Search for Long-lived Gluinos in Compressed SUSY Scenarios

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on behalf of the CMS collaboration

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Some CMS searches with Long-lived particles

Searches for long-lived particles require different strategies depending on the particle lifetime e final products.

- New long-lived particles; https://doi.org/10.1016/j.physletb.2018.03.019
- Stopped long-lived particles; https://doi.org/10.1007/JHEP05(2018)127
- Heavy stable charged particles;
- New physics in events with displaced jets and MET;
- Long-lived particles with displaced vertices multijet events;
- Displaced leptons in e-mu final state;
- Long-lived particles decaying into displaced jets;
- Long-lived Gluinos in Compressed SUSY Scenarios.

Motivation for the Search

Why haven't we found SUSY yet?

- Nature is not supersymmetric

Proof will be everything but straight forward

- SUSY cross-sections are too small

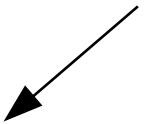
Will require more data

- SUSY masses are too large

Will require more data

- Analyses are not sensitive to SUSY

Will require a new analysis strategy



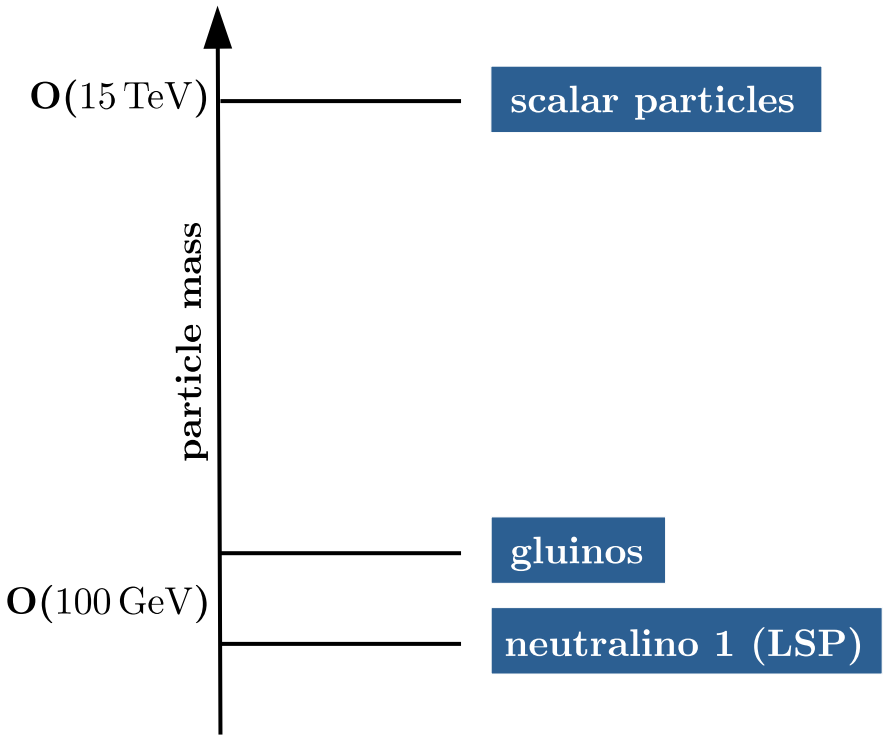
Compressed SUSY

Motivation for the Search

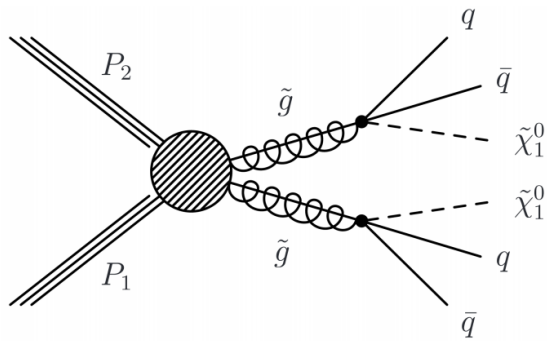
- Natural solution to the electroweak hierarchy problem
- Precision gauge coupling unification

Which is the effect on the spectrum of supersymmetric masses?

Compressed SUSY



Dominant production at LHC:
gluino pair production



$$\Gamma(\tilde{g} \to q\bar{q}+\tilde{\chi}_1^0) \propto \text{gaugino fraction} \times \frac{(m_{\tilde{g}} - m_{\tilde{\chi}_1^0})^5}{m_{\tilde{q}}^4}$$

arXiv:1306.0574v1 (Sven Krippendorf, Hans Peter Nilles, Michael Ratz, and Martin Wolfgang Winkler)

Simulation

- Simplified model with 2 parameters

  → gluino mass: $m_{\tilde{g}}$

  → mass difference between gluino and neutralino: Δm

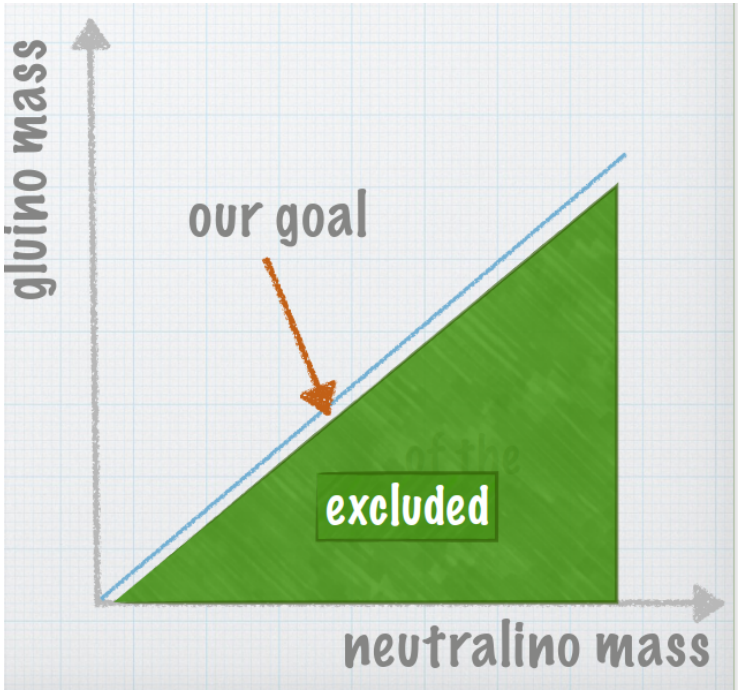
- Squark mass fixed to 40 TeV (compatible with $m_H = 125\,\mathrm{GeV}$)

