Tutorial
MG5 to Contur

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Tutorial
MG5 to Contur

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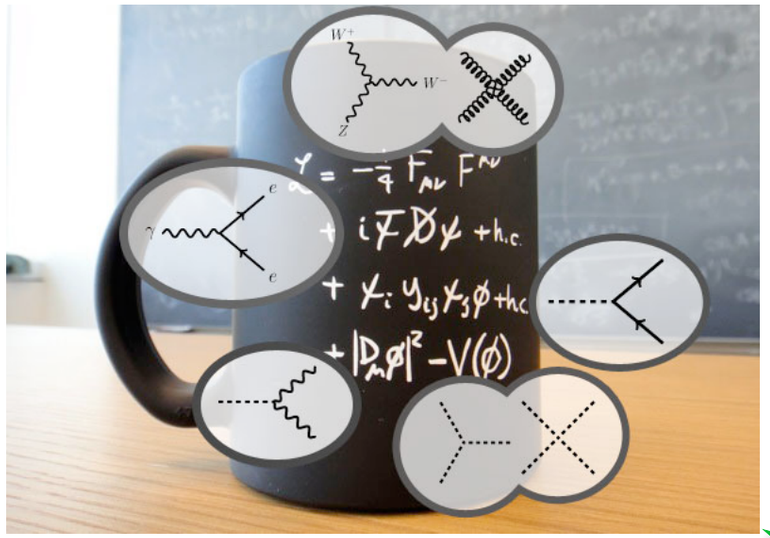
UCLouvain

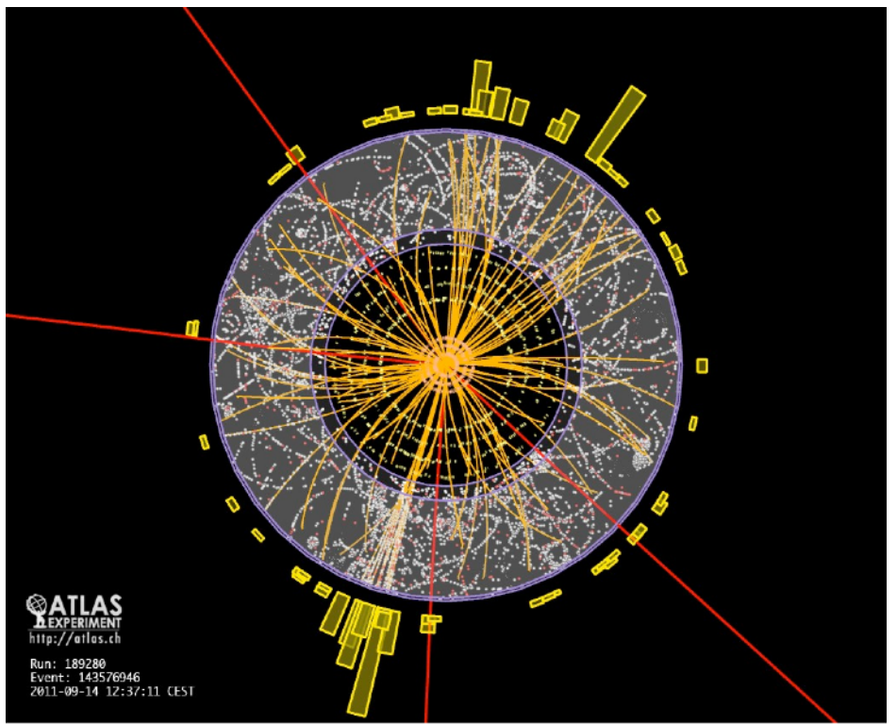
Setup the VM

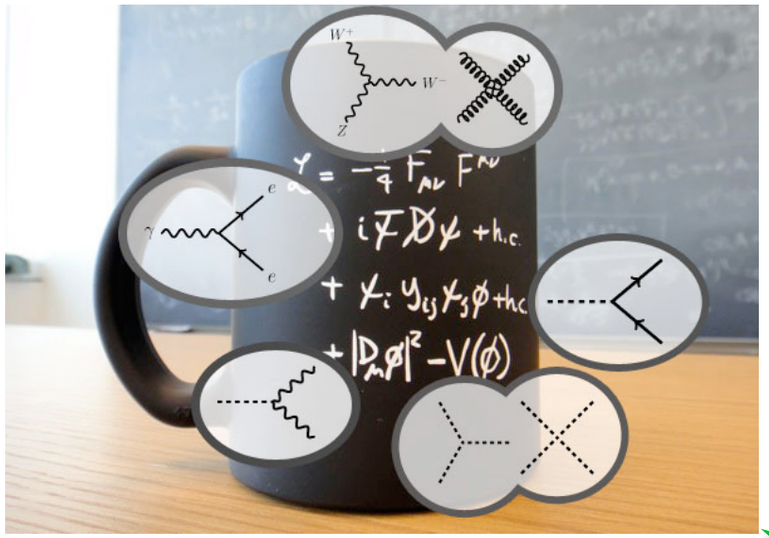
Docker image

```
docker run -it -v mgtutorial:/volume hepstore/rivet-mg5amcnlo  bash

# Useful to install vim or emacs:
apt-get update
apt-get install vim (or apt-get install emacs)

# Installation of contour
apt-get install pip
pip install contur
source conturenv.sh
cd $CONTUR_DATA_PATH
make
cd -
source conturenv.sh

# Update MG5aMC
cd MG5_aMC_v3_4_2/
./bin/mg5_aMC
-> answer yes to update (or run install update)
```



Monte-Carlo Physics

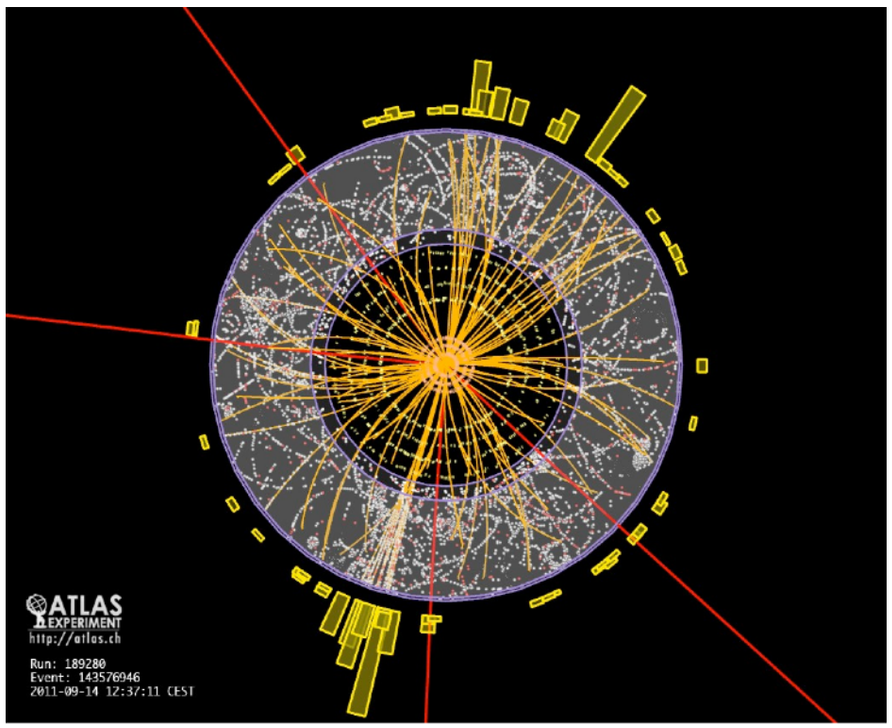




Monte-Carlo Physics

Our goal

- Cross-section
- Differential cross-section
- Un-weighted events



From Theory to Exclusion

Lagrangian

Exclusion plot

From Theory to Exclusion

Lagrangian

FeynmanRules

Exclusion plot

From Theory to Exclusion

Lagrangian

FeynmanRules

matrix-element

Exclusion plot

From Theory to Exclusion

Lagrangian

FeynmanRules

matrix-element

parton events

Exclusion plot

From Theory to Exclusion

Lagrangian

FeynmanRules

matrix-element

parton events

Showered events

Exclusion plot

From Theory to Exclusion

Lagrangian

FeynmanRules

matrix-element

parton events

Showered events

Hadronize events

Exclusion plot

From Theory to Exclusion

Lagrangian

FeynmanRules

matrix-element

parton events

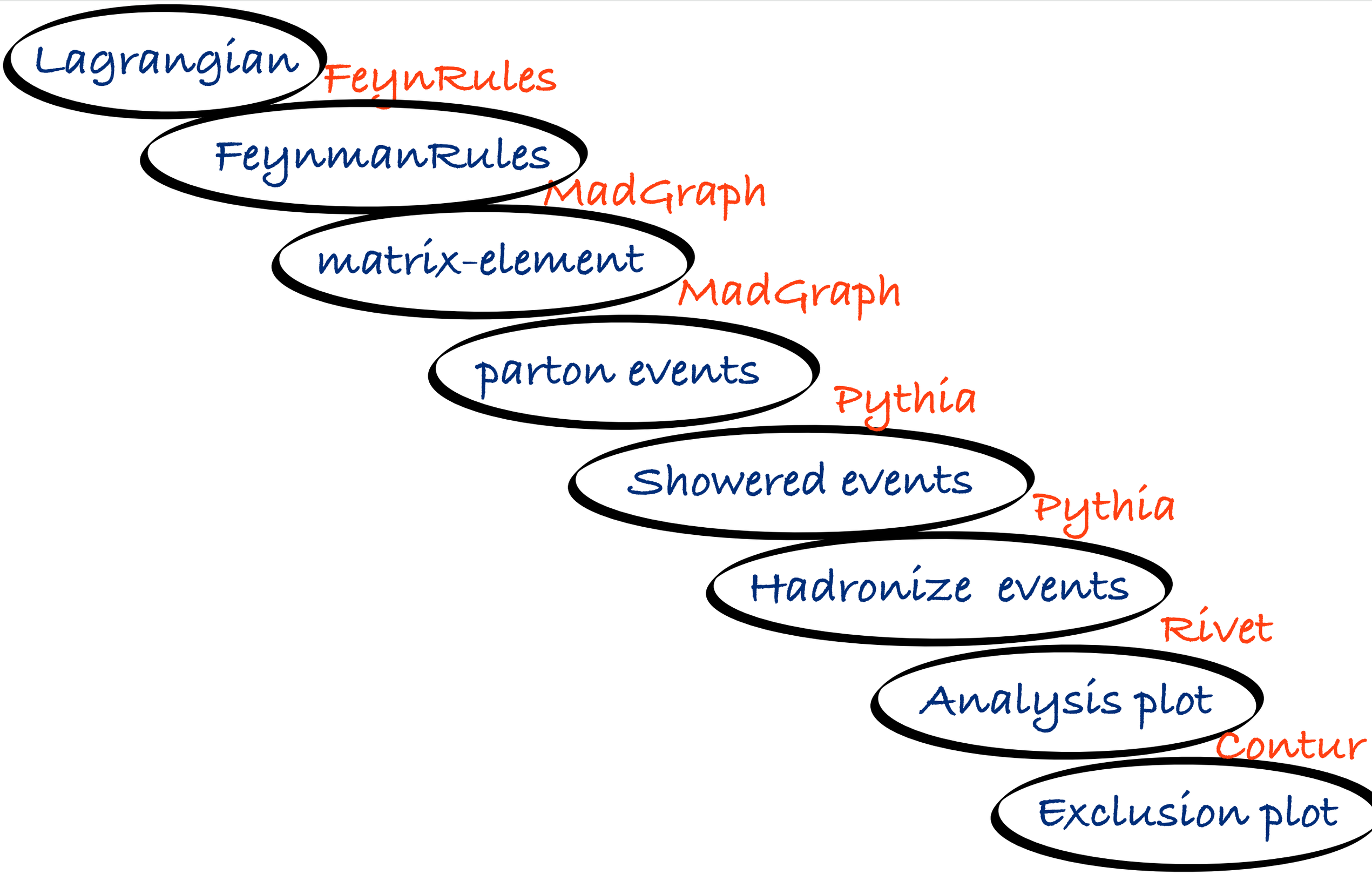
Showered events

Hadronize events

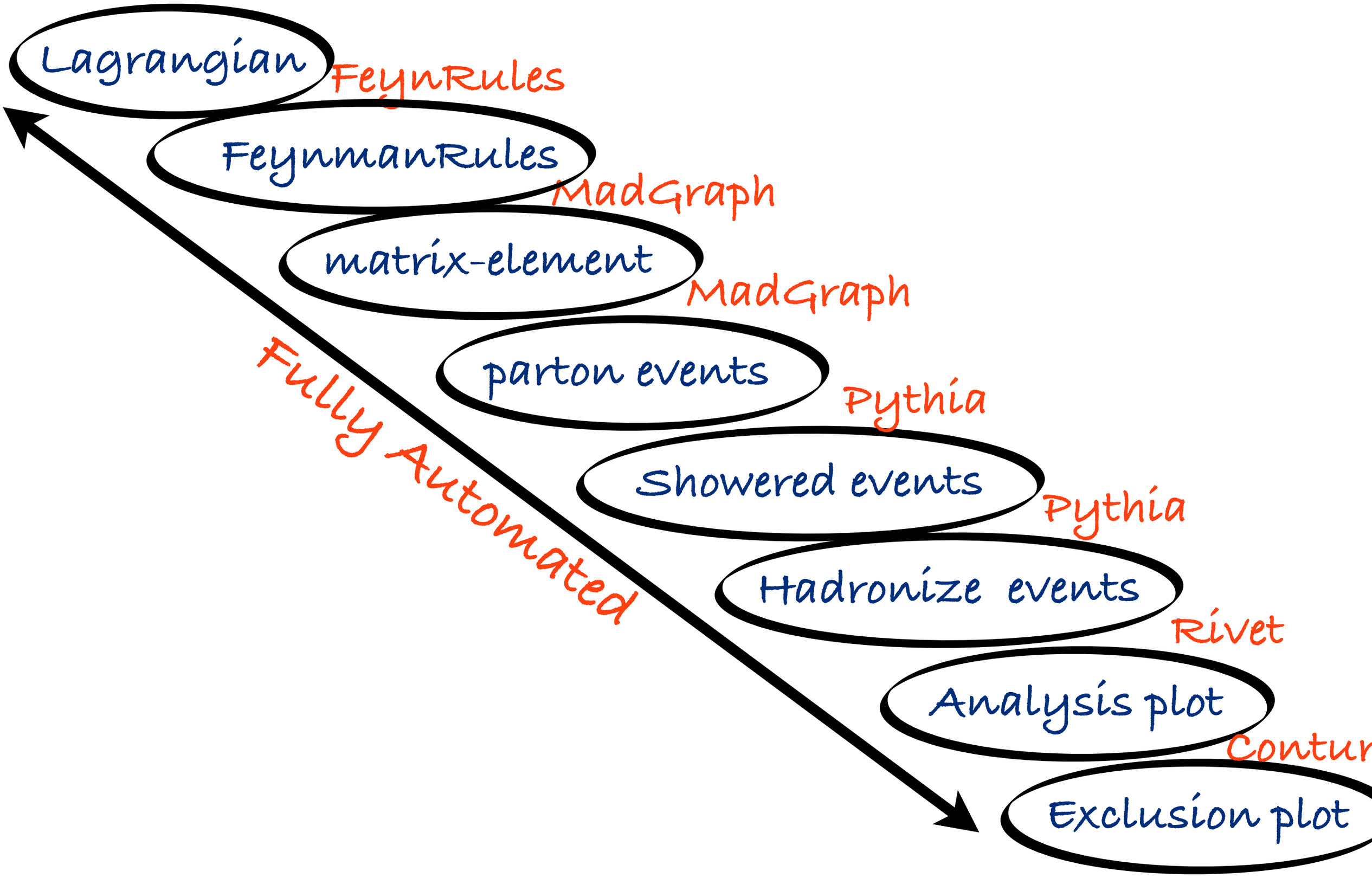
Analysis plot

Exclusion plot

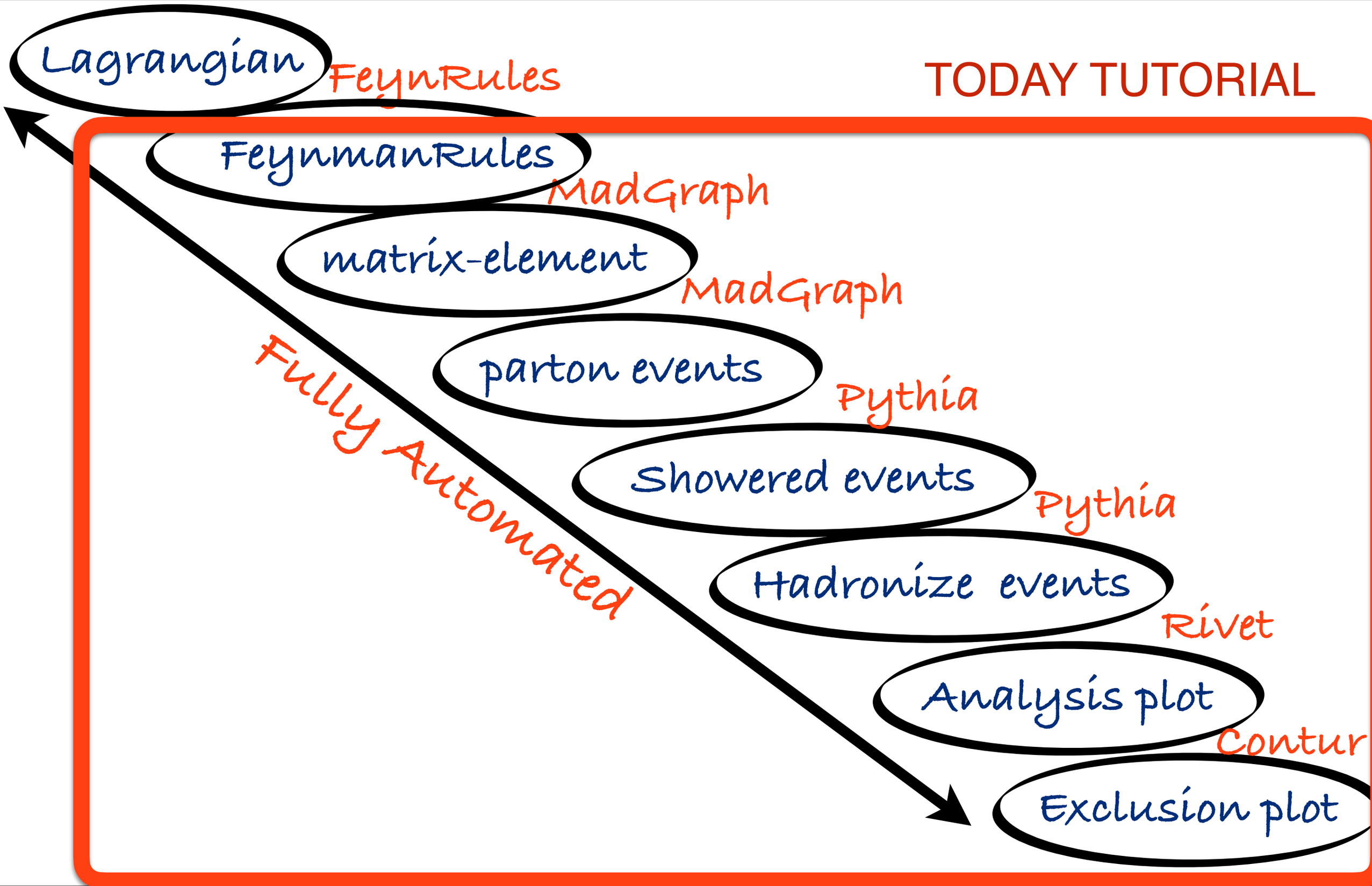
From Theory to Exclusion



From Theory to Exclusion



From Theory to Exclusion



MadGraph

Calculate a given process (e.g. gluino pair)

- Determine the production mechanism

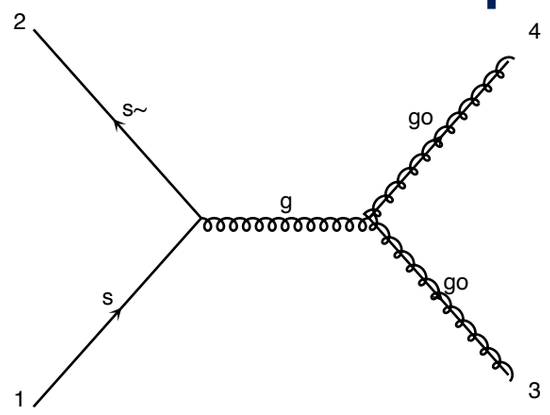


diagram 1 QCD=2, QED=0

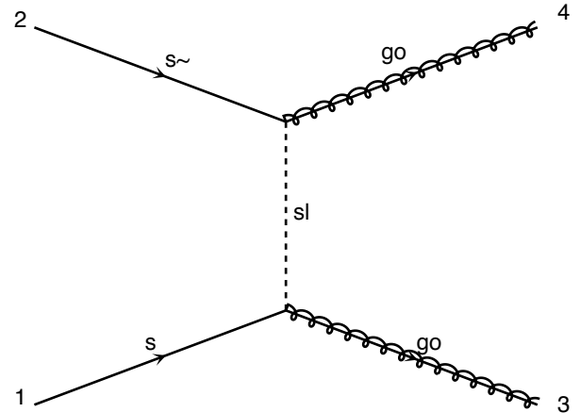


diagram 2 QCD=2, QED=0

- Evaluate the matrix-element

$$|\mathcal{M}|^2$$ ➡Need Feynman Rules!

