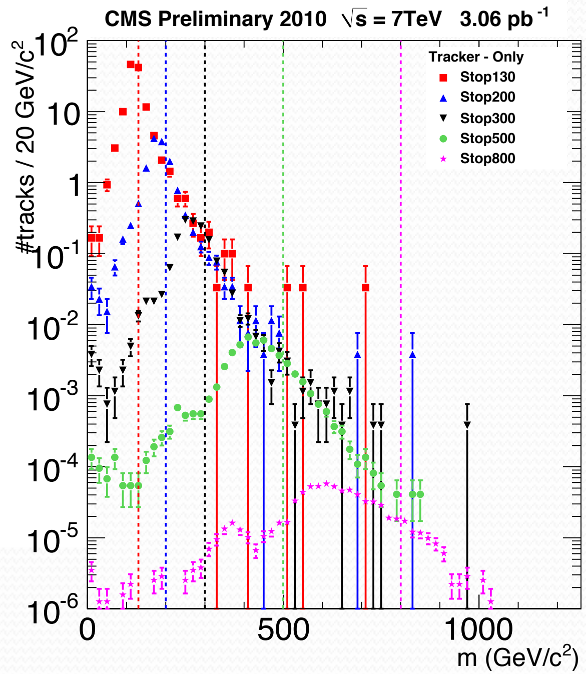
Minimum Bias DATA
p<2GeV/c -dE/dx>5 MeV/cm

Inverting the I_h=K m^2/p^2 + C fit



MC signal (stable stop)

ADC cut-off effects



HSCP Search

Counting experiment in the 75<m<1200 GeV/c^2 range

Cuts on p_T and I_{as} with constant background efficiencies

$\varepsilon(p_T)$=0.01-10% $\varepsilon(I_{as})$=0.03-3% required for each subsample

LOOSE	ϵ_{p_T}	p_T^{cut}	ϵ_I	I_{as}^{cut}
Tracker+Muon	$10^{-1.0}$	7.7 - 25.9	$10^{-1.5}$	0.0036 - 0.4521
Tracker only	$10^{-2.0}$	7.9 - 67.4	$10^{-2.0}$	0.0037 - 0.5293
TIGHT	ϵ_{p_T}	p_T^{cut}	ϵ_I	I_{as}^{cut}
Tracker+Muon	$10^{-3.0}$	7.7 - 125.9	$10^{-3.0}$	0.0036 - 0.6526
Tracker only	$10^{-4.0}$	7.9 - 259.0	$10^{-3.5}$	0.0037- 0.8901

I_{as}

C_i	D_i
A_i	B_i

p_T

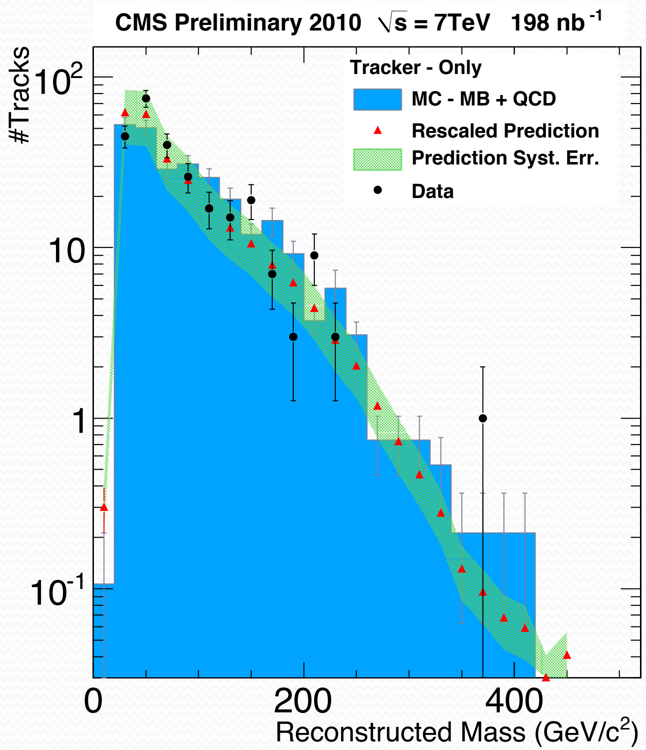
Data driven background estimation in the signal region $D_i=B_iC_i/A_i$ where the four regions are determined by the (uncorrelated) cuts on p_T and dE/dx(I_{as}).

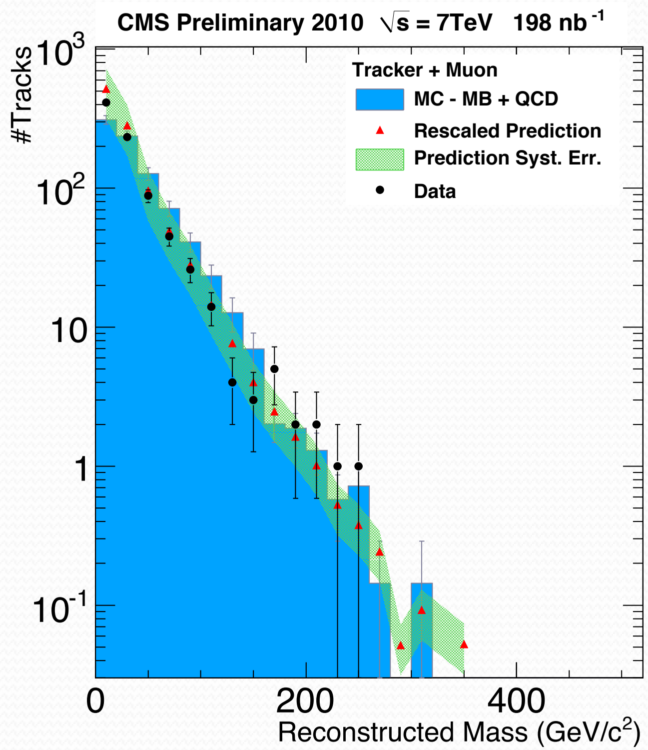
Observed discrepancies in control samples (with m<75 GeV/c^2) are used to correct the expected backgrounds +(5-10%) and the spreads are used to assign systematic uncertainties ~(14-17%)

HSCP Search Results

LOOSE	Exp.	Obs.	Exp. in full spectrum	Obs. in full spectrum
Tracker+Muon	82 ± 33	77	1007 ± 200	838
Tracker Only	108 ± 38	122	184 ± 250	260

TIGHT	Exp.	Obs.	Exp. in full spectrum	Obs. in full spectrum
Muon-like	0.153 ± 0.061	0	0.249 ± 0.050	0
Tk-only	0.060 ± 0.021	0	0.060 ± 0.011	0