- LSP is mainly gaugino

- Generated private MC with MadGraph+Pythia for

  → $m_{\tilde{g}}$: [250, 500, 750, 1000] GeV

  → Δm : [40, 60, 80, 100] GeV



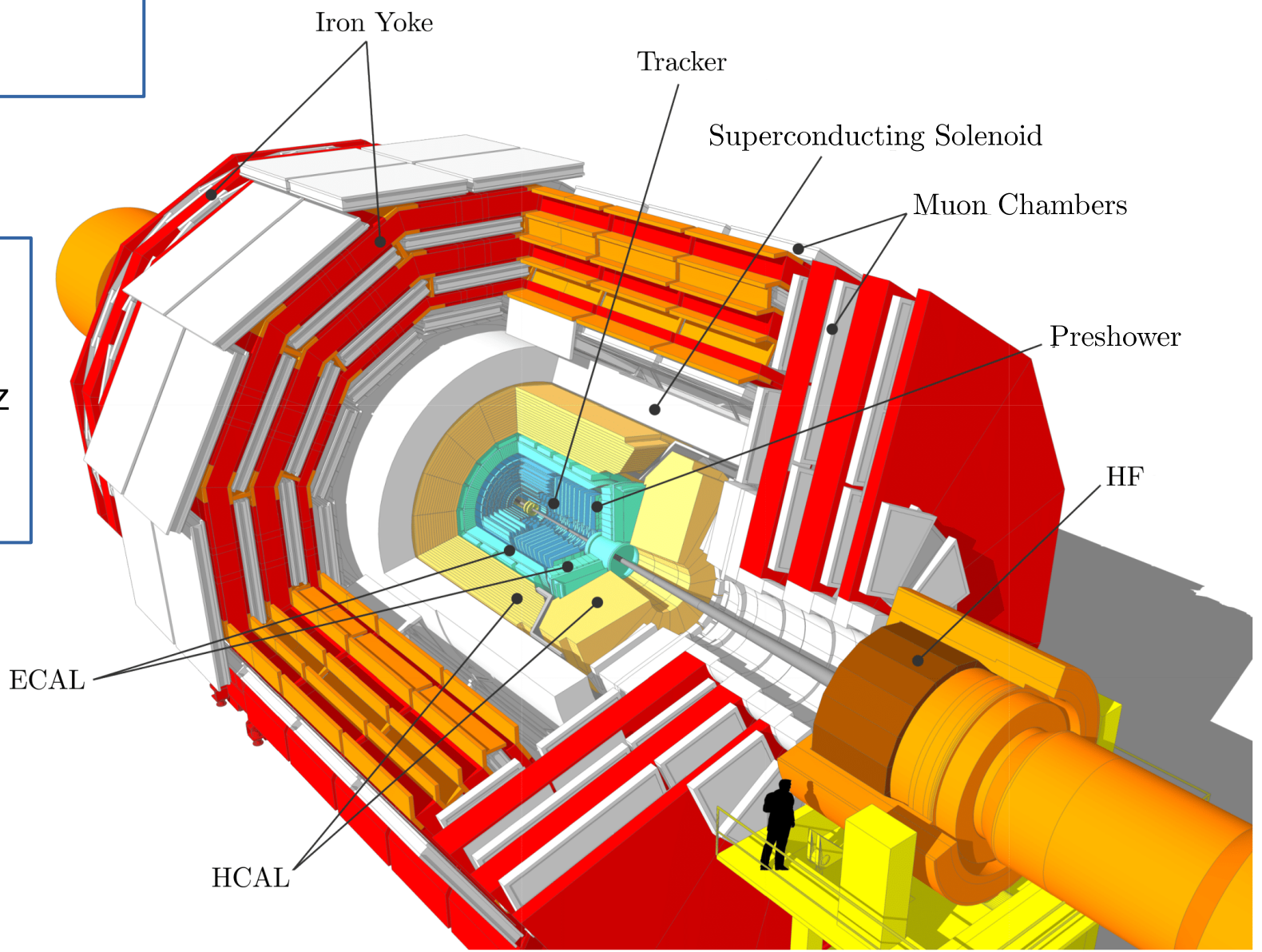
CMS

Overall Length: 28,7 m
Overall Diameter: 15 m
Mass: 12500 t
Magnetic field: 3.8 T

Rate of eventos produced: ~ 1 GHz

L1 trigger: ~ 100 KHz

HLT: ~ 400 Hz



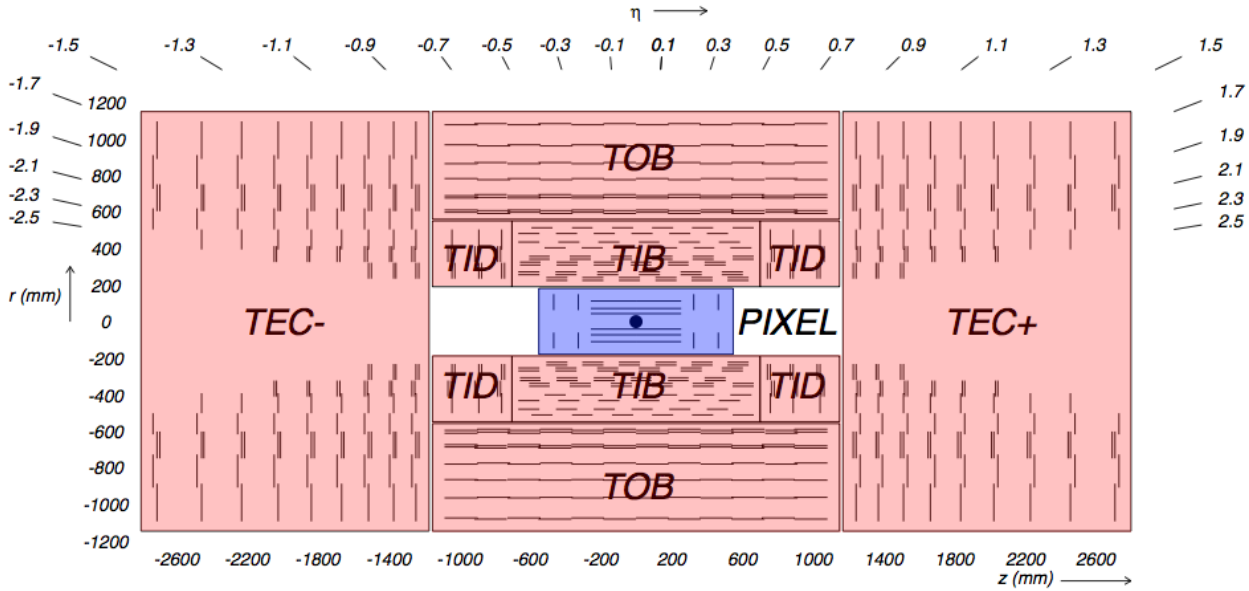
Gluinos decay distance

Primary Vertices (PVs): Reconstructed location of all particle collisions in the bunch crossing

Secondary Vertices (SVs): Reconstructed location of all particle decays.

