Brief Update on Ttbar without MET

L = 100 pb^{-1}

	S/B	Aε(%)
Sel A	3	5.5
Sel B	4.7	2.7

With MET cut

	S/B	Aε(%)
Sel A	2.36	5.99
Sel B	3.27	2.92

No MET Cut

The MET cut of 20 GeV doesn't seem to make
All that much difference.
We should be able to obtain a top rich sample
without which we can then look at to commission
The MET observable.

Preliminary!

The G2-MSSM at the LHC

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Abdus Salam ICTP and INFN Trieste

New Signatures for the LHC,
Michigan. January 10th 2008.

Based Upon

- Work done with the MCTP, Ann Arbor
  - K. Bobkov, P. Grajek, G. Kane, P. Kumar, J. Shao
- Two earlier foundational papers:
  - "M Theory Solution to the Hierarchy Problem", PRL 97, 191601, 2006
  - "Explaining the Electroweak Scale and Stabilising Moduli in M theory" hep-th/0701034
- Mostly taken from
  - "The G2-MSSM", arXiv 0801.0478
  - "The G2-MSSM at the LHC", to appear

Outline of Talk

- **Introducing the "G2-MSSM" - a supersymmetric particle physics model essentially derived from M theory.**
- **Mass Spectrum of the G2-MSSM**
- **The G2-MSSM at the LHC - unique and reasonably identifiable set of signatures**
- **Compare ATLAS and CMS detection of the G2-MSSM**

Introducing the G2-MSSM

- In the two earlier papers we explained how to stabilise all moduli whilst generating the hierarchy between M_W and M_{pl} , preserving Grand Unification
- M theory vacua without FLUX.
- G2-manifold - xtra dimensions + SUSY
- Strong Dynamics both generates a small scale and a potential for all moduli
- Unique de Sitter vacuum

- Can calculate most of the spectrum BSM

$$W^{np} = A_1 e^{ib_1 f_1} + A_2 e^{ib_2 f_2} \, . \quad f_k = \sum_{i=1}^{N} N_i^k \, z_i \; = \frac{\theta_k}{2\pi} + i \frac{4\pi}{g_k^2}$$

$$K = -3 \ln(4\pi^{1/3} V_X) \, , \tag{1}$$

where the volume of the G_2 holonomy manifold as a function of the N scalar moduli s_i is (in 11d units)

$$V_X = \prod_{i=1}^{N} s_i^{a_i}, \;\; \text{with} \;\; \sum_{i=1}^{N} a_i = 7/3 \, . \tag{2}$$

$$V = \frac{1}{48\pi V_X^3} [\sum_{k=1}^{2} \sum_{i=1}^{N} a_i \nu_i^k \left(\nu_i^k b_k + 3\right) b_k A_k^2 e^{-2b_k \vec{\nu}^k \cdot \vec{a}} + 3 \sum_{k=1}^{2} A_k^2 e^{-2b_k \vec{\nu}^k \cdot \vec{a}}$$

$$-2 \sum_{i=1}^{N} a_i \prod_{k=1}^{2} \nu_i^k b_k A_k e^{-b_k \vec{\nu}^k \cdot \vec{a}} - 3 \left(2 + \sum_{k=1}^{2} b_k \vec{\nu}^k \cdot \vec{a} \right) \prod_{j=1}^{2} A_j e^{-b_j \vec{\nu}^j \cdot \vec{a}}]$$

$$
\begin{aligned}
(m_{3/2})_0^{(1,2)} &= m_p\, 2^{1/2}\pi^3 \left(7+\sqrt{17}\right)^{\frac{7}{4}} (N_1\,N_2)^{\frac{7}{4}}\, A_2\,P \left|\frac{P-Q}{PQ}\right| \left(\frac{A_2\,P}{A_1\,Q}\right)^{-\frac{P}{P-Q}} \left(\frac{PQ}{P-Q}\ln\frac{A_2\,P}{A_1\,Q}\right)^{-\frac{7}{2}} \\
&\sim m_p\, 2.97\times 10^3\, (N_1\,N_2)^{\frac{7}{4}}\, A_2\,P \left|\frac{P-Q}{PQ}\right| \left(\frac{A_2\,P}{A_1\,Q}\right)^{-\frac{P}{P-Q}} \left(\frac{PQ}{P-Q}\ln\frac{A_2\,P}{A_1\,Q}\right)^{-\frac{7}{2}} \qquad (162)
\end{aligned}
$$

$$
M_{1/2} \approx -\frac{e^{-i\gamma_W}}{P\,\ln\left(\frac{A_1 Q}{A_2 P}\right)} \left(1+\frac{2}{\phi_0^2\,(Q-P)}+\frac{7}{\phi_0^2\,P\,\ln\left(\frac{A_1 Q}{A_2 P}\right)}\right)\times m_{3/2}\,,
$$

