Assessing the correlation between MadAnalysis and Rivet implementations

Reinterpretation Forum Workshop 2025

OpenMAPP

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27th February 2025

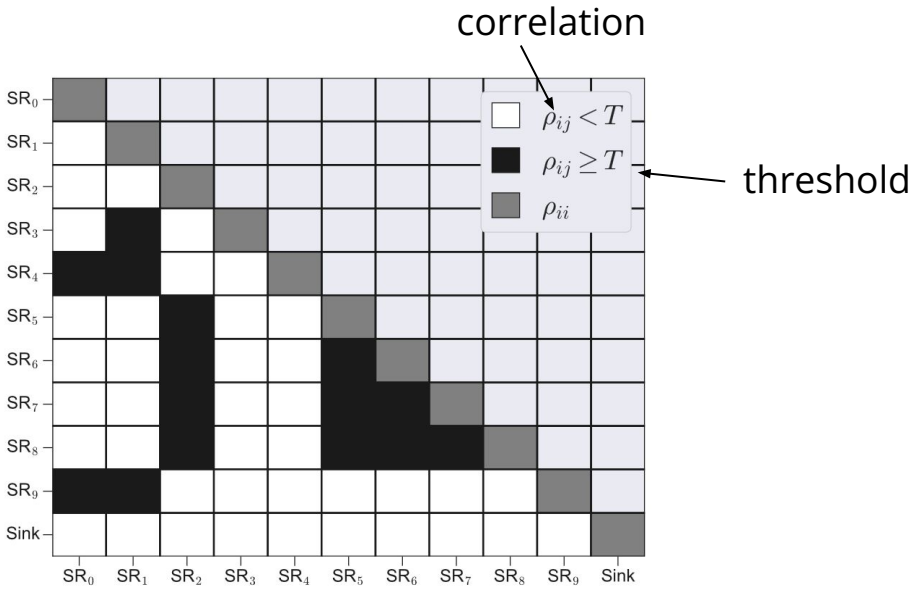
H E A L T H

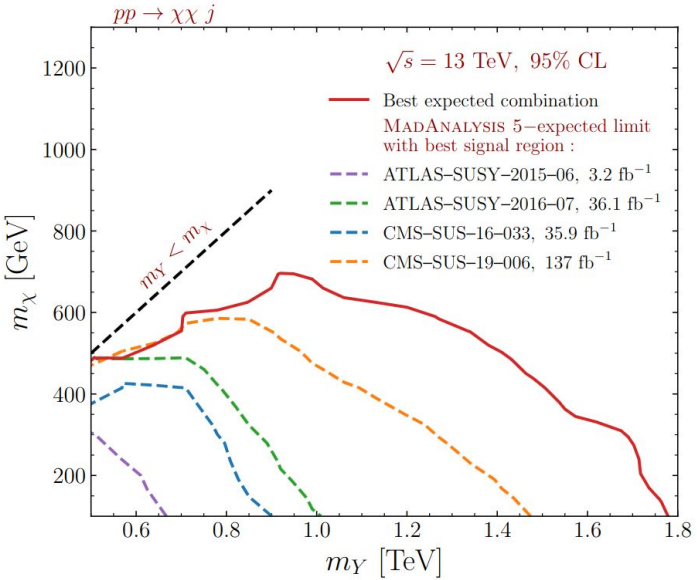
A D V I S O R Y

The following expresses my very own perspectives from a pheno point of view.

Motivation

- Cross-validation between implementations of analyses in different tools
- →Contur uses manual separation into orthogonal pools by e.g. multiplicity
- TACO method: →SciPost Phys. 14, 077 (2023)
  - Statistically combined multiple →MadAnalysis/→SModelS analyses





Motivation

REI WG — plans and action items (2/2)

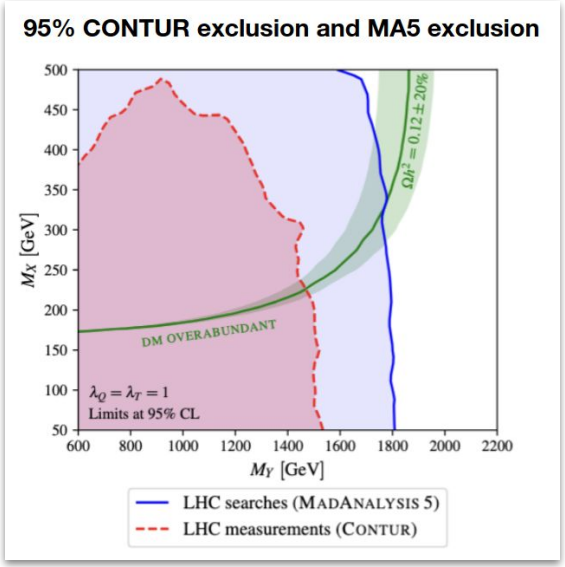
- Enhance visibility and recognition for auxiliary material provision
  → RAMP seminars, ideally in active collaboration with the other WGs. *[organisers needed]*
- Generally interact with other LPCC WGs, be as transversal a group as possible, have joint sessions in addition to generic REI workshops.
  (frequency of meetings t.b.d.)
- On the pheno side, provide active feedback to the experiments.
- Work on interoperability of tools.

→Sabine Kraml @ Mon (LHC BSM WG)

- Run events against all searches/measurements implemented in
  - MadAnalysis5 v1.9.60
  - CheckMATE v2.0.34
  - Rivet v3.1.5/Contur v2.2.1