Vertices are found using reconstructed tracks. Majority of the gluinos decay inside the tracker, this leads to reconstructed Secondary Vertices!

Signal $(m_{\tilde{g}}, \Delta m)$	Fraction of gluinos (%) decaying in the range:		
	< 1 cm	< 10 cm	< 1.2 m
(250,40)	9.3	55.2	99.1
(250,60)	42.8	96.1	100
(750,60)	63.0	99.7	100
(1000.100)	99.9	100	100

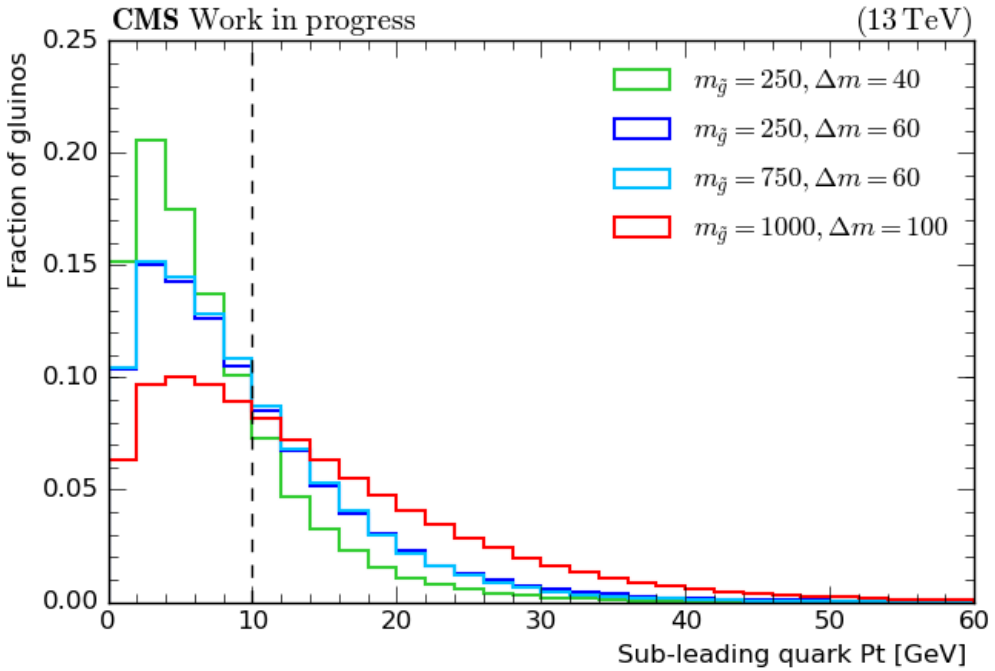


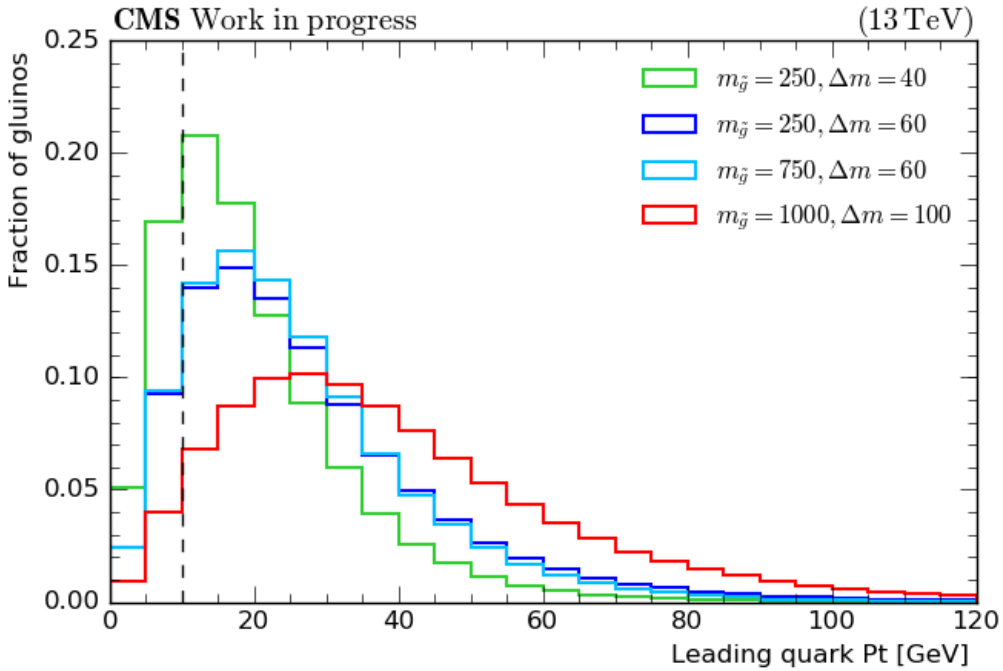
Silicon Tracker: PIXEL (blue) refers to silicon pixel detectors while TIB, TID, TOB and TEC (red) all refer to silicon strip detectors

Quarks from gluino decay

CMS reconstructs jets with Pt ≥ 10 GeV.

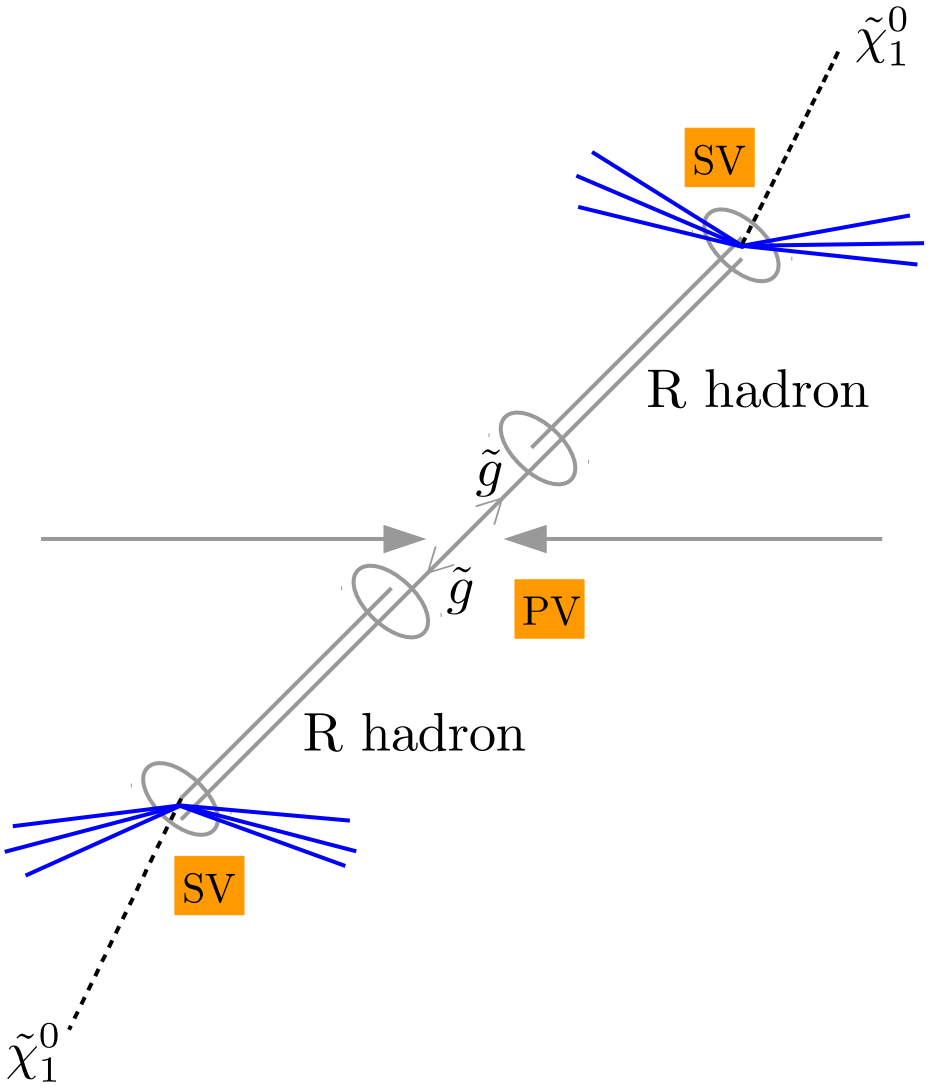
Very difficult to reconstruct all jets originated from gluino decays.