$$
M_{1/2} \approx -\frac{e^{-i\gamma_W}}{84}\left(1+\frac{2}{3\phi_0^2}+\frac{7}{84\phi_0^2}\right)\times m_{3/2}
$$

$$
\approx -e^{-i\gamma_W}\,0.024\times m_{3/2}\,.
$$

Introducing the G2-MSSM

- **The Spectrum is determined by the particular G2 manifold, X.**
    - **Many qualitative features don't depend on detailed properties of X:**
- **Heavy Squarks/Sleptons, Light Gauginos.**
- **Particular X's give values for "microscopic" constants**
    - **(eg rank of gauge groups, and other integers) which determine the detailed spectrum.**
- **These constants can be varied within reason:**
    - **Unification + the SUGRA approximation. Typical.**
- **This defines the G2-MSSM**

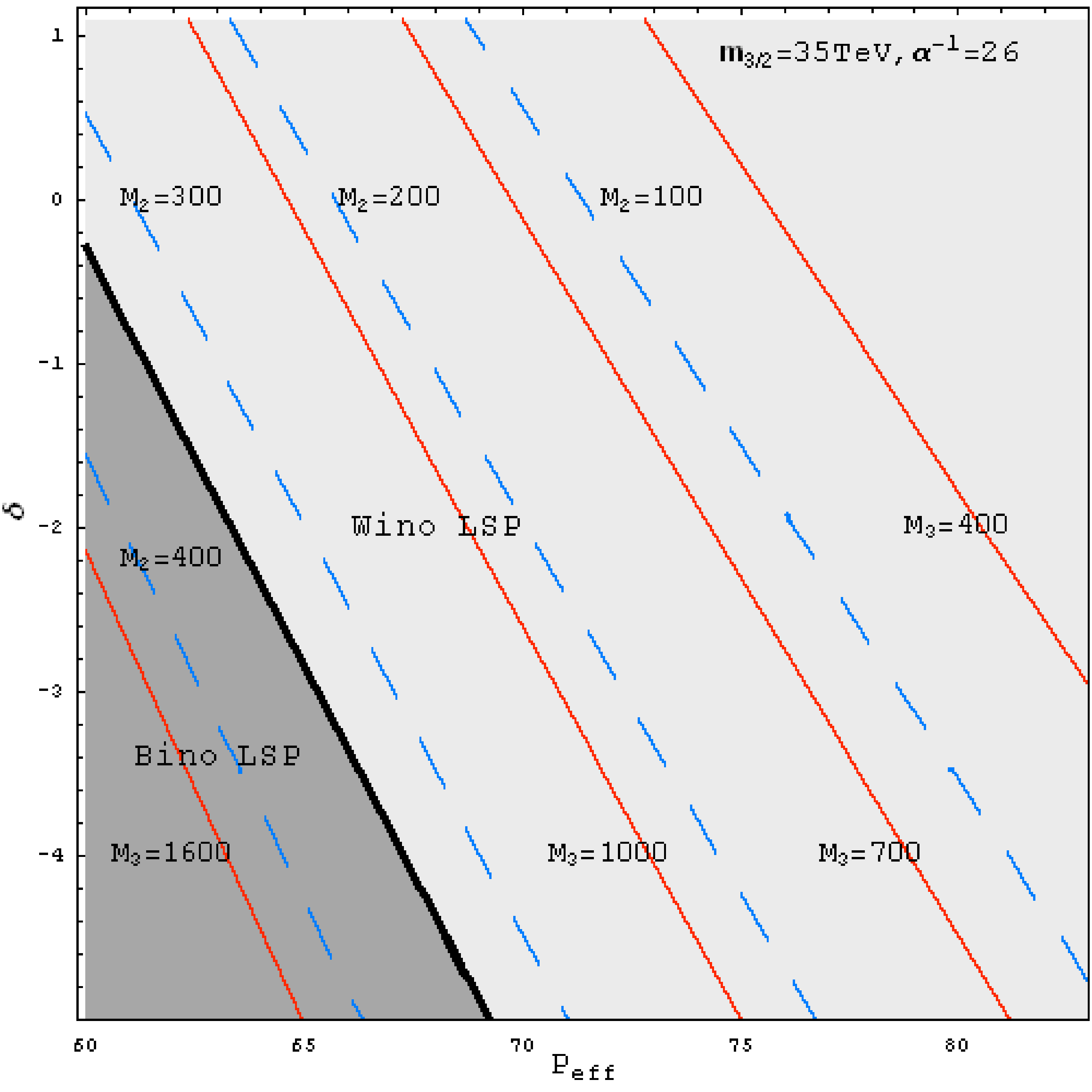
G2-MSSM Spectrum

- **At GUT scale:**
    - universal scalar masses - large eg 50 TeV
    - unified tree level gaugino masses -small eg 300 GeV
    - Large Higgsino mass eg 50 TeV
    - one loop gaugino masses partly cancel against suppressed tree contribution (unlike AMSB)
- **At the TeV scale:**
    - Right Handed Top Squark is the lightest Squark (several TeV)
    - Significant threshold corrections to Wino and Bino masses from the large Higgsino mass
- **LSP and Dark Matter:**
    - LSP usually Wino, but can also be Bino
    - For the Wino, non-thermal production dominates.