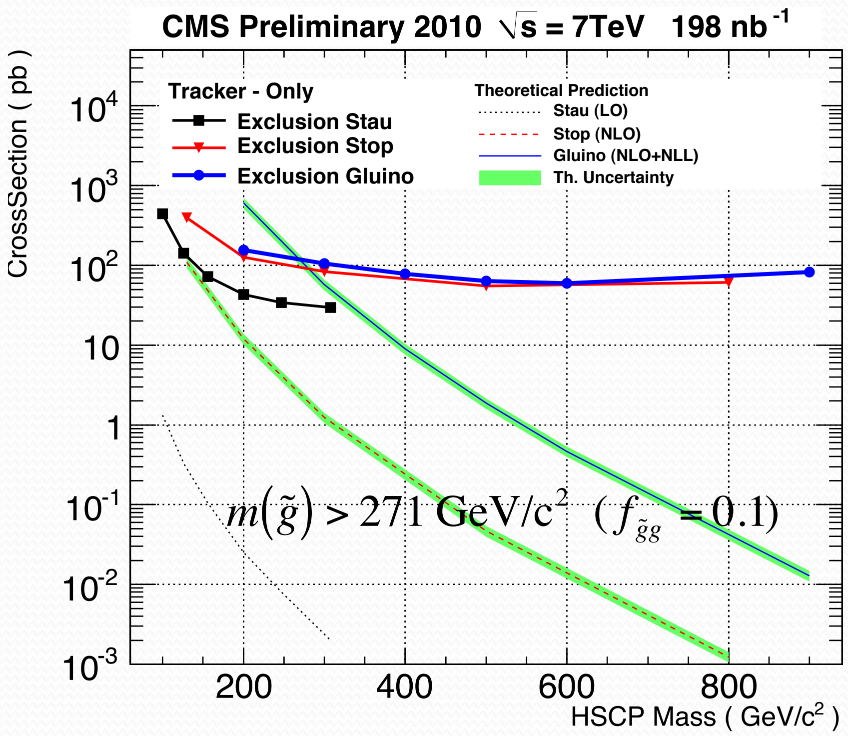


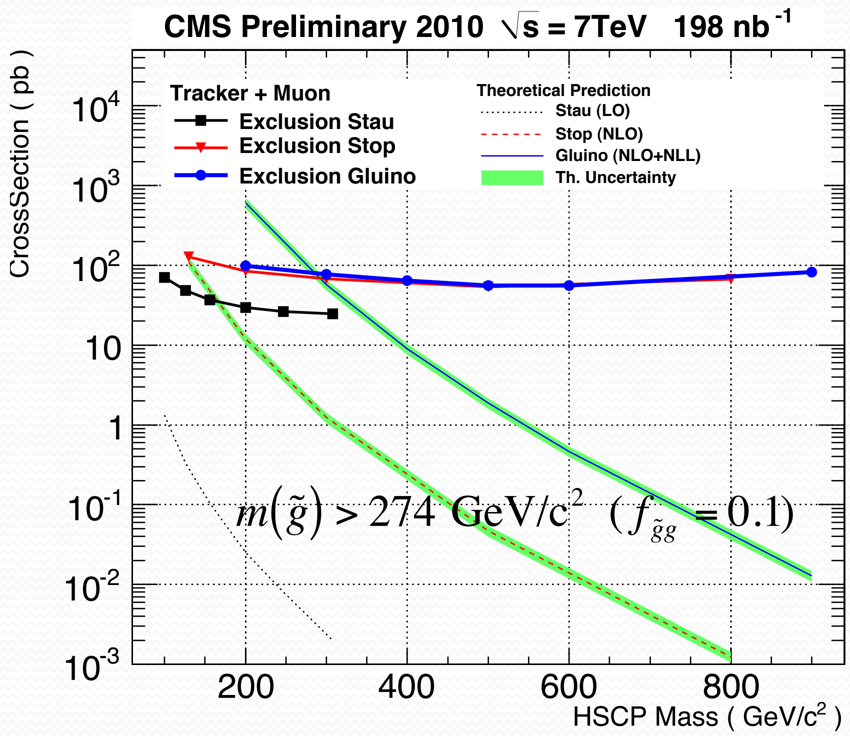


bayesian 95% CL upper limits on HSCP production

HSCP 95% CL limits

Bayesian limits with lognormal prior, no background subtraction





Tevatron: m(stop)>249 GeV/c^2, m(gluino)>322-397 GeV/c^2

Stopped gluinos

Address case of lower β (<0.3) gluinos that may lose more energy, are **stopped** while traversing the detector **and decay during no-beam periods**

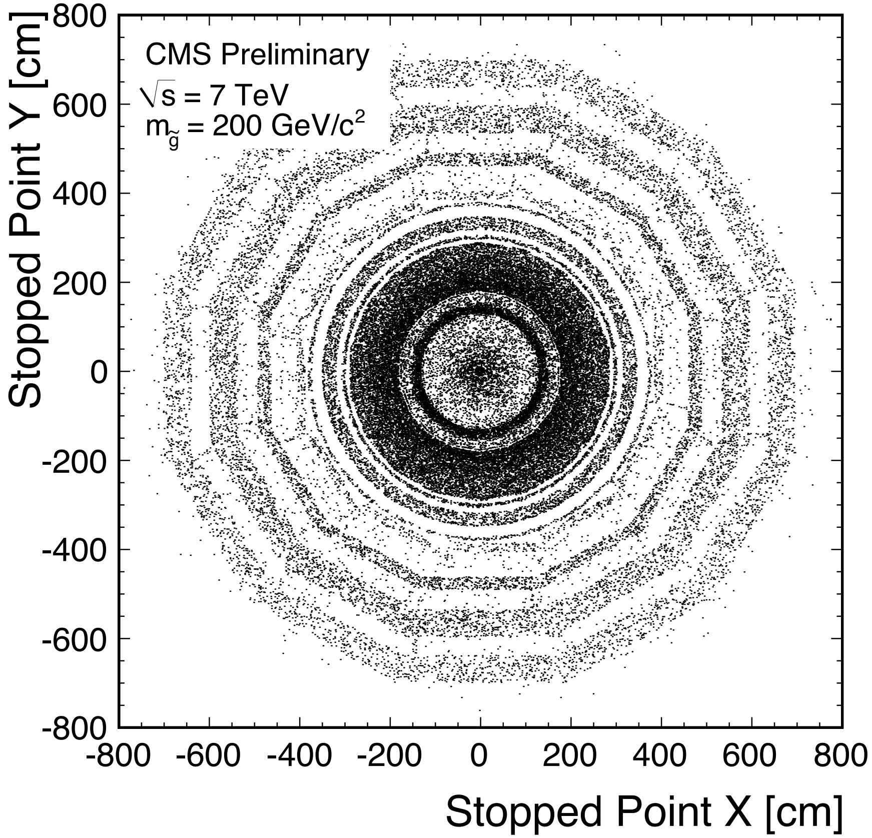
Dedicated triggers for signal decays during beam gaps (using beam position & timing monitors BPTX@z=±174m)

1 L1 jet with E_T (L1) > 10 GeV && 1 HLT jet with E > 20 GeV, $|\eta| < 3.0$

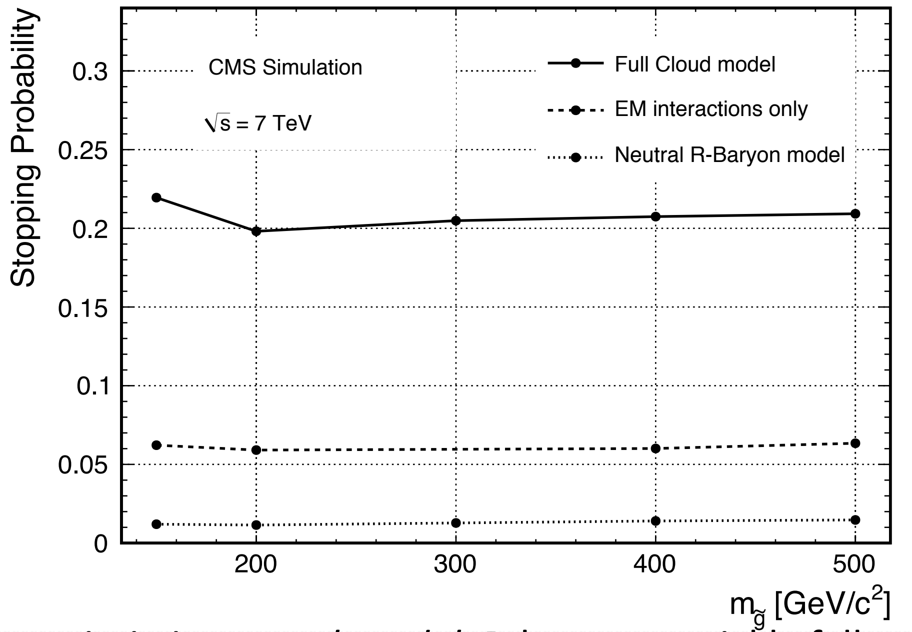
Background: Low luminosity minimum bias sample