and calculate cross section σ_{95} needed to exclude the events at 95% CL

→Manuel Kunkel @ Tue



→Clarisse Prat @ Tue

Motivation

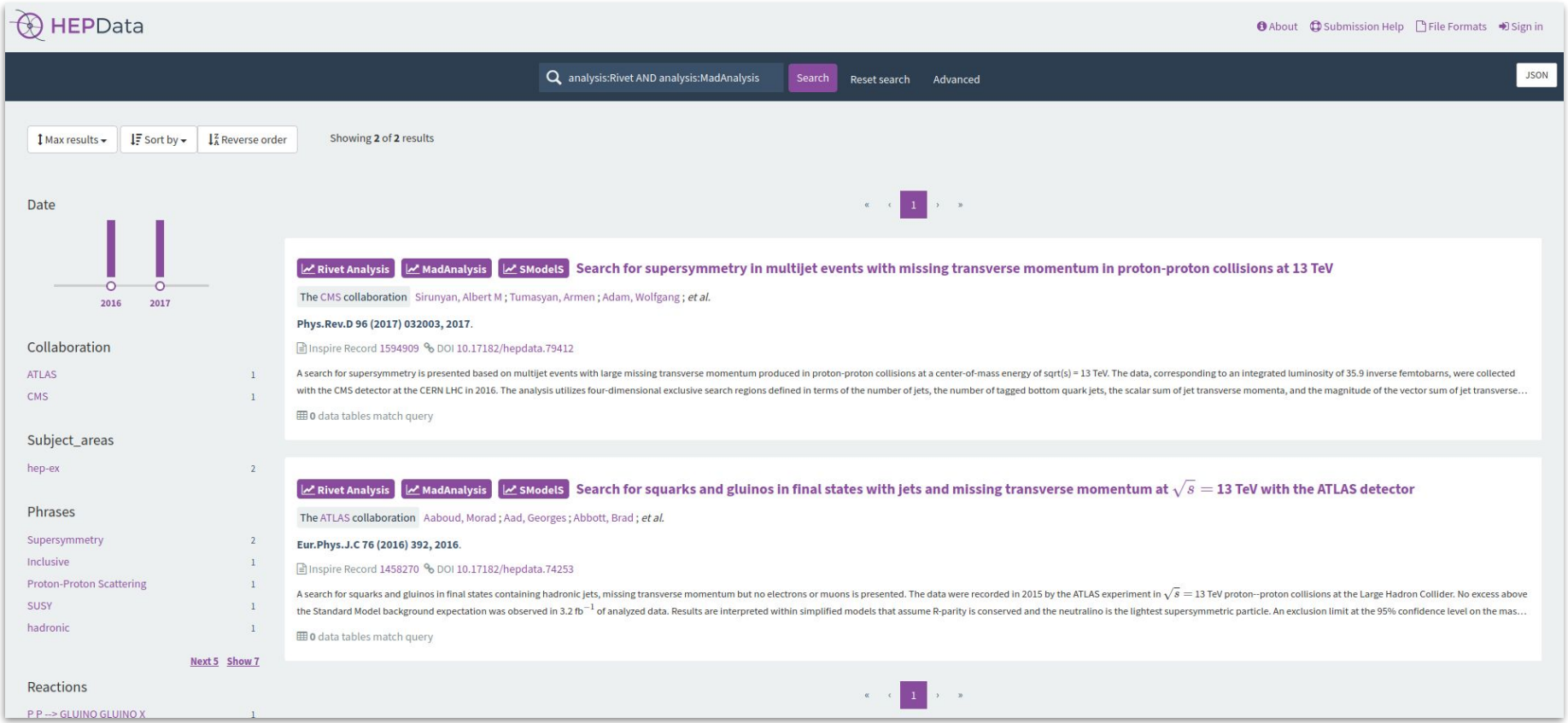
Correlation/ Overlap

→**MadAnalysis**

→**Rivet**

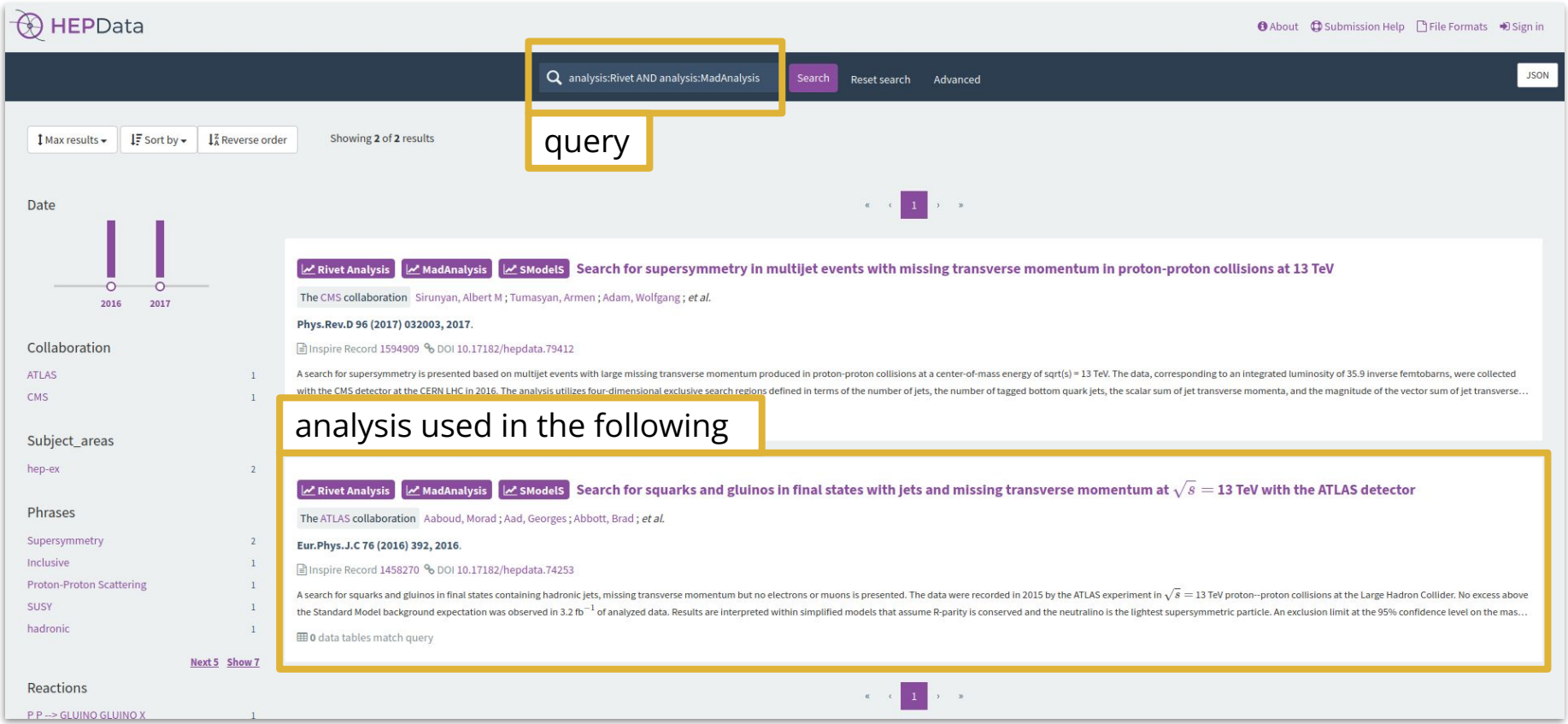
The case

How to find a suitable analysis for the study



→Query link

How to find a suitable analysis for the study

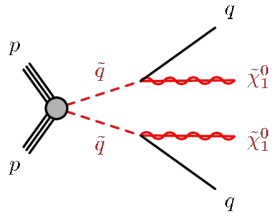


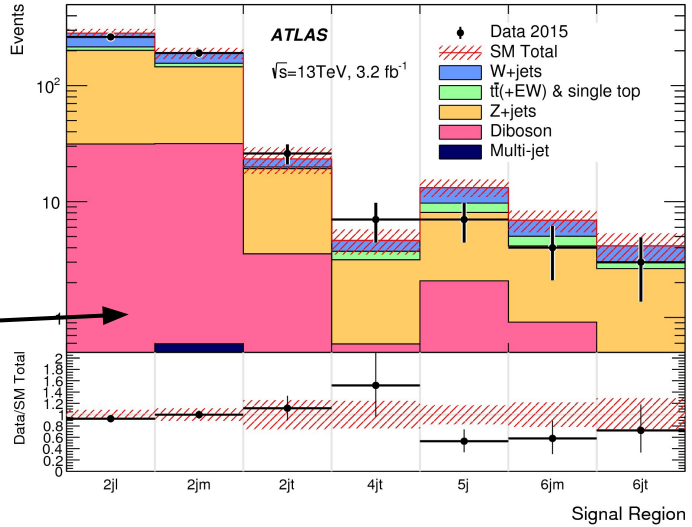
→Query link

The studied case

Search for squarks and gluinos in final states with jets and missing transverse momentum at √s=13 TeV with the ATLAS detector

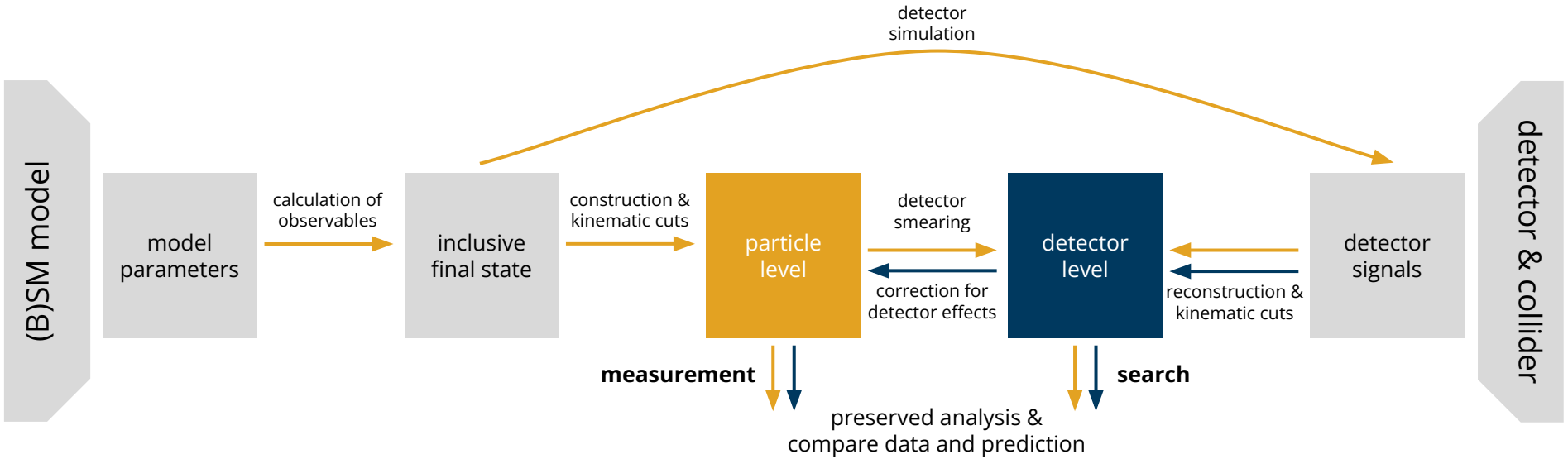
- →Webpage:SUSY-2015-06, L=3.2 fb^{-1}
- Selects events with
  - E_T^{miss} > 200 GeV
  - **No leptons**
- Signal regions based (a.o.) on inclusive jet multiplicity
- Published results on **detector level**
- Provided cutflow

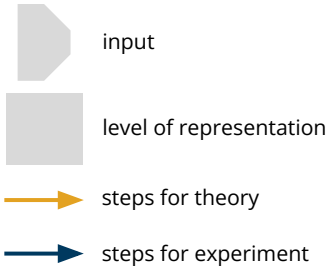




Selections	gluino pair m(gluino,N1)=(1600, 0) GeV	gluino pair m(gluino,N1)=(1100, 700) GeV	squark pair m(squark,N1)=(1000, 400) GeV
N_{gen}	10000	30000	20000
Pre-selection, E_T^{miss}>200 GeV, $p_T(jet_1)$>200 GeV	9018	17314	16956
Jet multiplicity	9018	17298	16704
$\min(\Delta\phi(E_T^{miss}, jet))$ cut	5497	12359	13211
$p_T(jet_2)$ cut	5426	6399	9851
$E_T^{miss}/\sqrt{H_T}$ cut	2919	2203	6361
m_{eff}(incl.) cut	2913	1636	5761