Comments on EWSB

- **Although a hierarchy is both generated and stabilised, the usual "Little Hierarchy Problem remains"**
  - **We don't solve this problem**
  - **Just assume that the microscopic constants (ie the G2 Manifold) are such that both**
    - **Radiative EWSB occurs and**
    - **M_Z is 91.1876 GeV +-0.0021 GeV**

  - **Just applying Giudice-Masiero without this additional fine tuning would give M_Z = O(few TeV).**
- **TanBeta turns out to be order ONE.**


$m_{3/2}$=35TeV, α^{-1}=26
M_2=300
M_2=200
M_2=100
Wino LSP
M_3=400
M_2=400
Bino LSP
M_3=1600
M_3=1000
M_3=700
δ
1
0
-1
-2
-3
-4
60
65
70
75
80
P_{eff}

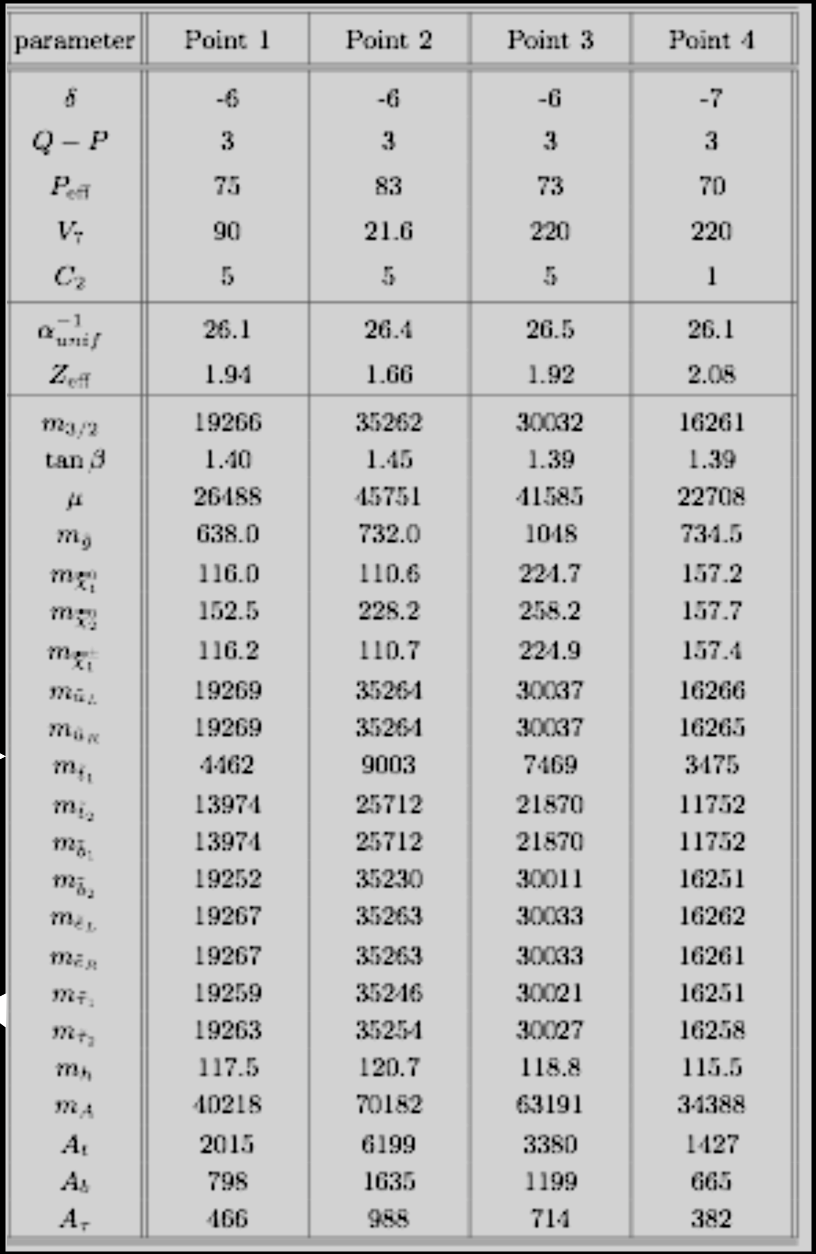
Spectrum at the LHC

Microscopic Constants

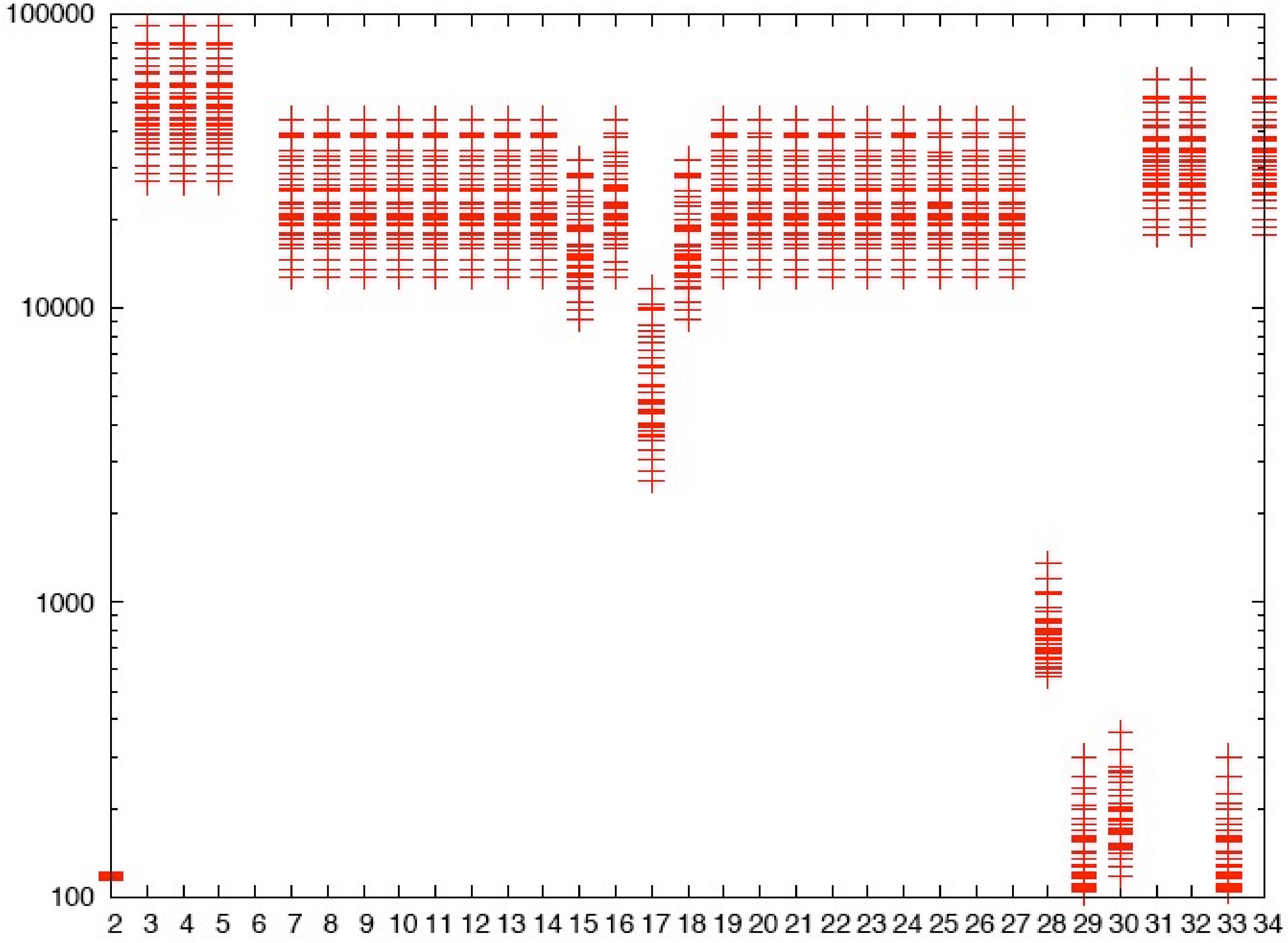
Light Gluino, Neutralinos
Charginos, Higgs