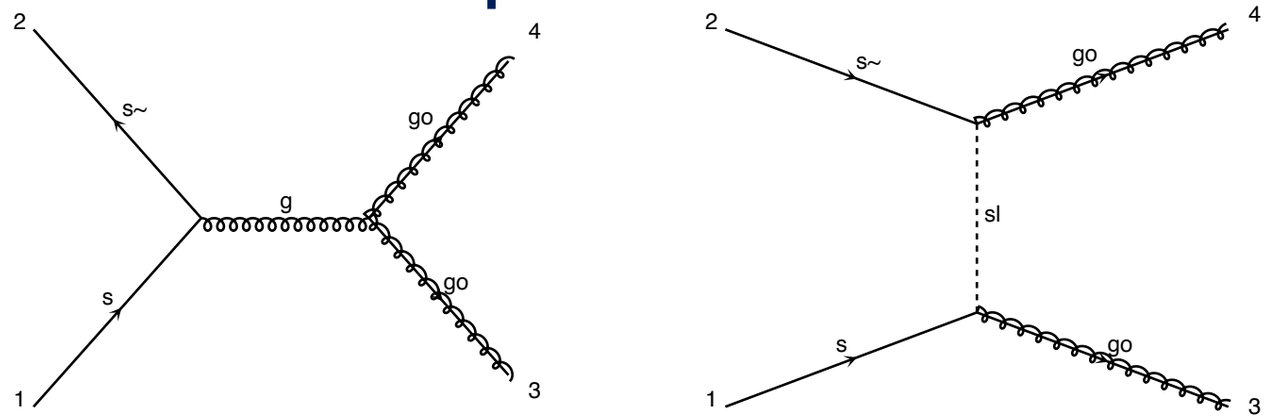
- Phase-Space Integration

$$\sigma = \frac{1}{2s} \int |\mathcal{M}|^2 d\Phi(n)$$

MadGraph

Calculate a given process (e.g. gluino pair)

- Determine the production mechanism



Easy enough

- Evaluate the matrix-element

$$|\mathcal{M}|^2$$

➡Need Feynman Rules!

Hard

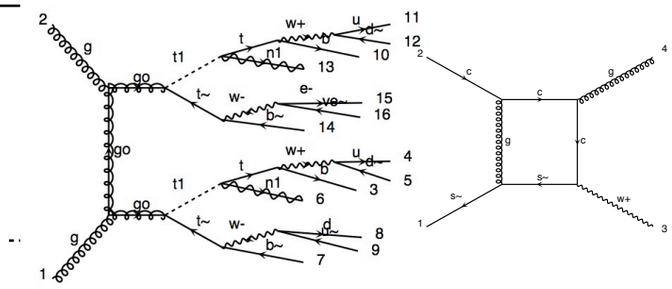
- Phase-Space Integration

$$\sigma = \frac{1}{2s} \int |\mathcal{M}|^2 d\Phi(n)$$

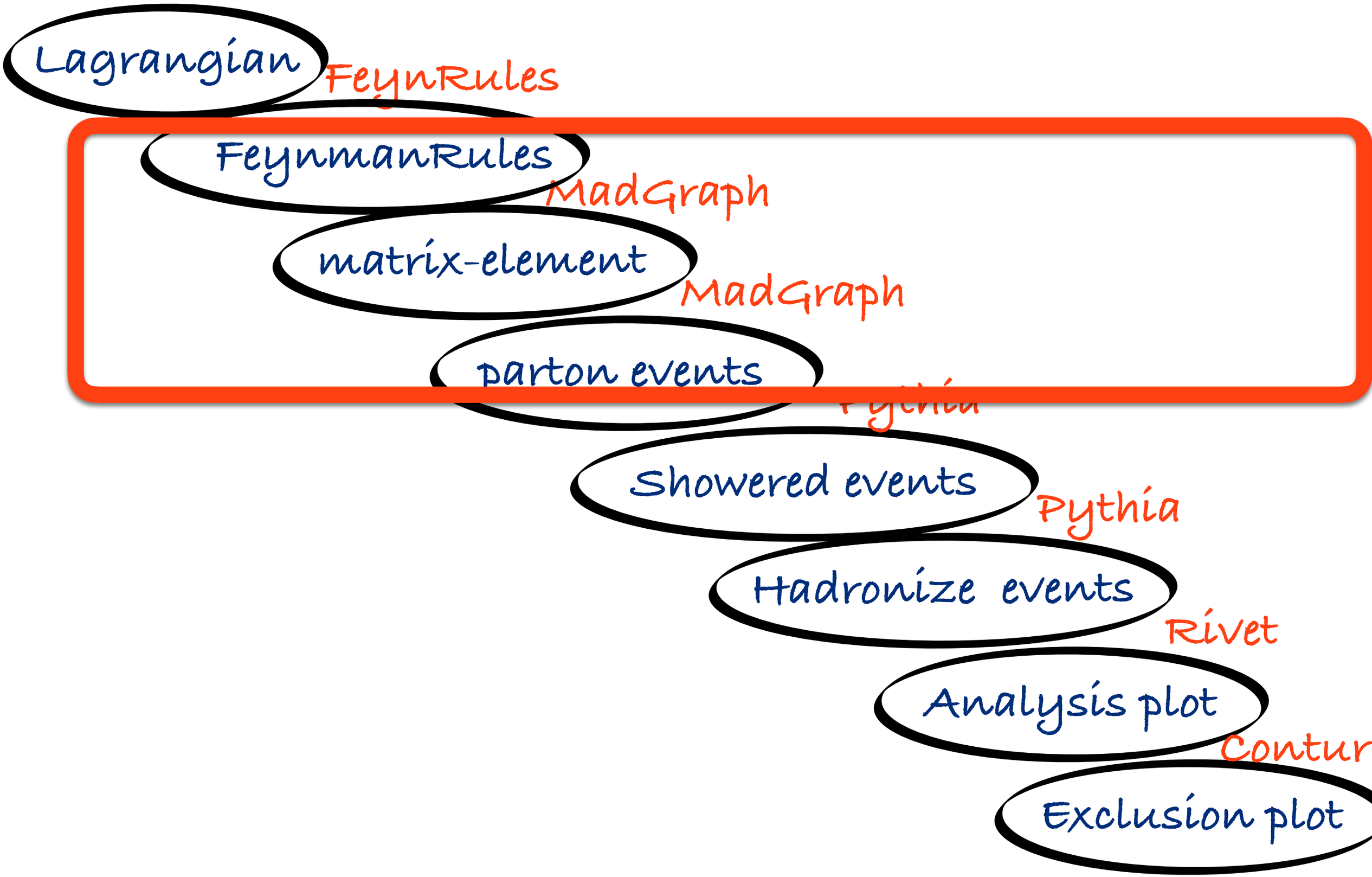
Very Hard (in general)

Type of generation

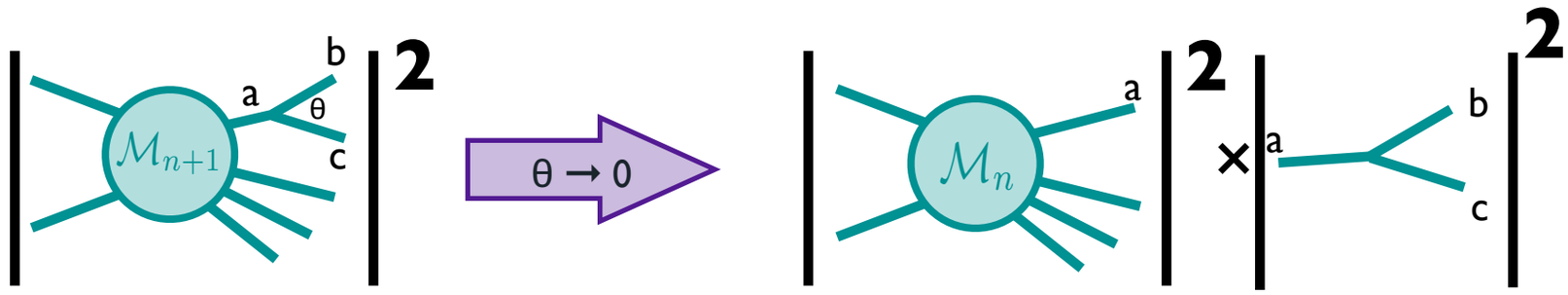
	Tree (B)SM	NLO (QCD) (SM)	NLO (QCD) (BSM)	NLO (EW) (SM)	Loop Induced (B)SM
Fix Order	✓	✓	✓	✓	✓



From Theory to Exclusion



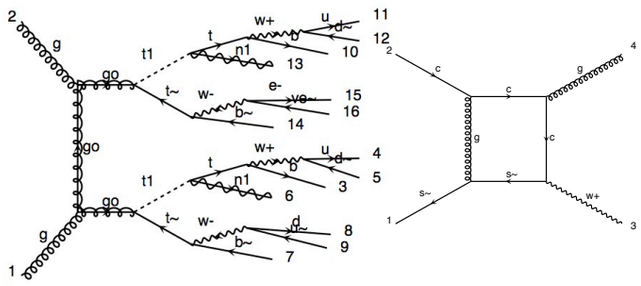
Parton Shower

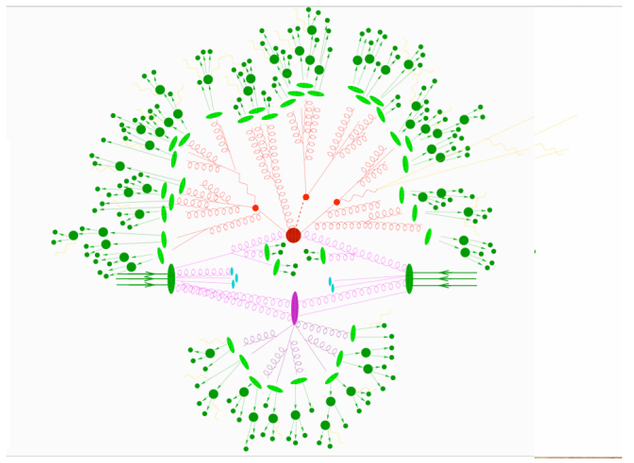


- Parton-shower use Markov chain
  - ➡ Convert inclusive events to exclusive events
    - ➡ Pure QCD process
    - ➡ Known from first principle
- Interface with LO “easy”
  - ➡Need Matching procedure at NLO
    - MC@NLO/Powheg/…

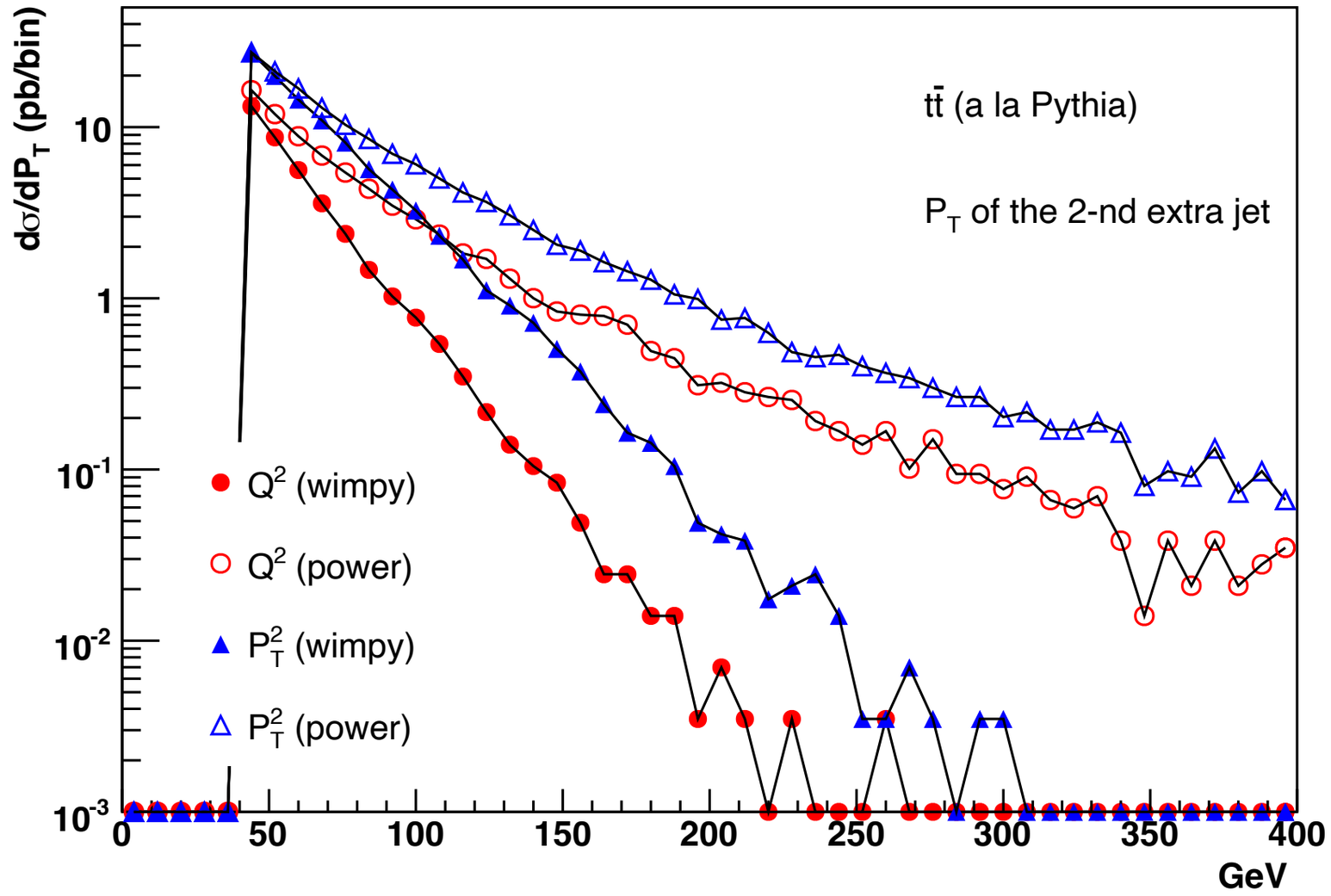
Type of generation

	Tree (B)SM	NLO (QCD) (SM)	NLO (QCD) (BSM)	NLO (EW) (SM)	Loop Induced (B)SM
Fix Order	✓	✓	✓	✓	✓
+Parton Shower	✓	✓	✓	✗	✓





PS or Matrix-Element

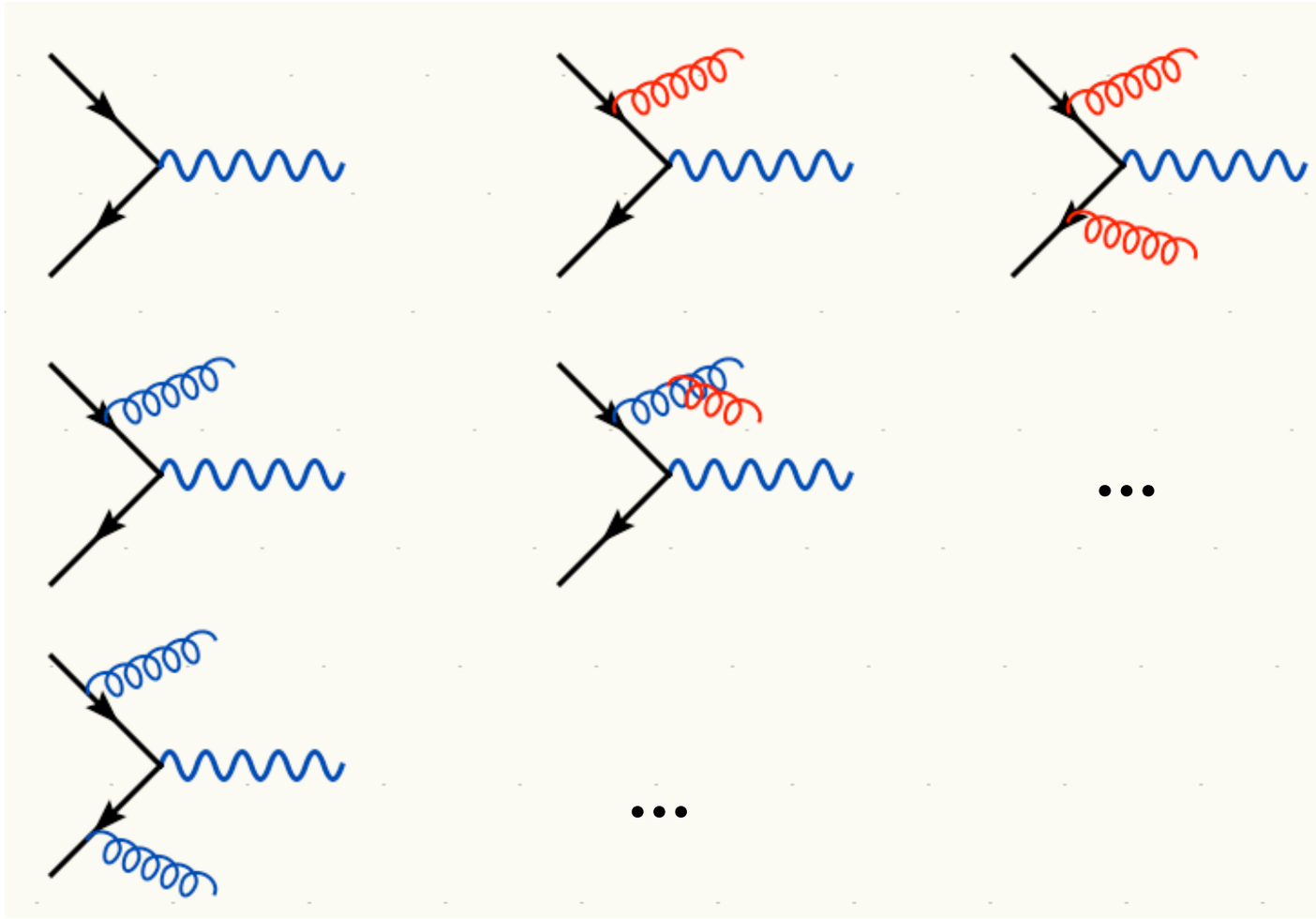


Merging ME with PS

[Mangano]
[Catani, Krauss, Kuhn, Webber]
[Lönnblad]