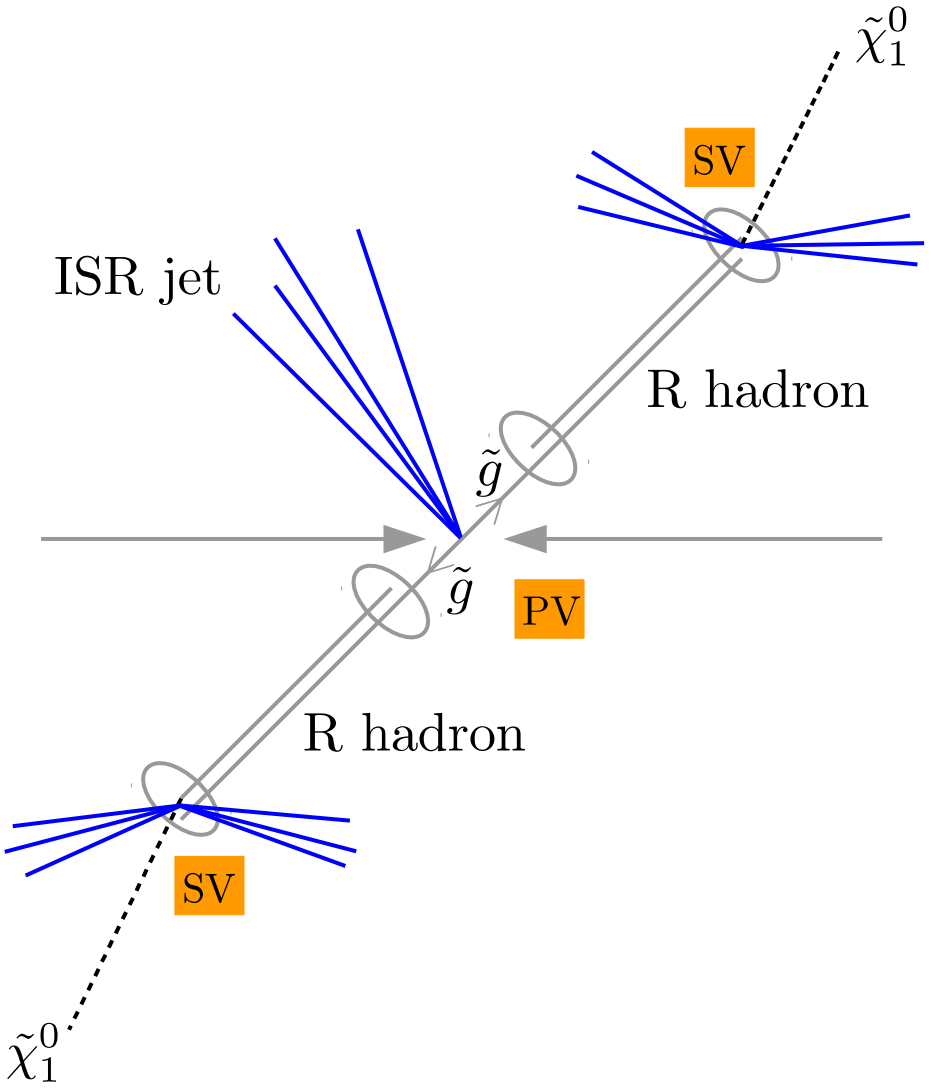
Signature

- Moderate amount of MET
- Secondary vertices with 2 soft jets



Signature

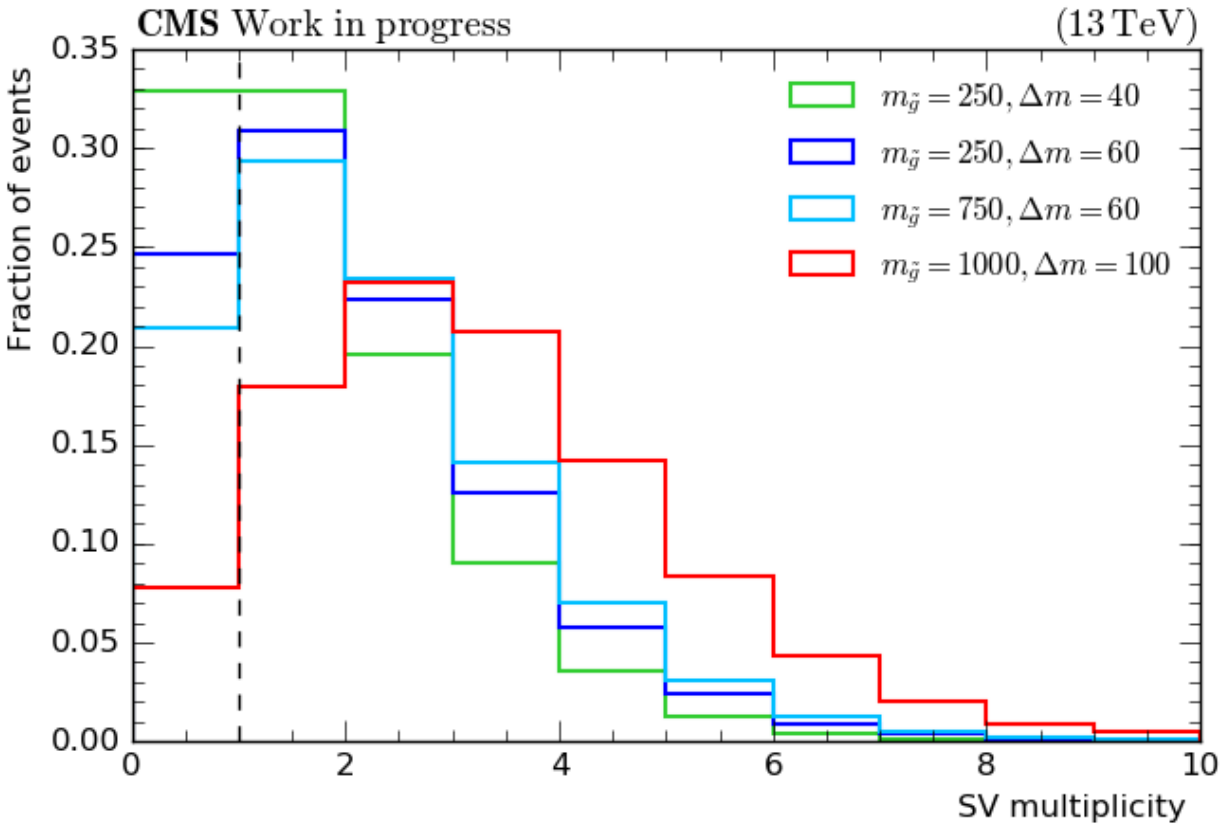
- Moderate amount of MET
- Secondary vertices with 2 soft jets
- Need hard ISR jet for triggering



SV multiplicity

Majority part of the signal events have SVs.