Stop Right Lightest Squark

Heavy Squarks/Sleptons



parameter	Point 1	Point 2	Point 3	Point 4
δ	-6	-6	-6	-7
$Q-P$	3	3	3	3
$P_{\rm eff}$	75	83	73	70
V_7	90	21.6	220	220
C_2	5	5	5	1
α_{unif}^{-1}	26.1	26.4	26.5	26.1
$Z_{\rm eff}$	1.94	1.66	1.92	2.08
$m_{3/2}$	19266	35262	30032	16261
$\tan\beta$	1.40	1.45	1.39	1.39
μ	26488	45751	41585	22708
$m_{\tilde g}$	638.0	732.0	1048	734.5
$m_{\tilde\chi_1^0}$	116.0	110.6	224.7	157.2
$m_{\tilde\chi_2^0}$	152.5	228.2	258.2	157.7
$m_{\tilde\chi_1^\pm}$	116.2	110.7	224.9	157.4
$m_{\tilde u_L}$	19269	35264	30037	16266
$m_{\tilde u_R}$	19269	35264	30037	16265
$m_{\tilde t_1}$	4462	9003	7469	3475
$m_{\tilde t_2}$	13974	25712	21870	11752
$m_{\tilde b_1}$	13974	25712	21870	11752
$m_{\tilde b_2}$	19252	35230	30011	16251
$m_{\tilde e_L}$	19267	35263	30033	16262
$m_{\tilde e_R}$	19267	35263	30033	16261
$m_{\tilde\tau_1}$	19259	35246	30021	16251
$m_{\tilde\tau_2}$	19263	35254	30027	16258
m_h	117.5	120.7	118.8	115.5
m_A	40218	70182	63191	34388
A_t	2015	6199	3380	1427
A_b	798	1635	1199	665
A_τ	466	988	714	382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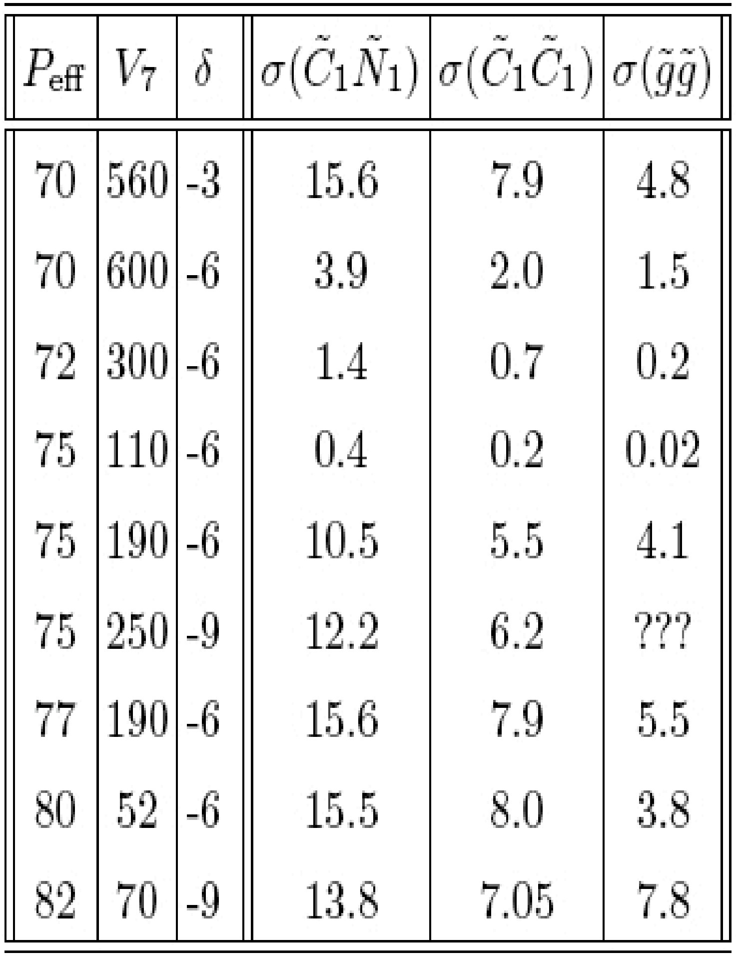
G2-MSSM at the LHC

