CheckMATE

Checkmating your favorite BSM model

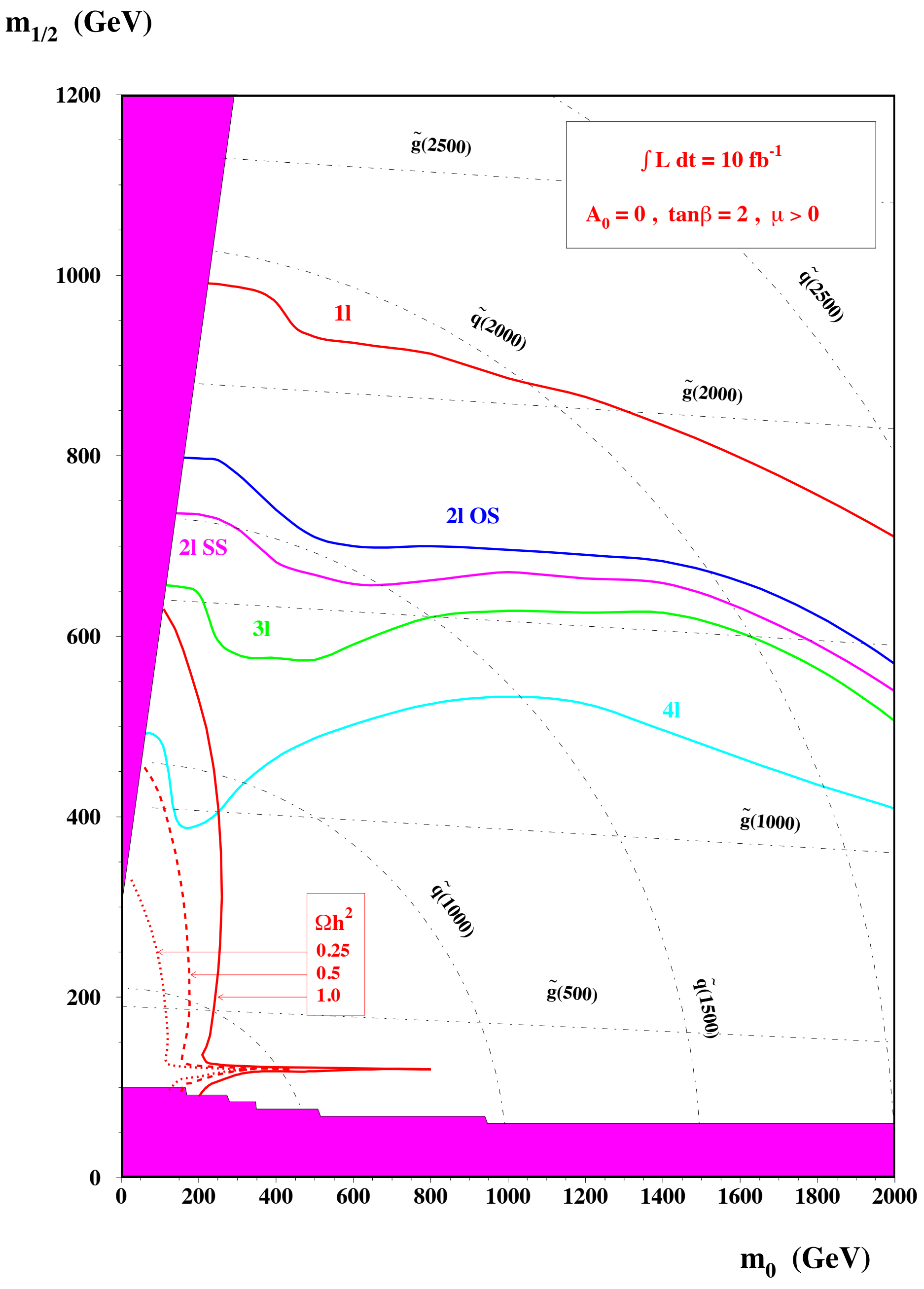
M. Drees, H. K. Dreiner, J. S. Kim, D. Schmeier, J. Tattersall

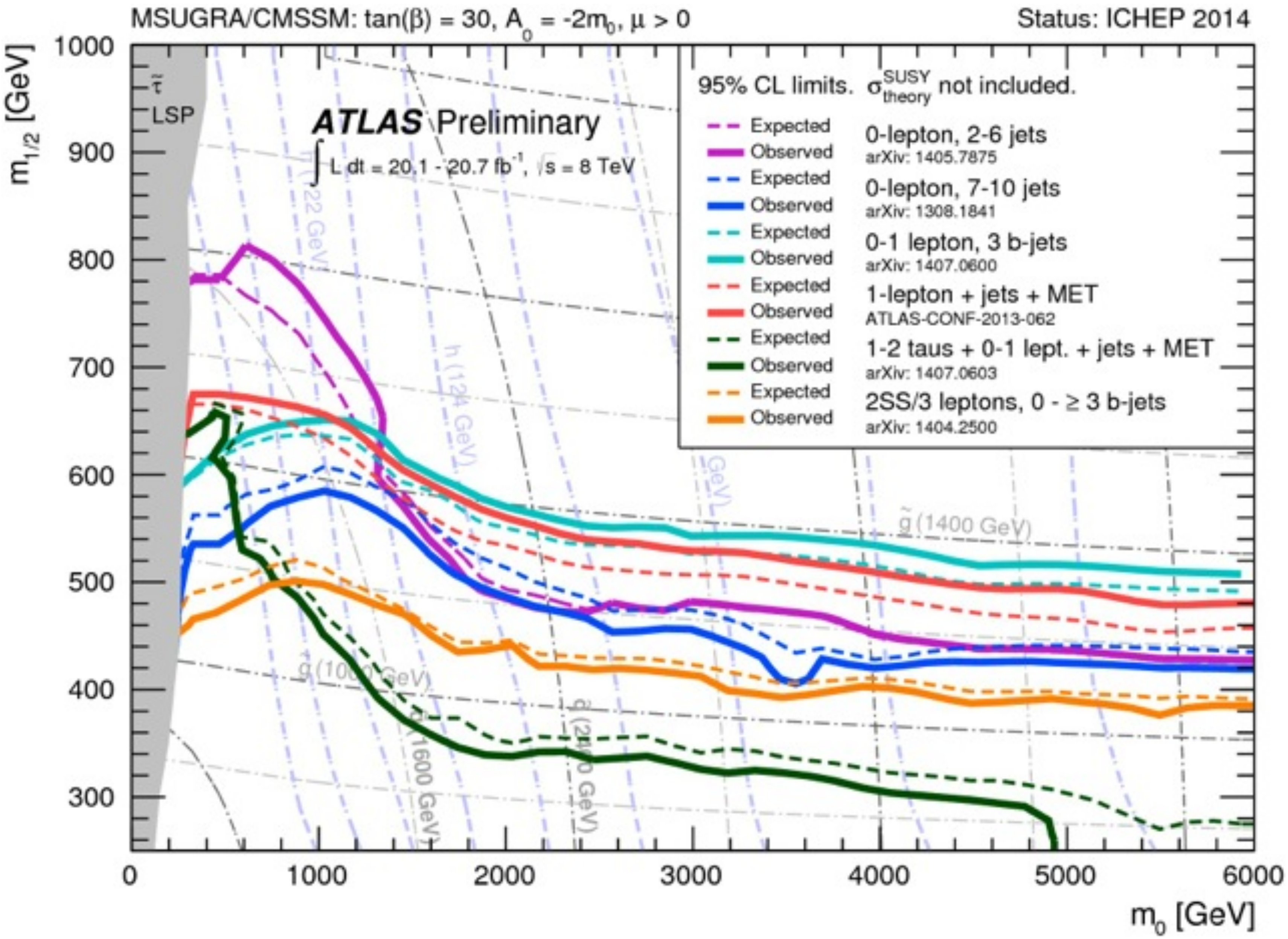
IFT UAM/CSIC Madrid

http:checkmate.hepforge.org

Before the LHC

- It was expected that if SUSY was realized in nature, it would be discovered soon
- If squarks/gluinos were roughly 1 TeV, ten thousands of events would be expected per year
- Two main objectives:
    - discover SUSY through excess
    - extract sparticle masses, couplings and spin