PS →

ME ↓



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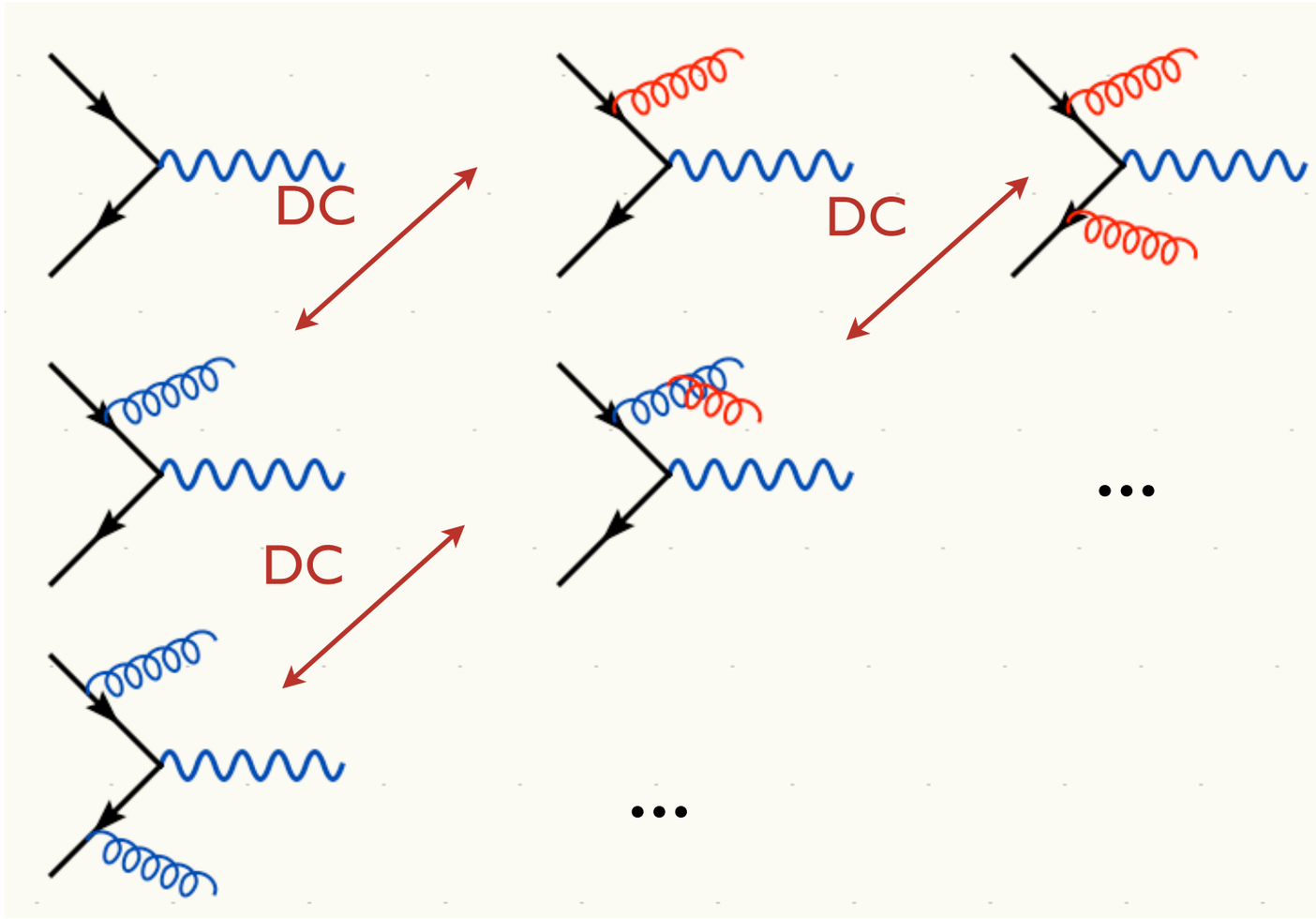

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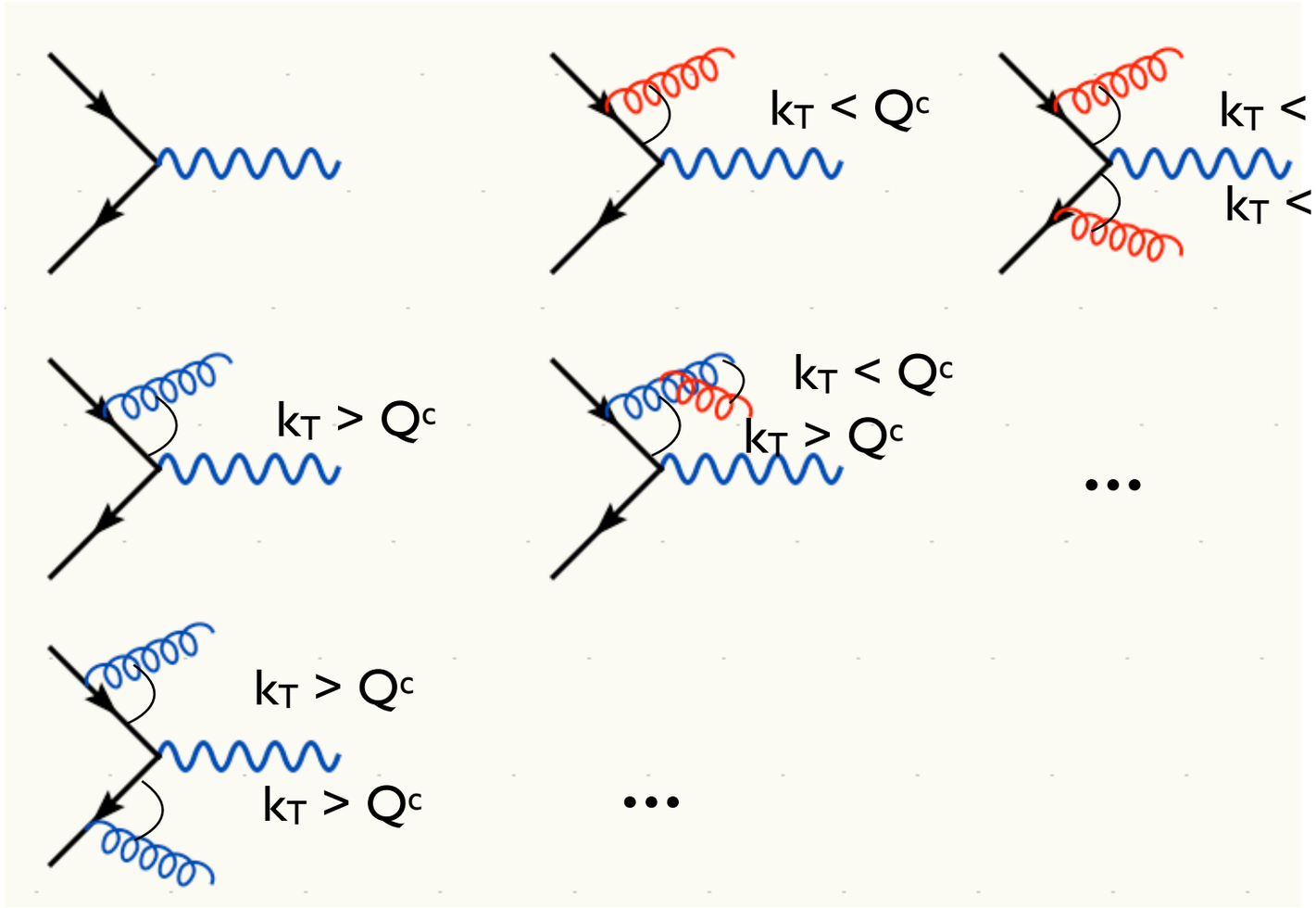

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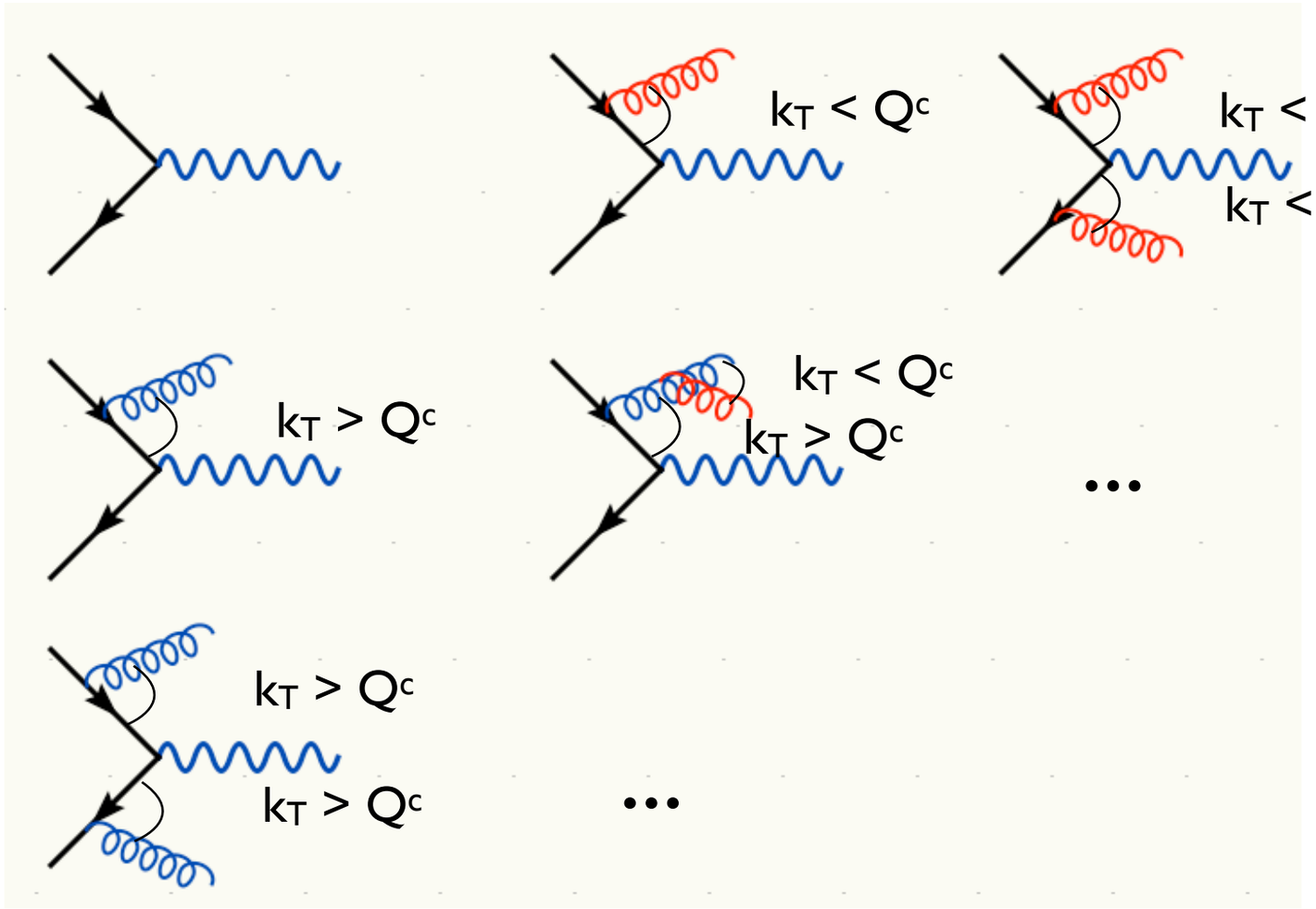
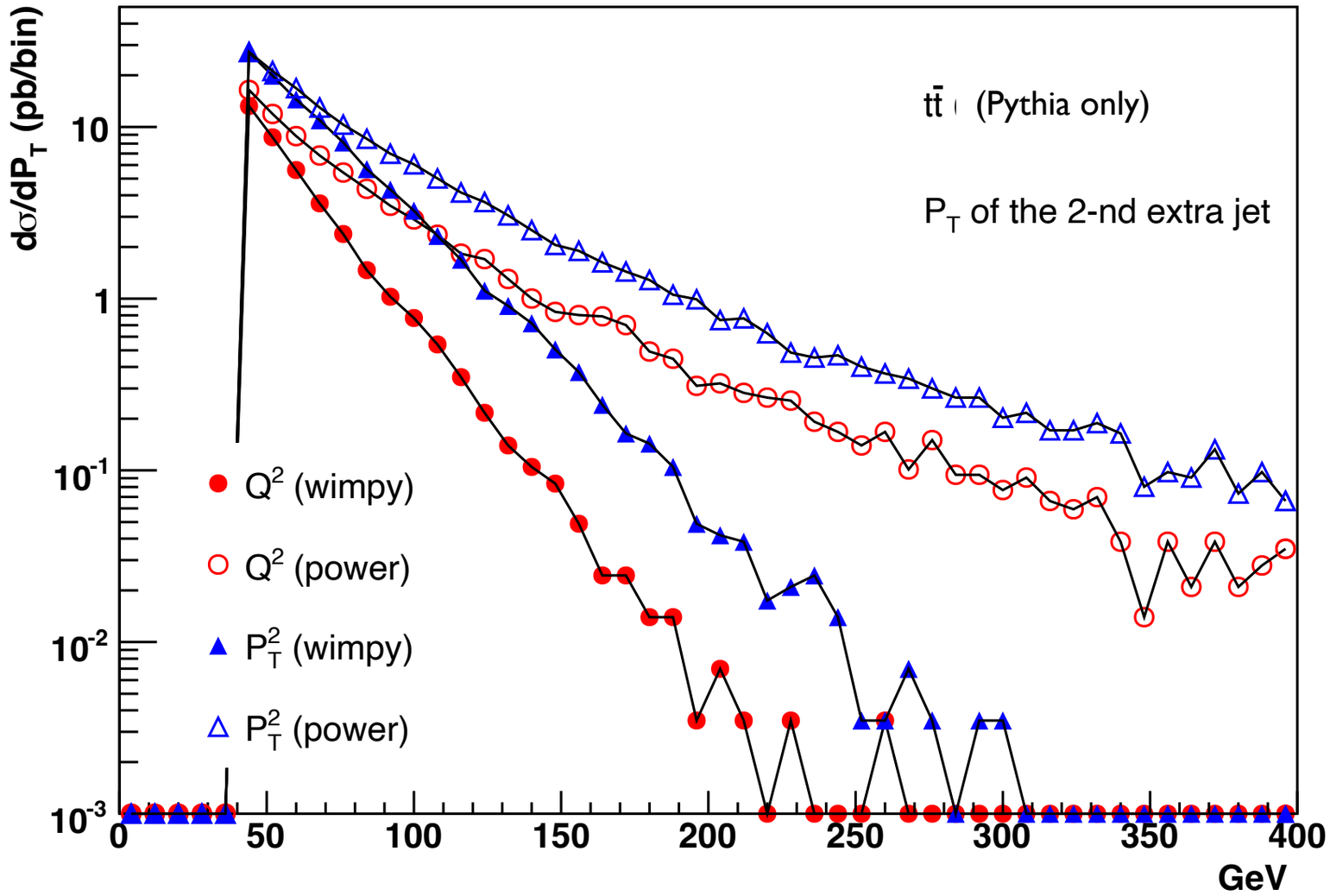


Double counting between ME and PS easily avoided using phase space cut between the two: PS below cutoff, ME above cutoff.

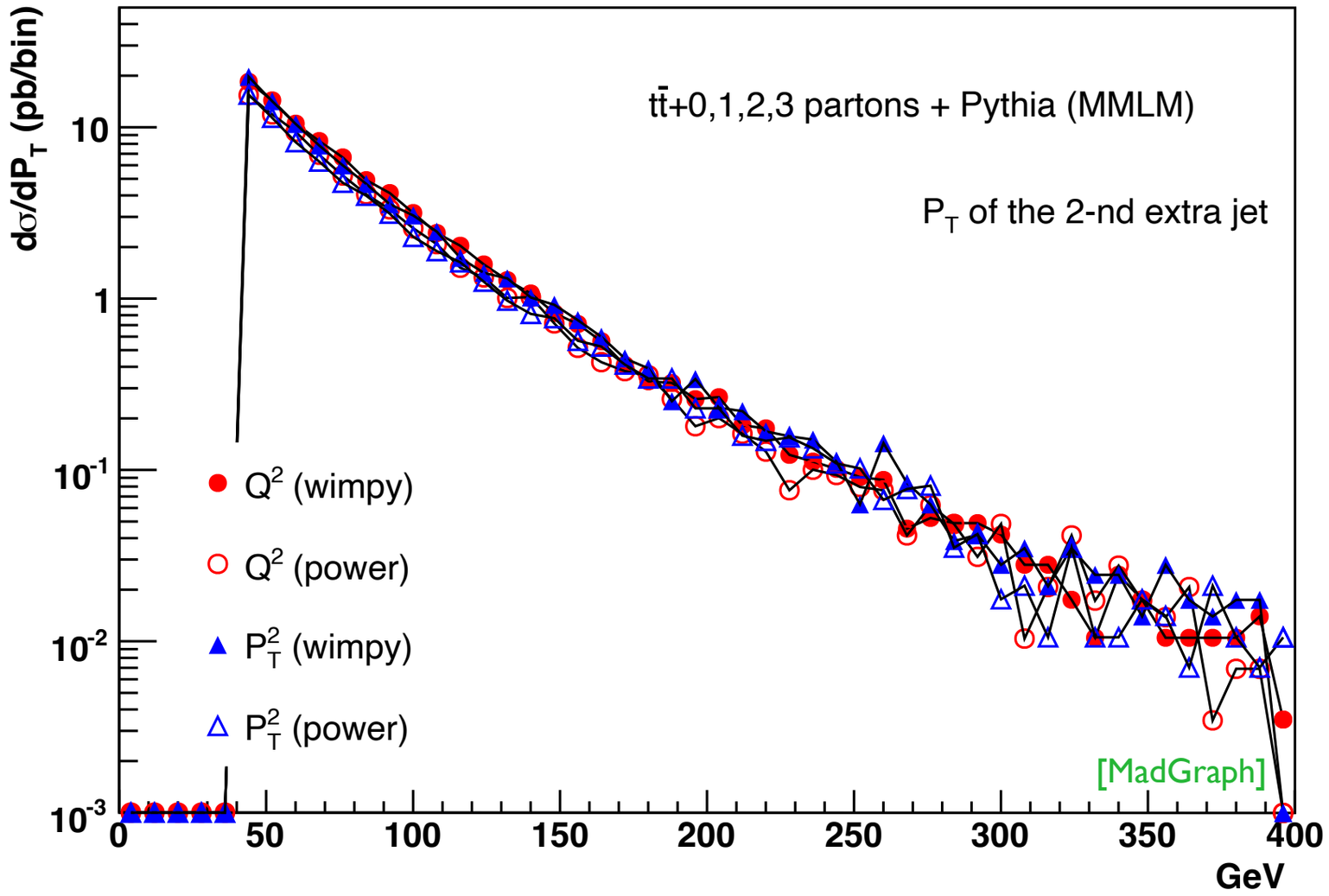
PS alone vs matched samples

In the soft-collinear approximation of Parton Shower MCs, parameters are used to tune the result ⇒ Large variation in results (small prediction power)



PS alone vs ME matching

In a matched sample these differences are irrelevant since the behavior at high pt is dominated by the matrix element.