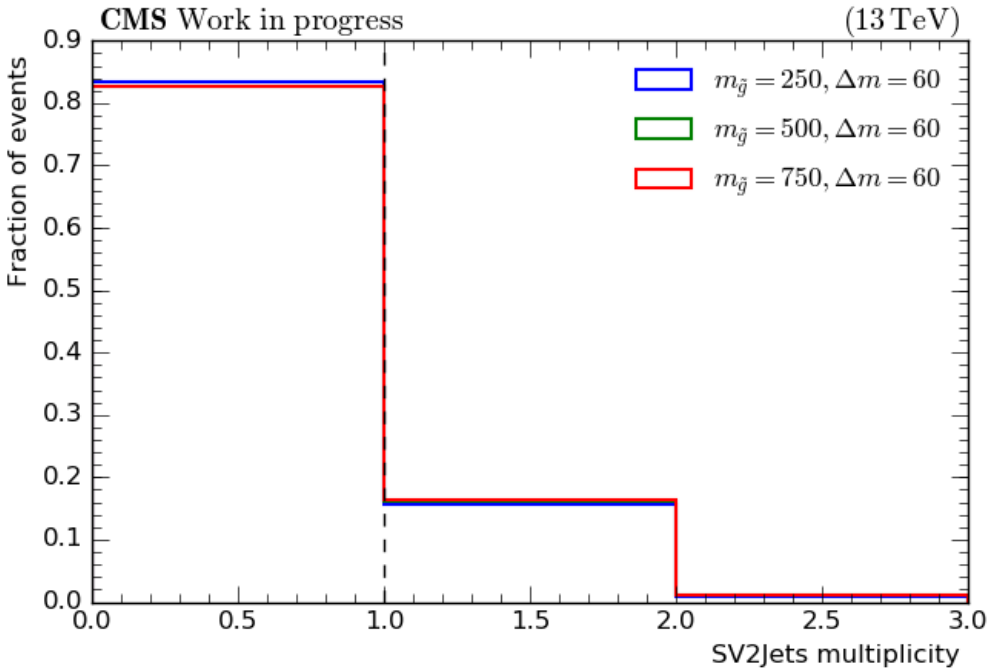
We require the signal regions to have at least one SV.

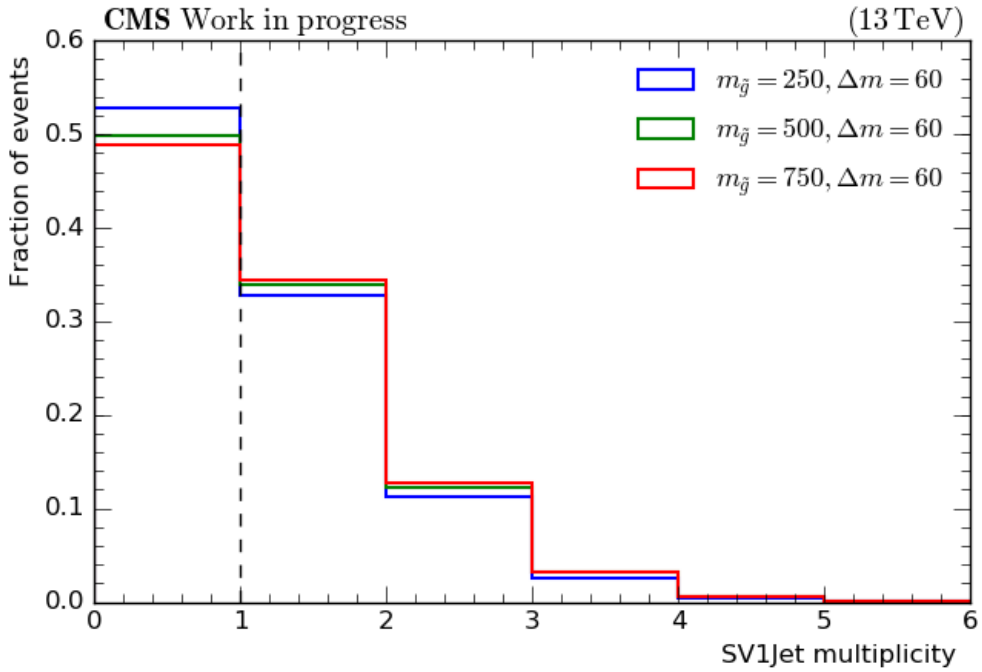


Jet-SV association

We use jets and vertices reconstructed by CMS, associating each jet to one vertex.

Gluino mass has small effect in the association of jets to SVs.