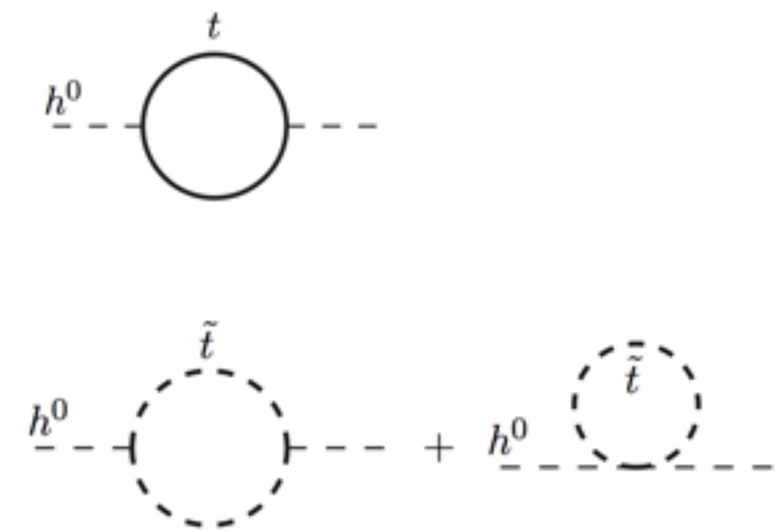
However…

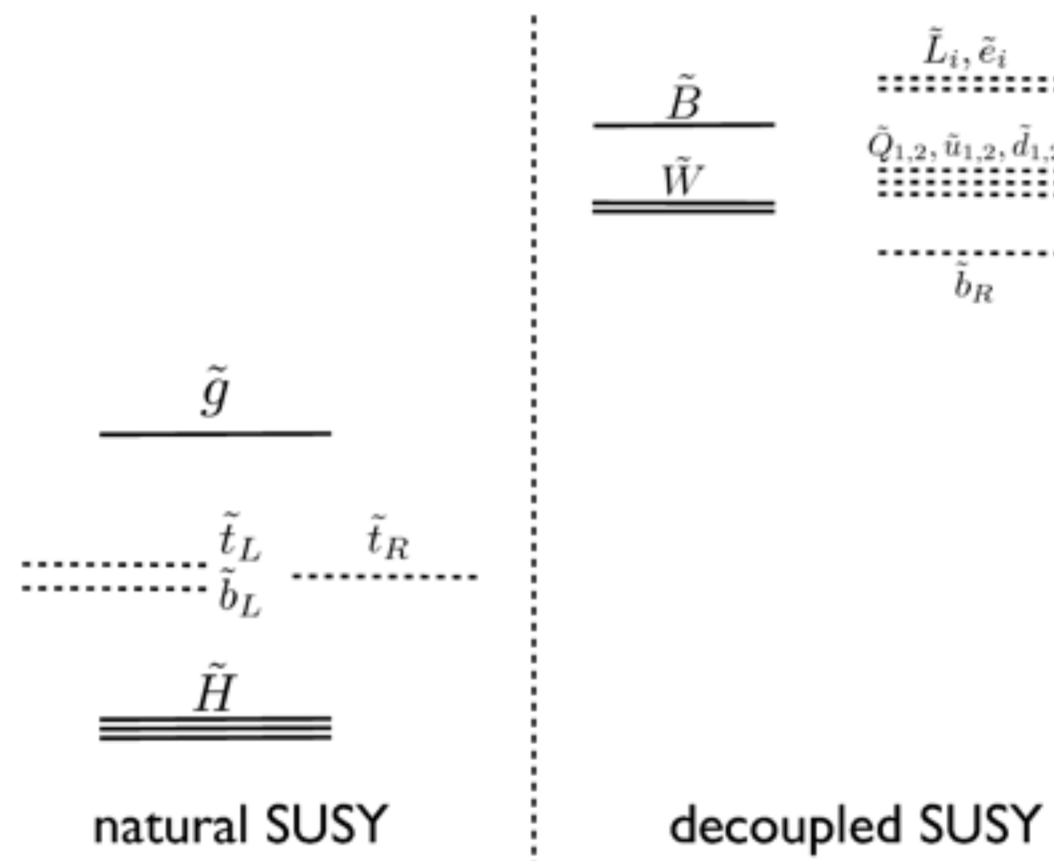
…no excess above SM expectation has been found so far

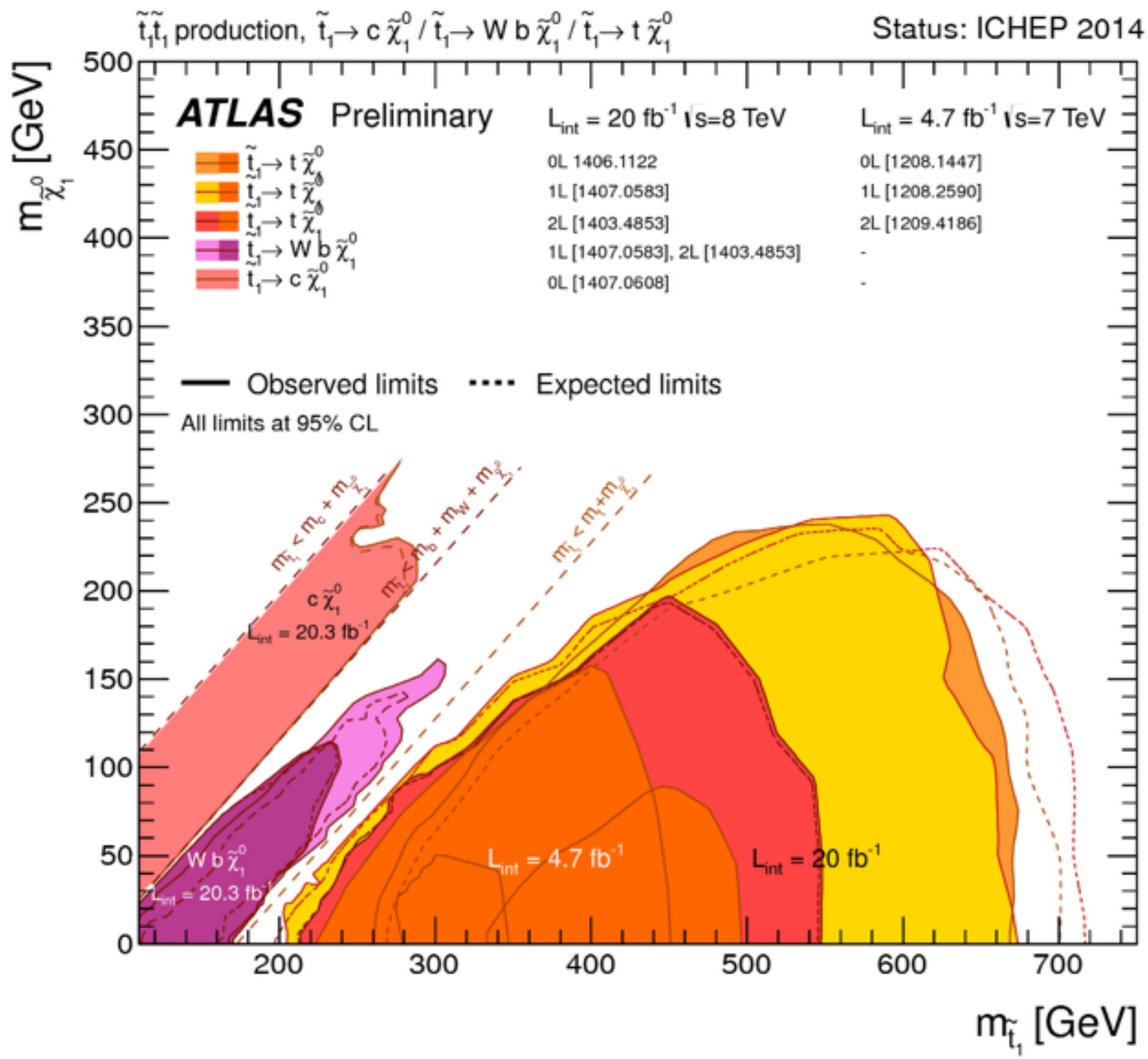
- 1./2. generation squark and gluino masses below 1.7 TeV are excluded (for degenerate squarks/ gluinos)

- This is somewhat worrisome if one believes in supersymmetry in order to stabilize the EW scale

- However, if higgsinos and third generation sparticles are light, SUSY is still natural