Type of generation

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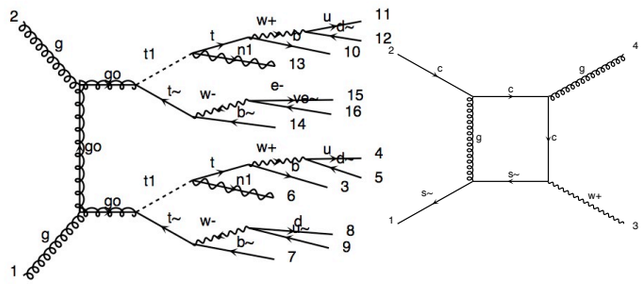
Fix Order	✓	✓	✓	✓	✓
+Parton Shower	✓	✓	✓	✗	✓
Merged Sample	✓	✓	?	✗	✓



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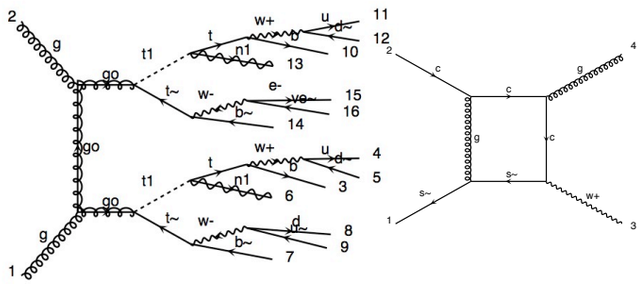

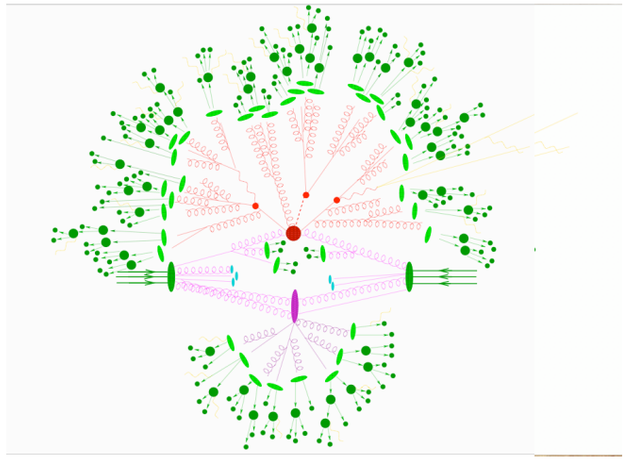

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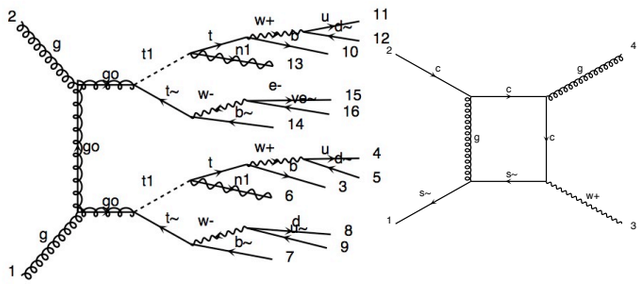
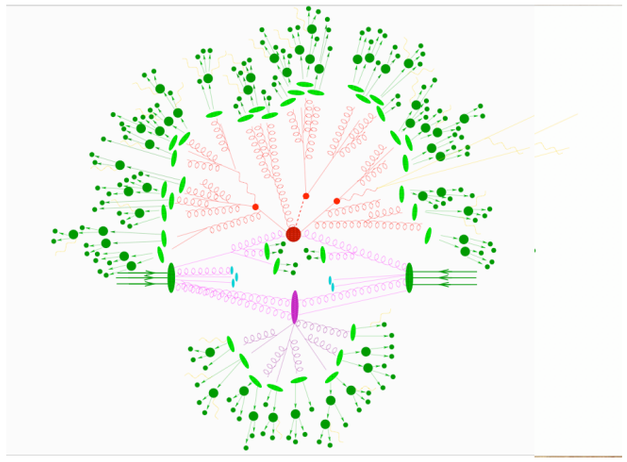
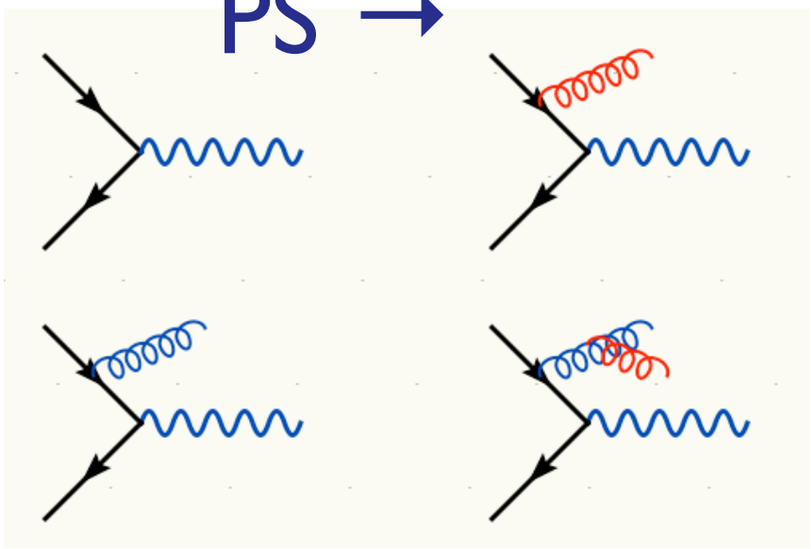
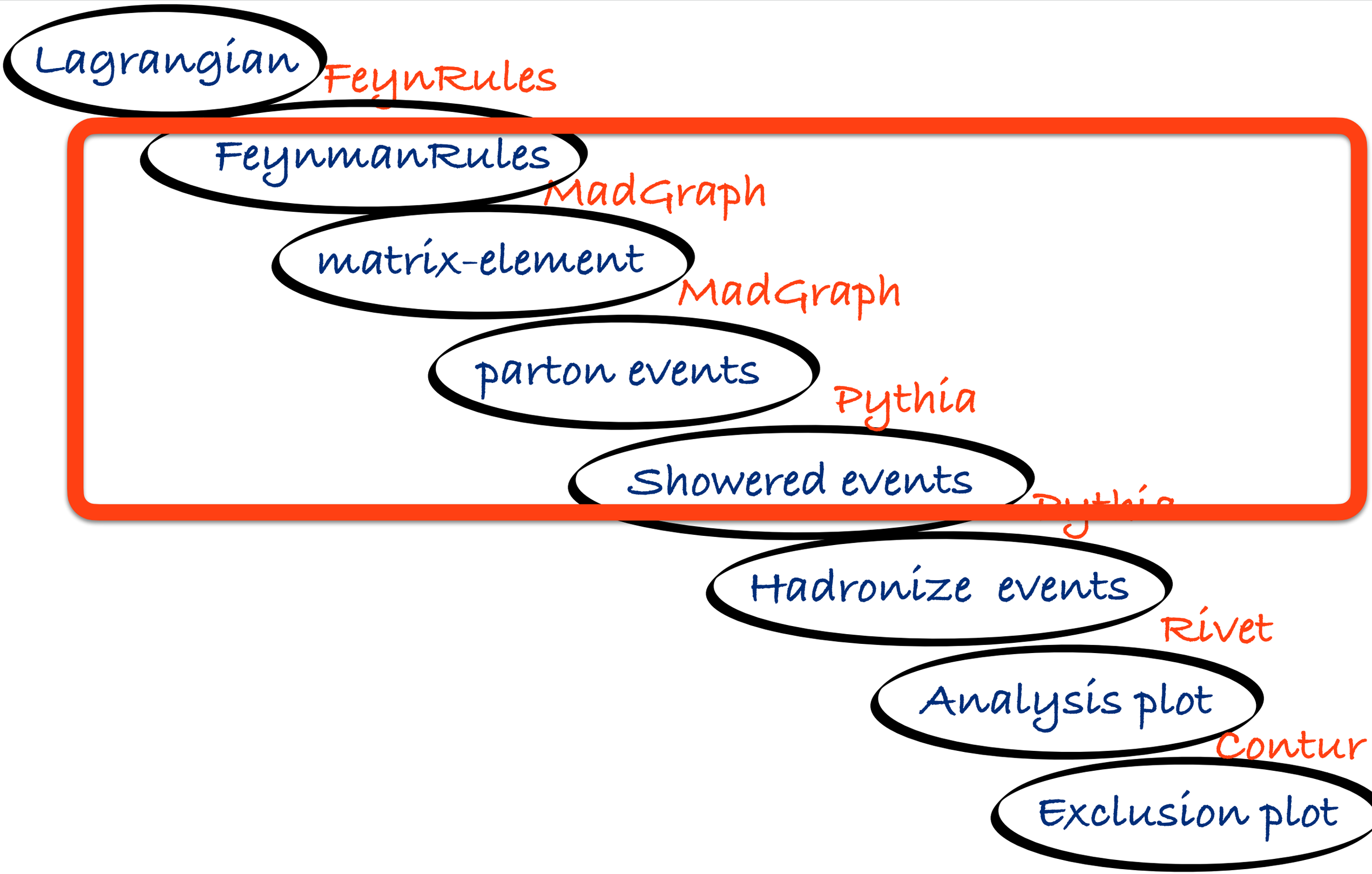




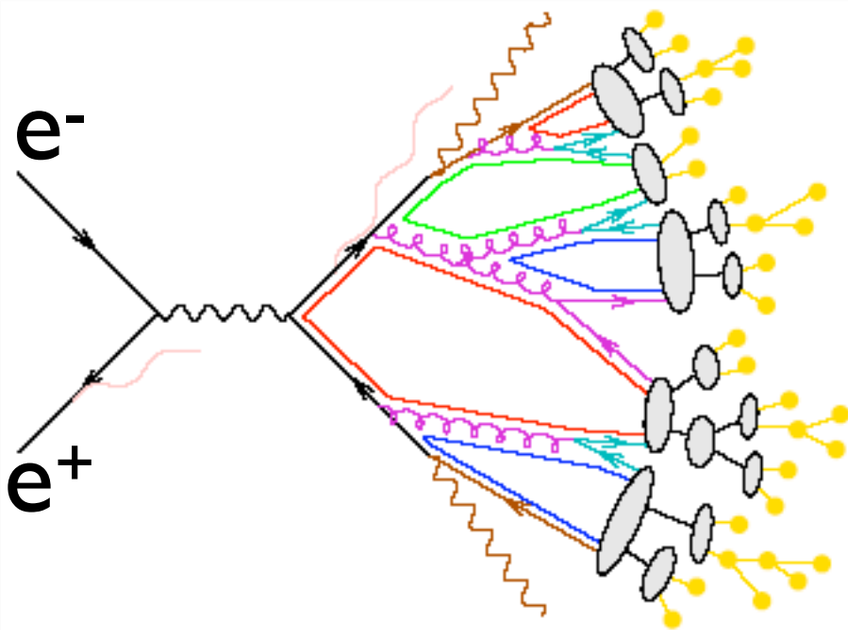


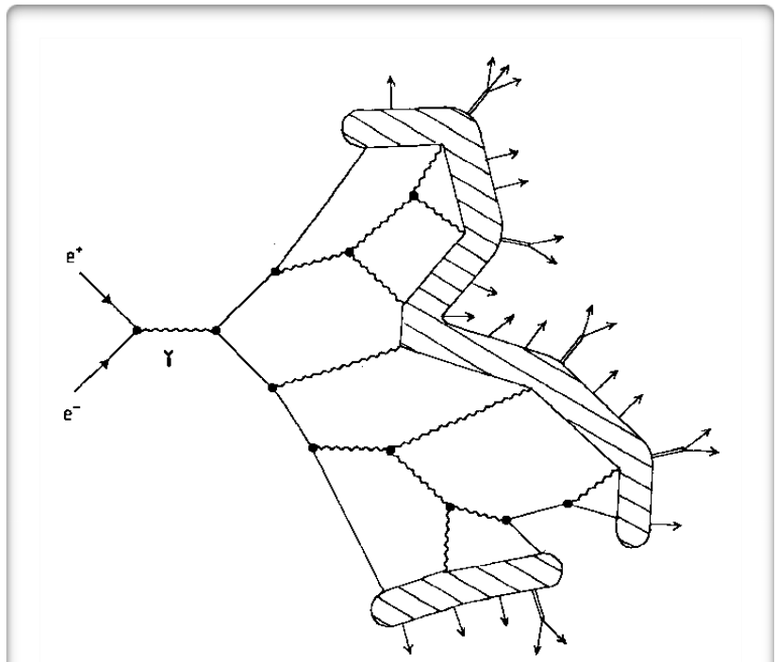
From Theory to Exclusion



Hadronization

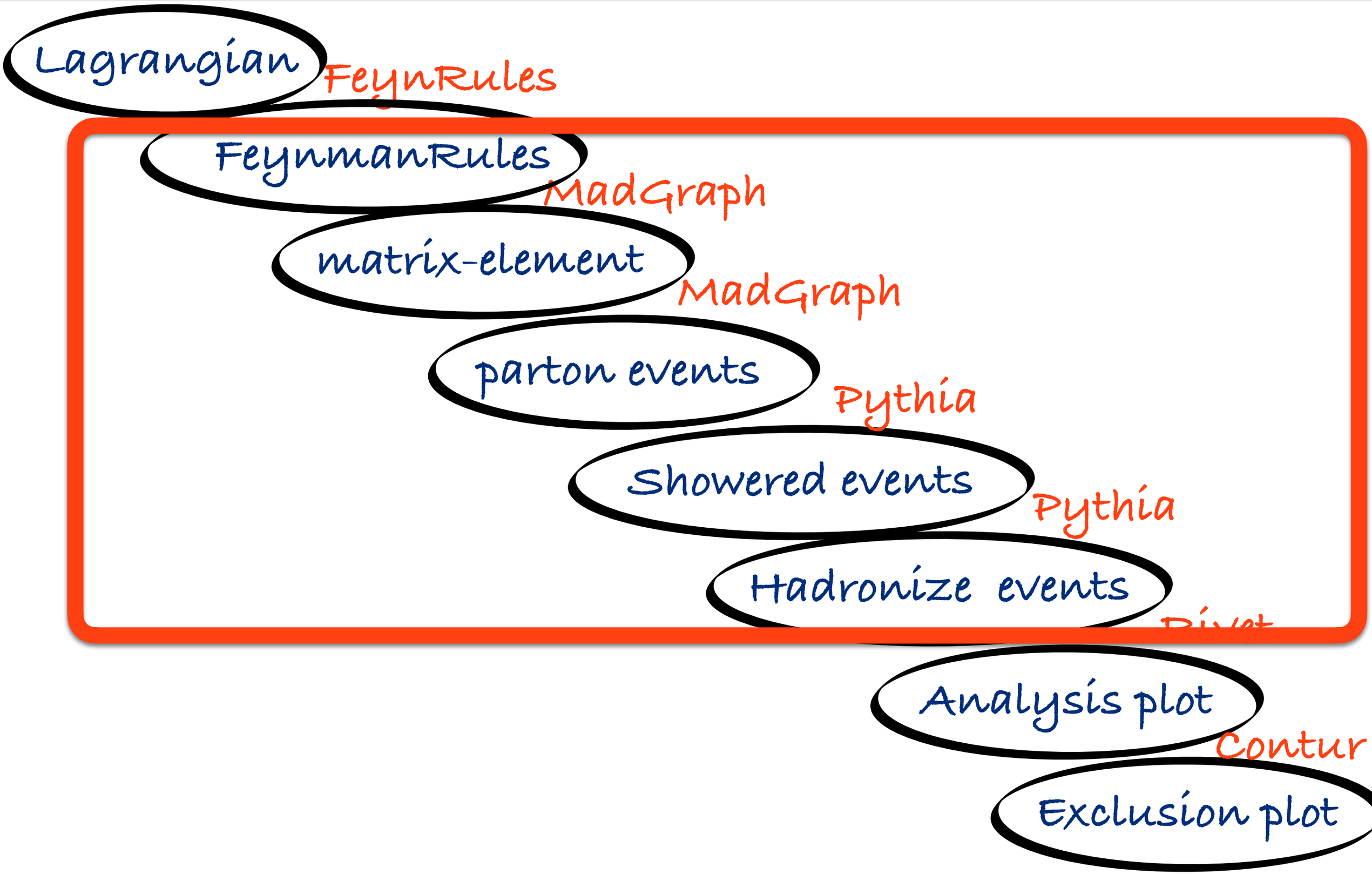
Conversion from parton to hadron
- clustering model
- string model





Lot of fitted parameter to describe this phase.
No fundamental/perturbative theory here

From Theory to Exclusion

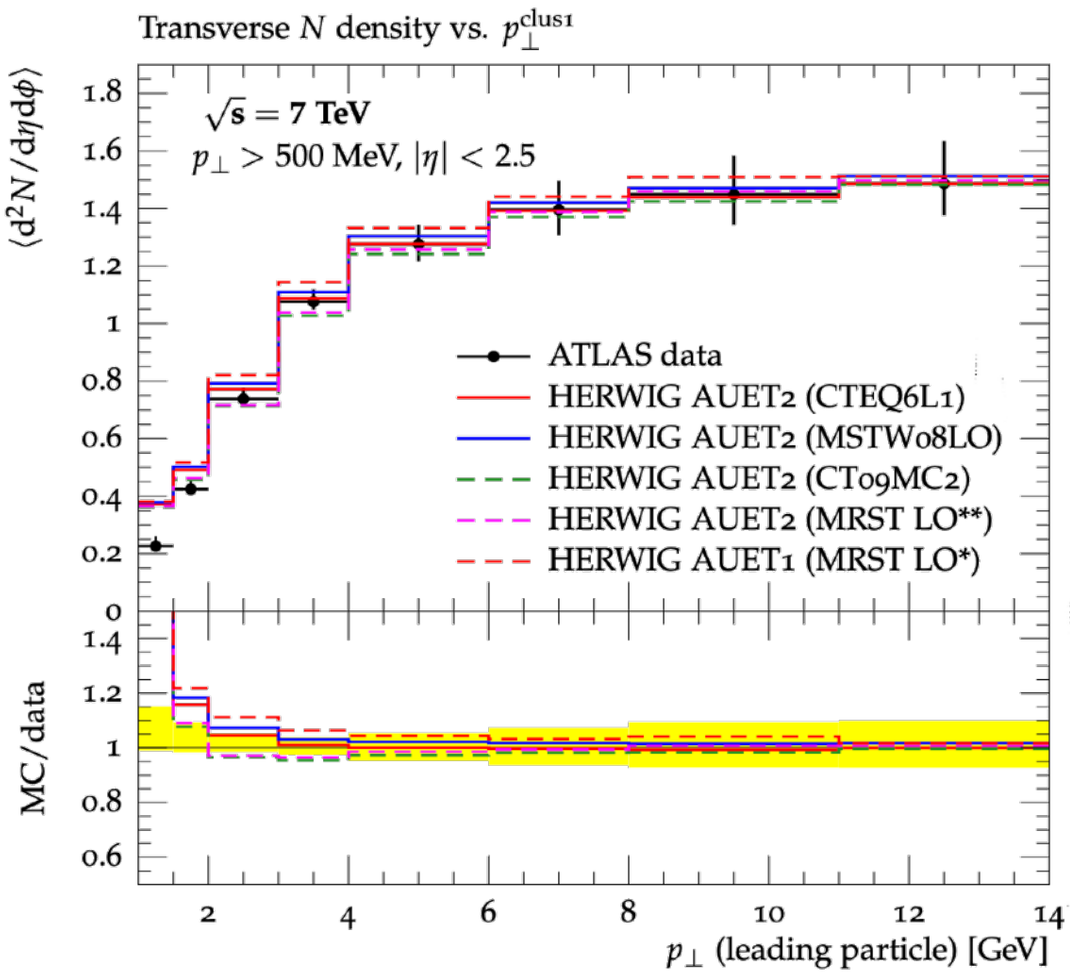


Introducing Rivet *and YODA*

"Robust Independent Validation of Experiment and Theory"

arXiv:1003.0694, arXiv:1912.05451

- Direct legacy from HERA (*1990s, HZTOOL*)
- Developed by MCnet for tuning and validation of new MC event generators
  - e.g. What does the underlying event look like in 7 TeV pp collisions?
- Vast library of measurements of final state particles produced in collisions, and variables derived from them