model independent search with split-SUSY gluino benchmark

Stopped gluinos simulation

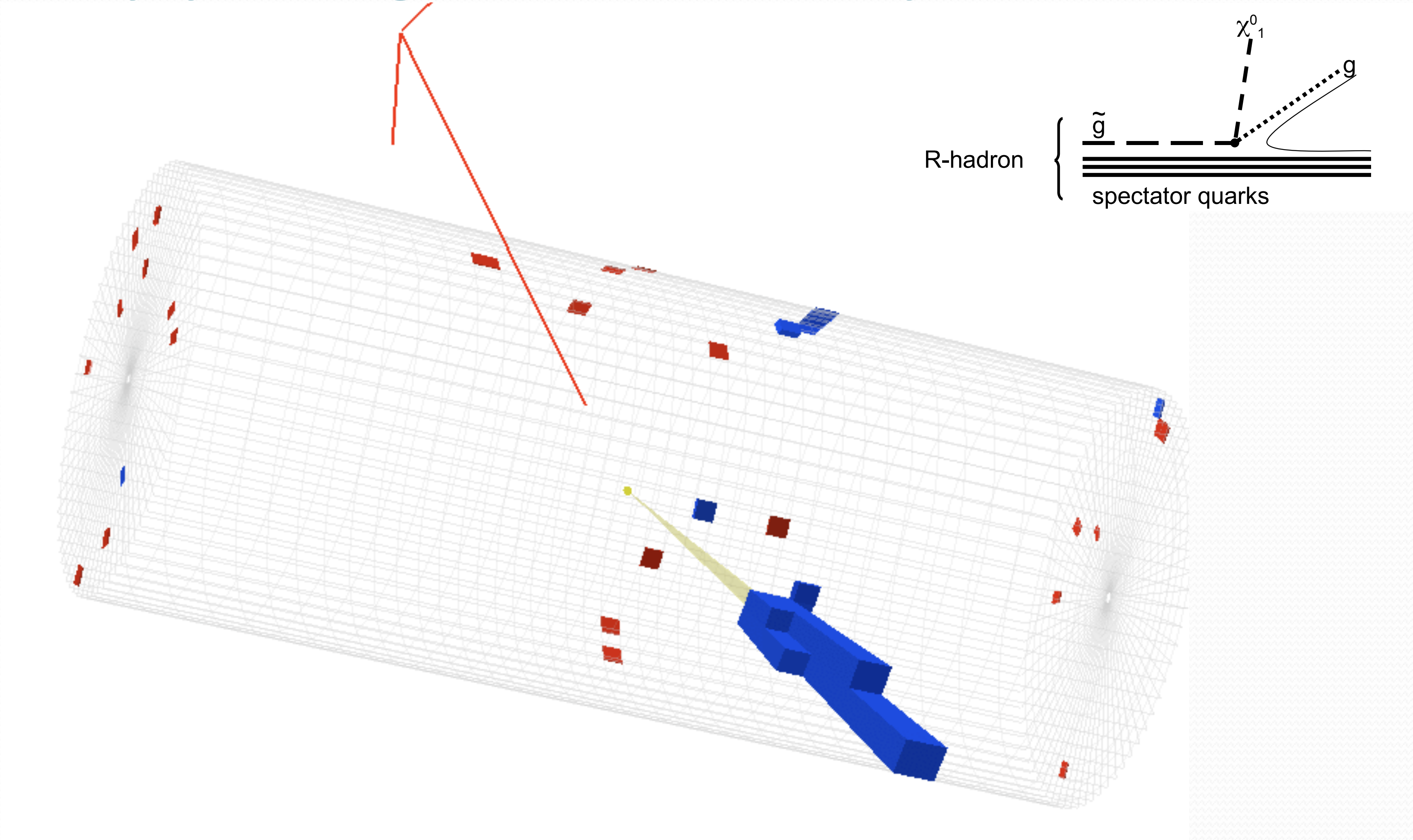


cloud model : R-hadrons undergo flavour changing interactions which enhance stopping



pessimistic *neutral model*: R-baryons quickly fall to lightest neutral R-baryon is neutral and stop interacting

Stopped gluino decay



Stopped gluino selection

•Search dataset: 15.5 pb–1 delivered by LHC (optimized for best S/B)

•Sensitive luminosity for out-of-time decays depends on lifetime: a maximum of 10.2 pb–1, for 90μs (τ_{LHC})<τ<T_{fill}

•Counting optimized time window: 1.25τ following each collision

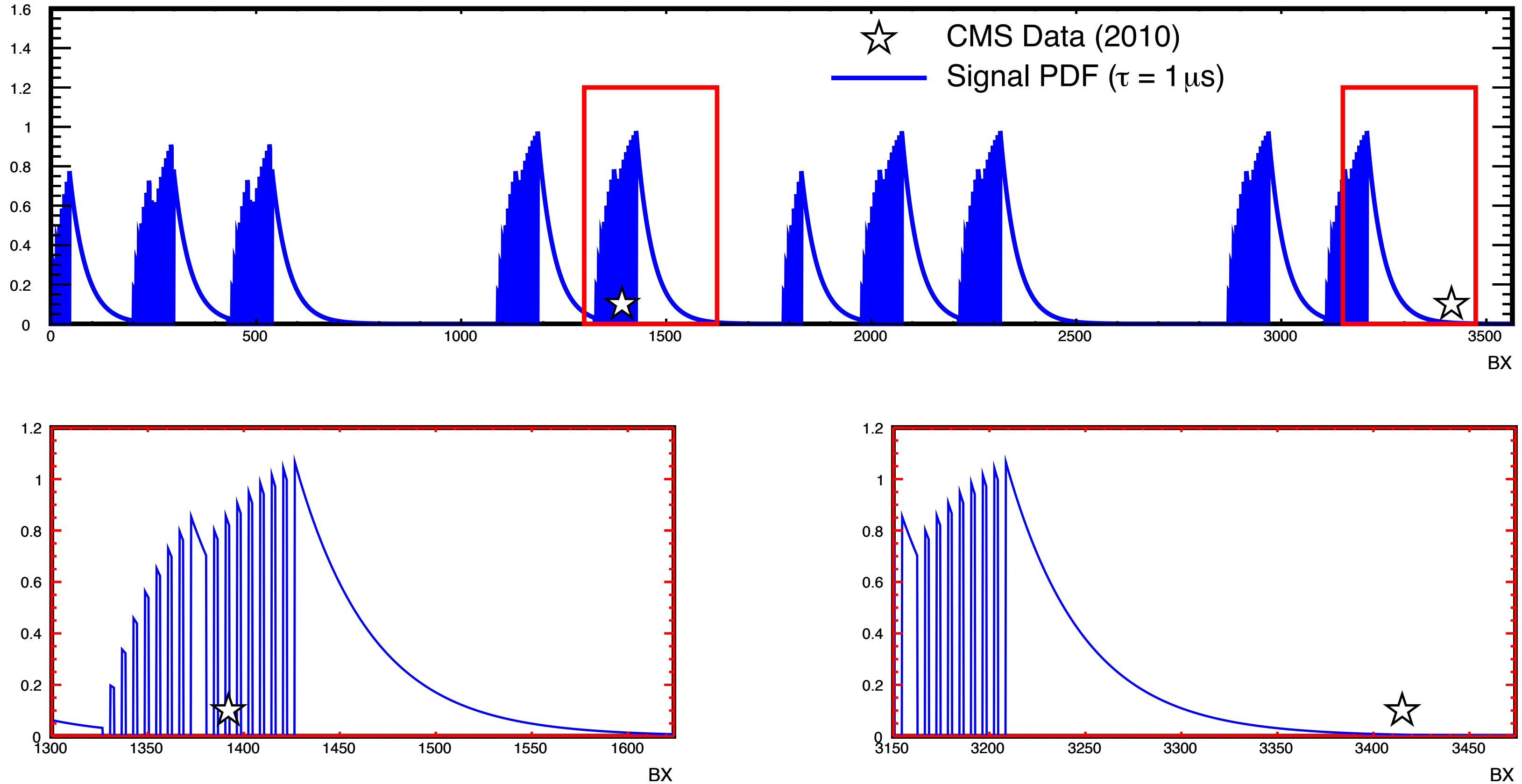
control sample rates

Cut	BG rate (Hz)
HLT	3.09
BPTX/BX veto	3.07
vertex veto	3.07
beam halo veto	3.07
muon veto	2.73
HBHE noise filter	6.9×10^{-1}
$E_{jet} > 50$ GeV, $\lvert\eta_{jet}\rvert < 1.3$	7.9×10^{-2}
$n_{90} > 3$	4.1×10^{-3}
$n_{phi} < 5$	7.9×10^{-5}
$R_1 > 0.15$	7.1×10^{-5}
$0.1 < R_2 < 0.5$	5.7×10^{-5}
$0.4 < R_{peak} < 0.7$	5.4×10^{-5}
$R_{outer} < 0.1$	5.1×10^{-5}