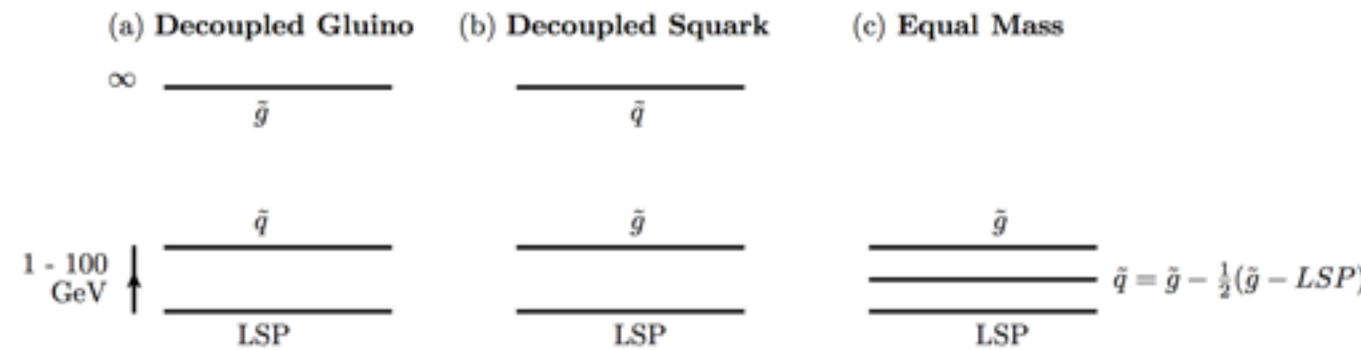


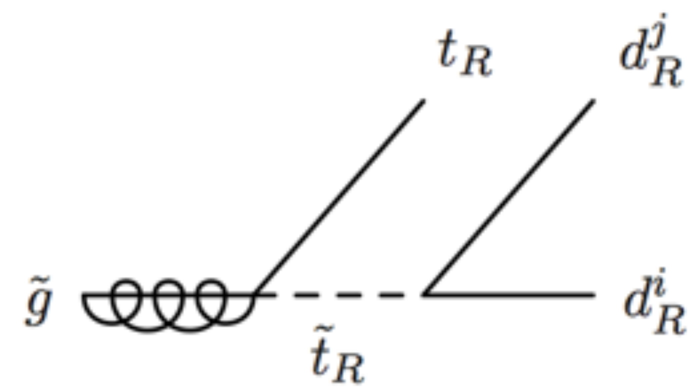


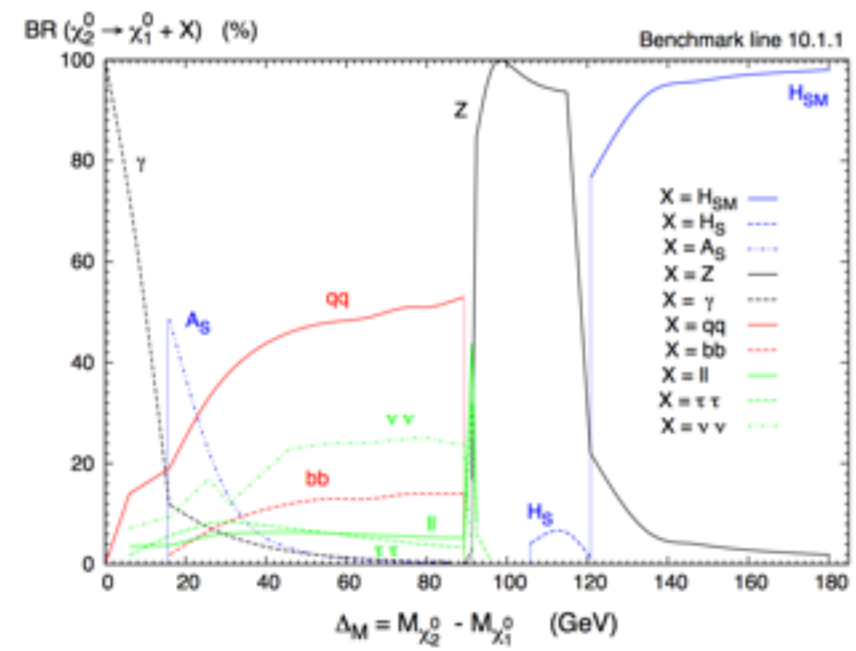
But even the limits for third generation sparticles becomes pretty strict

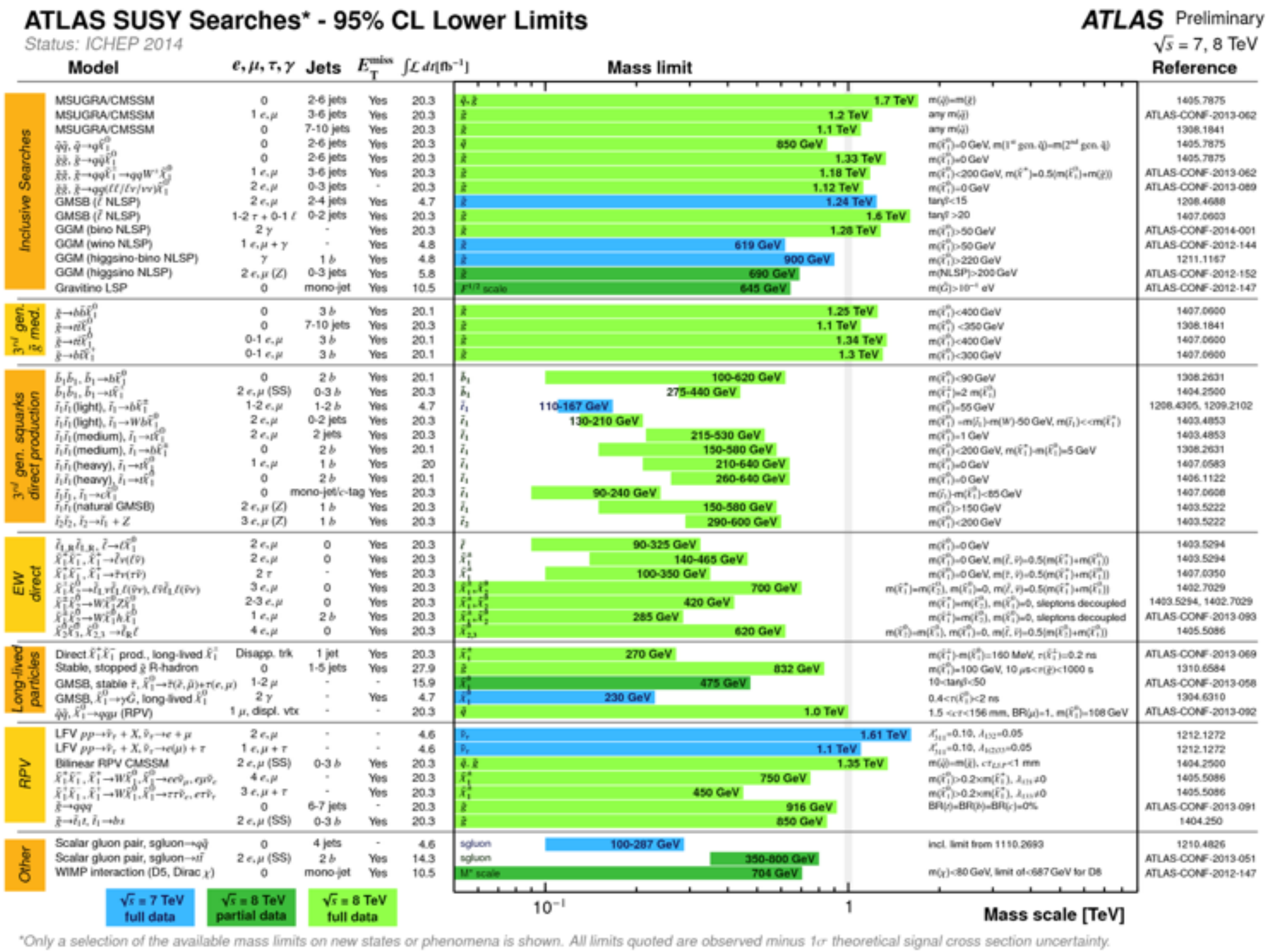
But SUSY could be hidden...

- A compressed spectrum is difficult to probe
- RPV can significantly reduce MET
- Extended particle content can modify the collider signature
- In Split SUSY, many sparticles are not accessible at the LHC









ATLAS/CMS have looked in many final state signatures and have derived limits on simplified models

Drawbacks…