From ATL-PHYS-PUB-2011-008

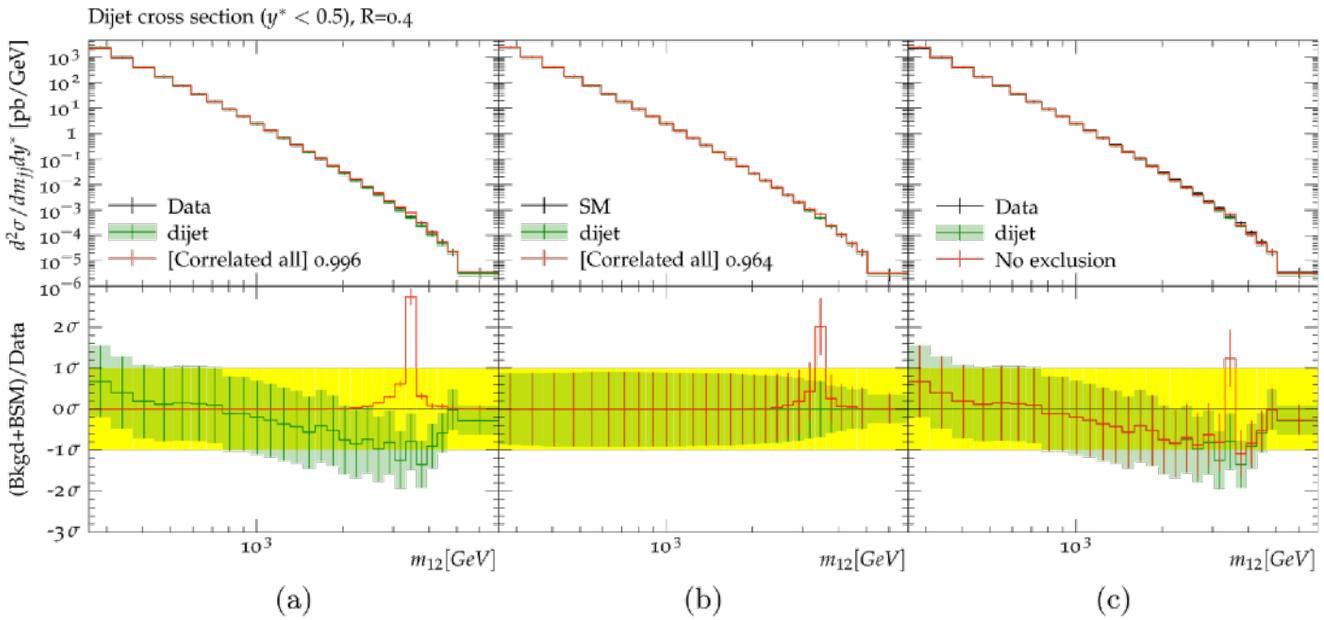
Buckley et al, Bierlich et al: **Tutorials**

Introducing Contur

"Constraints On New Theories Using Rivet"

arXiv:1605.05296, arXiv:2102.04377

- Extend the power of Rivet beyond the Standard Model
- Signal-injection of final-state particles from Beyond-the-SM physics events on to the measured cross sections in Rivet

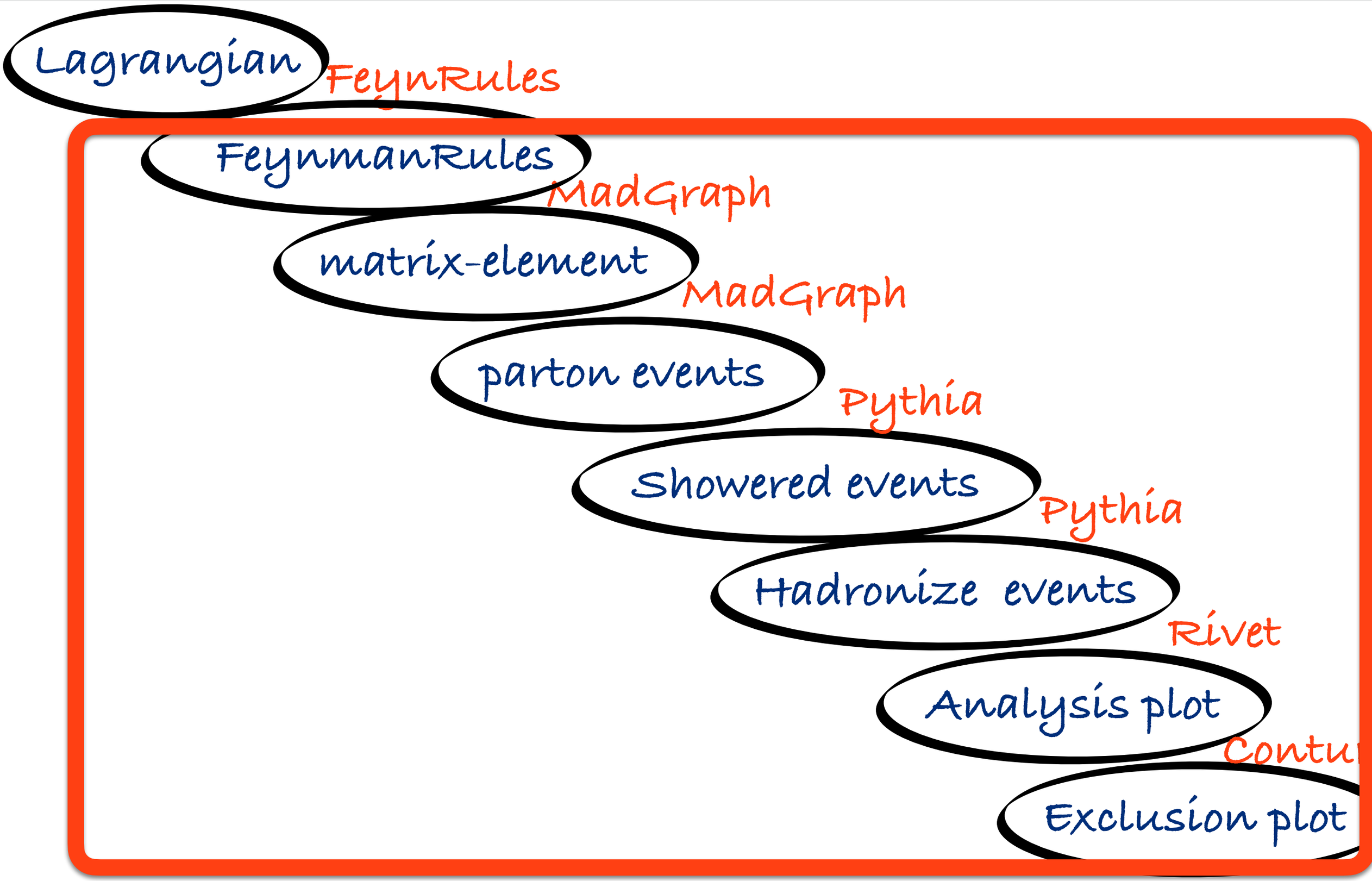


From Altakach, JMB, Ježo, Klasen, Schienbein arXiv:2111.15406

- Increasingly precise measurements and calculations **together** extend the reach

JMB, Grellscheid, Krämer, Sarrazin, Yallup; Buckley et al. **Tutorials**

From Theory to Exclusion



Ready to do ALL that?

Ready to do ALL that?
It is actually very easy

Ready to do ALL that?
It is actually very easy
But …

Ready to do ALL that?
It is actually very easy
But …

Tutorial

Olivier Mattelaer
CP3/UCLouvain
Marco Zaro
Milan

Tutorial map

Learning MG5

- follow the built-in tutorial
- cards meaning
- details of syntax ($/)
- BSM process
  - ➡ Compute cross-section
  - ➡ Exclusion plot

Setup the VM

Docker image

```
docker run -it -v mgtutorial:/volume hepstore/rivet-mg5amcnlo  bash

# Useful to install vim or emacs:
apt-get update
apt-get install vim (or apt-get install emacs)

# Installation of contour
apt-get install pip
pip install contur
source conturenv.sh
cd $CONTUR_DATA_PATH
make
cd -
source conturenv.sh

# Update MG5aMC
./bin/mg5_aMC
-> answer yes to update (or run install update)
```

Learning MG5_aMC

Where to find help?

- Ask us
- Use the command "help" / "help XXX"
  - ➡ "help" tell you the next command that you need to do.
- Launchpad:
  - ➡ https://answers.launchpad.net/madgraph5
  - ➡ FAQ: https://answers.launchpad.net/madgraph5/+faqs

Minimal tutorial

- Launch the code
  - ➡./bin/mg5_aMC
- Type tutorial
  - ➡ Follow instructions

Exercise 2

- Compute the LO cross-section for our BSM background
  - ➡ generate p p > mu+ mu-
- Check
  - ➡ What is the Z mass?
  - ➡ If they are any cuts? (Do we need cuts?)
  - ➡ Beam Energy
- Useful cards to check are
  - ➡ param_card: model parameters
  - ➡ run_card: beam/run parameters and cuts

Exercise III: Syntax

- Generate the cross-section and the distribution (invariant mass) for
  - ➡ p p > mu+ mu-
  - ➡ p p > z, z > mu+ mu-
  - ➡ p p > mu+ mu- $ z (warning set sde_strategy=1 in the run_card)
  - ➡ p p > mu+ mu- / z

Hint :To plot automatically distributions:
mg5> install MadAnalysis5

BSM MODEL

Use a new model (in mg5)

```
./bin/mg5_aMC
set auto_convert_model T
import model VPrime_NLO
```

Network issue/… copy the model by hand:

```
cp -r /usr/local/share/contur/data/Models/WZPrime/VPrime_NLO/ models/
```

Check the model

```
./bin/mg5_aMC
import model VPrime_NLO
check p p > mu+ mu-
Display particles zp
```

Exercise 4: Scan

- Compute the cross-section for
  - ➡ p p > zp
    - For zp mass 500 GeV, 1TeV, 1.5TeV, 2TeV
    - Trick you can use: scan:[500,1000,1500,200]
    - Is the cross-section decrease/increase (why should it be)?
  - ➡ p p > zp , zp > mu+ mu-
    - For zp mass 500 GeV, 1TeV, 1.5TeV, 2TeV
    - Is the cross-section decrease/increase (why should it be)?
    - What is the relation to the previous cross-section?
    - Compute the Branching Ratio

Exercise 5: Exclusion limit

- Setup contur/rivet
  - ➡ set rivet_path /usr/local/
  - ➡ set yoda_path /usr/local/bin/yoda-config
  - ➡ set contur_path /usr/local/bin/

- Run with Rivet as analysis
- generate p p > zp, zp > mu+ mu-
  - output

Choose additional code in the workflow

- Launch

```
The following switches determine which programs are run:
/================== Description ==================|================== values ==================|======== other options ========
| 1. Choose the shower/hadronization program       |        shower = OFF                         |     Pythia8
| 2. Choose the detector simulation program        |      detector = Not Avail.                  |     Please install module
| 3. Choose an analysis package (plot/convert)     |      analysis = MadAnalysis5                |     Rivet|OFF
| 4. Decay onshell particles                       |       madspin = OFF                         |     ON|onshell|full
| 5. Add weights to events for new hypp.           |      reweight = OFF                         |     ON
\=================================================================================================================================
Either type the switch number (1 to 5) to change its setting,
Set any switch explicitly (e.g. type 'shower=Pythia8' at the prompt)
Type 'help' for the list of all valid option
Type '0', 'auto', 'done' or just press enter when you are done.[60s to answer]
```

- Type analysis=rivet

```
The following switches determine which programs are run:
/================== Description ==================|================== values ==================|======== other options ========
| 1. Choose the shower/hadronization program       |        shower = Pythia8      ⇐ ~~OFF~~      |     Pythia8
| 2. Choose the detector simulation program        |      detector = Not Avail.                  |     Please install module
| 3. Choose an analysis package (plot/convert)     |      analysis = Rivet                       |     OFF|MadAnalysis5
| 4. Decay onshell particles                       |       madspin = OFF                         |     ON|onshell|full
| 5. Add weights to events for new hypp.           |      reweight = OFF                         |     ON
\=================================================================================================================================
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Set any switch explicitly (e.g. type 'shower=Pythia8' at the prompt)
Type 'help' for the list of all valid option
Type '0', 'auto', 'done' or just press enter when you are done.
```

- Type enter (note that PY8 is turned on automatically)

Setup your code

- Here two more card (Pythia and rivet/contur)

```
Do you want to edit a card (press enter to bypass editing)?
/------------------------------------------------------------\
|  1. param   : param_card.dat                               |
|  2. run     : run_card.dat                                 |
|  3. pythia8 : pythia8_card.dat                             |
|  4. rivet   : rivet_card.dat                               |
\------------------------------------------------------------/
```

- Let's edit as follows

```
set mzp scan:[1000, 2000] # define Z' mass grid points
set kl scan:[1.e-2, 1.e-1] # define Z' coupling grid points
set wzp auto # let Z' width to be computed on-the-fly
set no_parton_cut # remove all generator level cuts
set use_syst False # PDF systematic runs will not be used for rivet/contur
set mmll 10 # safe cut from divergence (not necessary but still just in case)
set nevents 100 # minimal number of events
set run_contur True
set xaxis_var mzp
set yaxis_var kl
```

Solution Learning MG5_aMC

Exercise II: Cards Meaning

- How do you change
  - ➡ top mass
  - ➡ top width
  - ➡ W mass

Param_card

  - ➡ beam energy
  - ➡ pt cut on the lepton

Run_card

- top mass

```
###################################
## INFORMATION FOR MASS
###################################
Block mass
    6 1.730000e+02 # MT
   23 9.118800e+01 # MZ
   25 1.200000e+02 # MH
## Dependent parameters, given by model restrictions.
## Those values should be edited following the
## analytical expression. MG5 ignores those values
## but they are important for interfacing the output of MG5
## to external program such as Pythia.
  1 0.000000 # d : 0.0
  2 0.000000 # u : 0.0
  3 0.000000 # s : 0.0
  4 0.000000 # c : 0.0
  11 0.000000 # e- : 0.0
  12 0.000000 # ve : 0.0
  13 0.000000 # mu- : 0.0
  14 0.000000 # vm : 0.0
  16 0.000000 # vt : 0.0
  21 0.000000 # g : 0.0
  22 0.000000 # a : 0.0
  24 80.419002 # w+ : cmath.sqrt(MZ__exp__2/2. + cmath.sqrt(MZ__exp__4/4. - (aEW*cmath.pi*MZ__exp__2)/(Gf*sqrt__2)))
```

```
###################################
## INFORMATION FOR MASS
###################################
Block mass
    5 4.700000e+00 # MB
    6 1.730000e+02 # MT
   15 1.777000e+00 # MTA
   23 9.118800e+01 # MZ
   25 1.200000e+02 # MH
## Dependent parameters, given by model restrictions.
## Those values should be edited following the
## analytical expression. MG5 ignores those values
## but they are important for interfacing the output of MG5
## to external program such as Pythia.
  1 0.000000 # d : 0.0
  2 0.000000 # u : 0.0
  3 0.000000 # s : 0.0
  4 0.000000 # c : 0.0
 11 0.000000 # e- : 0.0
 12 0.000000 # ve : 0.0
 13 0.000000 # mu- : 0.0
 14 0.000000 # vm : 0.0
 16 0.000000 # vt : 0.0
 21 0.000000 # g : 0.0
 22 0.000000 #
 24 80.419002 # w+ : cmath.sqrt(MZ__exp__2/2. + cmath.sqrt(MZ__exp__4/4. - (aEW*cmath.pi*MZ__exp__2)/(Gf*sqrt__2)))
```

W Mass is an internal parameter!

MG5 didn't use this value!

So you need to change MZ or Gf or alpha_EW

Exercise skipped: Syntax

- What's the meaning of the order QED/QCD
- What's the difference between
  - ➡ p p > t t~
  - ➡ p p > t t~ QED=2
  - ➡ p p > t t~ QED=0
  - ➡ p p > t t~ QCD^2==2

Solution 1 : Syntax

- What's the meaning of the order QED/QCD
  - ➡ By default MG5 takes the lowest order in QED!
  - ➡ p p > t t~ => p p > t t~ QED=0
  - ➡ p p > t t~ QED=2
    - additional diagrams (photon/z exchange)

p p > t t~

Cross section (pb)
555 ± 0.84

p p > t t~ QED=2

Cross section (pb)
555.8 ± 0.91

No significant QED contribution

- QED<=2 is the SAME as QED=2
  - ➡ quite often source of confusion since most of the people use the = syntax
- QCD^2==2
  - ➡ returns the interference between the QCD and the QED diagram

Cross section (pb)
5.455e-17 ± 4.7e-19 ± systematics

Solution 1 Syntax

- generate p p > w+ w- j j
  - ➡ 76 processes
  - ➡ 1432 diagrams
  - ➡ None of them are VBF

- generate p p > w+ w- j j QED = 2
  - ➡ 76 processes
  - ➡ 1432 diagrams
  - ➡ None of them are VBF

- generate p p > w+ w- j j QED = 4
  - ➡ 76 processes
  - ➡ 5332 diagrams
  - ➡ VBF present! + those not VBF

- generate p p > w+ w- j j QCD = 0
  - ➡ 60 processes
  - ➡ 3900 diagrams
  - ➡ VBF present!