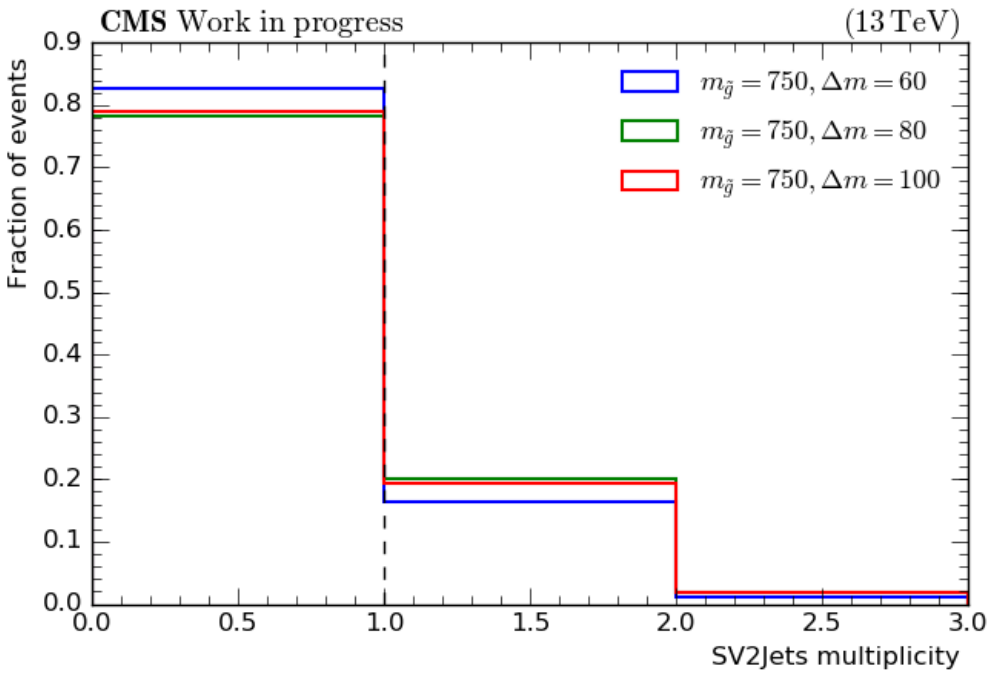


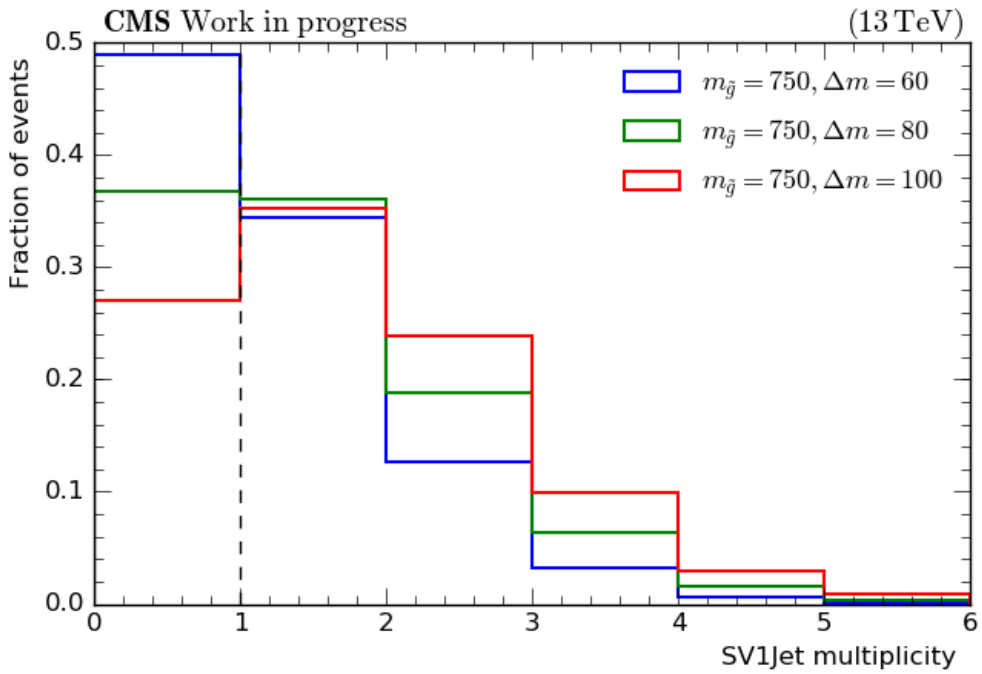


SV2Jets – SV with 2 jets associated to it.
SV1Jet – SV with 1 jet associated to it.

Jet-SV association

Mass difference between gluino and neutralino affects the association of jets to SVs because jets originated from gluino decays are more difficult to be reconstruct in events with lower Δm.





Signal Regions

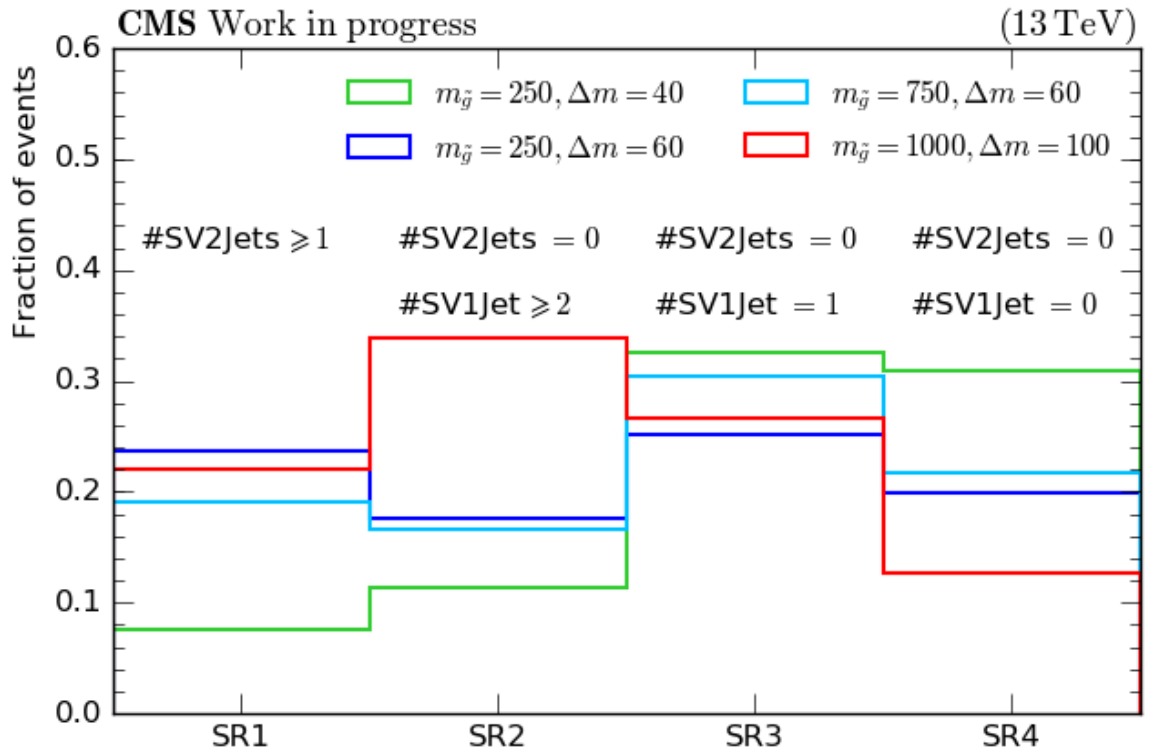
1) Trigger (MET 170 GeV)
2) MET > 350 GeV
3) VetoLeptons