signal
ε=17%

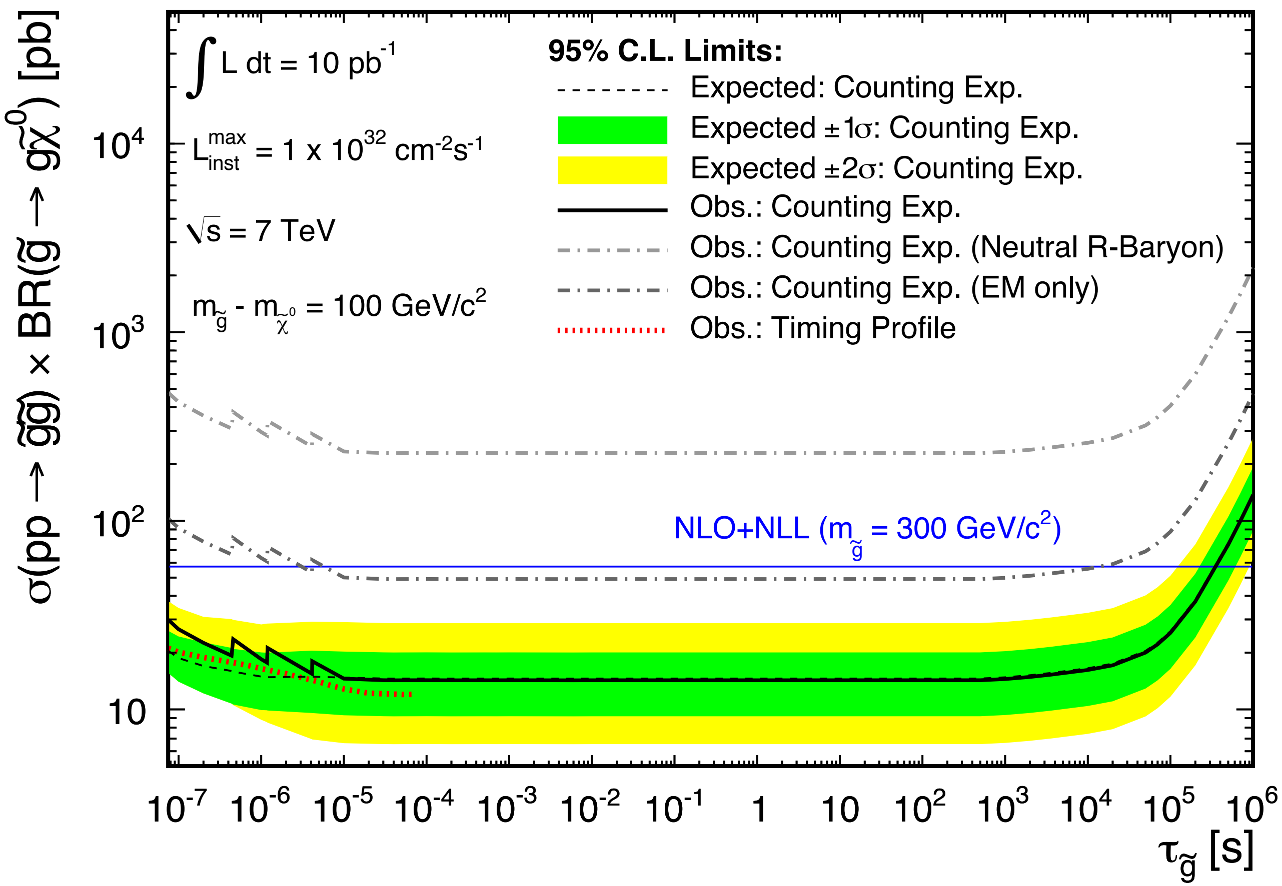
Lifetime [s]	Expected Background (± stat. ± syst.)	Observed
1×10^{-7}	$0.8 \pm 0.2 \pm 0.2$	2
1×10^{-6}	$1.9 \pm 0.4 \pm 0.5$	3
1×10^{-5}	$4.9 \pm 1.0 \pm 1.3$	5
1×10^{6}	$4.9 \pm 1.0 \pm 1.3$	5

Stopped gluinos time profile



bunch crossing (BX) number veto : (-2,+1 wrt collision)

Stopped gluinos limits

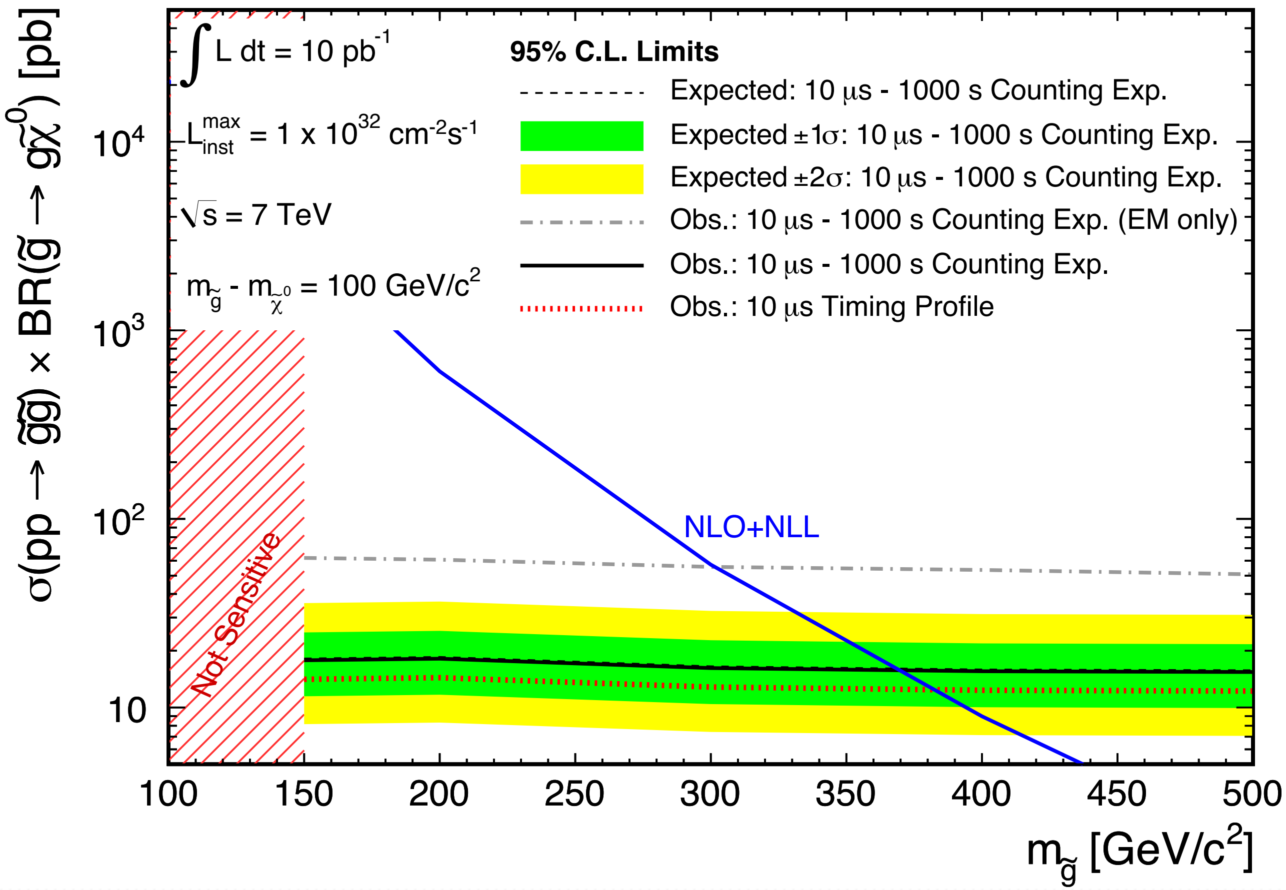


95% CL production upper limits derived using a frequentist CLs method

τ < few 100 ns : Decays occur during vetoed BXs

$\tau > T_{fill}$:Lose sensitivity as most decays occur post-fill

Stopped gluinos mass limits



$B(\tilde{g} \rightarrow g\chi_1^0) = 100\%$

$m(\tilde{g}) - m(\chi_1^0) = 100\ \mathrm{GeV/c^2}$

$m(\tilde{g}) > 382\ \mathrm{GeV/c^2}$

with $\tau(\tilde{g}) = 10\,\mu s$

$m(\tilde{g}) > 370\ \mathrm{GeV/c^2}$

with $10\,\mu s < \tau(\tilde{g}) < 1000\,s$

arXiv: 1011.5861
to appear in PRL

Conclusions

… Nothing New Yet from CMS on :

- Di-Jet masses & centrality

- Stable Massive Particle searches

- many TeVatron Limits Extended up to x2

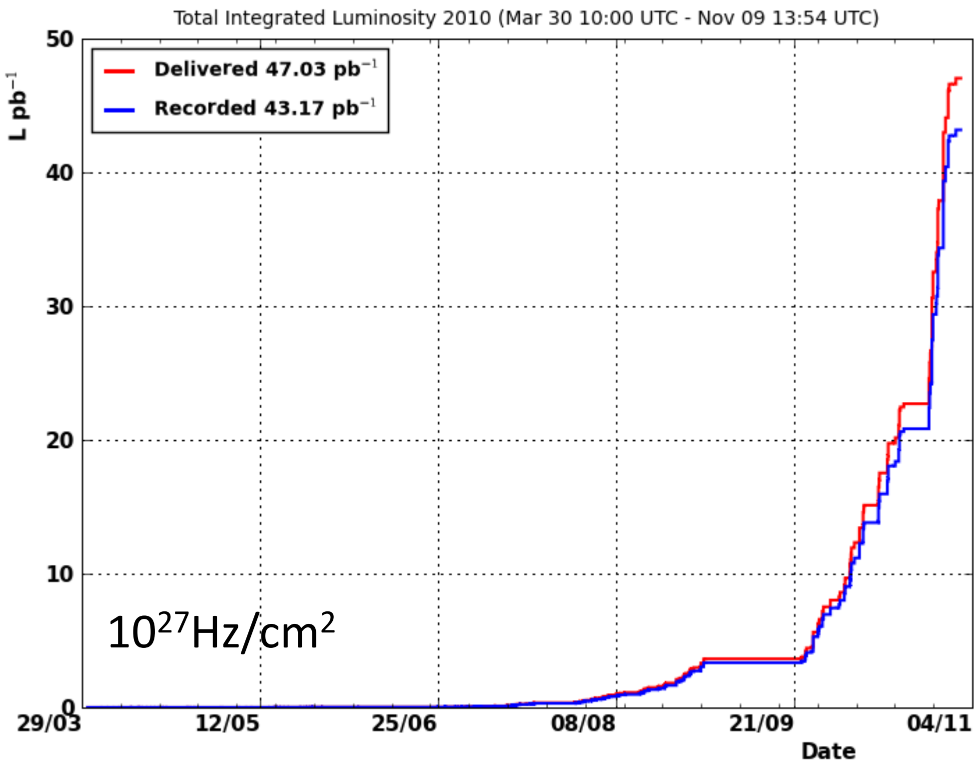
m(S)>2.5 TeV   m(q*)>1.58 TeV m(A,C)>1.17 TeV

stable gluino: m>274 GeV & m>370 GeV** **with 10μs<τ<10^3s (Δm>100GeV)