Common approach of a physics analysis





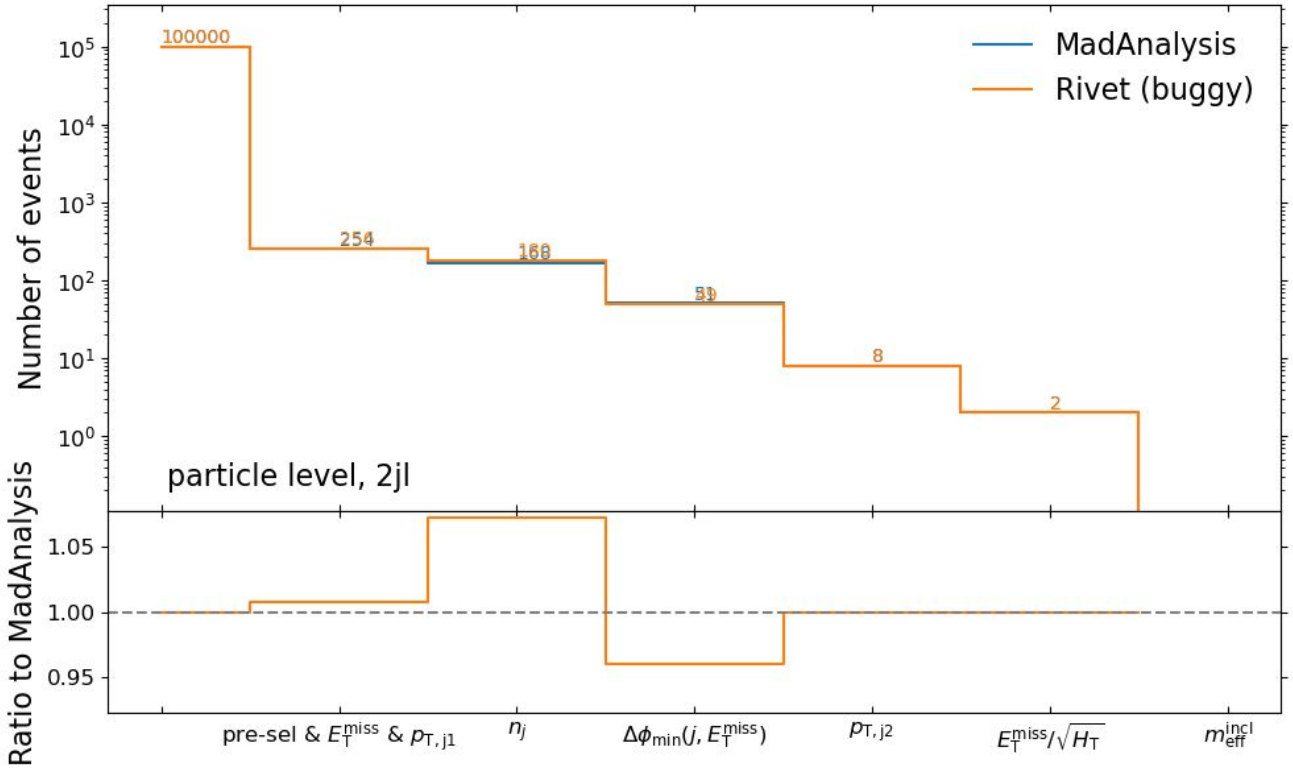
Technical setup

- Sample: →Sherpa v3.0.0 ***W*+jets**
- Tools:
  - →MadAnalysis v2.0.4_beta
    - Uses Delphes for estimation of detector effects
    - Achieved "particle level" representation by using smearing (SFS card) with perfect efficiencies if within detector acceptance
  - →Rivet v4.0.0
    - Uses smearing for estimation of detector effects
- Correlations estimated with →TACO
- All code available →here

Particle Level

Cutflow challenge - particle level, buggy

- On particle level, without overlap removal
- Some **disagreement of unclear origin** in first cuts



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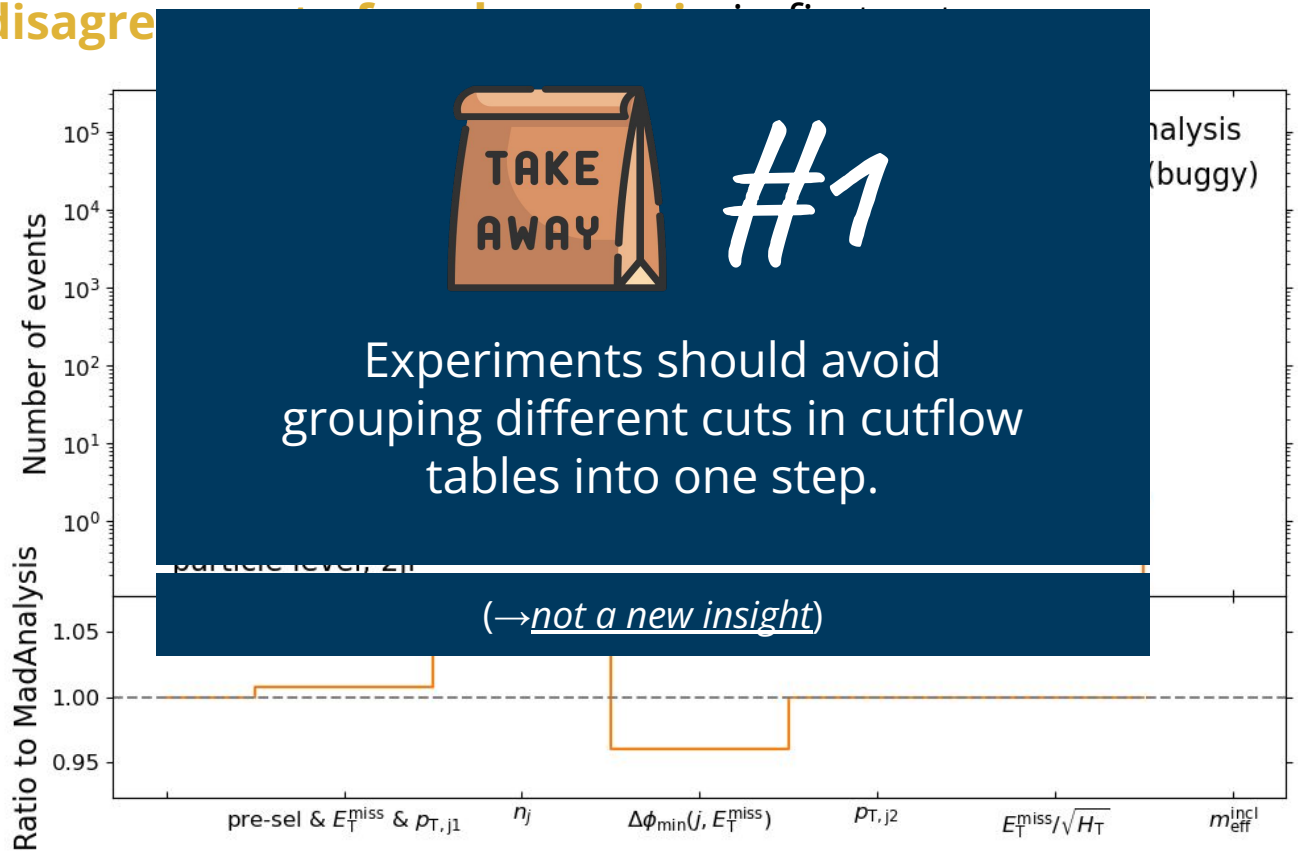
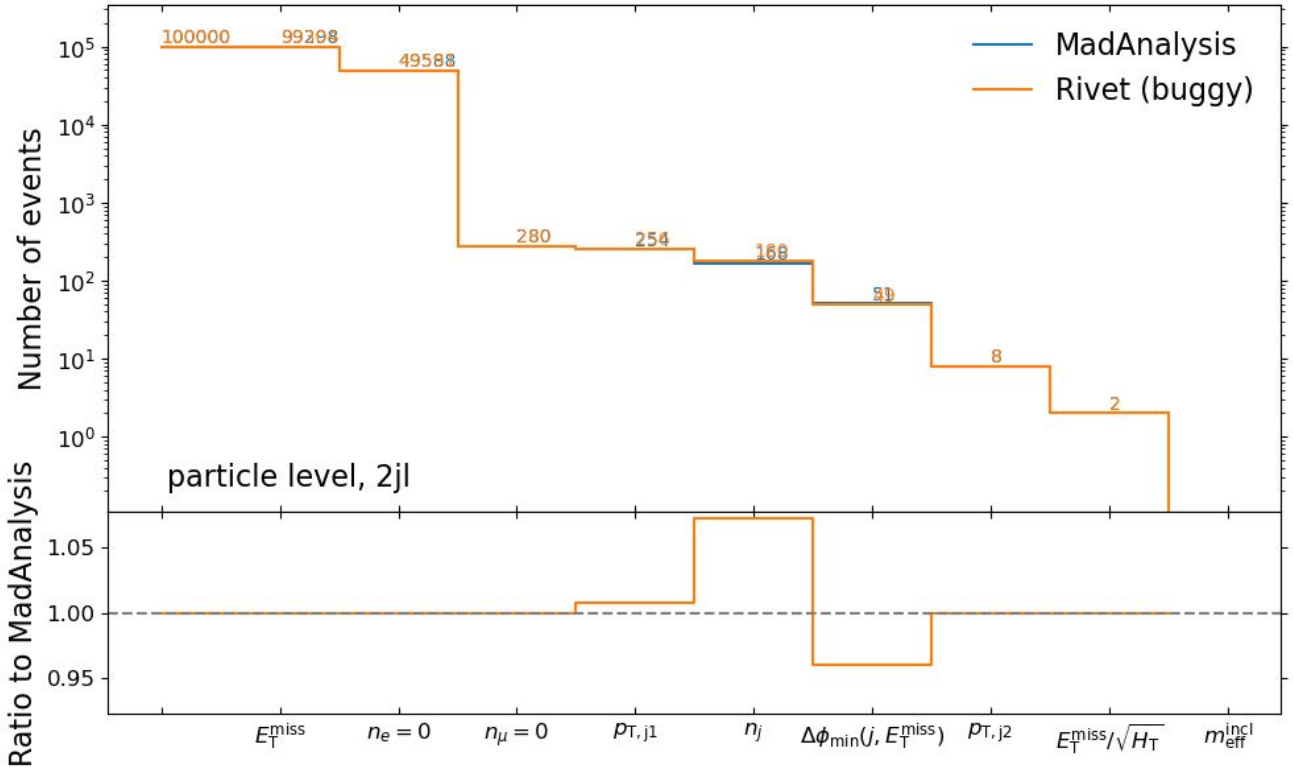


Cutflow challenge - particle level, buggy, ext.