SR1: #SV2Jets ≥ 1

SR2: #SV2Jets = 0 and #SV1Jet ≥ 2

SR3: #SV2Jets = 0 and #SV1Jet = 1

SR4: #SV2Jets = 0 and #SV1Jet = 0



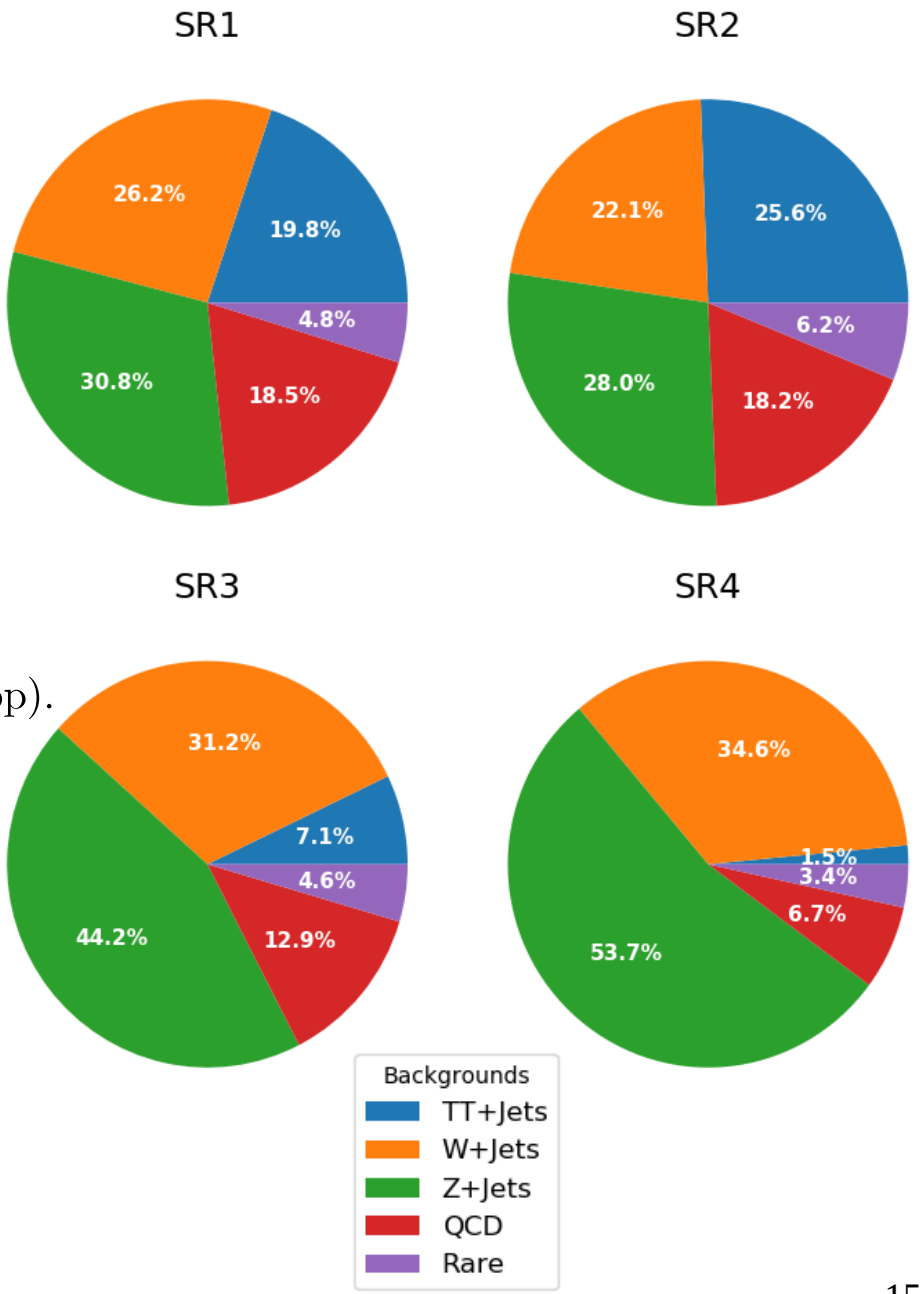
Backgrounds

1) Trigger (MET 170 GeV)
2) MET > 350 GeV
3) VetoLeptons

- Quarks top and anti-top $(t\bar{t})$ + jets,
- Boson W $(\rightarrow l\nu_l)$ + jets,
- Boson Z $(\rightarrow \nu\bar{\nu})$ + jets,
- Multijet (QCD),
- Rare (WW, ZZ, WZ, G+Jets, Drell-Yan+jets, Single Top).

The four dominant backgrounds will be estimated using data-driven methods.

MC information



Multivariate Analysis

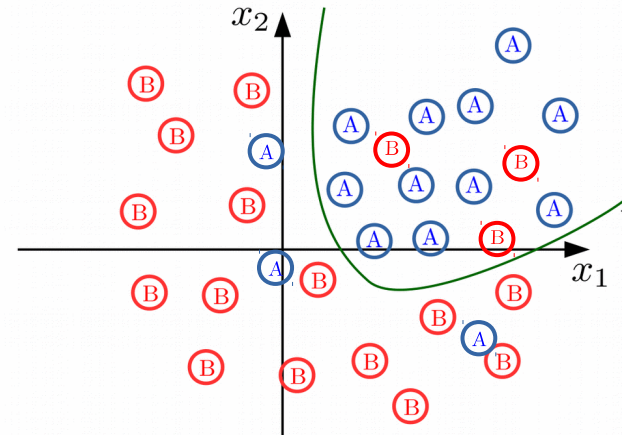
Cut-based approach is not sensitive at large gluino masses (low cross-section).
We can improve it using multivariate methods!