- Looking Forward to Higher Luminosity

Backup

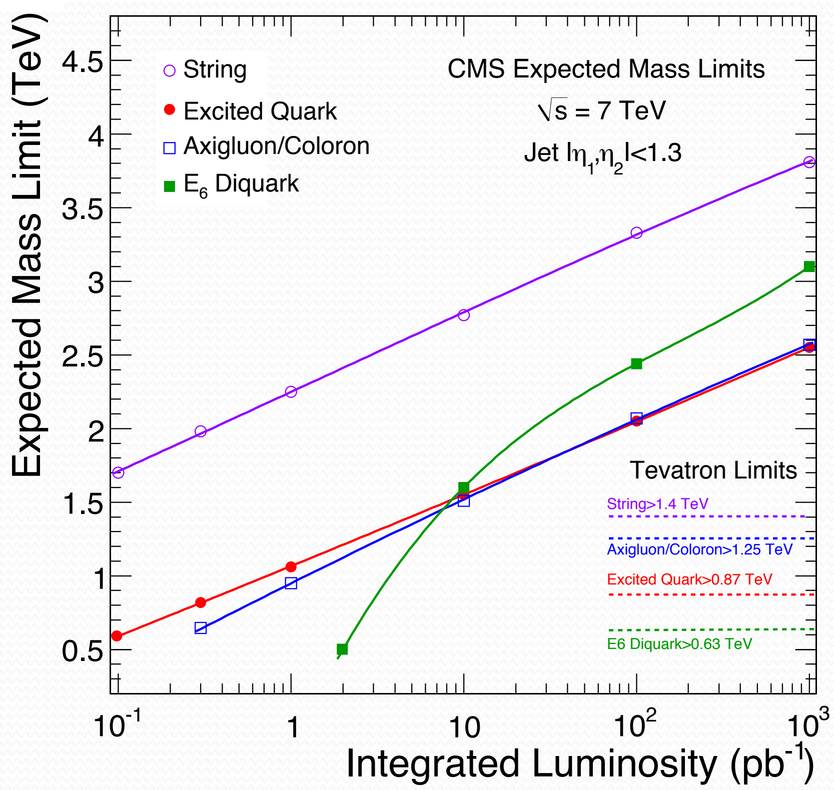
CMS Luminosity



Di-jet resonances: Specific models

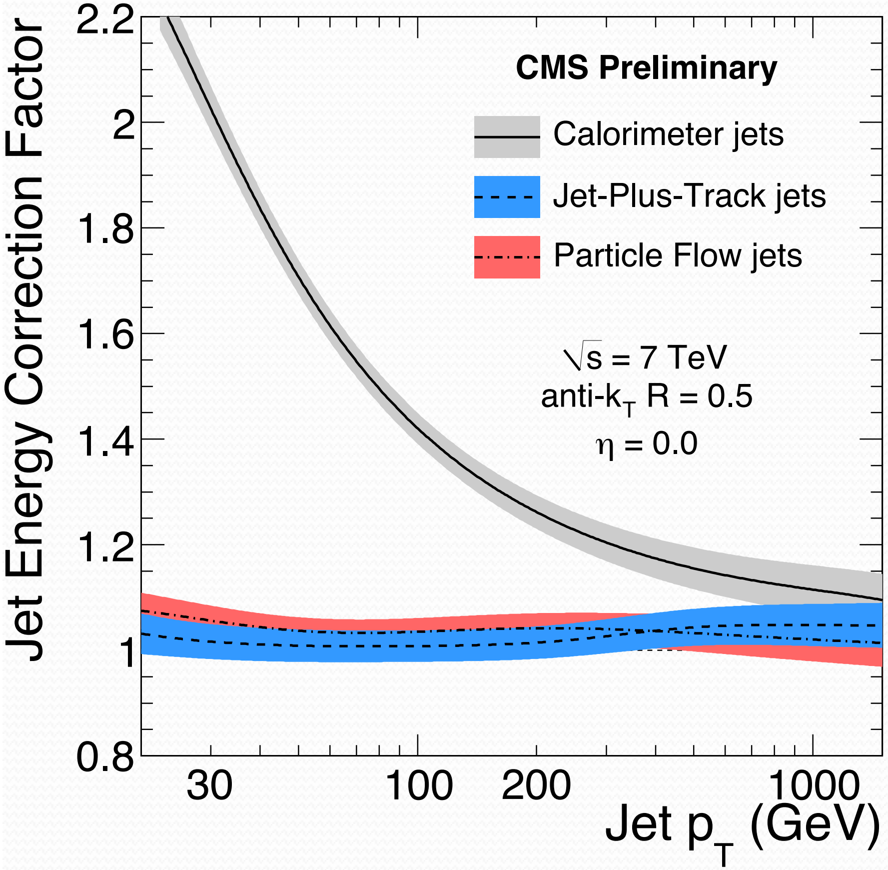
Model Name	X	Color	J^P	$\Gamma/(2M)$	Final-state Partons
String	S	mixed	mixed	0.003-0.037	$q\bar{q}$, qq, gg and qg
Axigluon	A	Octet	1^+	0.05	$q\bar{q}$
Coloron	C	Octet	1^-	0.05	$q\bar{q}$
Excited Quark	q*	Triplet	$1/2^+$	0.02	qg
E_6 Diquark	D	Triplet	0^+	0.004	qq
RS Graviton	G	Singlet	2^+	0.01	$q\bar{q}$, gg
Heavy W	W′	Singlet	1^-	0.01	$q\bar{q}$
Heavy Z	Z′	Singlet	1^-	0.01	$q\bar{q}$