- However, many simplified models are *unrealistic*
- Limits would be heavily modified if one changes the assumptions on the sparticle spectrum and couplings
- E.g., softer jets/leptons, reduced MET, BR <1
- How can we constrain all kinds of models (even non-SUSY) by experimental data?

Recast experimental limits I

- SModels (arXiv:1312.4175) decomposes the signal into simplified topologies and compare their rates with experimental limits

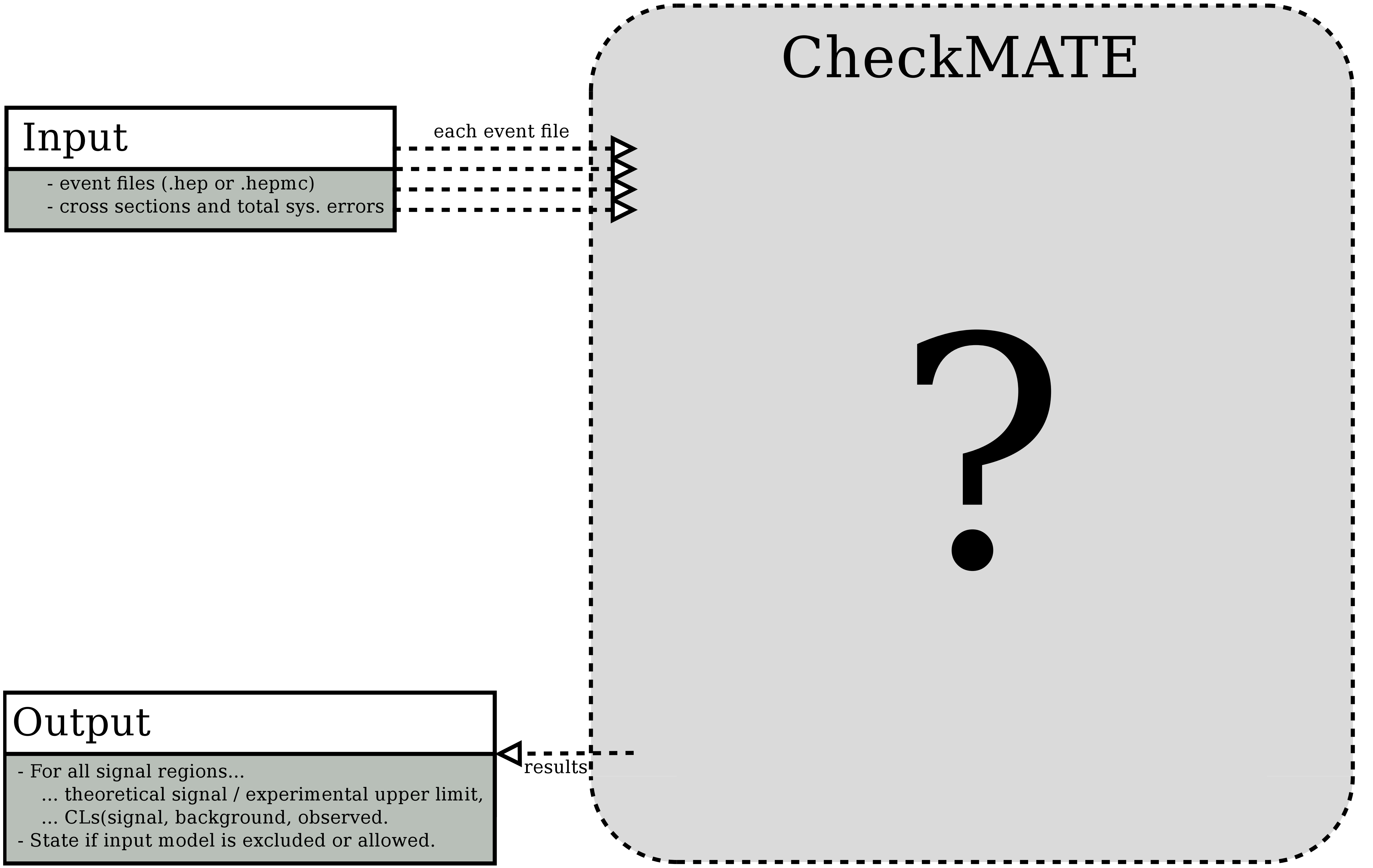
- FastLim (arXiv:1402.0492) calculates limits based on simplified models by providing pre-calculated efficiency tables for each simplified topology