- On particle level, without overlap removal, **extended first cutflow cut**
- **Diagreement** (mostly) from **jet multiplicity**



Cutflow challenge - particle level, buggy, ext.

- On particle level, without overlap removal, extended first cutflow cut
- Disagreement (mostly) from jet multiplicity

What is the problem?

Jet definition in Rivet implementation:
✖: Was - include prompt muons (JetMuons::ALL)
✔: Should be - include only muons from decay (JetMuons::DECAY)

Why was this not detected before?

- Cutflow didn't include muon multiplicity (=0) cut
- Cutflow samples were for signal only (=0 leptons)

Selections	gluino pair m(gluino,N1)=(1600, 0) GeV	gluino pair m(gluino,N1)=(1100, 700) GeV	squark pair m(squark,N1)=(1000, 400) GeV
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Cutflow challenge - particle level, buggy, ext.

- On particle level, without overlap removal, extended first cutflow cut
- ltiplicity

Wha

Jet c

✖: W ons::ALL)

✔: S m deca

Why

- plicity
- nly (=0

#2

Experiments should include all cuts in cutflows.

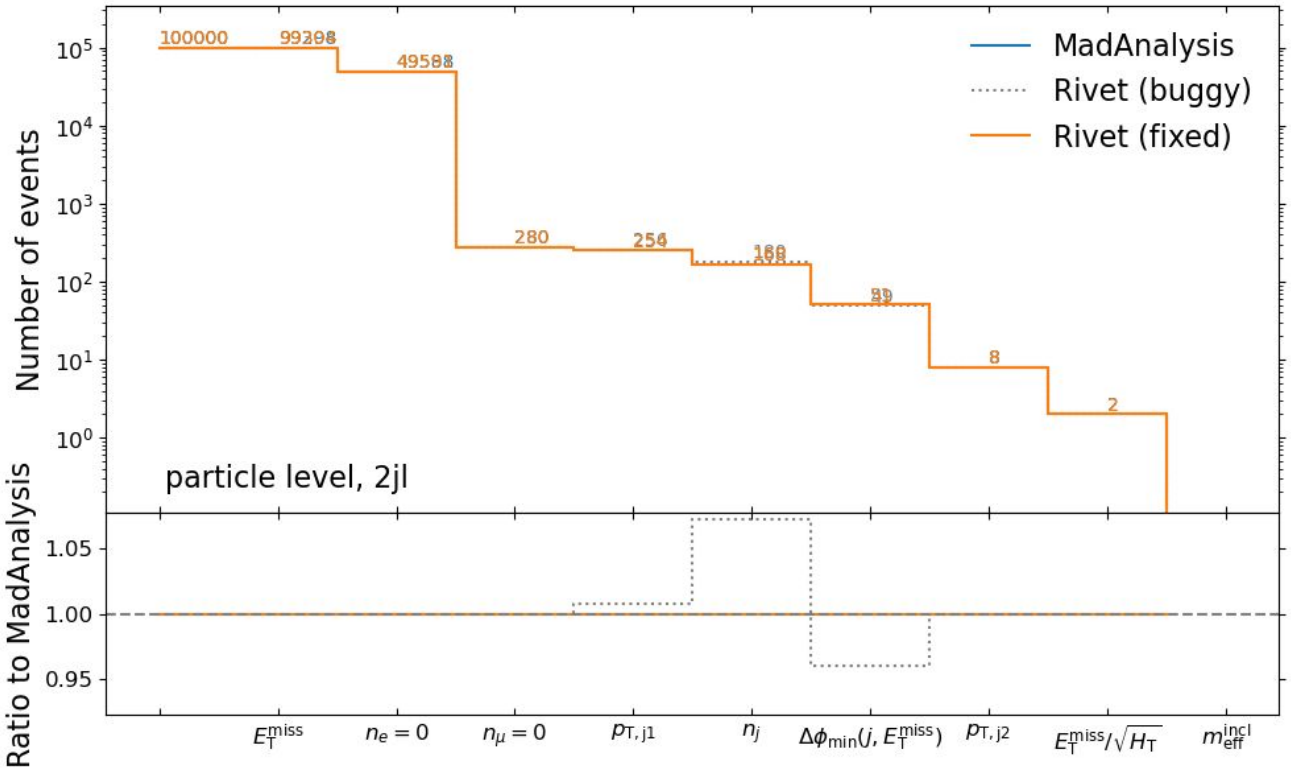
(→*not a new insight*)

#3

Experiments should provide cutflows for multiple *different* MC samples (e.g. incl. backgrounds).

Cutflow challenge - particle level, fixed, ext.

- On particle level, without overlap removal, extended first cutflow cut
- Fixed jet definition in Rivet → **Perfect agreement**!



Cutflow challenge - particle level, fixed, ext.

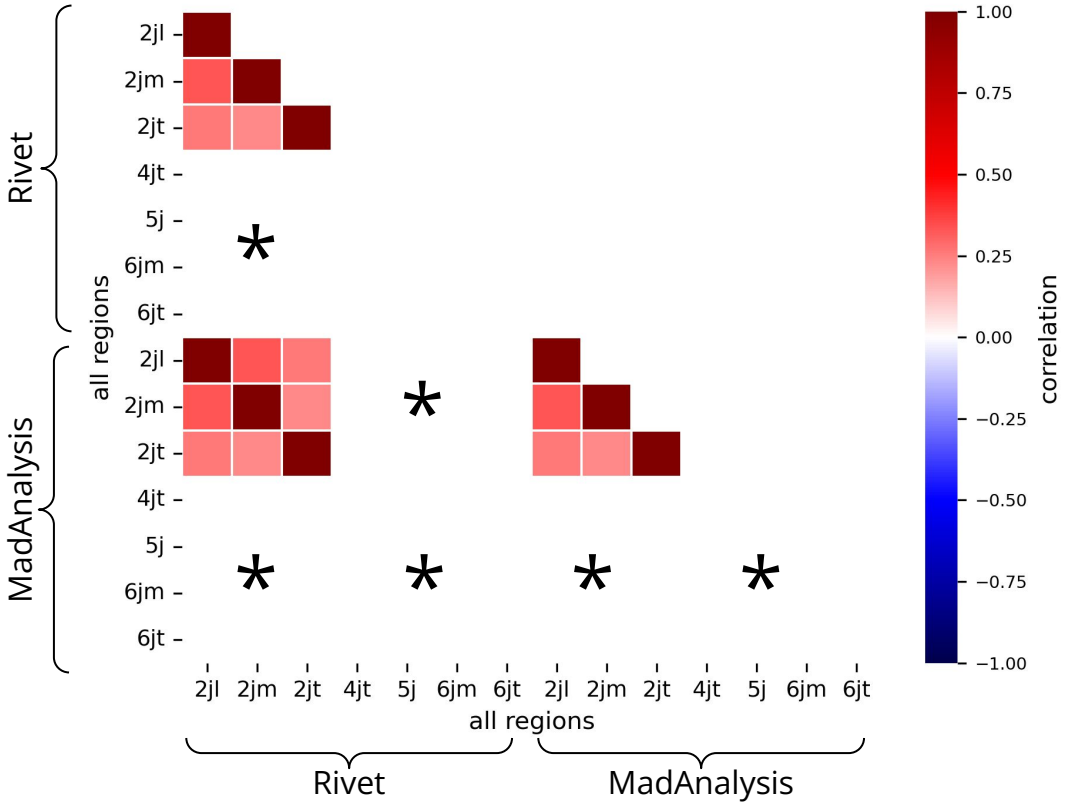
- On particle level, without overlap removal, extended first cutflow cut
- Fixed jet defin

#4

MadAnalysis and Rivet give exactly the same results on particle level.

Correlation - particle level, fixed

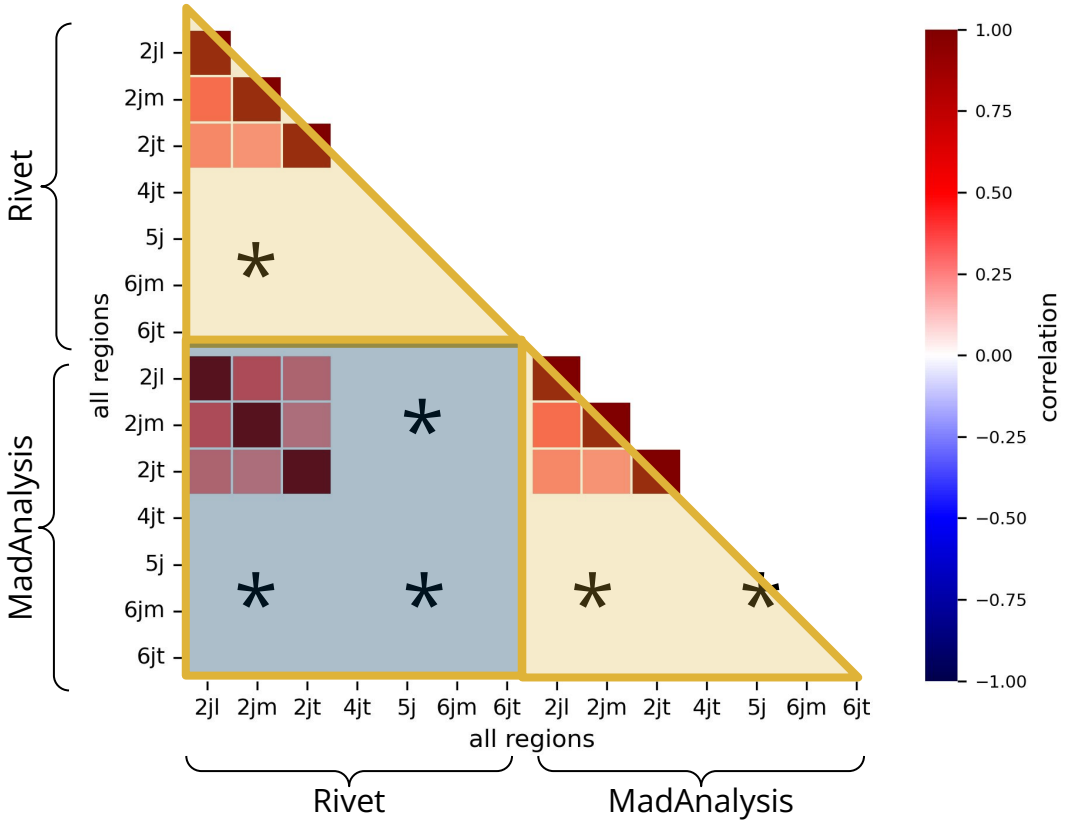
- On particle level, without overlap removal, extended first cutflow cut
- **Correlation:**