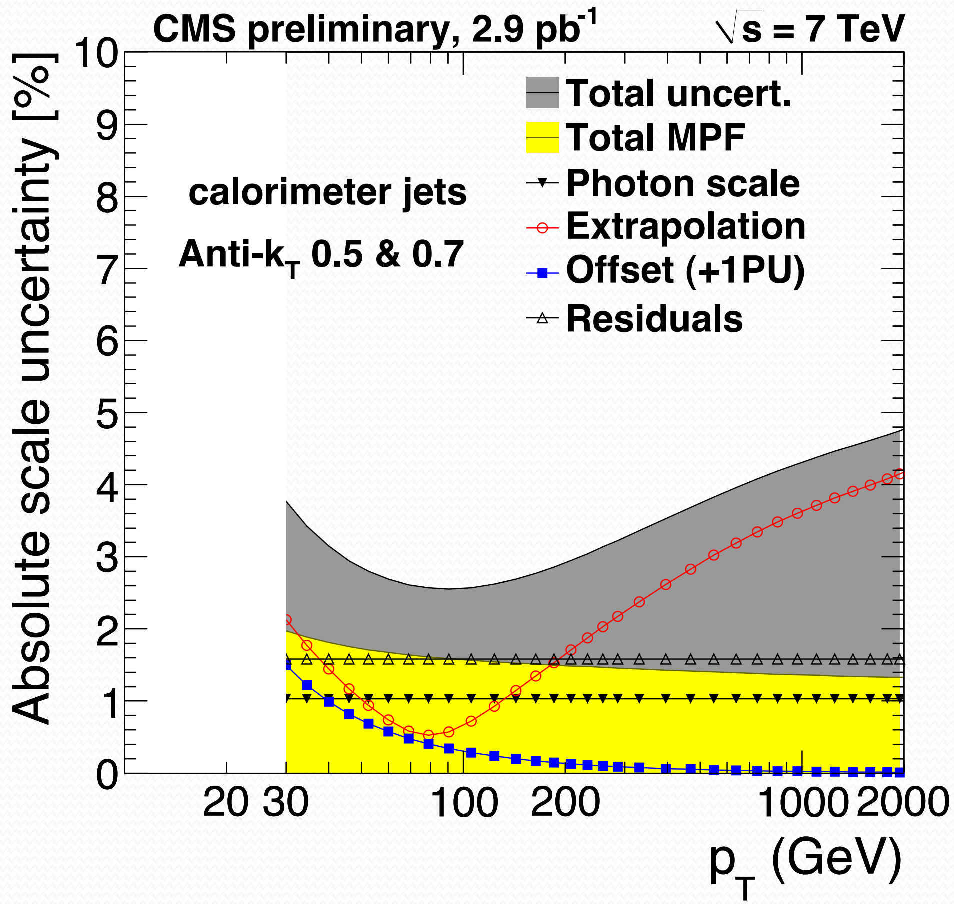
Specific Dijet Resonance Models



expected mass limits

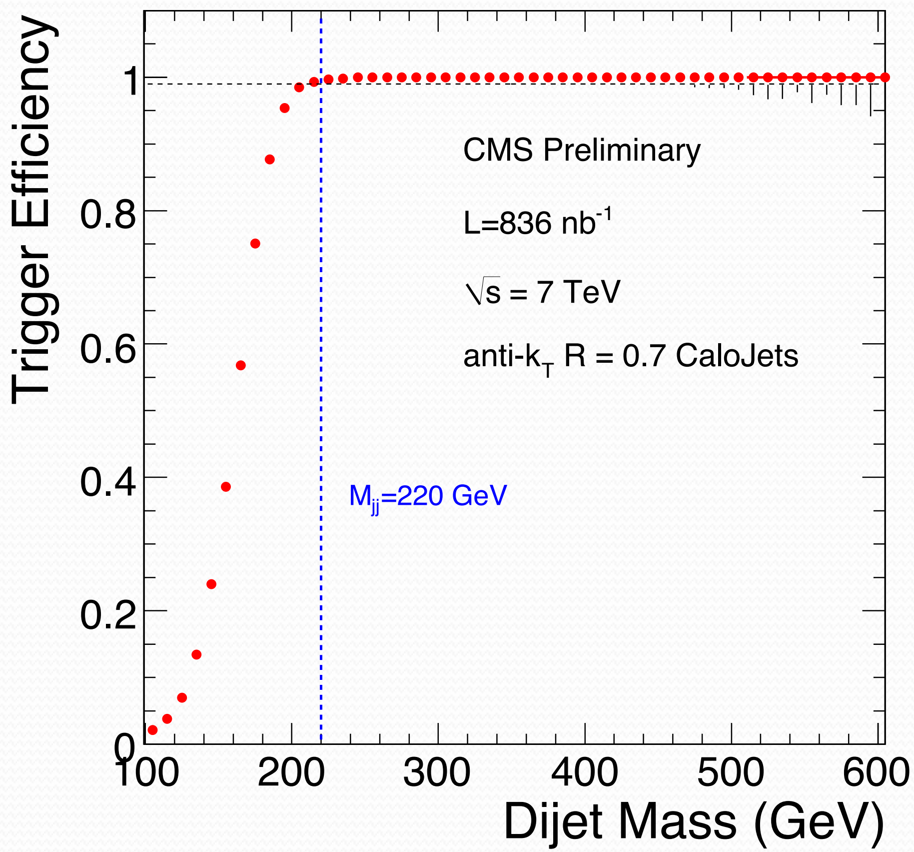
Di-jets: energy corrections



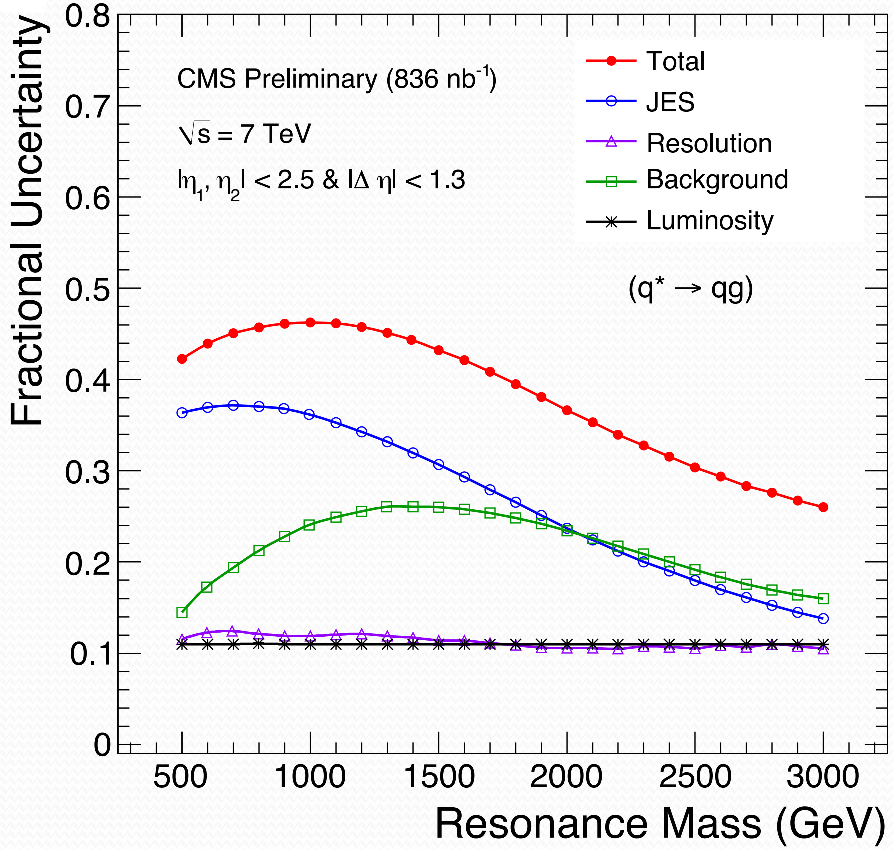


corrections factors & estimated uncertainties
(CMS PAS JME-10-010)

Di-jet resonances



single 50U trigger efficiency



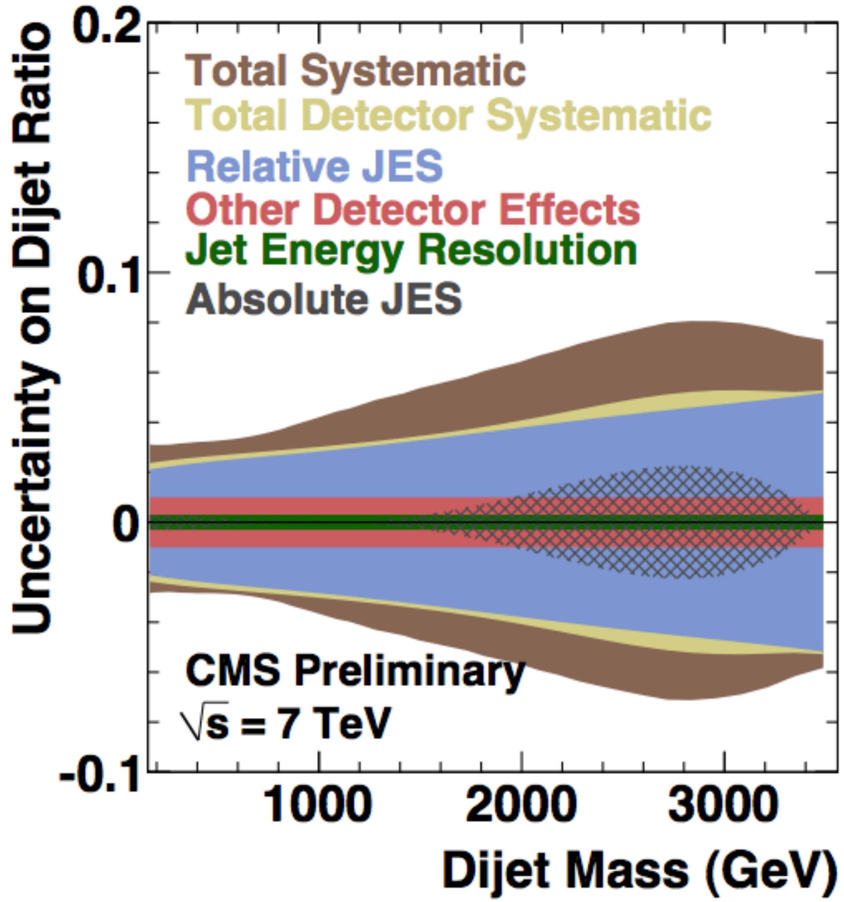
syst uncertainty on signal production for q*->qg