- Both are very fast but the topology must be very simple

Recast experimental limits II

- Generate MC events with Pythia, Herwig, Sherpa,...
- Simulate the detector response with Delphes/PGS
- Code up the relevant experimental study
- Validate the detector simulation and the analysis code
- This is very time consuming

Our Idea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each event file
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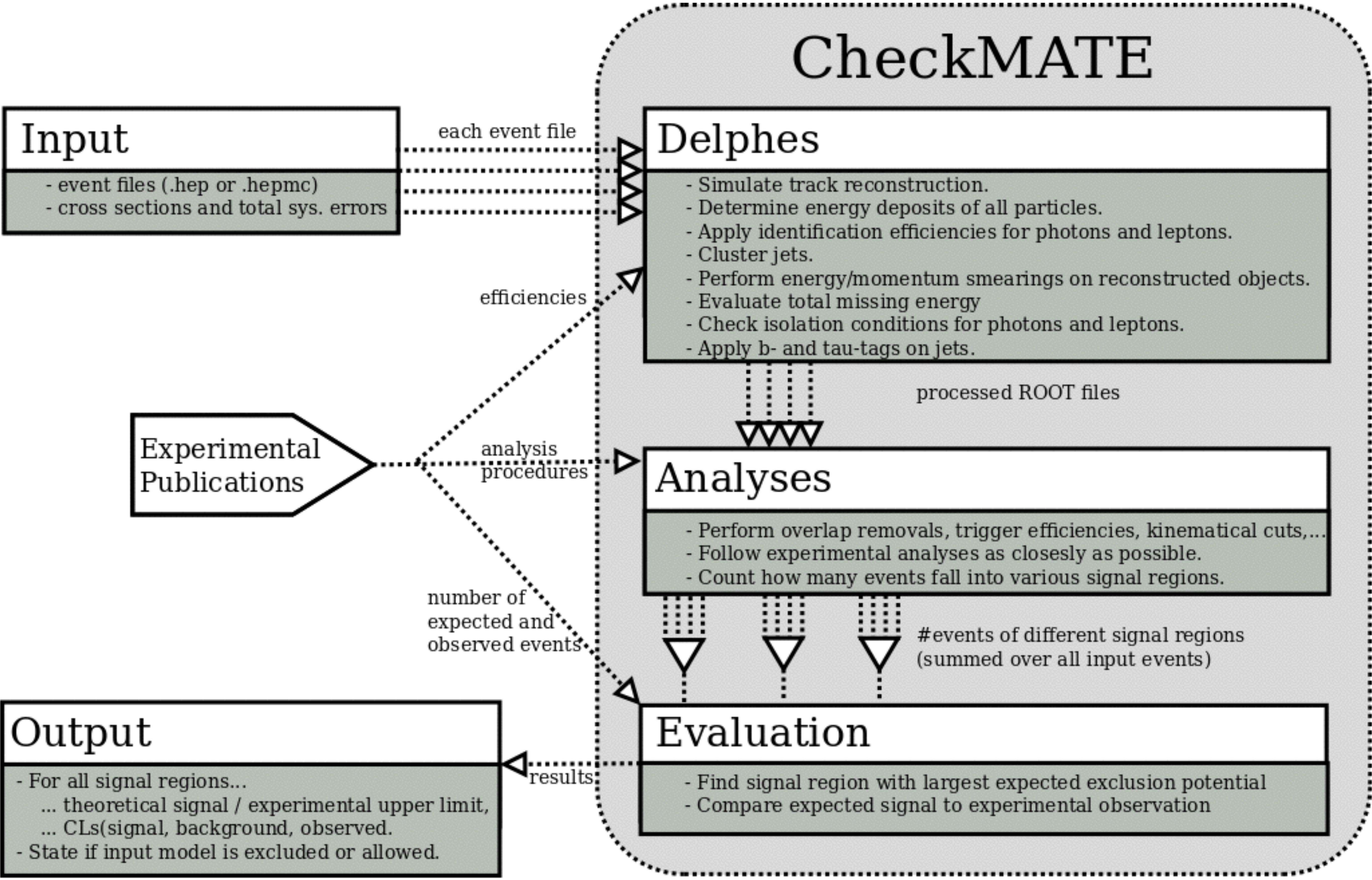
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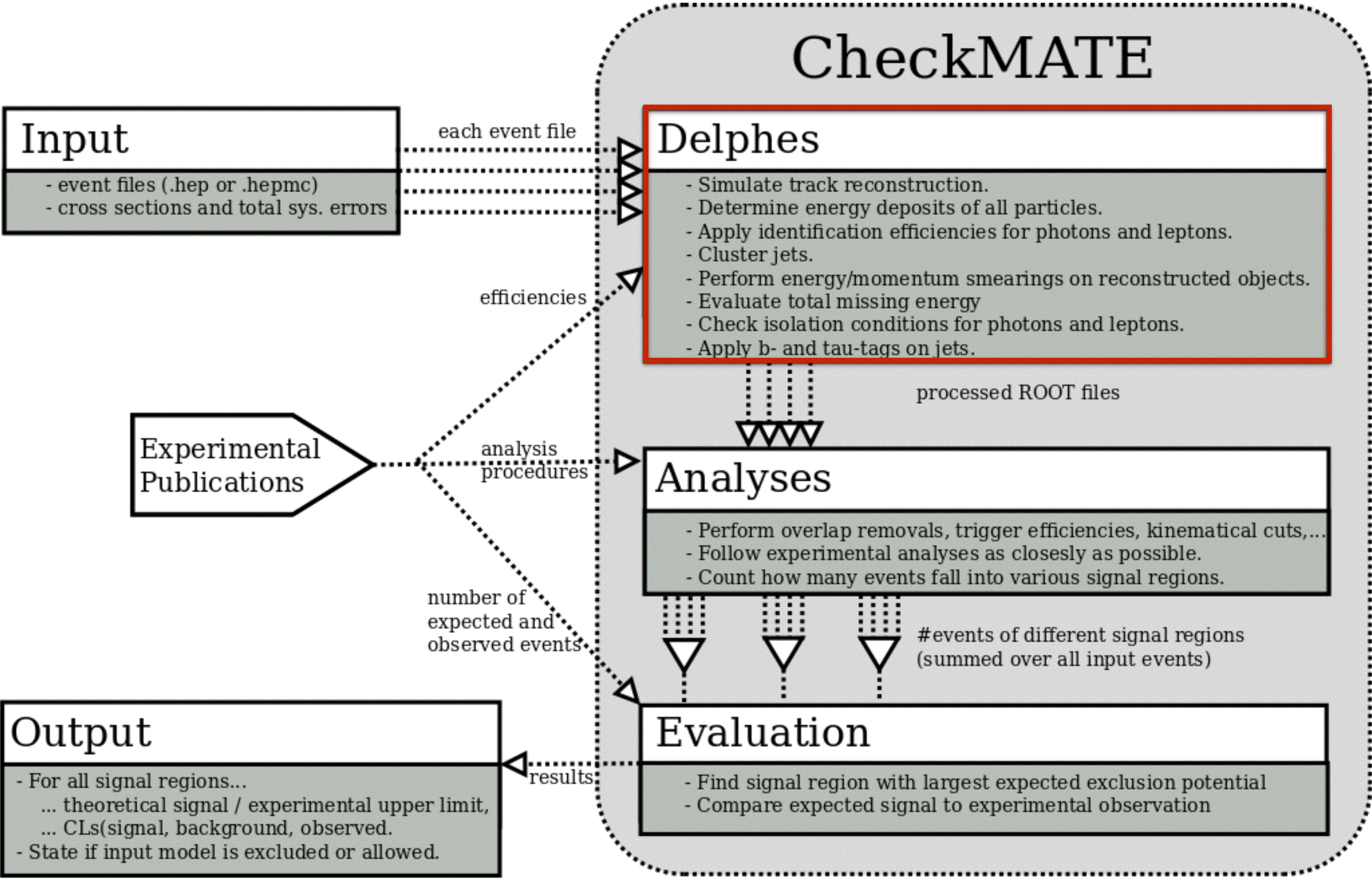
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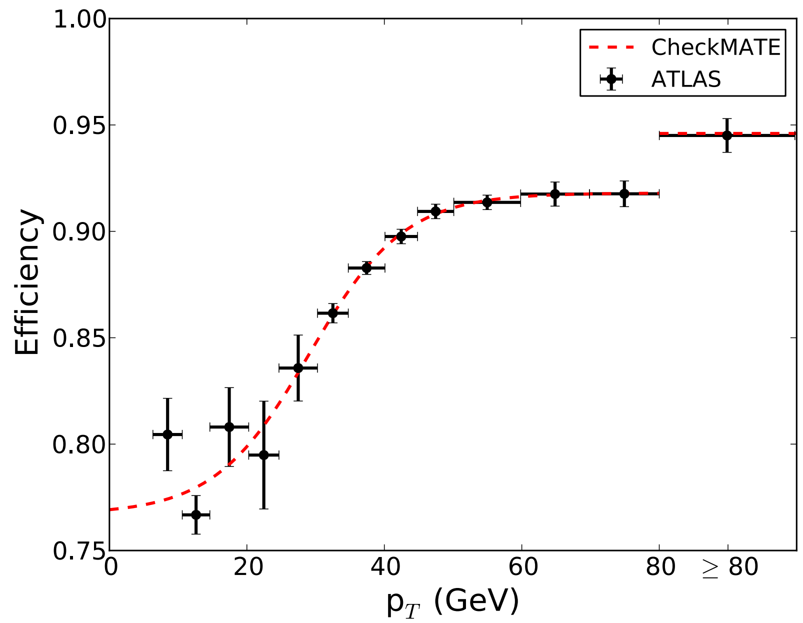
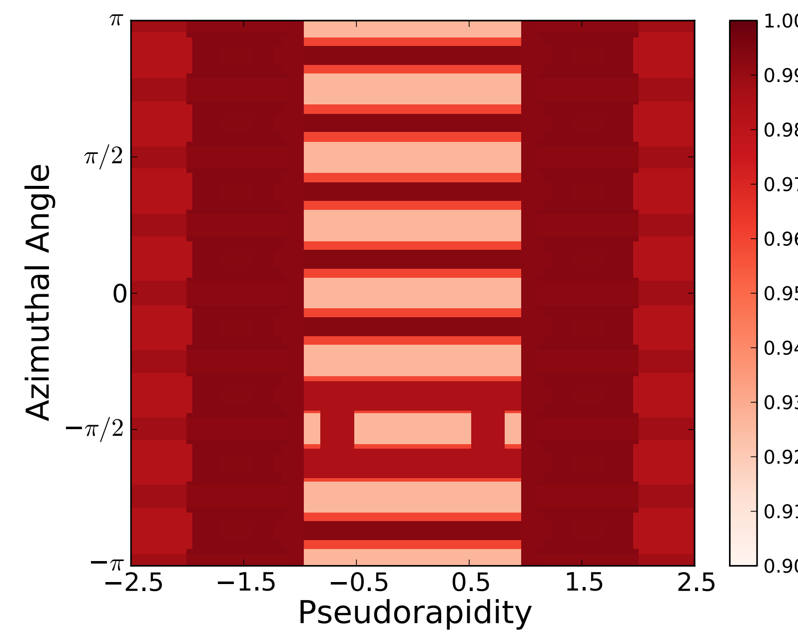
Detector simulation