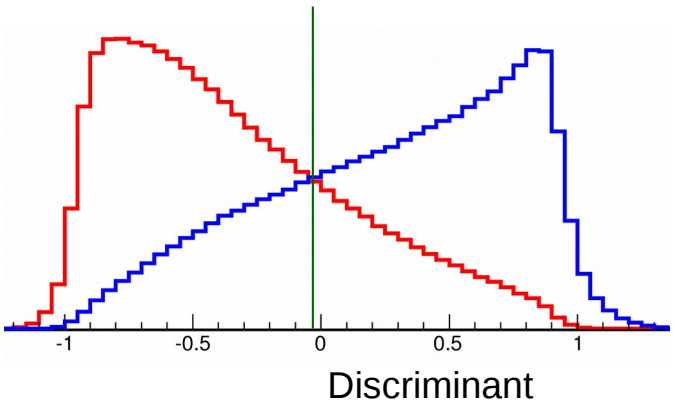
Event Information:
- SV Info
- Jets Info
- Bjets Info
- MET
-…

MVA

Neural Network,
Boosted Decision Tree, …

Discriminant





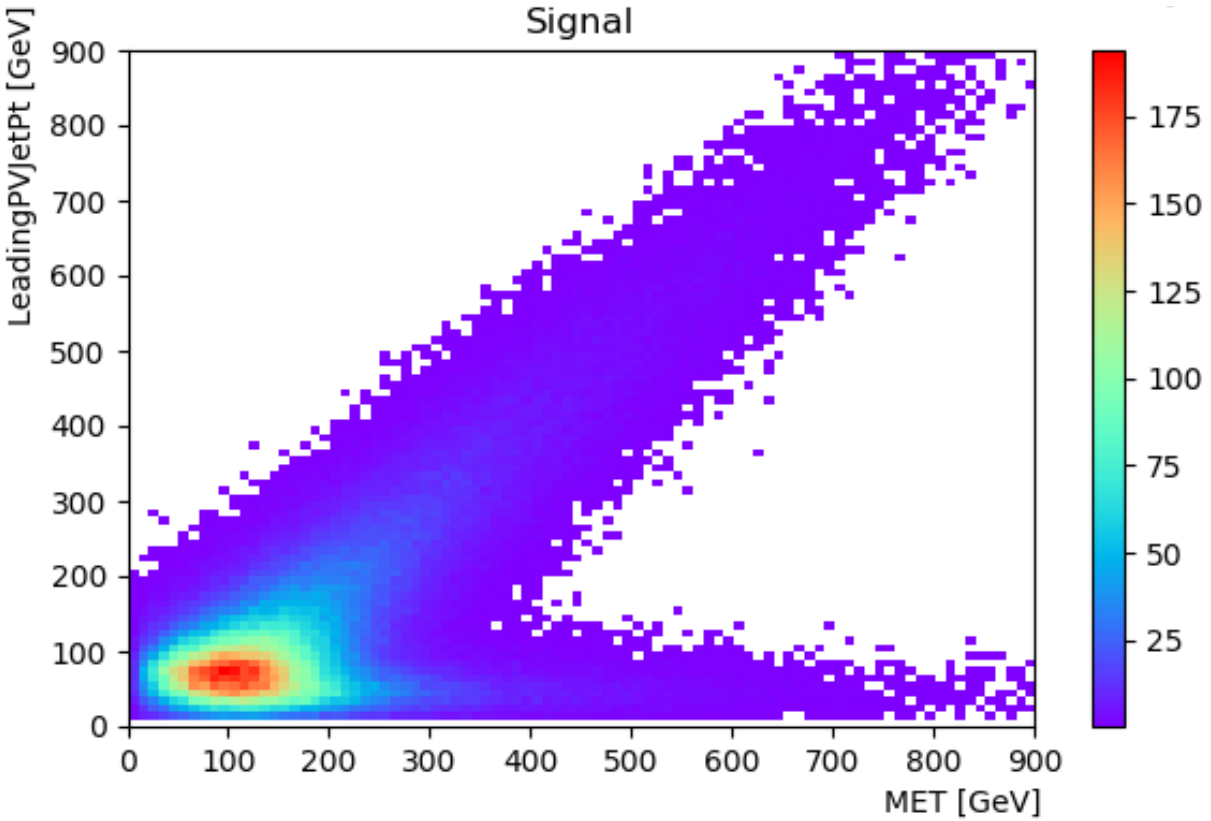
Outlook

- The compressed scenario studied has a signature of difficult reconstruction. In general, we are only able to reconstruct part of the signal event's signature.
- Jets are associated to secondary vertices in order to produce objects that have information about the gluino decay and help to discriminate the signal from the background.
- Due the low analysis sensitivity for large gluino masses, we will make use of multivariate methods in order to improve the sensitivity.
- Goal: We plan to have results ready for 2019.

Backup

MET X LeadingPVJetPt

Dataset: Signal_750_80_Summer16



Backup

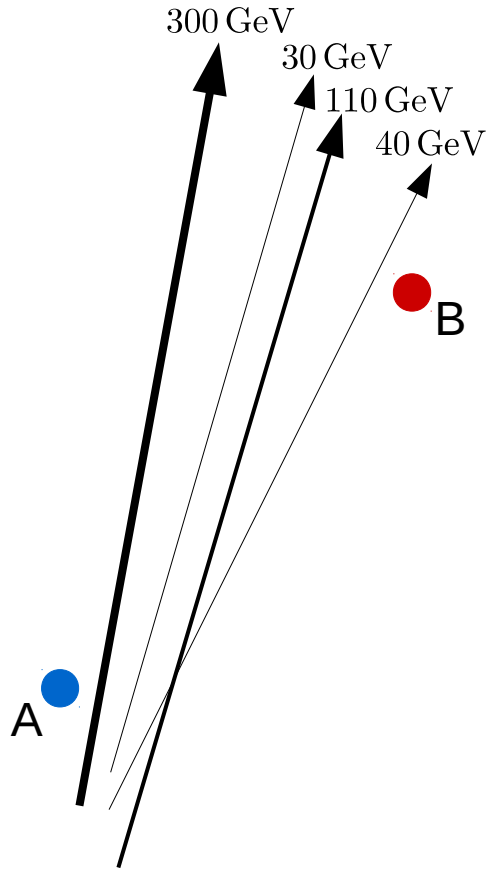
SV2Jets Variables

MinJetPt – Minimum Jet Pt MaxJetPt – Maximum Jet Pt DphiJJ – Δφ between the jets DetaJJ – Δη between the Jets DRJJ – ΔR between the jets MJJ – Invariant dijet mass	Reco Jet
Chi2 – χ^2 of the SV recostruction Ndof – Number of Degrees of freedom in the SV reconstruction SVPt – Pt sum of the tracks used in the SV reconstruction SVError – SV position error	Reco SV
Score – Sum of the score log of the two jets NumConst – Sum of the number of constituents of the two jets	Jet-SV Association

Backup

Associate Jets to Vertices

- use charged jet constituents to assign jet to vertex
- assume straight or curved track
- use constituent 3-momentum and point of closest approach (PCA) to leading PV to define pseudo track
- find the vertex closest to this track
- define score per vertex: constituent pT / PCA to the vertex
- associate jet to vertex with highest score



Jet close to
2 vertices