Di-jet centrality: systematics

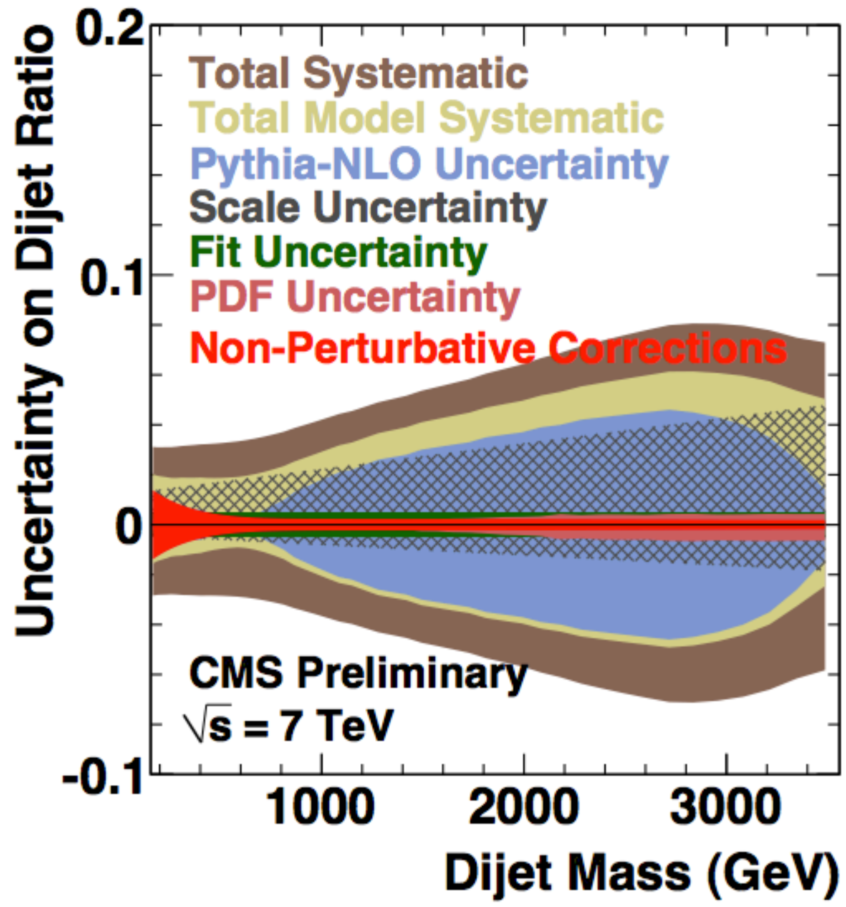
Table 1: Systematic uncertainties on R_η related to the measurement of R_η (detector uncertainties) and to the QCD model (model uncertainties). For each source of uncertainty, we show the range of values over the entire m_{jj} range and at a representative point in the signal region.

Source	Full Range	$m_{jj} = 1.6$ TeV
Detector uncertainty		
Relative JES	0.02-0.05	0.032
Absolute JES	0.00-0.03	0.003
Jet Energy Resolution	0.003	0.003
Other	0.01	0.010
Total Detector	**0.02-0.05**	**0.034**
Model uncertainty		
PYTHIA6−NLO	0.00-0.05	0.032
Offset	0.021	0.021
Scale	$+(0.01\text{-}0.05)$ $-(0.01\text{-}0.02)$	$+0.029$ -0.011
PDF	$+(0.002\text{-}0.004)$ $-(0.002\text{-}0.007)$	$+0.002$ -0.003
MC Statistics	0.005	0.005
Non-pert. Corr.	0.002-0.014	0.002
Total Model	$\mathbf{+(0.02\text{-}0.07)}$ $\mathbf{-(0.01\text{-}0.05)}$	$\mathbf{+0.044}$ $\mathbf{-0.034}$
Total	$\mathbf{+(0.03\text{-}0.09)}$ $\mathbf{-(0.03\text{-}0.08)}$	$\mathbf{+0.055}$ $\mathbf{-0.048}$

Di-jet centrality: systematics



Detector uncertainties



Model uncertainties

HSCP dE/dx MIP estimator

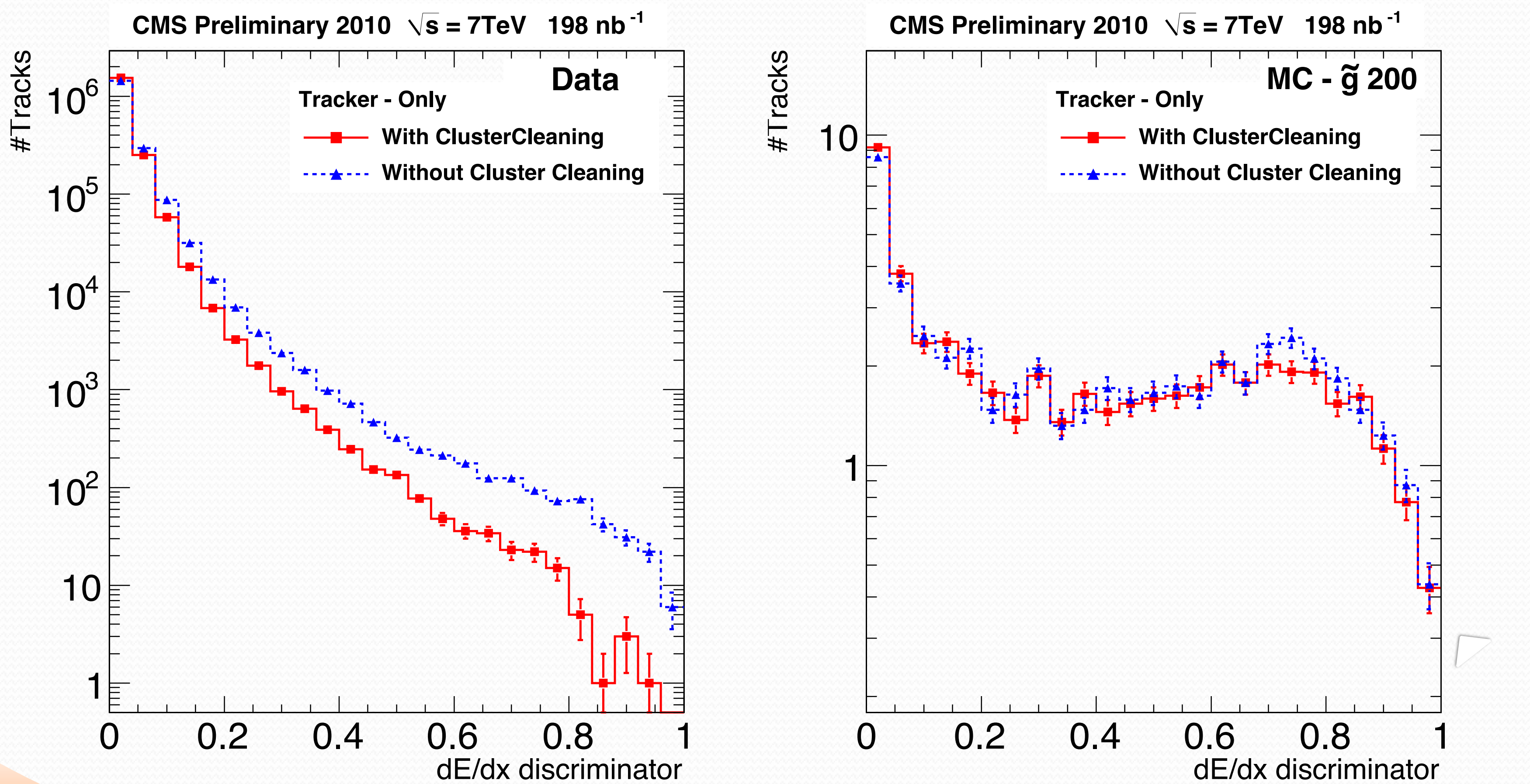
MIP hypothesis dE/dx estimator based on Smirnov - Cramer – von Mises

$$I_{as} = \frac{3}{N}\left(\frac{1}{12N} + \sum_{i=1}^{N}\left[P_i\left(P_i - \frac{2i-1}{2N}\right)\right]^2\right)$$

P_i: probability a MIP produces a equal or smaller ionization charge in layer-i taking into account the actual MIP energy loss distribution (with ADC the cutoff), ordered in increasing P_i. For an ideal HSCP all P_i=1 and I_{as}=1.

HSCP Cluster cleaning

Clusters capacitive coupling of neighboring strips ~10%. (10^{-n} at n-strips distance)
Clusters with multiple charge maxima are discarded.