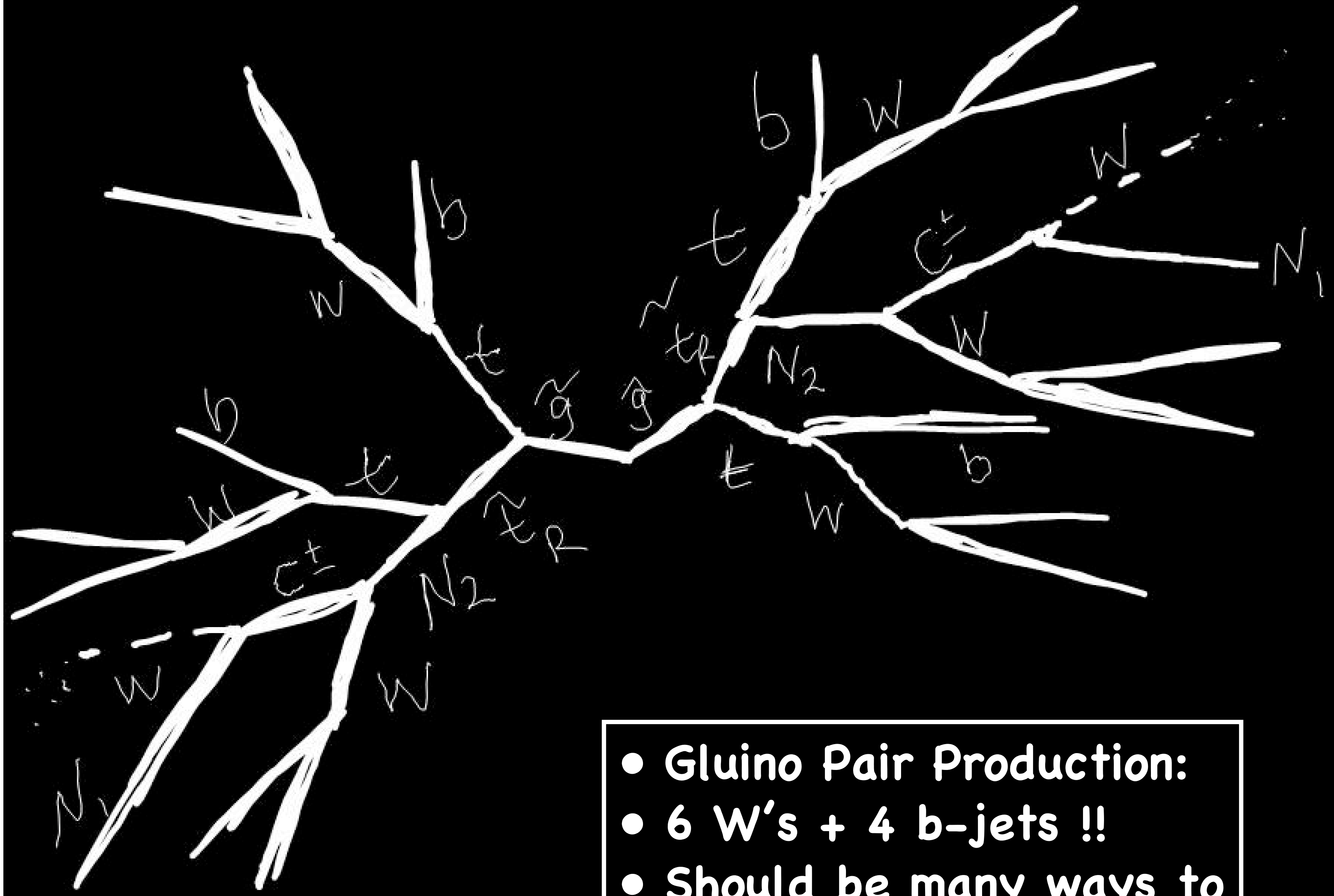
- X-sections
- Event topologies
- Discovery strategy

Production X-sections (pb)



$P_{\rm eff}$	V_7	δ	$\sigma(\tilde{C}_1\tilde{N}_1)$	$\sigma(\tilde{C}_1\tilde{C}_1)$	$\sigma(\tilde{g}\tilde{g})$
70	560	-3	15.6	7.9	4.8
70	600	-6	3.9	2.0	1.5
72	300	-6	1.4	0.7	0.2
75	110	-6	0.4	0.2	0.02
75	190	-6	10.5	5.5	4.1
75	250	-9	12.2	6.2	???
77	190	-6	15.6	7.9	5.5
80	52	-6	15.5	8.0	3.8
82	70	-9	13.8	7.05	7.8

TABLE II: Production Cross Section for $\tilde{C}_1\tilde{N}_1$, $\tilde{C}_1\tilde{C}_1$, and $\tilde{g}\tilde{g}$ pair production (units are in pb)



- Gluino Pair Production:
- 6 W's + 4 b-jets !!
- Should be many ways to find these events!!