* no events passed event selection

Correlation - particle level, fixed

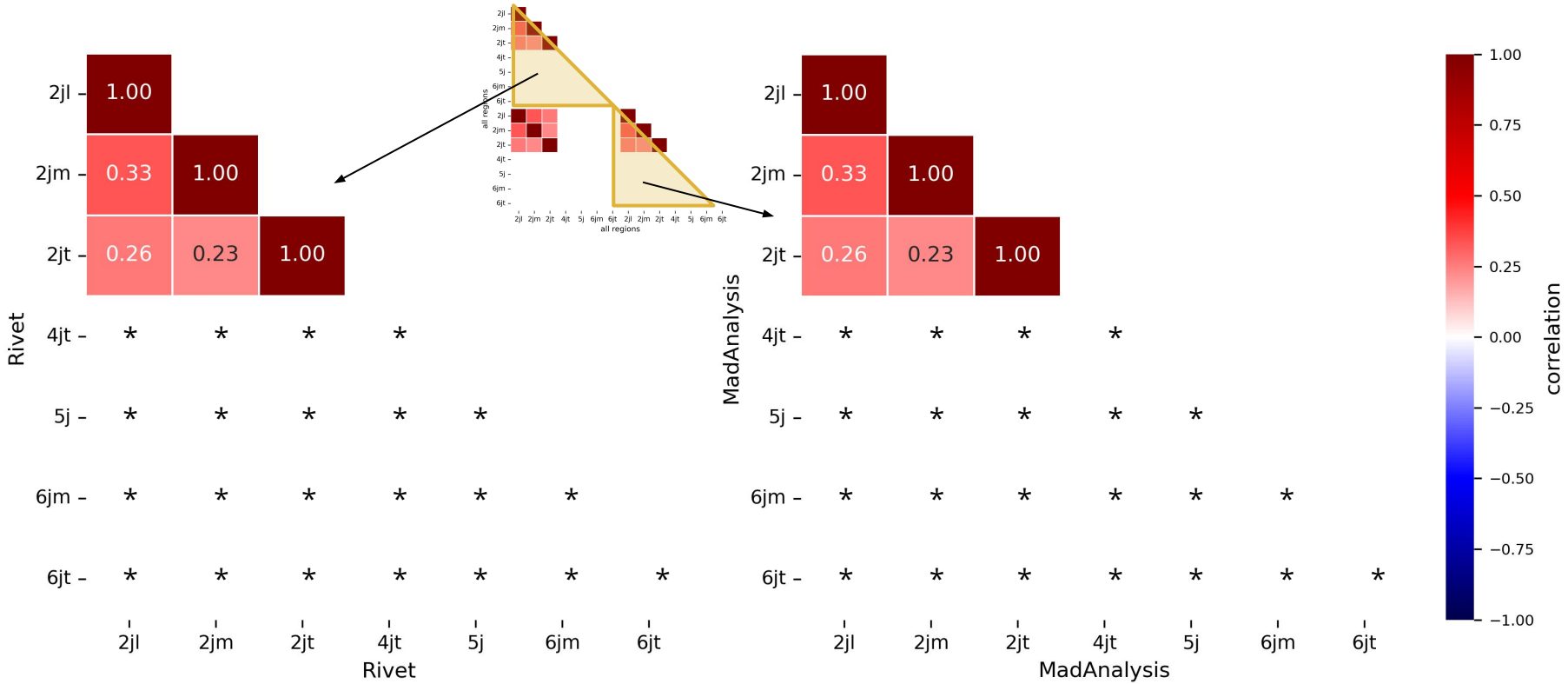
- On particle level, without overlap removal, extended first cutflow cut
- **Correlation:**



* no events passed event selection

Correlation - particle level, fixed

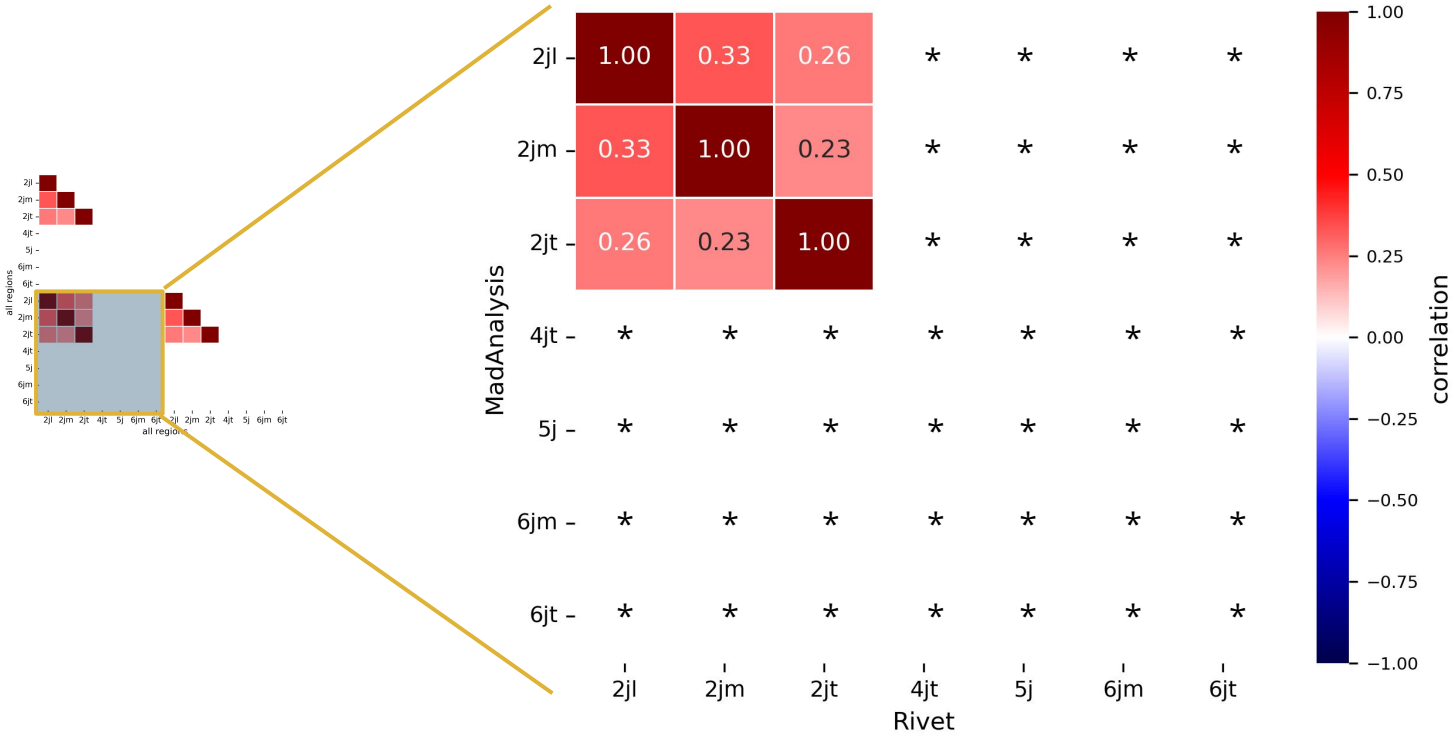
- On particle level, without overlap removal, extended first cutflow cut
- **Self-correlation** looks **healthy** but **sparse**