HSCP 95%CL limits (tracker only)

gluino mass (GeV/c^2)	200	300	400	500	600	900
Total acceptance (%)	11	16	21	26	28	20
Expected 95% C.L. limit (pb)	161	109	81	66	61	85
Observed 95% C.L. limit (pb)	156	105	78	63	59	83
Theoretical cross section (pb)	606	57.2	8.98	1.87	0.46	0.013
stop mass (GeV/c^2)	130	200	300	500	800	
Total acceptance (%)	4	13	20	29	27	
Expected 95% C.L. limit (pb)	409	131	87	57	63	
Observed 95% C.L. limit (pb)	395	127	84	55	61	
Theoretical cross section (pb)	109	11.9	1.23	0.047	0.00123	
stau mass (GeV/c^2)	100	126	156	200	247	308
Total acceptance (%)	4	12	23	38	48	56
Expected 95% C.L. limit (pb)	461	146	74	45	35	31
Observed 95% C.L. limit (pb)	445	141	72	43	34	29
Theoretical cross section (pb)	1.32	0.33	0.105	0.025	0.008	0.002

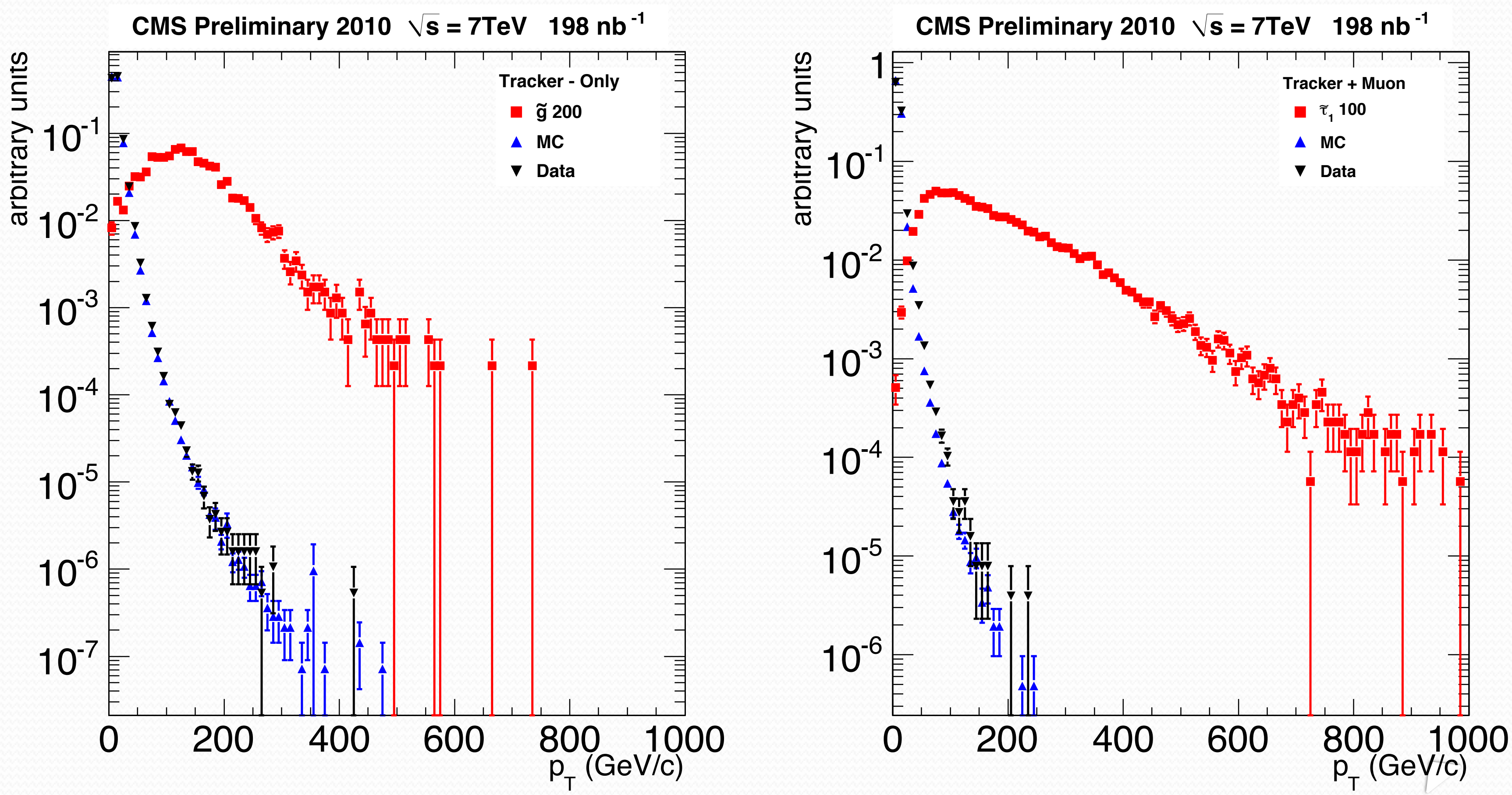
HSCP 95%CL limits (tracker+muon)

gluino mass (GeV/c^2)	200	300	400	500	600	900
Total acceptance (%)	17	21	25	29	29	20
Expected 95% C.L. limit (pb)	106	84	69	60	60	89
Observed 95% C.L. limit (pb)	98	77	64	56	52	83
Theoretical cross section (pb)	606	57.2	8.98	1.87	0.46	0.013
stop mass (GeV/c^2)	**130**	**200**	**300**	**500**	**800**	
Total acceptance (%)	12	19	24	30	25	
Expected 95% C.L. limit (pb)	139	91	74	58	72	
Observed 95% C.L. limit (pb)	128	85	68	53	67	
Theoretical cross section (pb)	109	11.9	1.23	0.047	0.00123	
stau mass (GeV/c^2)	**100**	**126**	**156**	**200**	**247**	**308**
Total acceptance (%)	23	34	44	55	63	67
Expected 95% C.L. limit (pb)	76	53	40	32	28	27
Observed 95% C.L. limit (pb)	70	49	37	30	26	25
Theoretical cross section (pb)	1.32	0.33	0.105	0.025	0.008	0.002

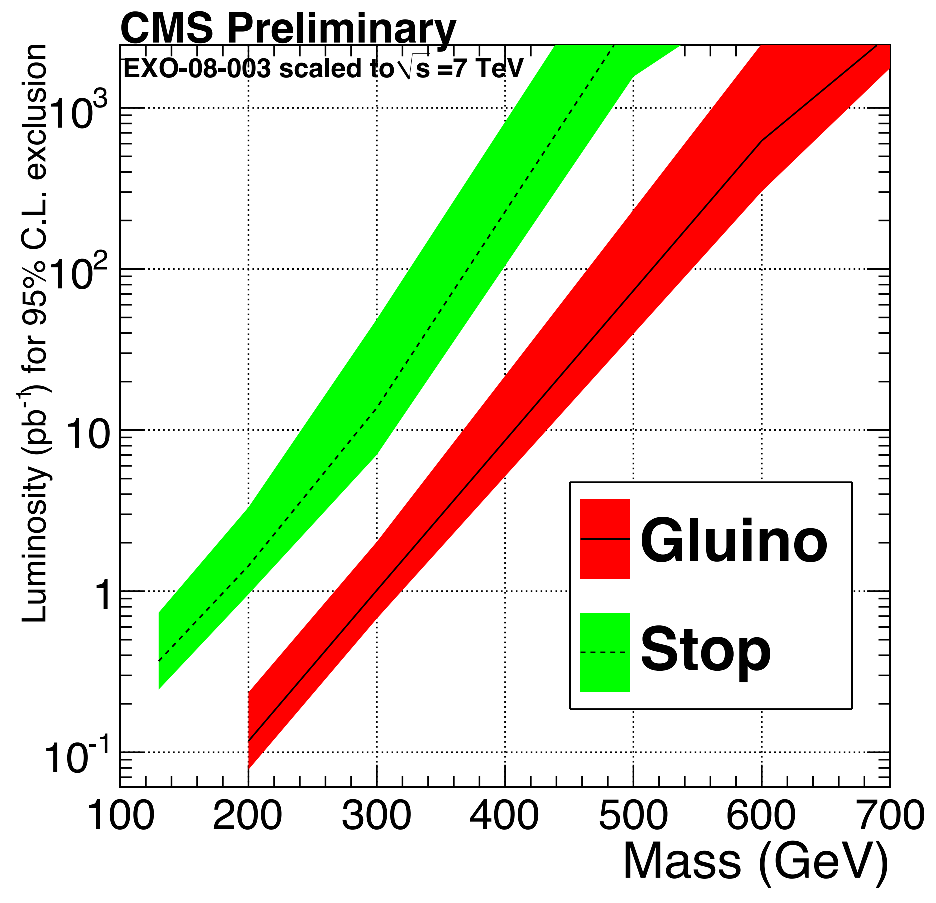
HSCP searches systematic errors

Source of Systematic Error	Relative Uncertainty (%)
Theoretical cross section	15 ($\tilde{t}_1$and $\tilde{g}$)
Expected background	36(Tk) ; 40 (Tk+Mu)
Integrated luminosity	11
Trigger efficiency	15
Muon reconstruction efficiency	5
Track reconstruction efficiency	< 5
Momentum scale	< 5
Ionization energy loss scale	< 3 (8 for 100 GeV$/c^2$ $\tilde{\tau}_1$)
Total uncertainty on signal acceptance	20

HSCP searches: p_T spectrum



HSCP searches: projected reach



Stopped gluinos