- generate p p > w+ w- j j QCD = 2
  - ➡ 76 processes
  - ➡ 5332 diagrams

- generate p p > w+ w- j j QCD = 4
  - ➡ 76 processes
  - ➡ 5332 diagrams

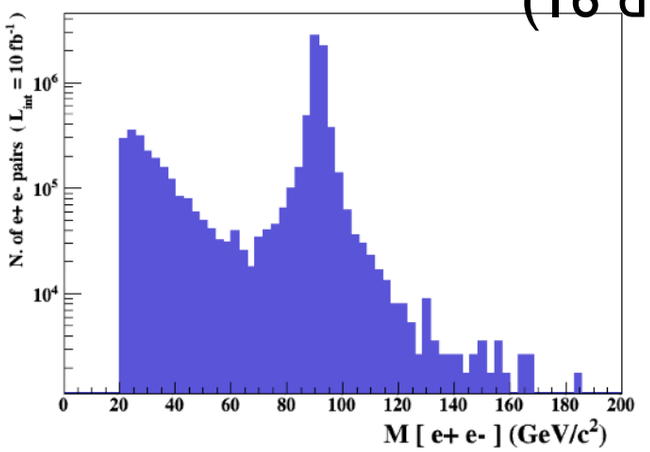
Exercise IV: Syntax

- Generate the cross-section and the distribution (invariant mass) for
  - ➡ p p > e+ e-
  - ➡ p p > z, z > e+ e-
  - ➡ p p > e+ e- $ z
  - ➡ p p > e+ e- / z

Hint :To have automatic distributions:
mg5> install MadAnalysis

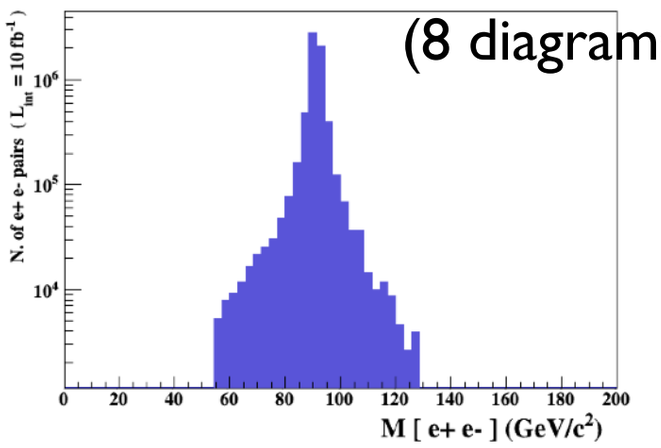
p p > e+ e-

(16 diagrams)



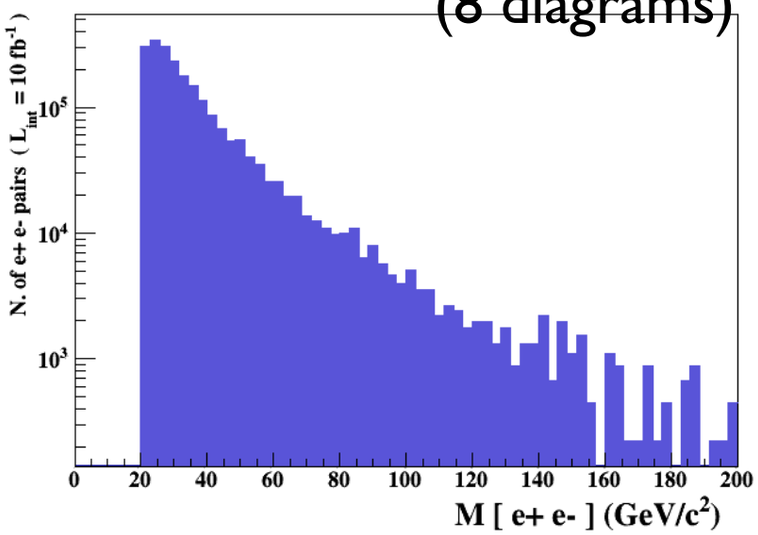
p p >z , z > e+ e-

(8 diagrams)



p p > e+ e- /z

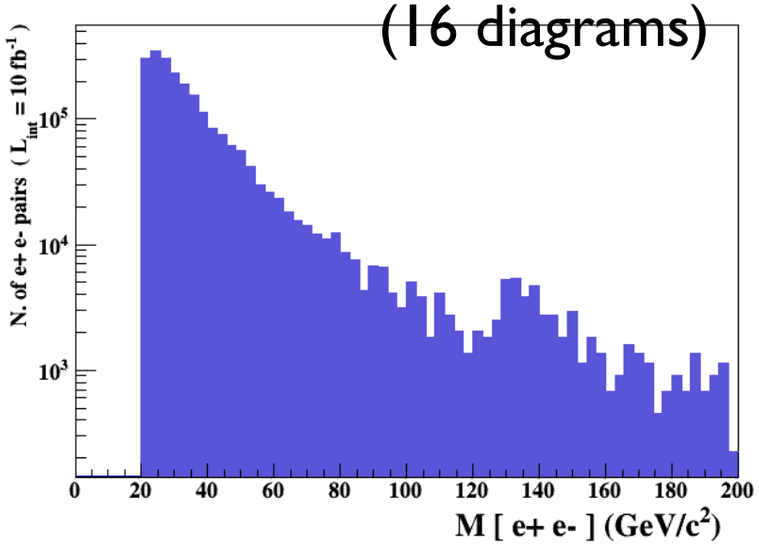
(8 diagrams)



No Z

p p > e+ e- $ z

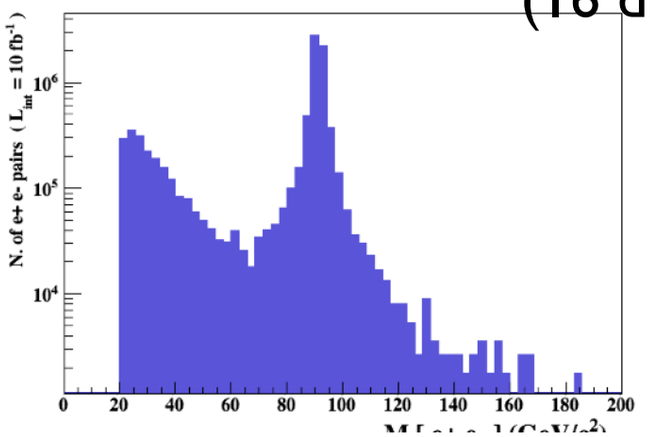
(16 diagrams)



Z- onshell veto

p p > e+ e-

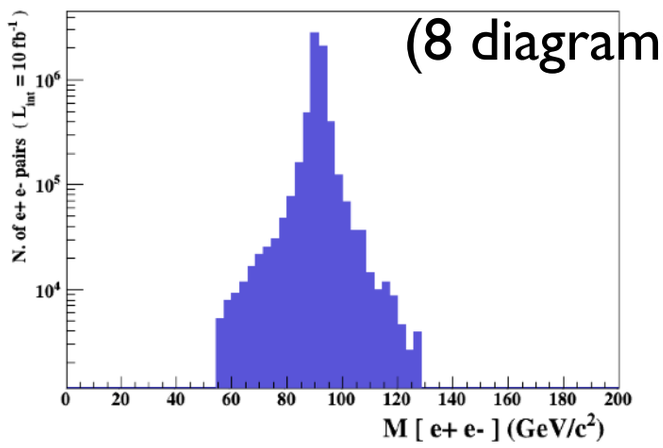
(16 diagrams)



Correct Distribution

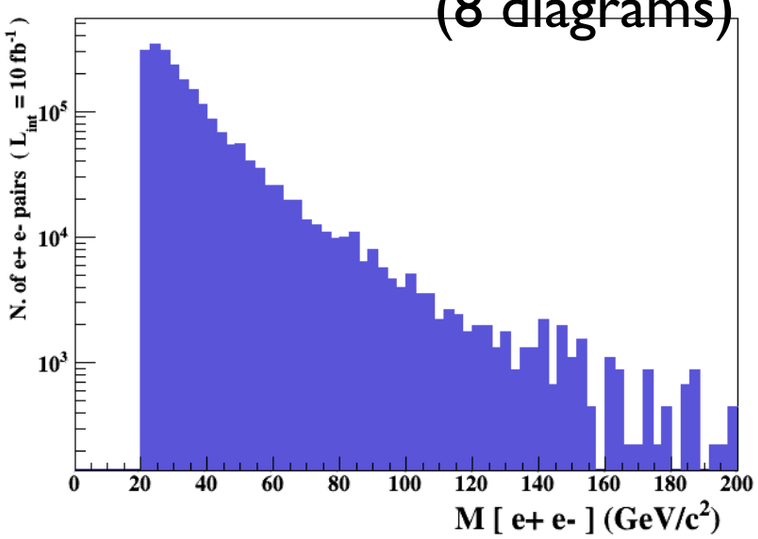
p p >z , z > e+ e-

(8 diagrams)



p p > e+ e- /z

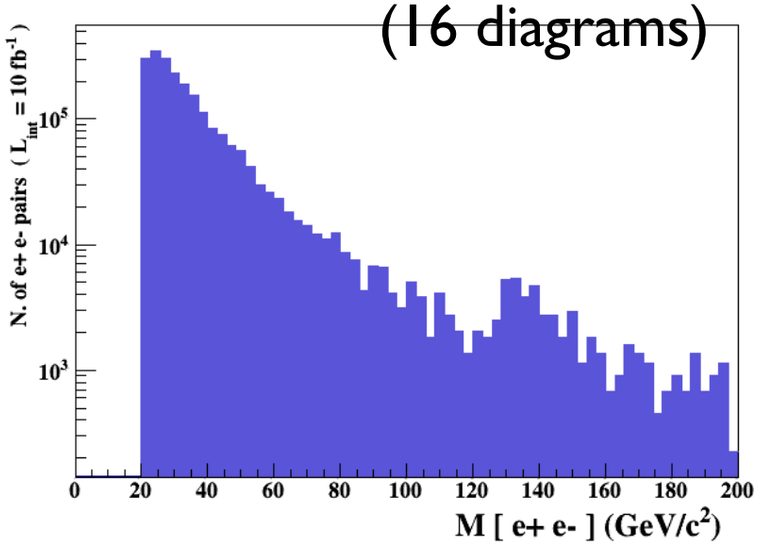
(8 diagrams)



No Z

p p > e+ e- $ z

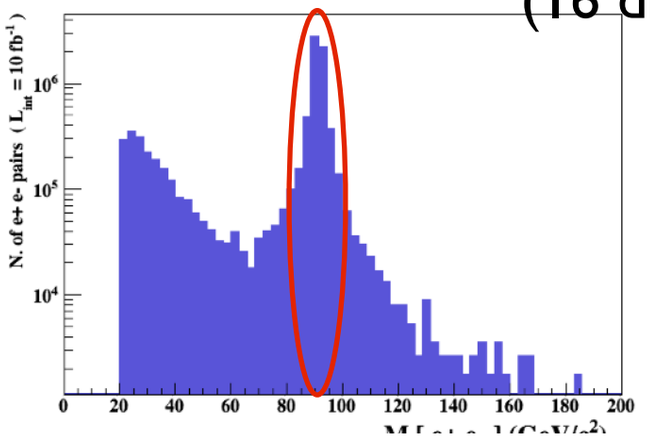
(16 diagrams)



Z- onshell veto

p p > e+ e-

(16 diagrams)

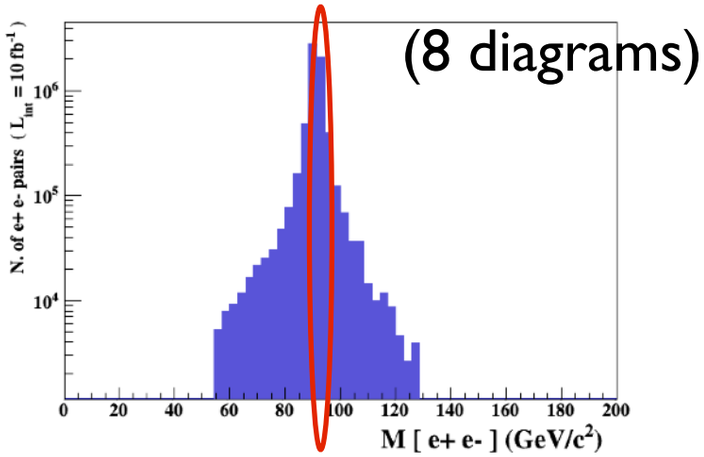


Correct Distribution

Z Peak

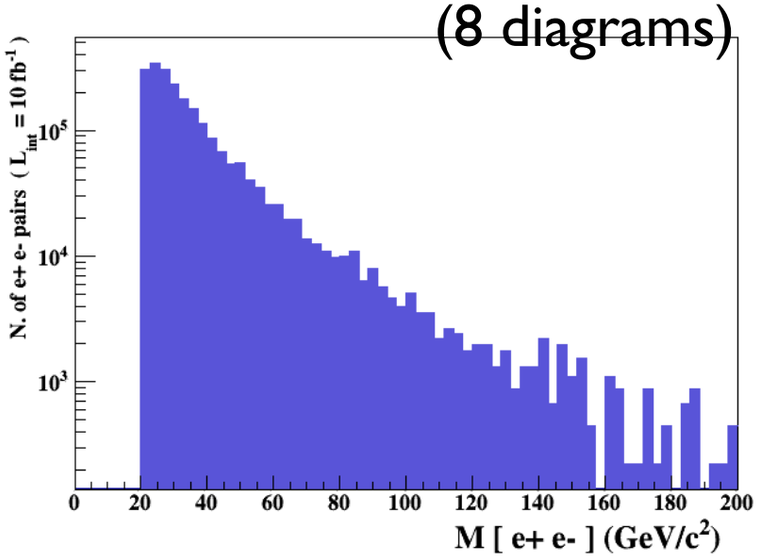
p p >z , z > e+ e-

(8 diagrams)



p p > e+ e- /z

(8 diagrams)

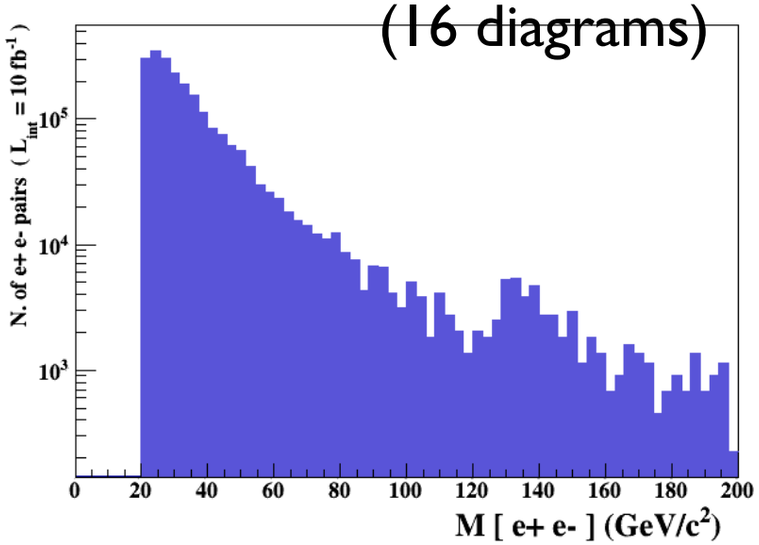


No Z

NO Z Peak

p p > e+ e- $ z

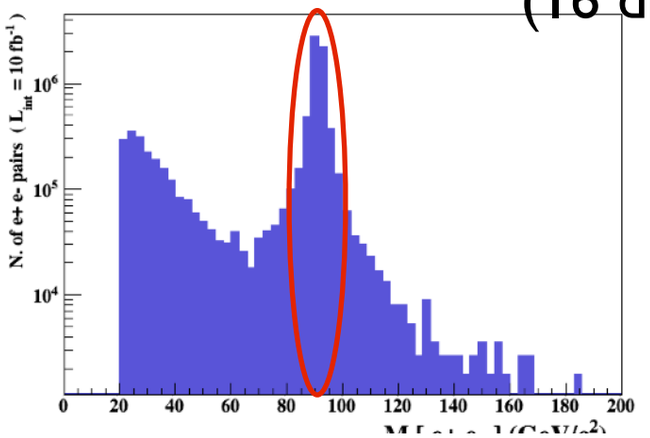
(16 diagrams)



Z- onshell veto

p p > e+ e-

(16 diagrams)

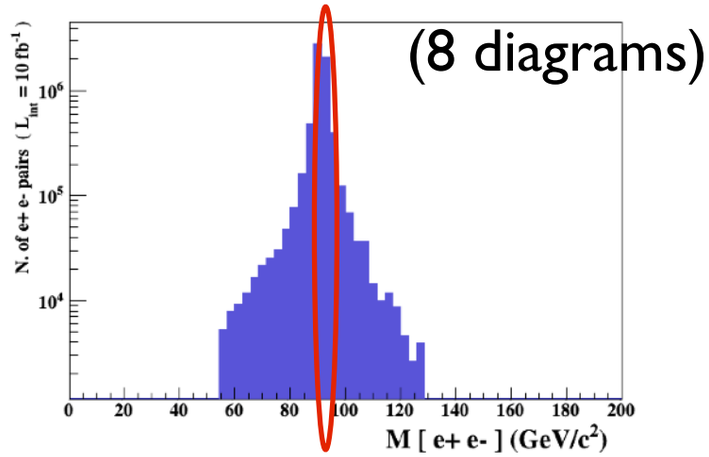


Correct Distribution

Z Peak

p p >z , z > e+ e-

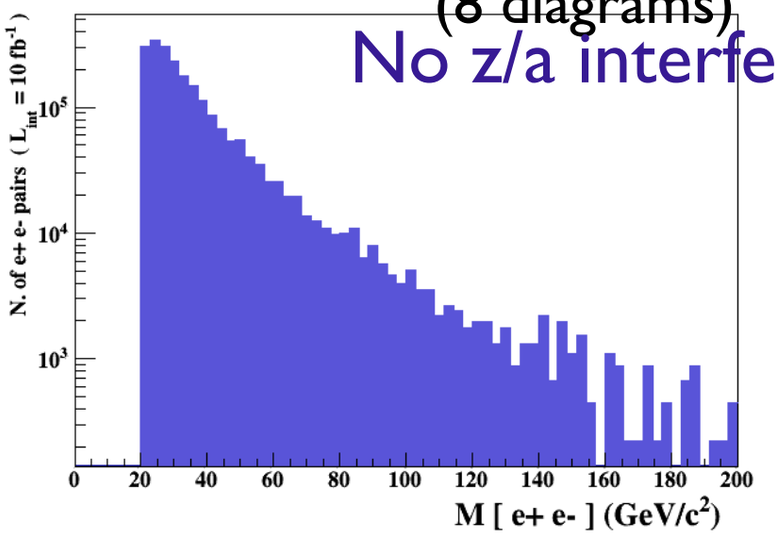
(8 diagrams)



p p > e+ e- /z

(8 diagrams)

No z/a interference



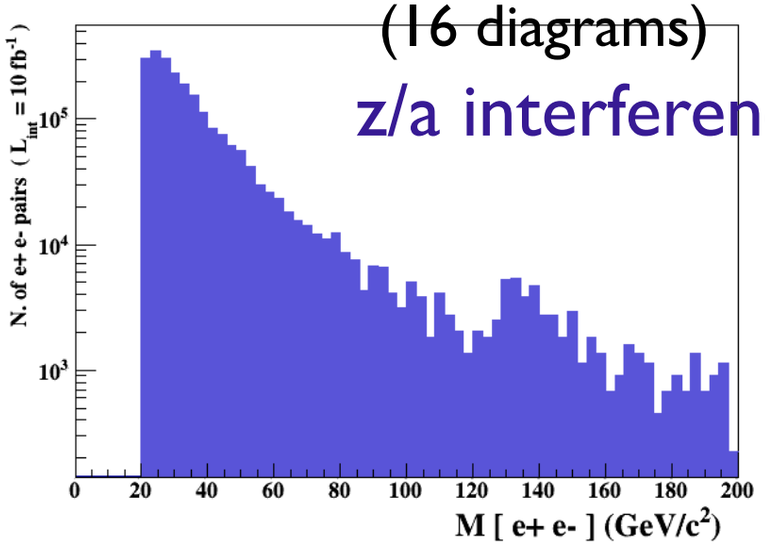
No Z

NO Z Peak

p p > e+ e- $ z

(16 diagrams)