* no events passed event selection

Correlation - particle level, fixed

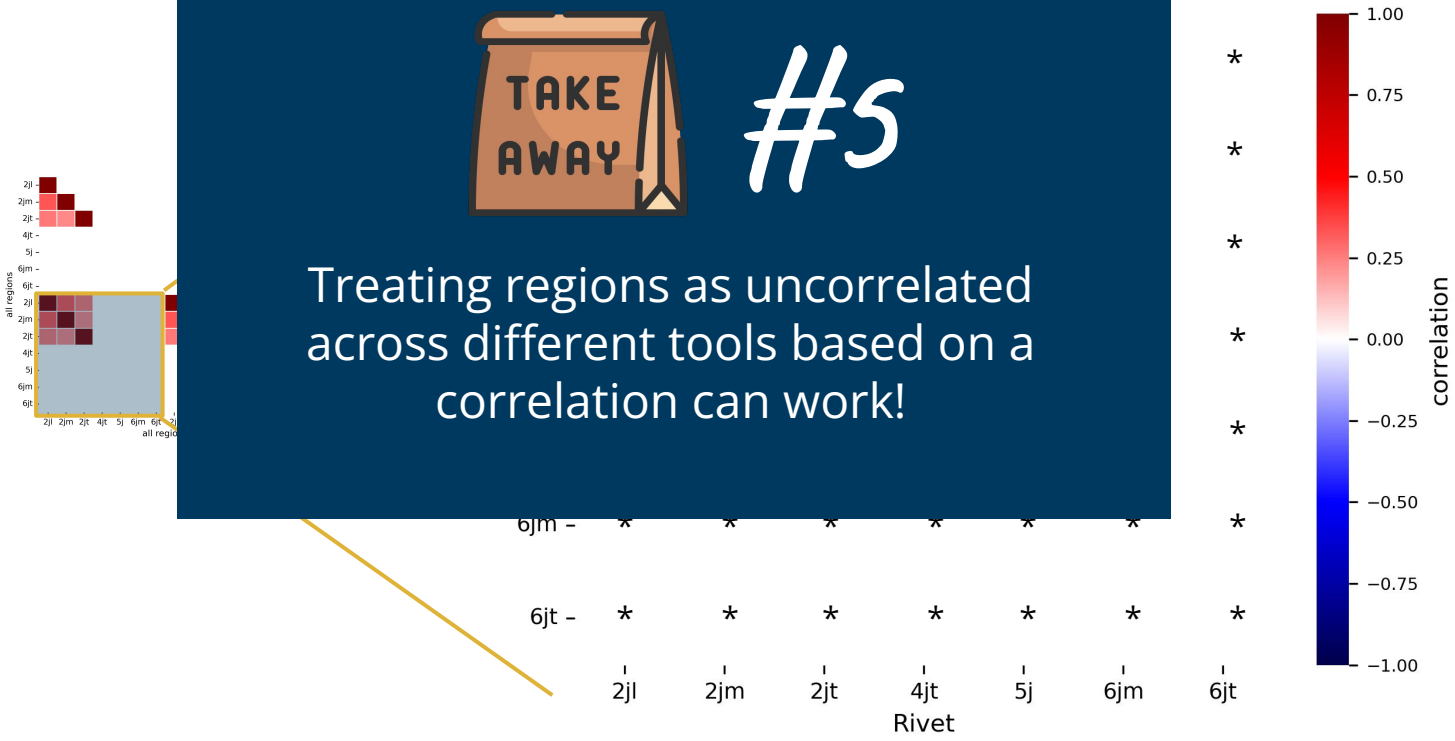
- On particle level, without overlap removal, extended first cutflow cut
- **Selected events** are **perfectly correlated** between MadAnalysis and Rivet



* no events passed event selection

Correlation - particle level, fixed

- On particle level, without overlap removal, extended first cutflow cut
- **Selected even** … nalysis and Rivet

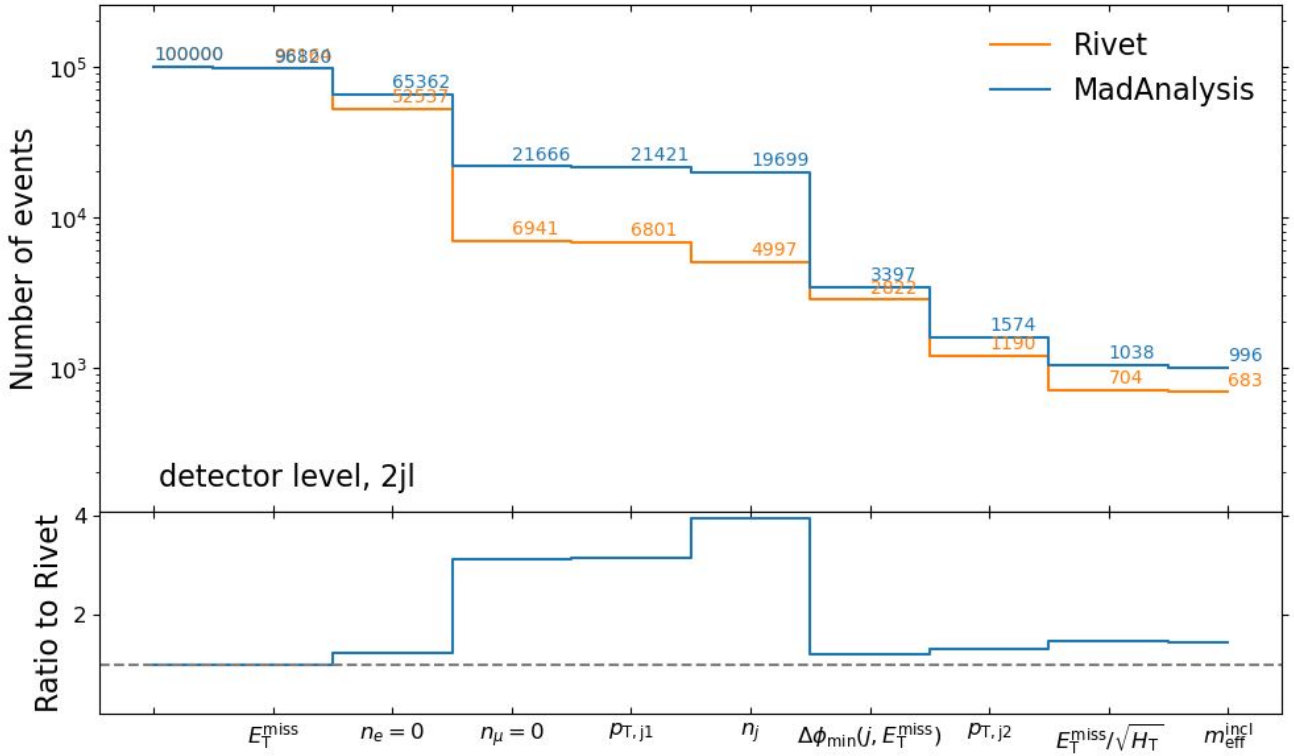


* no events passed event selection

Detector Level

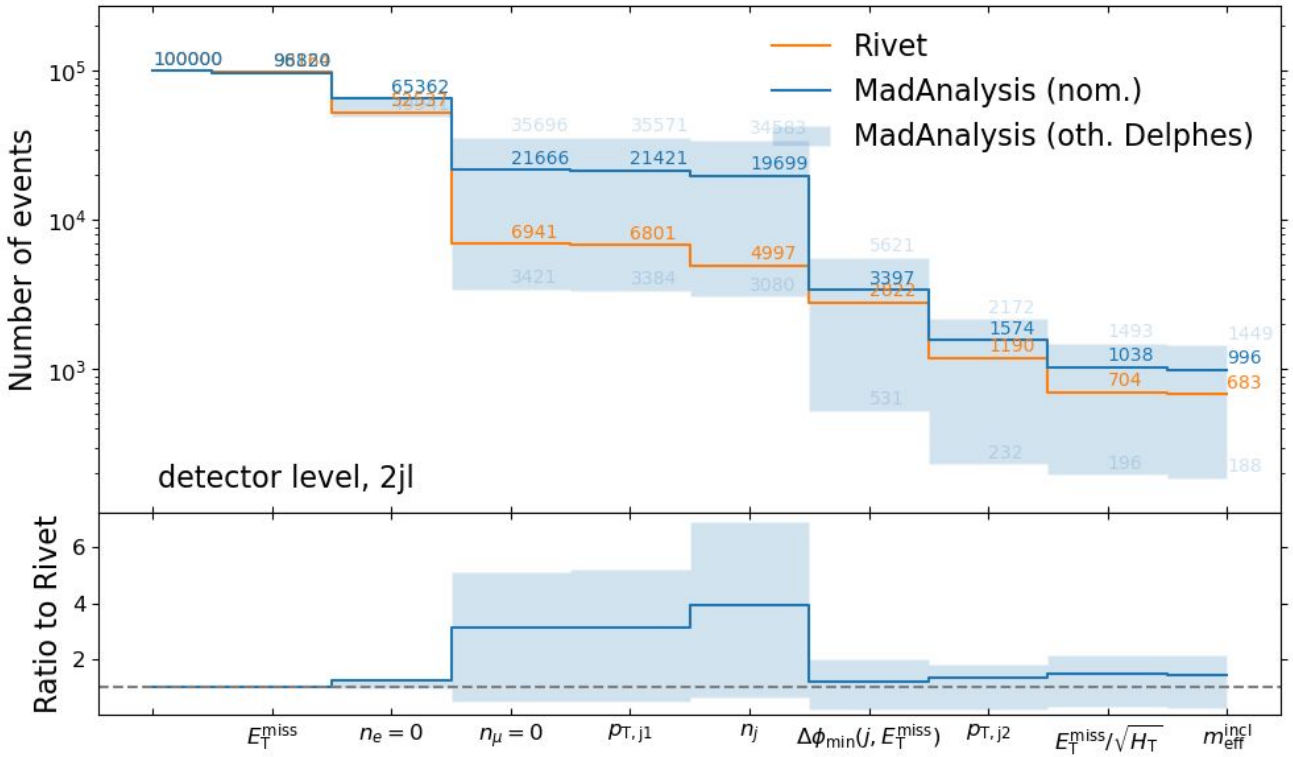
Cutflow challenge - detector level, fixed, ext.