- We heavily rely on the fast detector simulation Delphes 3
- However, we have modified the default Delphes
  - Many studies require multiple “types” of the same final state
  - The need of several isolation criteria for the same object
  - Retune of the detector response for many final state objects

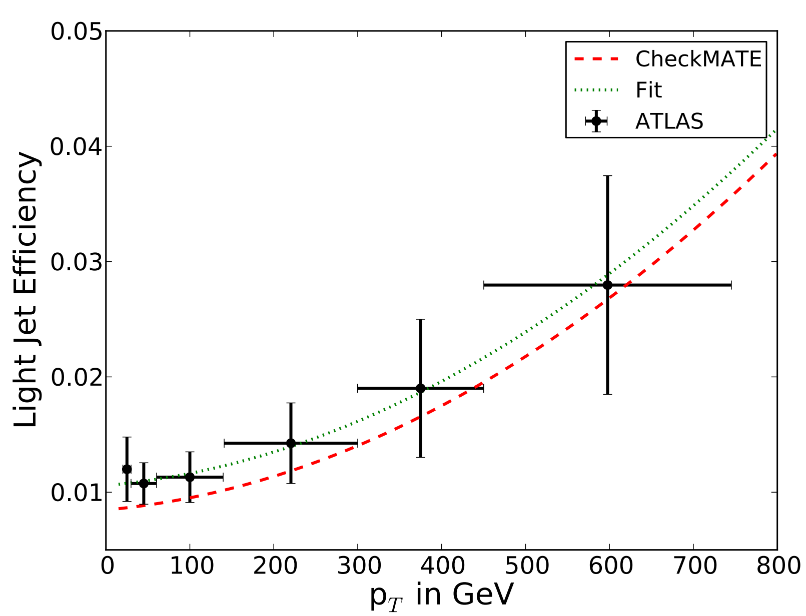
Retune of Delphes



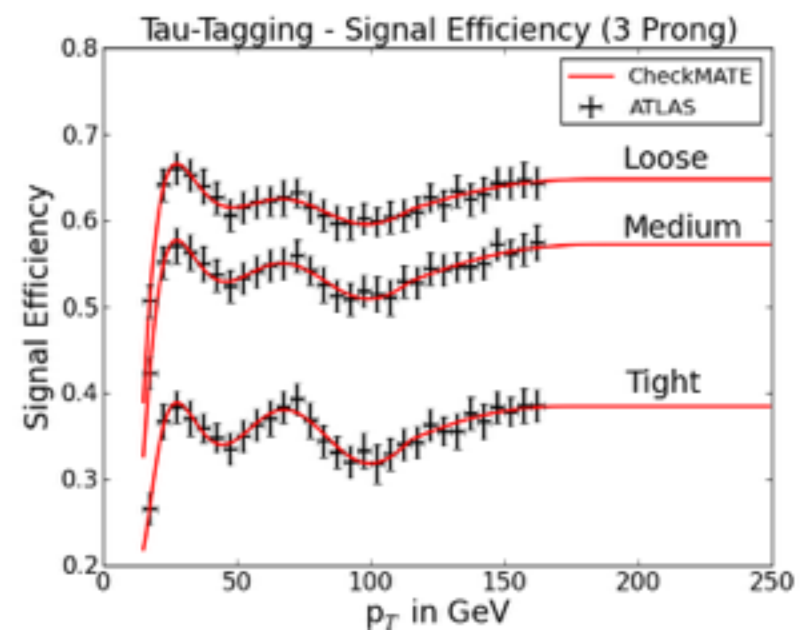
Id efficiency for “medium” electrons



Efficiency for muon objects

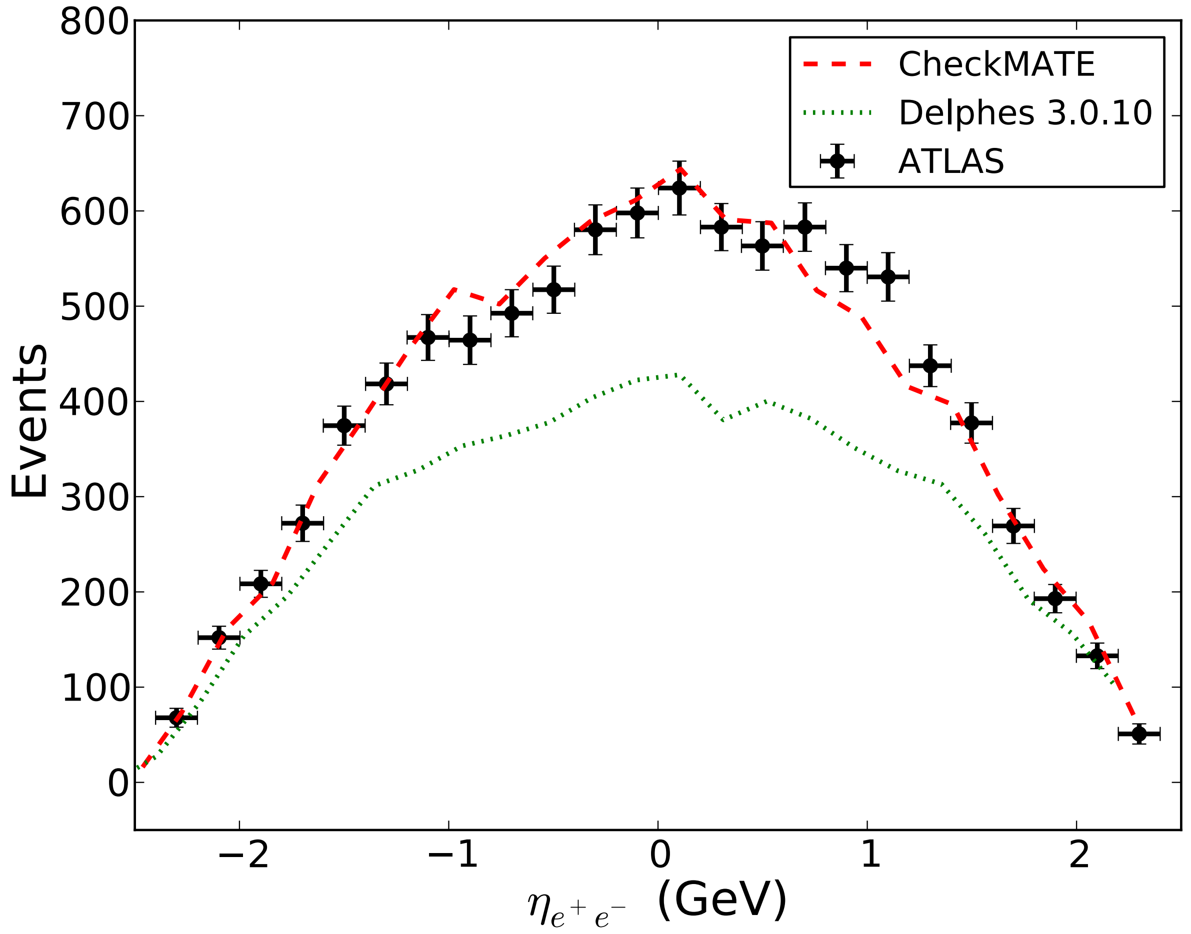


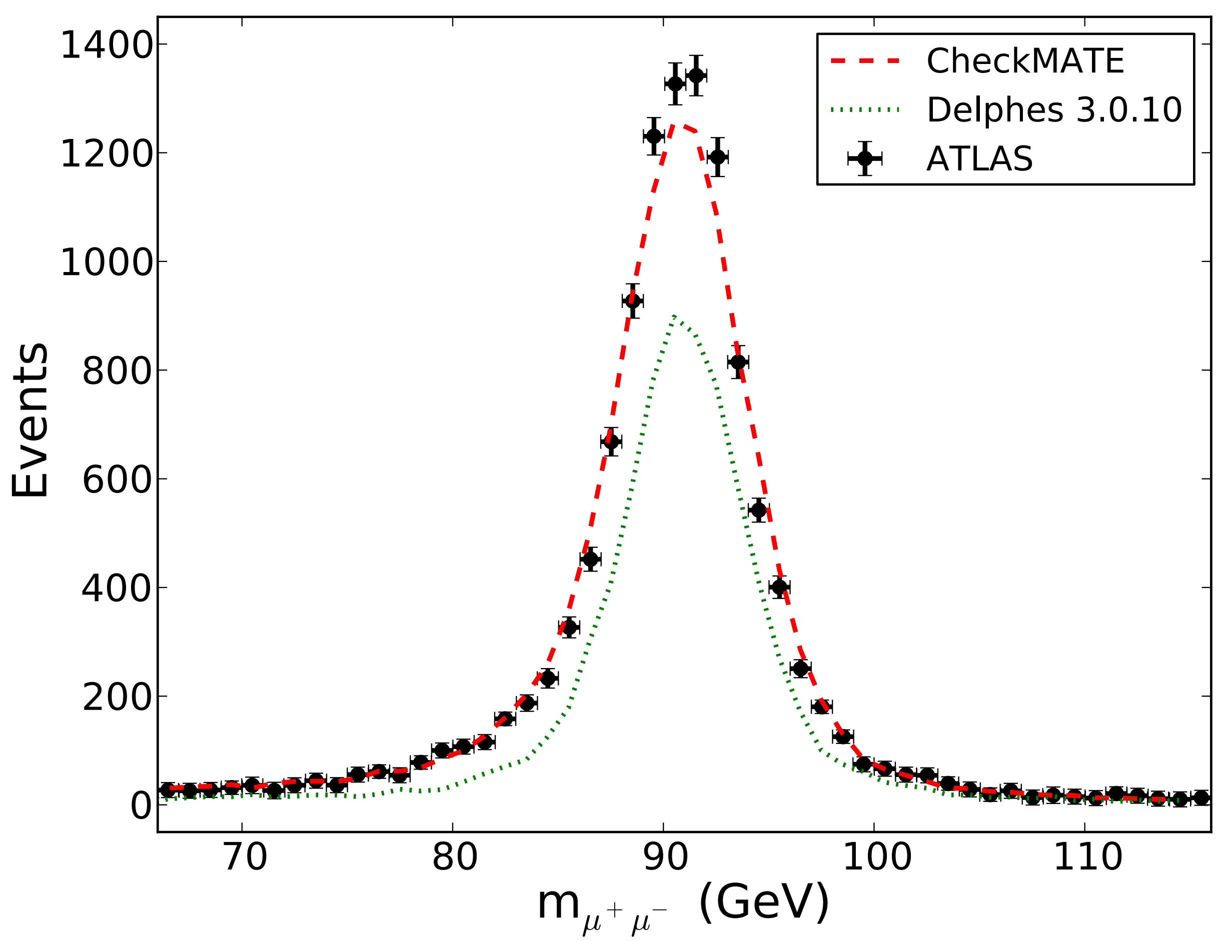
B tagging efficiency of jets containing light quarks