The Meta-Stable Chargino

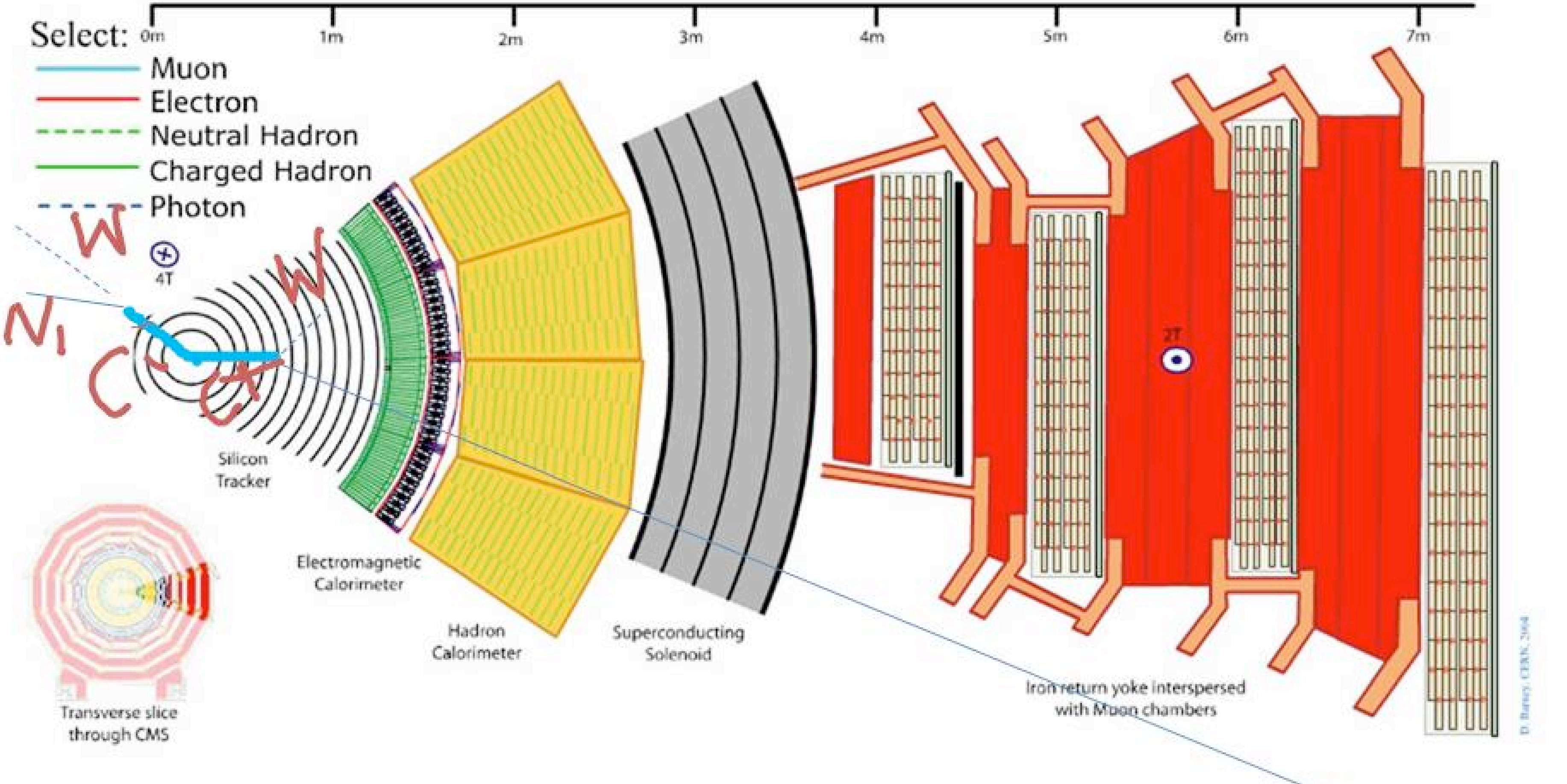
- The Lightest Chargino and N_1 (lightest neutralino) have the same mass at tree level (they are both W-ino's and there's little mixing)

- Their masses get small 1-loop corrections and the mass difference is between one and two PION masses. (Similar to some AMSB models, but the combined set of signatures different).

- The Chargino decays into N_1 and a "W"
- The "W" decays either into a soft PION or lepton

- The Chargino decays inside the detector (few cm's)

IN C.M.S.