- On **detector level**, with overlap removal, fixed jet definition
- More events passing due to lepton efficiency
- **Considerable disagreement** of unclear origin



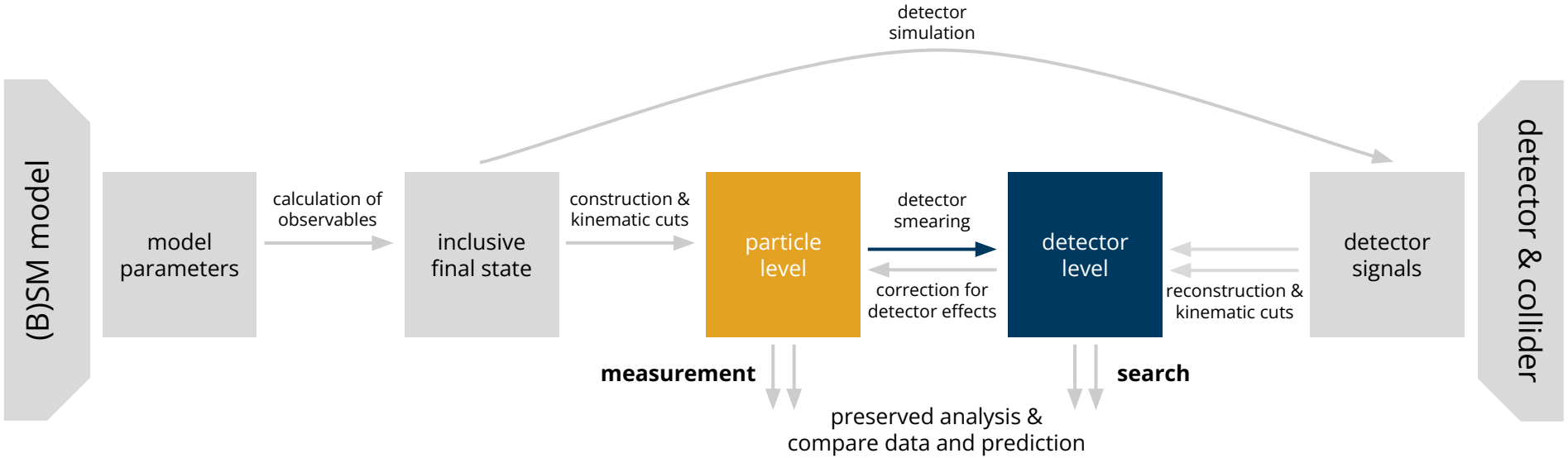
Cutflow challenge - detector level, fixed, ext.

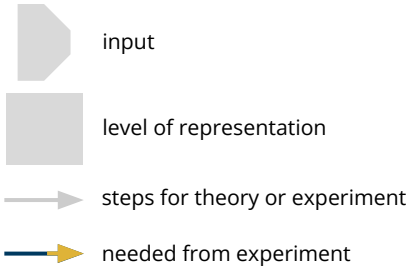
- On **detector level**, with overlap removal, fixed jet definition
- Testing different* Delphes cards → would **explain disagreement**



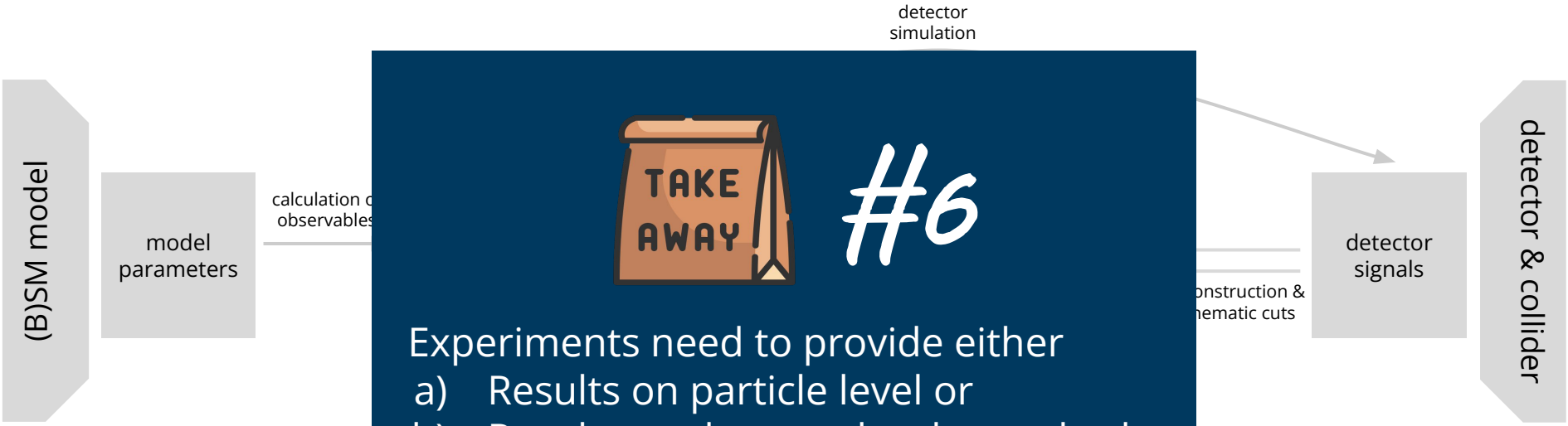
* all delphes cards used by MadAnalysis that are more recent than the card used nominally for the analysis

Common approach of a physics analysis





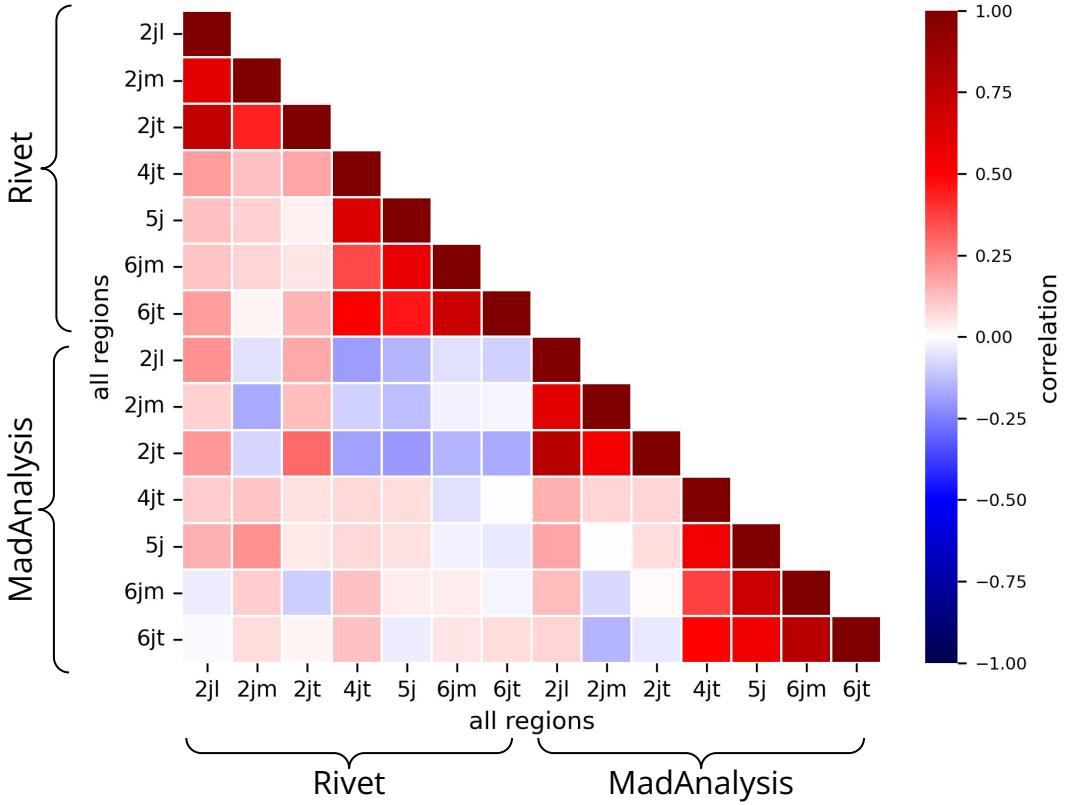
Common approach of a physics analysis



* it doesn't really matter whether smearing functions, delphes cards, efficiency maps, folding matrices, ... as long as there is *something*