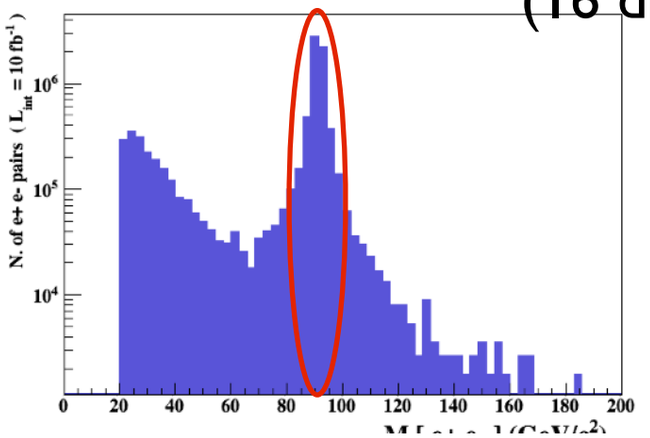
z/a interference



Z- onshell veto

p p > e+ e-

(16 diagrams)

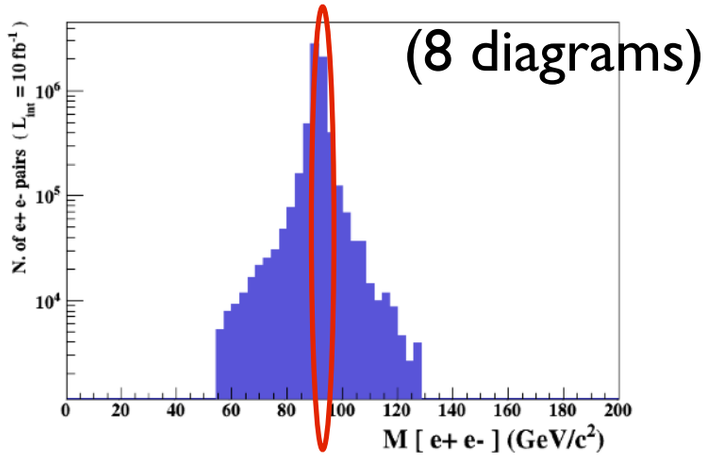


Correct Distribution

Z Peak

p p >z , z > e+ e-

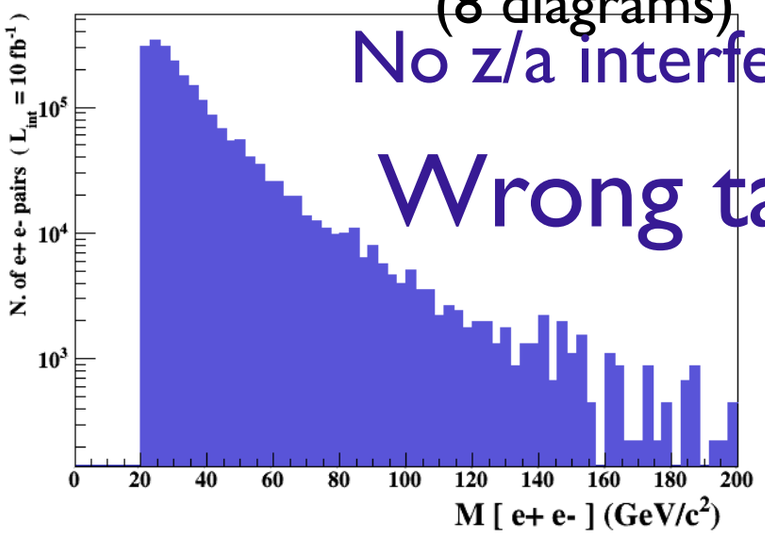
(8 diagrams)



p p > e+ e- /z

(8 diagrams)

No z/a interference



NO Z Peak

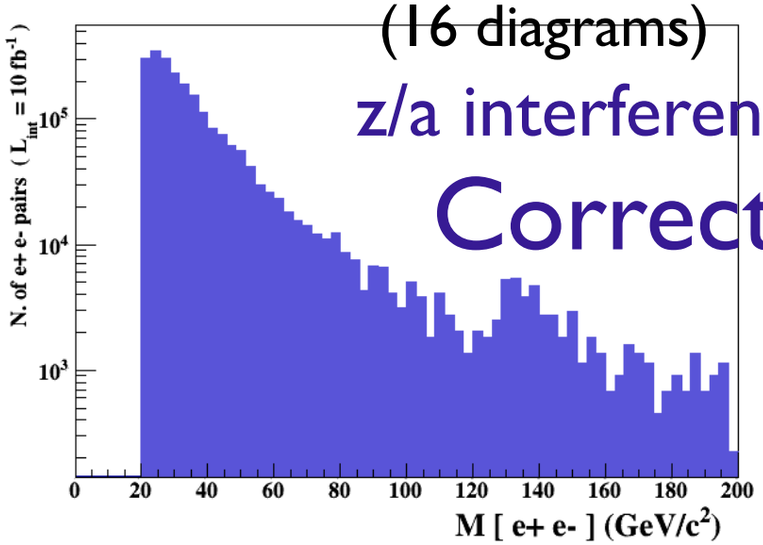
Wrong tail

No Z

p p > e+ e- $ z

(16 diagrams)

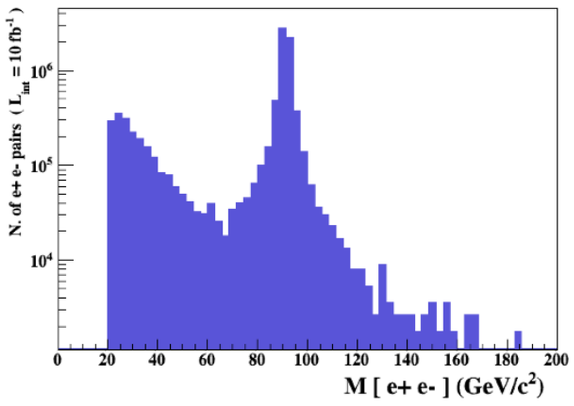
z/a interference



Correct tail

Z- onshell veto

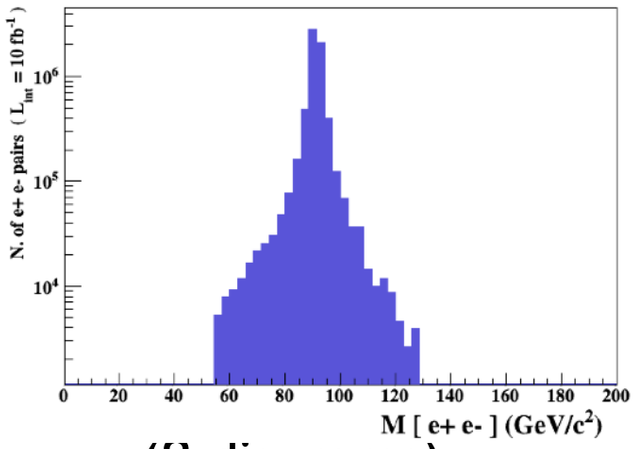
p p > e+ e-



(16 diagrams)

=

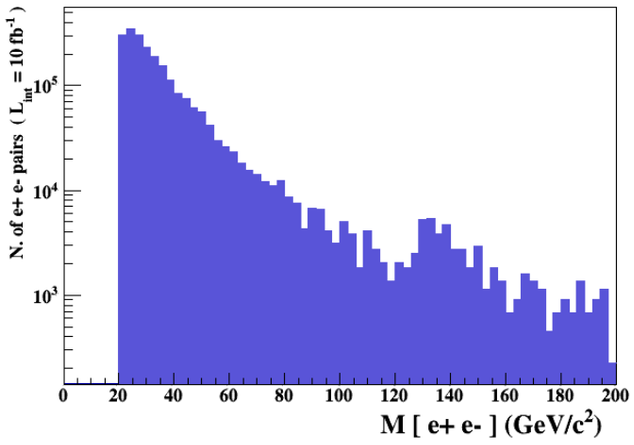
p p >z , z > e+ e-



(8 diagrams)

+

p p > e+ e- $ z



(16 diagrams)

Onshell cut: BW_cut

$$|M^* - M| < BW_{cut} * \Gamma$$

- The Physical distribution is (very close to) exact sum of the two other one.
- The "$" forbids the Z to be onshell but the photon invariant mass can be at MZ (i.e. on shell substraction).
- The "/" is to be avoid if possible since this leads to violation of gauge invariance.

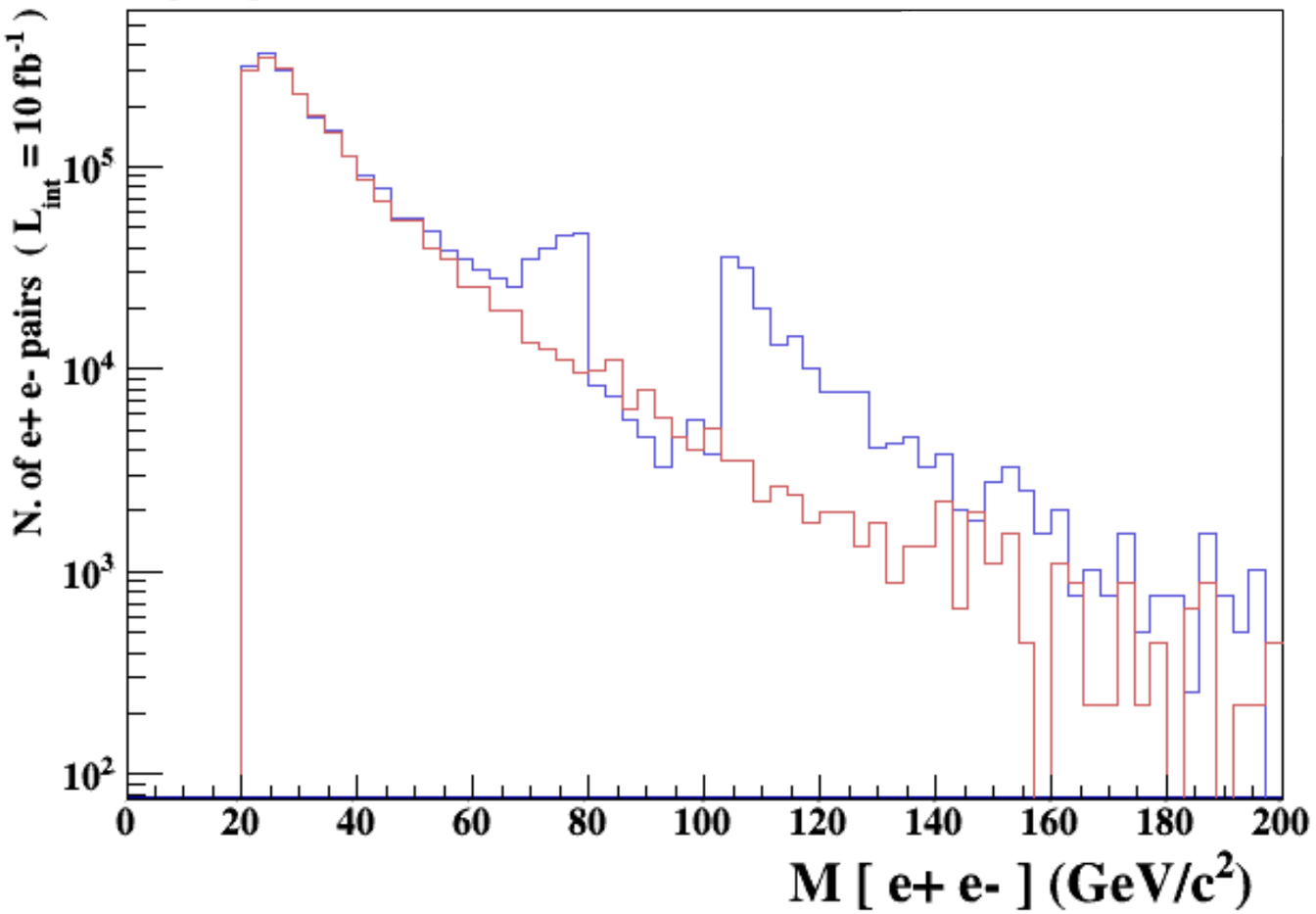
WARNING

- NEXT SLIDE is generated with bw_cut =5
- This is TOO SMALL to have a physical meaning (15 the default value used in previous plot is better)
- This was done to illustrate more in detail how the "$" syntax works.

$ explanation

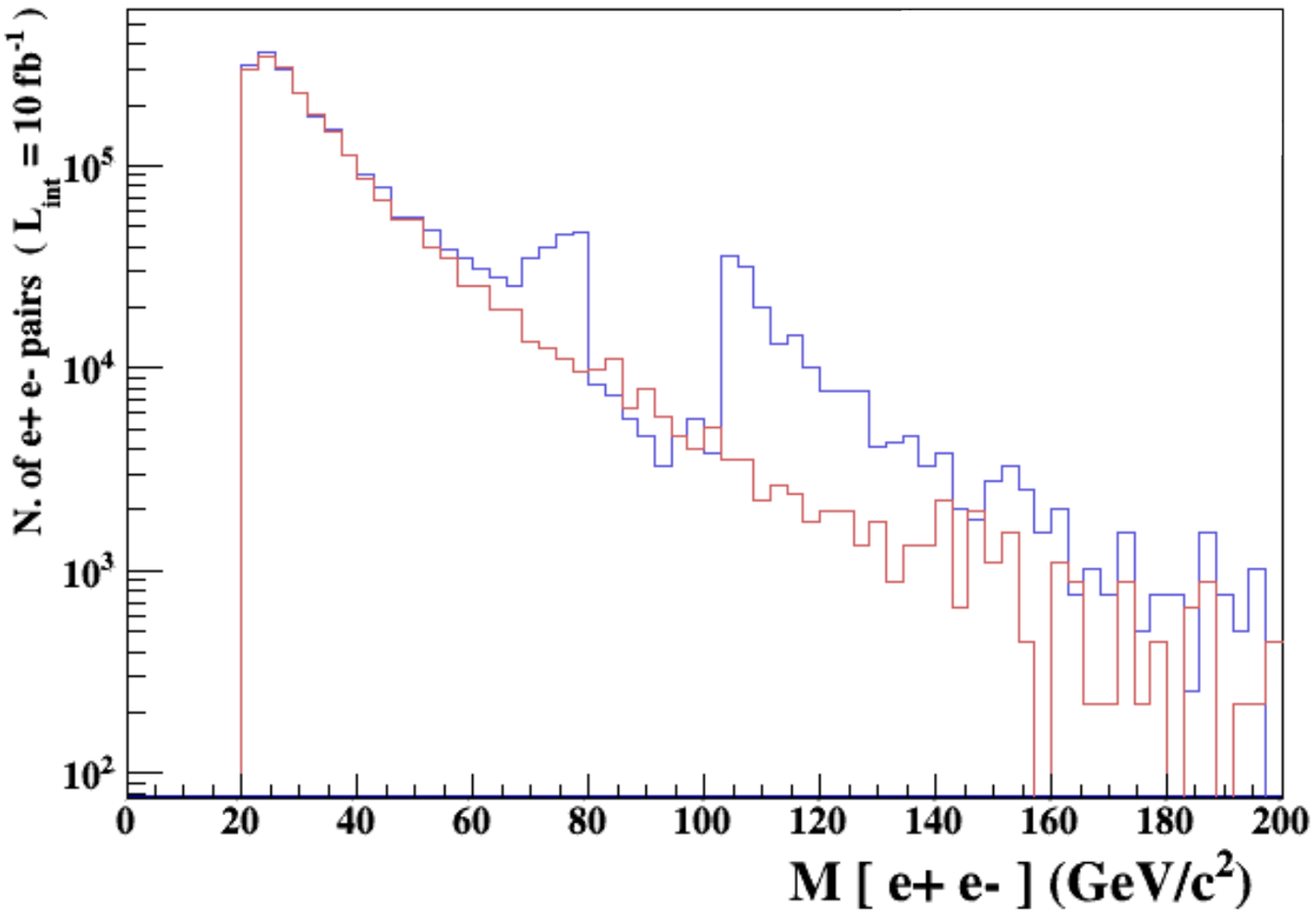
p p > e+ e- / Z (red curve)

(blue curve)



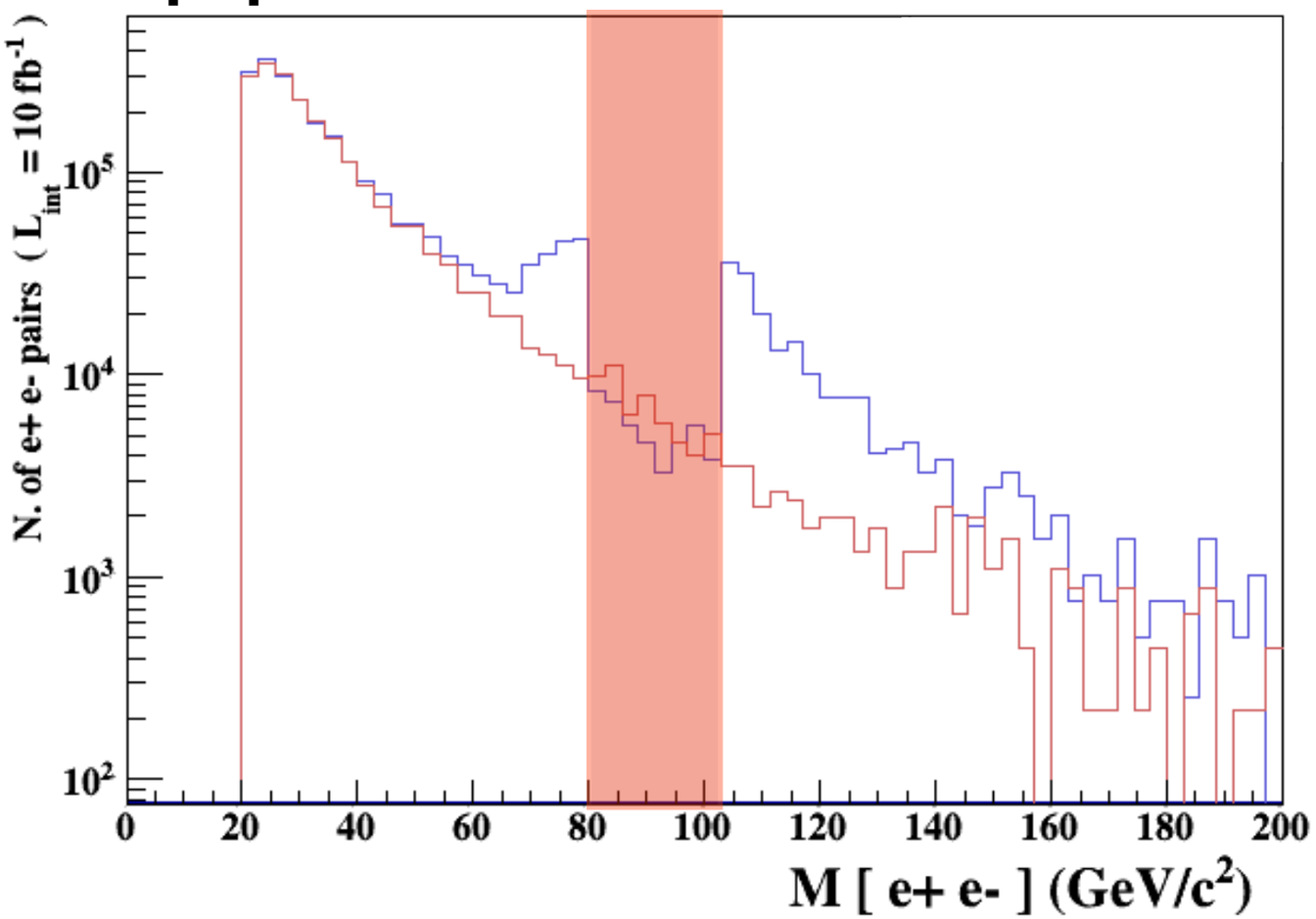
$ explanation

p p > e+ e- / Z (red curve) adding p p > e+ e- $ Z (blue curve)