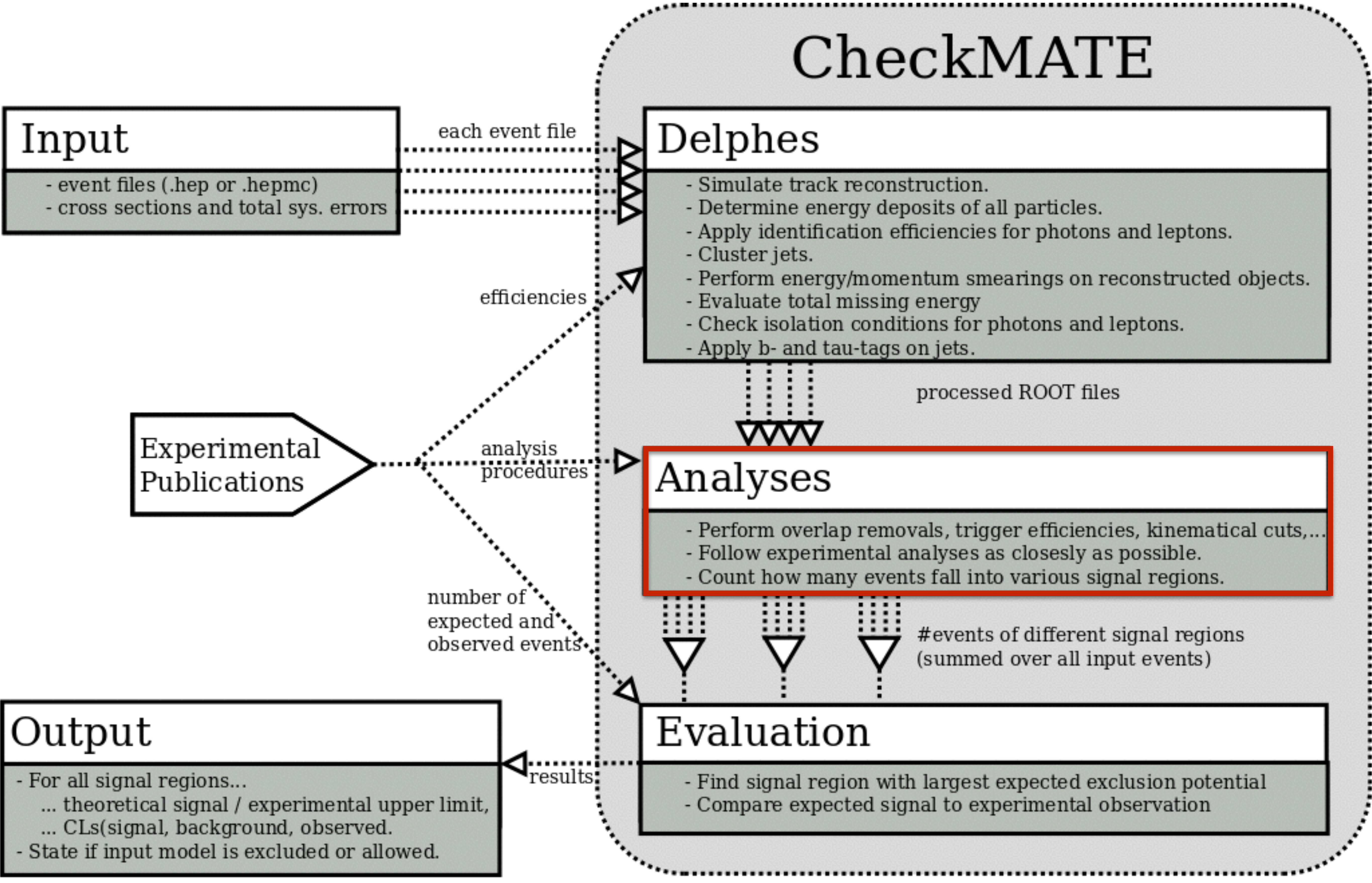


Signal efficiencies for 3 prong taus

Validation plots



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Analyses

- CheckMATE uses a C++ framework to process Delphes' results
- All analyses are written in the same structural form
- We have implemented kinematical functions and methods for object removal
- A typical analysis consists of
  - choosing final state objects
  - trigger efficiencies/vetoing events
  - define signal/control regions
  - count number of events in each SR

```
#include "example.h"

void Example::initialize() {
  setAnalysisName("example");
  setInformation(""
    "@#Example Analysis\n"
  "");
  setLuminosity(10*units::INVFB);
  ignore("towers");
  ignore("tracks");
  bookSignalRegions("jets;jets_plus_e;jets_plus_m");
  bookCutflowRegions("singlelep;twojets");
}

void Example::analyze() {
  electronsMedium = filterPhaseSpace(electronsMedium, 20, -2.5, 2.5, true)

  std::vector<Electron*> isoElecs = filterIsolation(electronsMedium);


  muonsCombined = filterPhaseSpace(muonsCombined, 25, -2.0, 2.0);
  std::vector<Muon*> isoMuons = filterIsolation(muonsCombined);
  missingET->addMuons(isoMuons);


  jets = filterPhaseSpace(jets, 50);
  jets = overlapRemoval(jets, electronsMedium, 0.2);


  if (isoElecs.size() + isoMuons.size() == 1)
    return;
  countCutflowEvent("singlelep");

  if (jets.size() < 2)
    return;
  countCutflowEvent("twojets");

  double E_tot = 0;
  for(int j = 0; j < jets.size(); j++)
    E_tot += jets[j]->PT;

  if (E_tot >= 150) {
     countSignalEvent("jets");
     if ((isoElecs.size() == 1)&&
         (fabs(isoElecs[0]->P4().DeltaPhi(missingET->P4())) < 0.3))
       countSignalEvent("jets_plus_e");

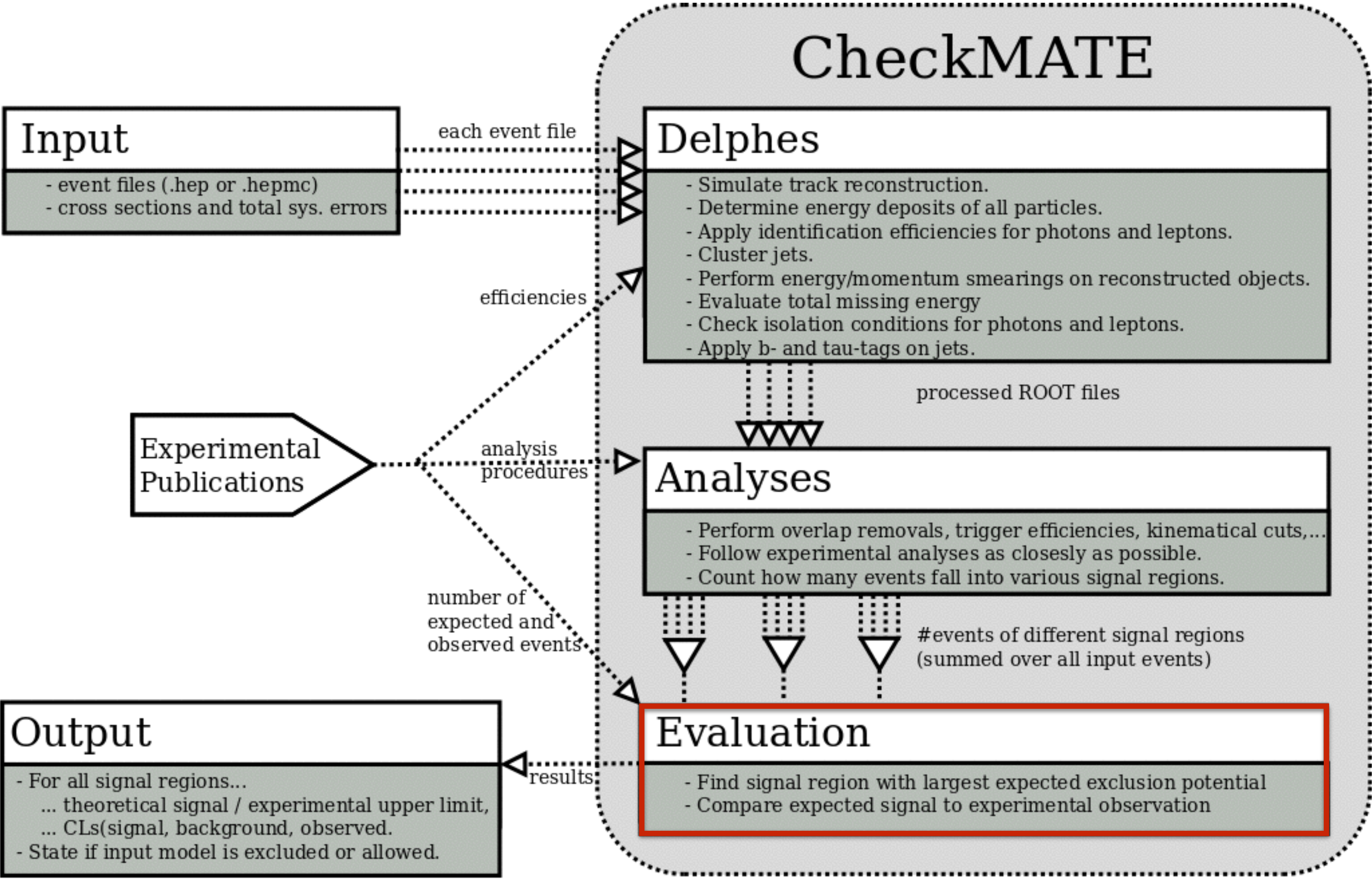
     else if ((isoMuons.size() == 1)&&
              (fabs(isoElecs[0]->P4().DeltaPhi(missingET->P4())) < 0.15))
       countSignalEvent("jets_plus_m");

  }
}

void Example::finalize() {
}
```

Analyses

Name	NSR	Description	Lumi
atlas_1403_4853	12	ATLAS, 2 leptons + etmiss (direct stop)	20.3
atlas_1308_2631	6	ATLAS, 0 leptons + 2 b-jets + etmiss	20.1
atlas_1404_2500	5	ATLAS, Same sign dilepton or 3l	20.3
atlas_1407_0583	27	ATLAS, 1 lepton + (b-)jets + etmiss (stop)	20.3
atlas_1407_0600	9	ATLAS, 3 b-jets + 0-1 lepton + etmiss	20.1
atlas_conf_2012_104	2	ATLAS, 1 lepton + >= 4 jets + etmiss	5.8
atlas_conf_2012_147	4	ATLAS, Monojet + etmiss	10.0
atlas_conf_2013_024	3	ATLAS, 0 leptons + 6 (2 b-)jets + etmiss	20.5
atlas_conf_2013_036	5	ATLAS: 4 leptons + etmiss	20.7
atlas_conf_2013_037	6	ATLAS, 1 lepton + (b-)jets + etmiss (stop)	20.7
atlas_conf_2013_047	10	ATLAS, 0 leptons + 2-6 jets + etmiss	20.3
atlas_conf_2013_049	9	ATLAS, 2 leptons + etmiss	20.3
atlas_conf_2013_061	9	ATLAS, 0-1 leptons + >= 3 b-jets + etmiss	20.1
atlas_conf_2013_089	12	ATLAS, 2 leptons (razor)	20.3
atlas_conf_2014_014	1	ATLAS, 2 leptons + b-jets (stop)	20.3
cms_1303_2985	59	CMS, alpha_T + b-jets	11.7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Setting limits

- Directly compare S to 95% upper limit on signal S95
- Calculate the ratio r=S/S95. If r>1: Excluded!
- Choose signal region with strongest expected exclusion
- Use its observed result to state “excluded” or “allowed”
- Alternatively, calculate CL. If CL < 0.05: Excluded!