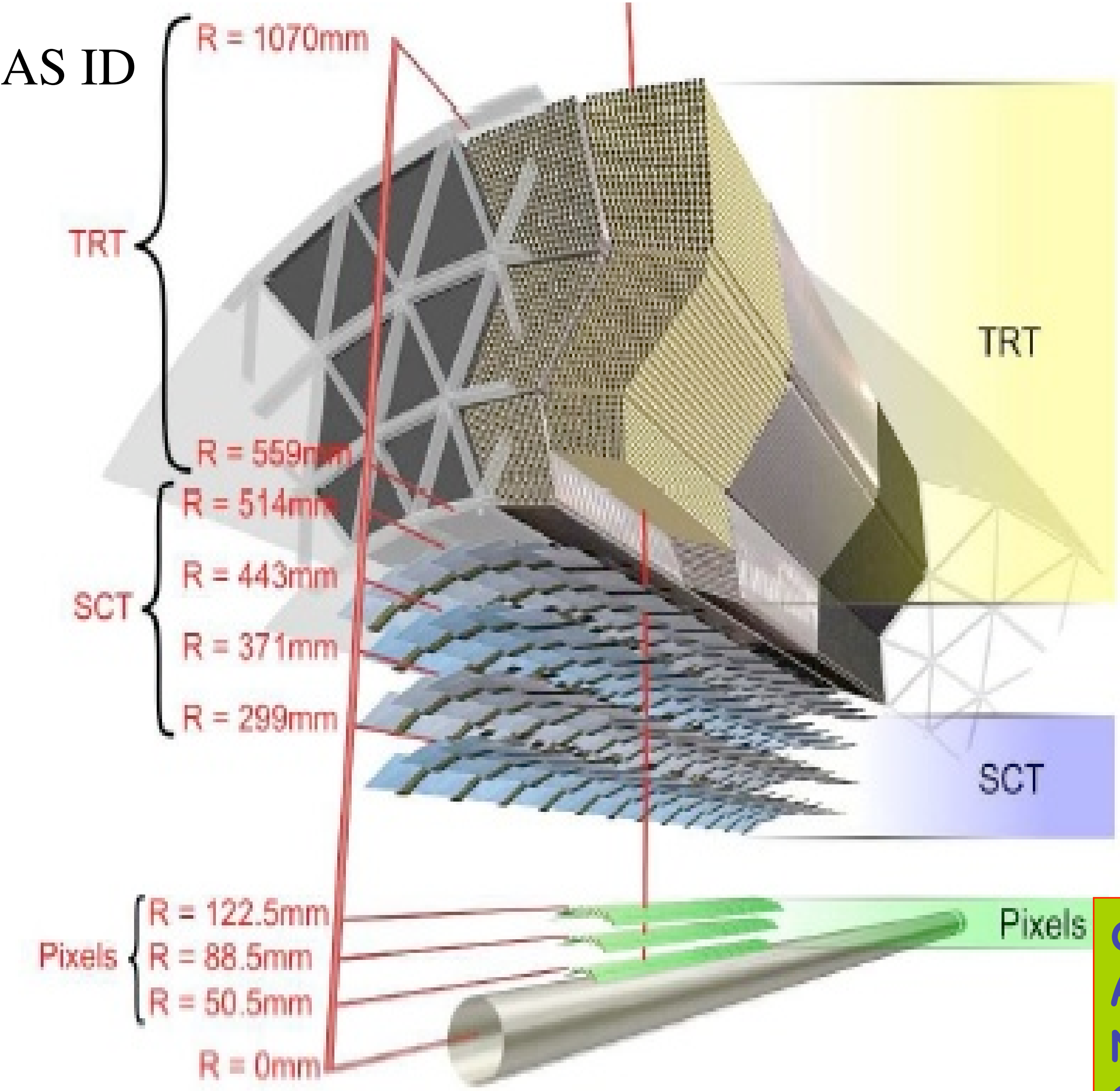
SHORT TRACK STUBS.

With only these partons the C-N and C-C events will not Trigger.

The Big Question is:

Are some events with short track Stubs Triggered on???

ATLAS ID



CMS has pixels
At 4, 7, 10 cm.
Next layer at
20cm.

Discovery and Triggers

- **Gluino pair production:**
  - Many hard jets and missing Energy. Trigger often.
  - Order 10^4 events at L = 10 fb-1. (few per hour if this is one LHC year)
  - Many b-jets and W-bosons originating from tops.
- **Chargino Production channels:**
  - More events (10^5 at 10fb-1), but do they trigger?
  - Naively difficult since there are no quarks/leptons/photons in the main process
  - Since the main signature is the short Track Stub, the events have to be triggered and searched for later, “offline”.
  - We find that often there is initial state radiation which produces a jet with a PT > 35 GeV. This really helps for Triggering.

Comparing CMS/ATLAS

- **CMS Triggering Charginos:**
  - **With current low L (10^32) triggers, CMS has a pure Missing ET trigger of 65GeV, which triggers these events more than 10% of the time :))**
  - **However, this is only for the first 100 pb-1 or so and there will be a few hundred events.**
  - **Latest Trigger menus (after September 07) ?**
  - **At Higher L (10^33) this moves to 91 GeV and very few events will pass this :((**
  - **The ID has layers at 4cm, 7cm, 10cm and 20cm**
  - **The "C" in CMS is a very good thing for these phenomena!**

Comparing CMS/ATLAS

- **ATLAS Triggering Charginos:**
  - **Low L (10^32) trigger menu has a jet45GeV+MET50GeV trigger which keeps > 10% of evts :))**
  - **ATLAS ID has pixel layers at 5cm, 9cm and 12cm with the first SCT layer at 30cm**
  - **In ATLAS the only information about the direct Chargino production will be from the pixel detector, unlike CMS, which will sometimes have more than three hits.**
- **Overall, both CMS and ATLAS have plus and minus points.**
  - **Clearly needs more serious Detector sim. Study.**
  - **Underway (in both CMS and ATLAS).**

Conclusions

- The G2-MSSM is a well motivated phenomenological model
- It has a very distinctive set of signatures
- If we discover evidence for events with many tops, W's, b-jets we should also start looking for short track stubs in monojet + EtMiss events
- Though non-trivial, it seems possible and challenging to find these in the CMS and ATLAS detectors