Correlation - detector level, fixed

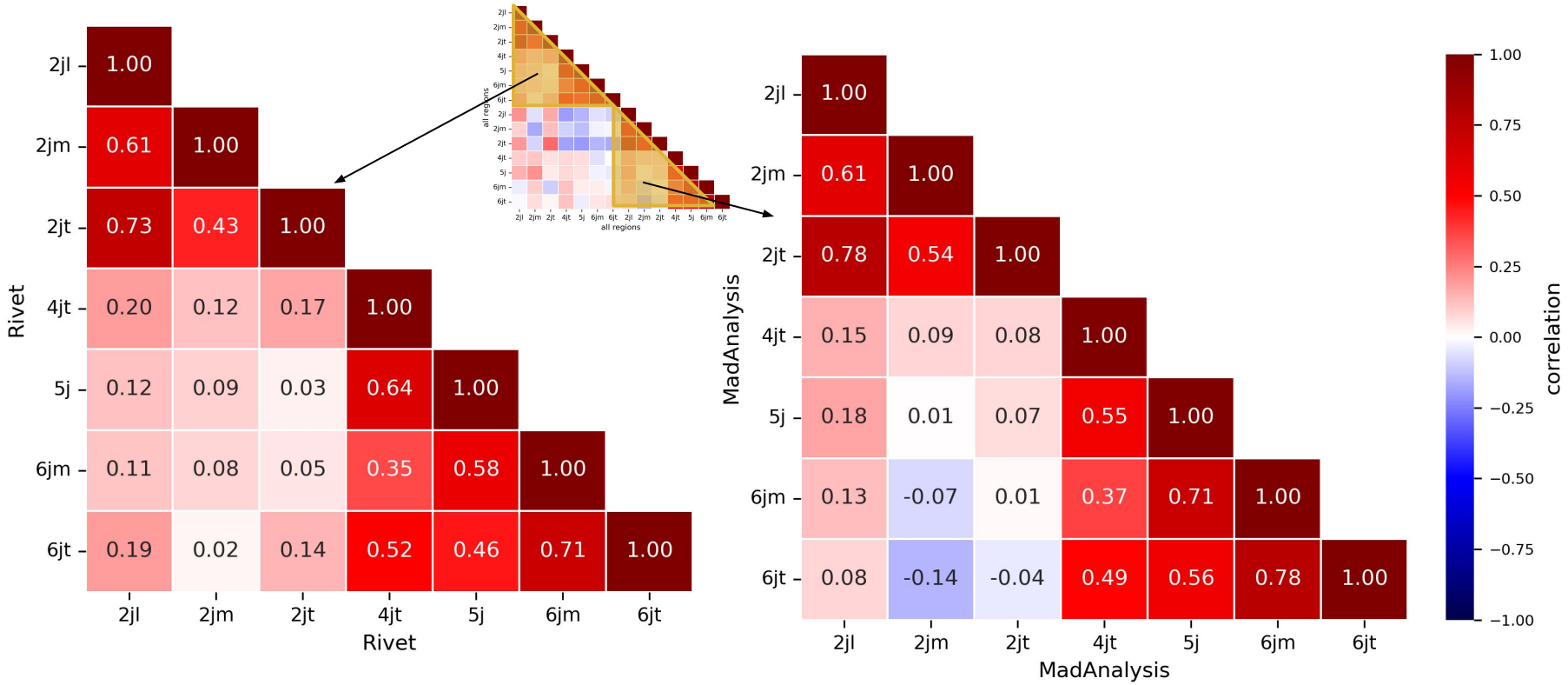
- On detector level, with overlap removal, fixed jet definition
- **Correlation:**



* no events passed event selection

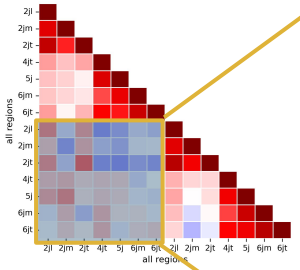
Correlation - detector level, fixed

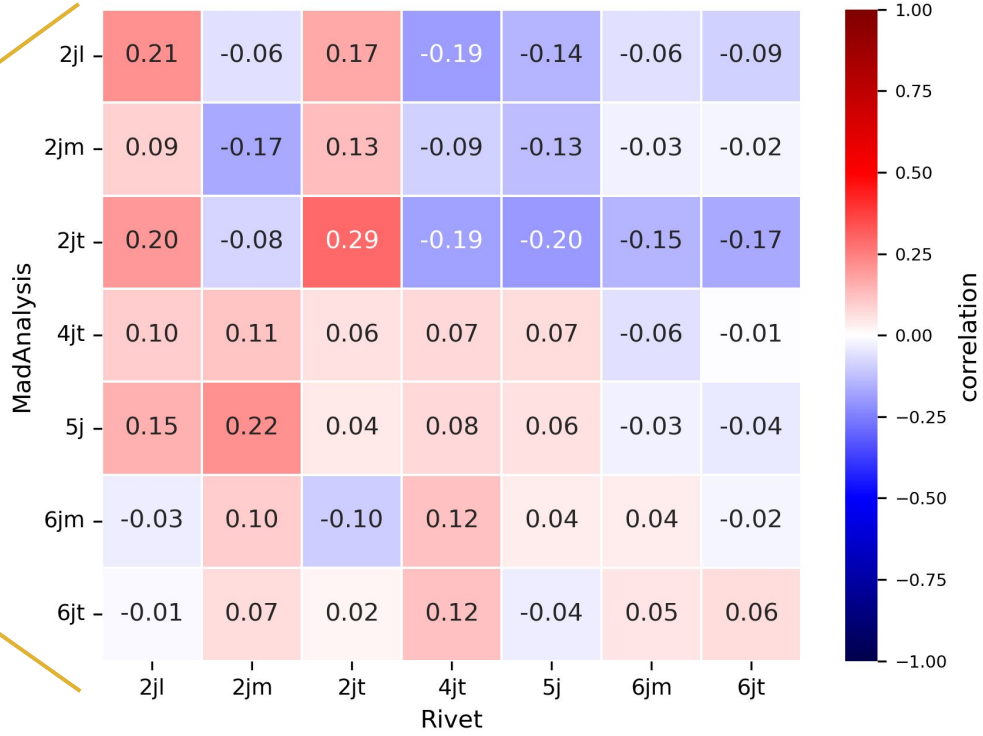
- On detector level, with overlap removal, fixed jet definition
- **Self-correlation** looks **healthy**



Correlation - detector level, fixed

- On detector level, with overlap removal, fixed jet definition
- Selected events have **small**, **non-zero correlation** between MA/ Rivet

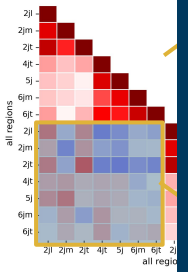


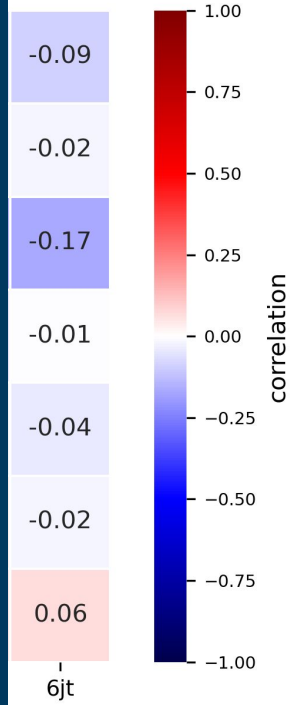


Correlation - detector level, fixed

- On detector le
- Selected event

n MA/ Rivet





#5b

Treating regions as uncorrelated across different tools based on a correlation can work!

But:
Need caution at detector level.
Correlation thresholds across tools on detector level should at least be < 0.04.

Summary

Summary

Key take-aways:

1. Experiments should
   a. **avoid grouping different cuts** in cutflow tables into one step.
   b. **include all cuts** in cutflows.
   c. provide cutflows for **multiple *different* MC samples**.
   d. provide either
      i. Results on particle level or
      ii. Results on detector level + method to obtain det. level from part. level.
2. MadAnalysis and Rivet give
   a. exactly the same results on particle level.
   b. very different results on detector level.
3. Treating events **across tools as correlated**:
   a. **Can work!**
   b. Needs caution at detector level, corr. thresholds should not exceed 0.04.

Backup

Detailed event selection for SUSY-2015-06

Requirement	Signal Region						
	2jl	**2jm**	**2jt**	**4jt**	**5j**	**6jm**	**6jt**
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV] >	200						
$p_{\mathrm{T}}(j_1)$ [GeV] >	200	300	200				
$p_{\mathrm{T}}(j_2)$ [GeV] >	200	50	200	100			
$p_{\mathrm{T}}(j_3)$ [GeV] >	–			100			
$p_{\mathrm{T}}(j_4)$ [GeV] >	–			100			
$p_{\mathrm{T}}(j_5)$ [GeV] >	–				50		
$p_{\mathrm{T}}(j_6)$ [GeV] >	–					50	
$\Delta\phi(\mathrm{jet}_{1,2,(3)}, \boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ >	0.8	0.4	0.8	0.4			
$\Delta\phi(\mathrm{jet}_{i>3}, \boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ >	–			0.2			
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$ [GeV$^{1/2}$] >	15		20	–			
Aplanarity >	–			0.04			
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(N_{\mathrm{j}})$ >	–			0.2	0.25		0.2
m_{eff}(incl.) [GeV] >	1200	1600	2000	2200	1600	1600	2000

The studied case: theoretical setup

W+jets sample

- 100k (cutflows) or 950k (correlation) events
- Enhanced for high transverse momentum
- Run card:

```
BEAMS: 2212
BEAM_ENERGIES: 6500

MI_HANDLER: None
FRAGMENTATION: None

PROCESSES:
- 93 93 -> 90 91 93{1}:
    CKKW: 20
    2->2:
        Enhance_Function: VAR{(PPerp2(p[2])/10000)*(PPerp2(p[3])/10000)}
    2->3:
        Enhance_Function: VAR{(PPerp2(p[2])/10000)*(PPerp2(p[3])/10000)*(PPerp2(p[4])/10000)}

HARD_DECAYS:
    Enabled: true
    Decay_Tau: true

SELECTORS:
- [PTmis, 200, E_CMS]

EVENT_OUTPUT:
    - HepMC3[events.hepmc]
HEPMC3_IO_TYPE: 2
```

Available statistics for correlation

Particle level

	2jl	2jm	2jt	4jt	5j	6jm	6jt
MadAnalysis	15	20	1	0	0	0	0
Rivet	15	20	1	0	0	0	0

Detector level

	2jl	2jm	2jt	4jt	5j	6jm	6jt
MadAnalysis	9352	17363	5154	427	373	144	151
Rivet	6165	12863	3171	229	170	56	70

each of 950k events