Demonstration

Input

```
## General Options
[Mandatory Parameters]
Name: My_New_Run
Analyses: atlas_conf_2013_047

[Optional Parameters]

## Process Information (Each new process 'X' must start with [X])
[gluinogluino]
XSect: 3.53*FB
XSectErr: 1e-5*PB
Events: testfile.hep
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Output

SR	S	dS_stat	dS_sys	dS_tot	S95_obs	S95_exp	r^c_obs	r^c_exp
AL	37.41	0.43	4.10	4.12	1341.20	1135.00	0.02	0.03
AM	5.37	0.15	0.56	0.58	51.30	42.70	0.08	0.10
BM	7.33	0.18	0.76	0.78	14.90	17.00	0.39	0.34
BT	0.84	0.05	0.10	0.11	6.70	5.80	0.09	0.11
CM	18.22	0.30	2.04	2.07	81.20	72.90	0.17	0.19
CT	2.32	0.08	0.27	0.28	2.40	3.30	0.74	0.54
D	12.15	0.24	1.29	1.32	15.50	13.60	0.62	0.70
EL	21.56	0.33	2.38	2.41	92.40	57.30	0.18	0.29
EM	16.08	0.29	1.79	1.81	28.60	21.40	0.44	0.59
ET	8.10	0.20	0.89	0.91	8.30	6.50	0.76	0.97

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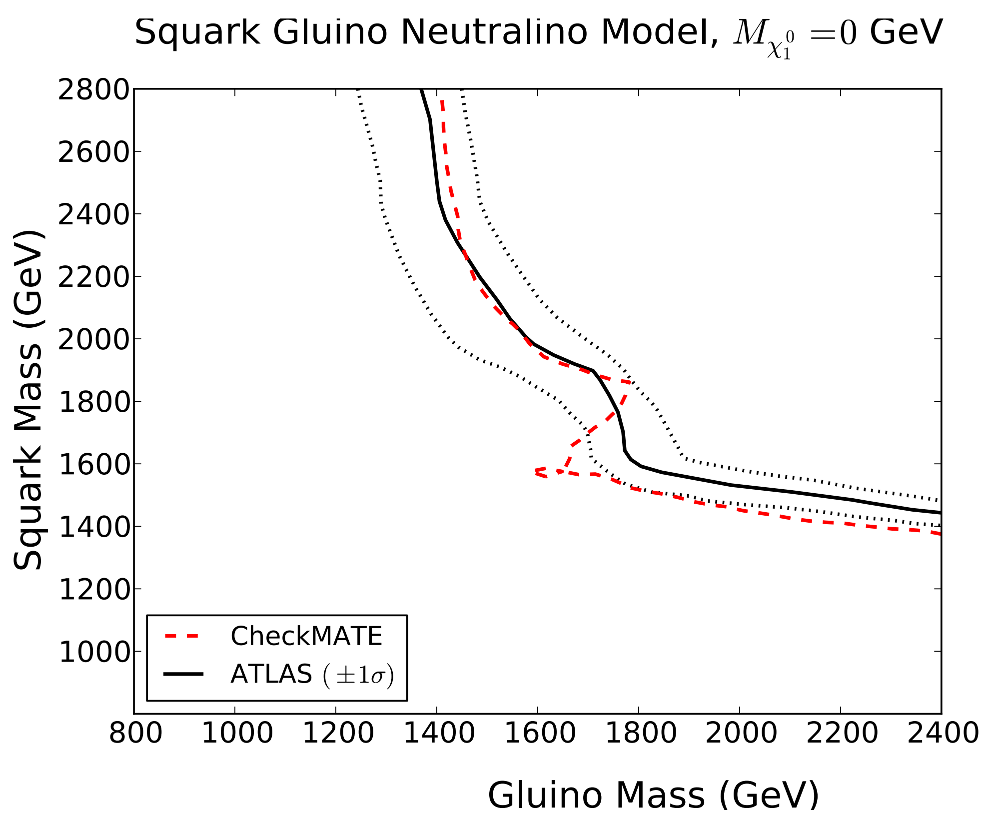
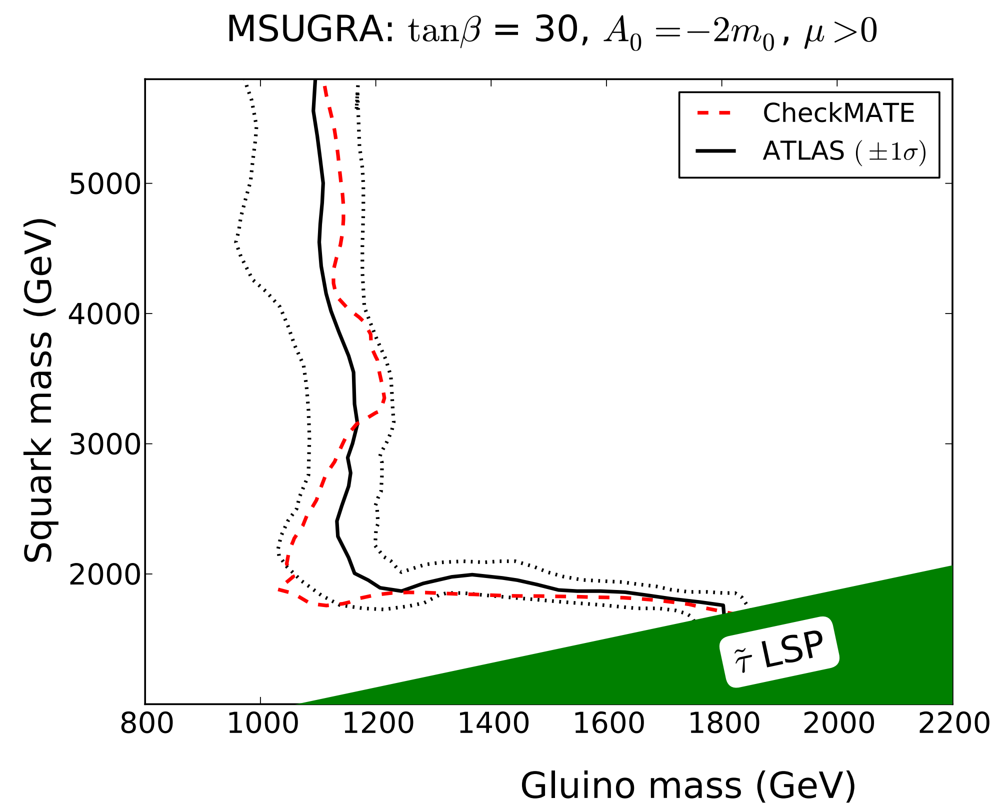
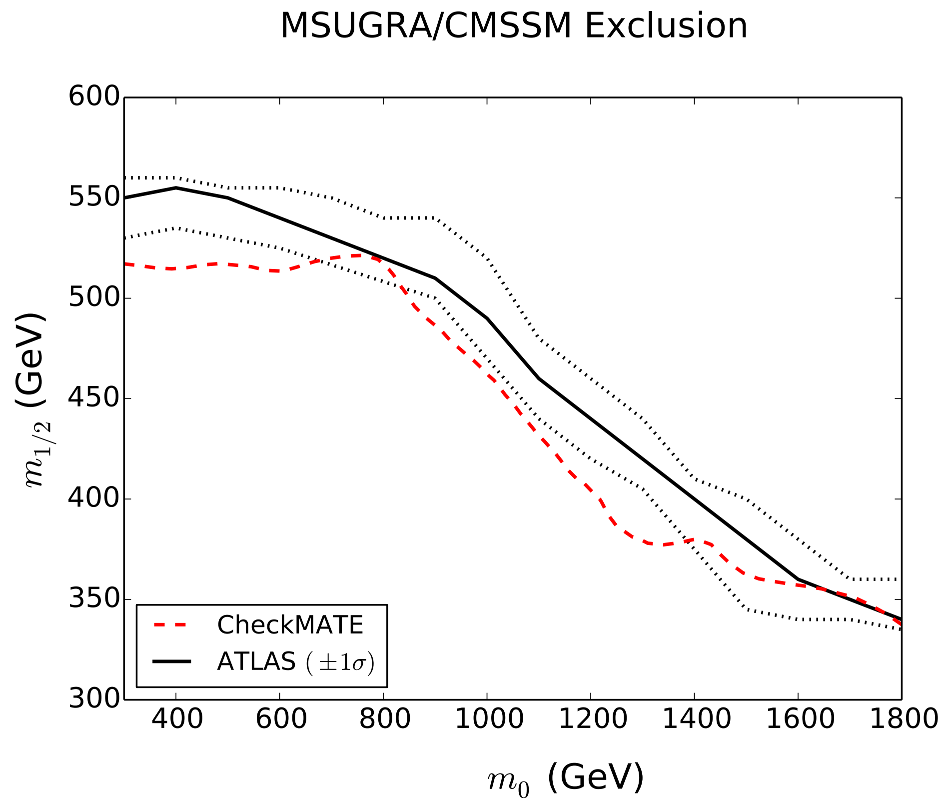
Result

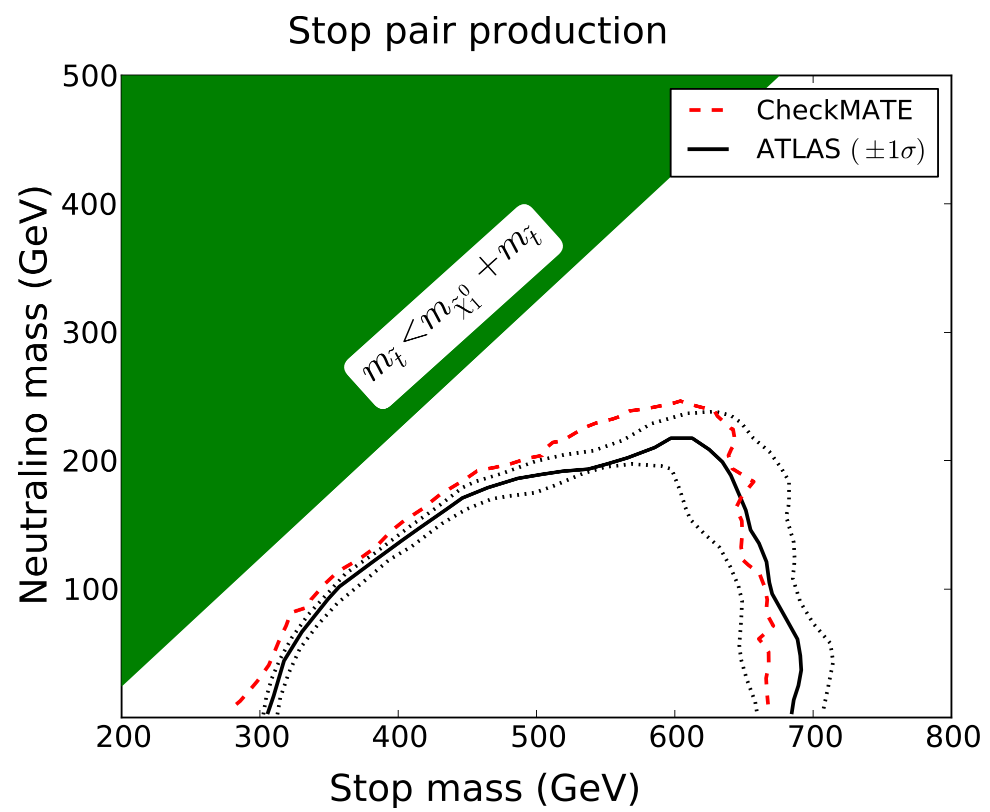
analysis	bestSR	r_obs^c	r_exp^c	CLs_obs	dCLs_obs	CLs_exp	dCLs_exp	[...]
atlas_conf_2013_047	ET	0.76	0.97	0.0609	0.0027	0.0077	0.0013	[...]

Numerical Results









Conclusion

- CheckMATE test any event + cross section combination against current LHC results
- …is very easy to use (for the lazy physicist)
- …is transparent in its functionality (for the curious physicist)
- …it is simple to extend (for the talented physicist)

http:checkmate.hepforge.org