$ explanation

p p > e+ e- / Z (red curve) adding p p > e+ e- $ Z (blue curve)

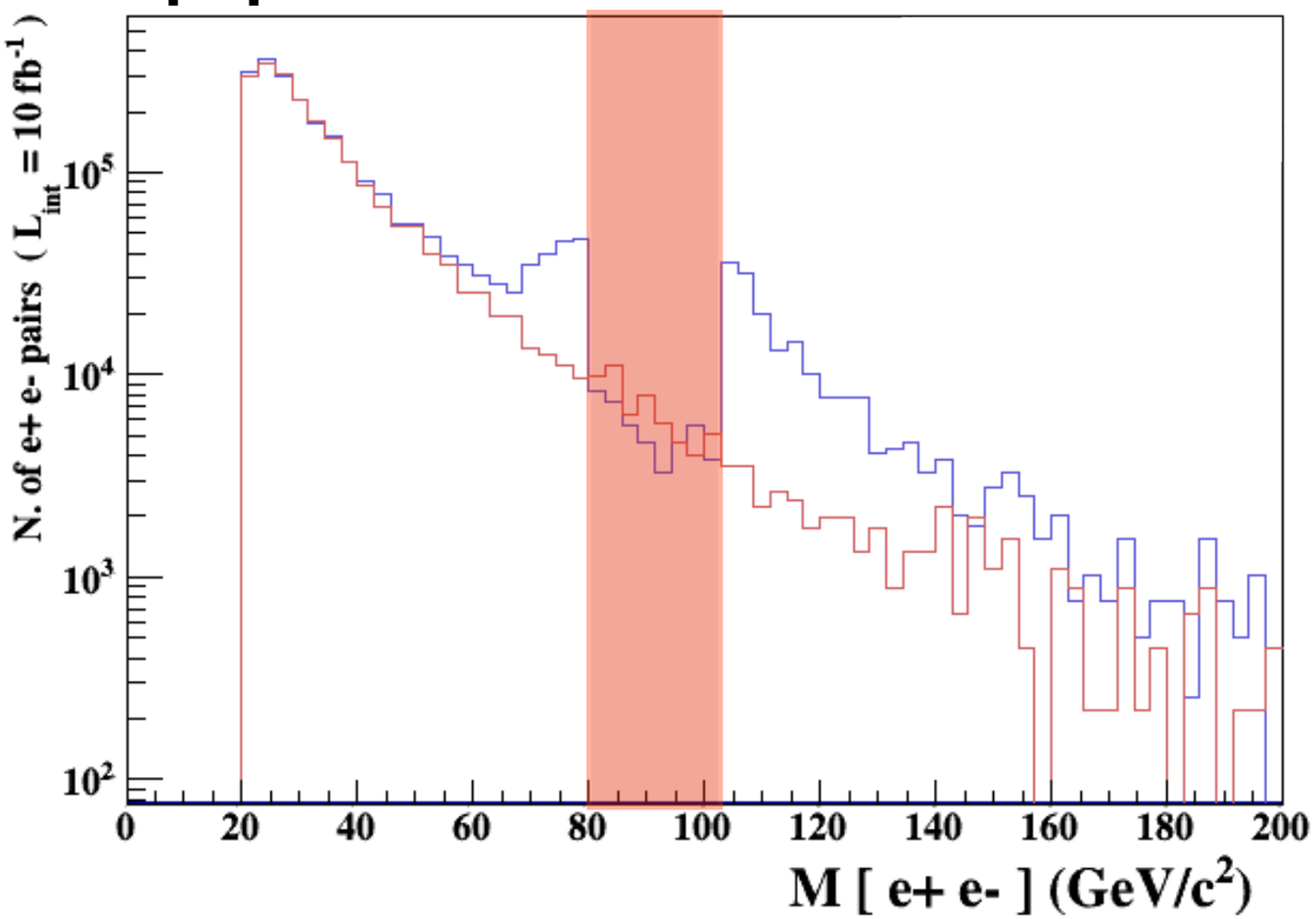


- Z onshell veto

5 times width area

$ explanation

p p > e+ e- / Z (red curve) adding p p > e+ e- $ Z (blue curve)

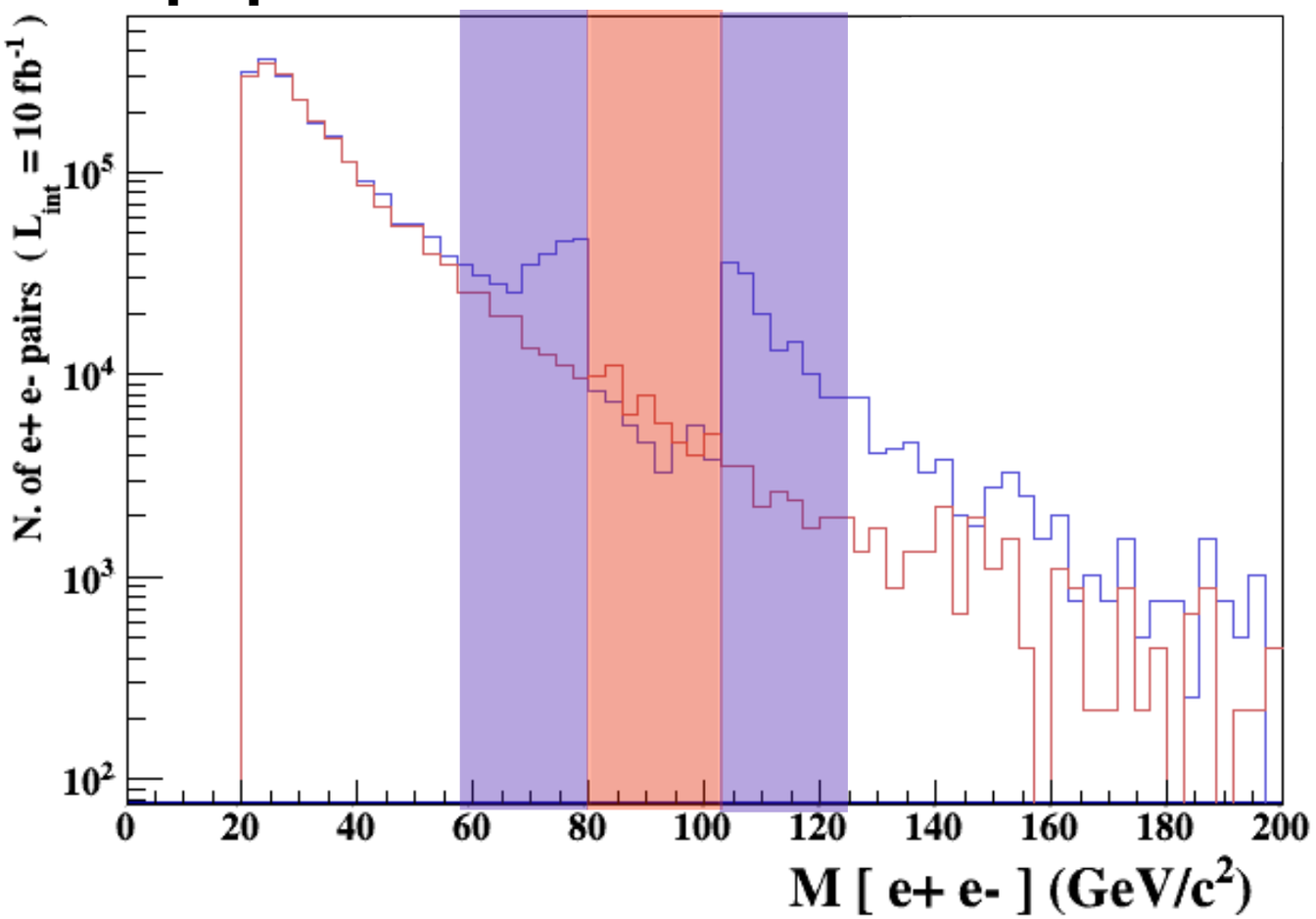


- Z onshell veto
- In veto area only photon contribution

5 times width area

$ explanation

p p > e+ e- / Z (red curve) adding p p > e+ e- $ Z (blue curve)



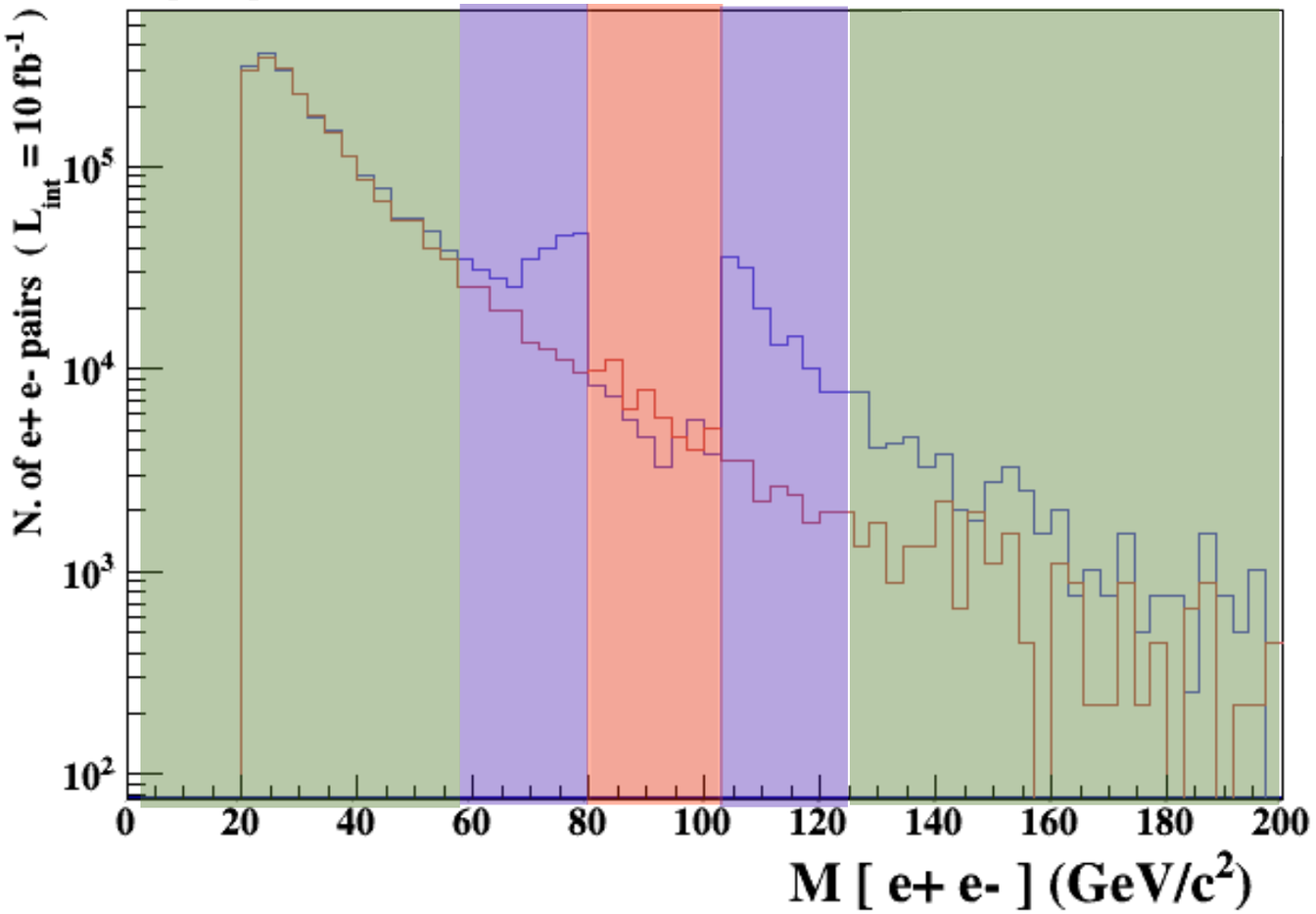
- Z onshell veto
- In veto area only photon contribution
- area sensitive to z-peak

5 times width area

15 times width area

$ explanation

p p > e+ e- / Z (red curve) adding p p > e+ e- $ Z (blue curve)



- Z onshell veto
- In veto area only photon contribution
- area sensitive to z-peak
- very off-shell Z, the difference between the curve is due to interference which are need to be KEPT in simulation.

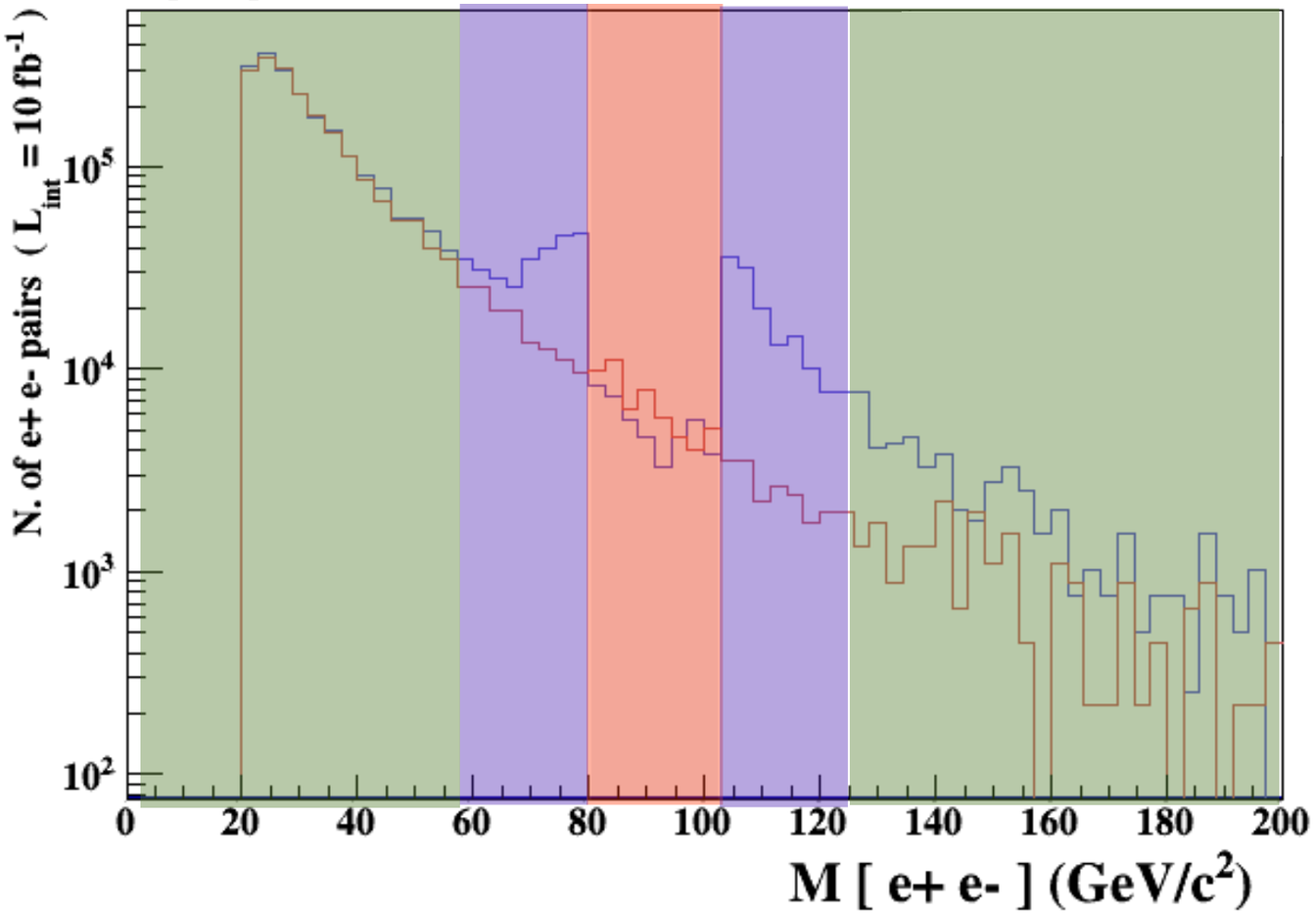
5 times width area

15 times width area

>15 times width area

$ explanation

p p > e+ e- / Z (red curve) adding p p > e+ e- $ Z (blue curve)



- Z onshell veto
- In veto area only photon contribution
- area sensitive to z-peak
- very off-shell Z, the difference between the curve is due to interference which are need to be KEPT in simulation.

5 times width area

15 times width area

>15 times width area

The "$" can be use to split the sample in BG/SG area

- Syntax Like
  - ➡ p p > z > e+ e- (ask one S-channel z)
  - ➡ p p > e+ e- / z (forbids any z)
  - ➡ p p > e+ e- $$ z (forbids any z in s-channel)
- ARE NOT GAUGE INVARIANT !
- forgets diagram interference.
- can provides un-physical distributions.

- Syntax Like
  - ➡ p p > z > e+ e- (ask one S-channel z)
  - ➡ p p > e+ e- / z (forbids any z)
  - ➡ p p > e+ e- $$ z (forbids any z in s-channel)
- ARE NOT GAUGE INVARIANT !
  - forgets diagram interference.
  - can provides un-physical distributions.

Avoid Those as much as possible!

- Syntax Like
  - ➡ p p > z > e+ e- (ask one S-channel z)
  - ➡ p p > e+ e- / z (forbids any z)
  - ➡ p p > e+ e- $$ z (forbids any z in s-channel)
- ARE NOT GAUGE INVARIANT !
  - forgets diagram interference.
  - can provides un-physical distributions.

Avoid Those as much as possible!

check physical meaning and gauge/Lorentz invariance if you do.

- Syntax like
  - p p > z, z > e+ e- (on-shell z decaying)
  - p p > e+ e- $ z (forbids s-channel z to be on-shell)

- Are linked to cut $|M^* - M| < BW_{cut} * \Gamma$
- Are more safer to use
- Prefer those syntax to the previous slides one

Exercise 4: Result

Available Results

Run	Collider	Banner	Cross section (pb)	Events	Data	Output	Action
run_01	p p 6500.0 x 6500.0 GeV	tag_1	175 ± 0.18 ± systematics	10000	parton madevent	LHE	remove run / launch detector simulation
run_02	p p 6500.0 x 6500.0 GeV	tag_1	12.03 ± 0.012 ± systematics	10000	parton madevent	LHE	remove run / launch detector simulation
run_03	p p 6500.0 x 6500.0 GeV	tag_1	1.981 ± 0.0017 ± systematics	10000	parton madevent	LHE	remove run / launch detector simulation
run_04	p p 6500.0 x 6500.0 GeV	tag_1	0.4651 ± 0.00043 ± systematics	10000	parton madevent	LHE	remove run / launch detector simulation

Available Results

Run	Collider	Banner	Cross section (pb)	Events	Data	Output	Action
run_01	p p 6500.0 x 6500.0 GeV	tag_1	0.9164 ± 0.00088 ± systematics	10000	parton madevent	LHE MA5_report_analysis1	remove run / launch detector simulation
run_02	p p 6500.0 x 6500.0 GeV	tag_1	0.1304 ± 0.00025 ± systematics	10000	parton madevent	LHE MA5_report_analysis1	remove run / launch detector simulation
run_03	p p 6500.0 x 6500.0 GeV	tag_1	0.03253 ± 6.5e-05 ± systematics	10000	parton madevent	LHE MA5_report_analysis1	remove run / launch detector simulation
run_04	p p 6500.0 x 6500.0 GeV	tag_1	0.009965 ± 1.4e-05 ± systematics	10000	parton madevent	LHE MA5_report_analysis1	remove run / launch detector simulation

Main Page

- Ratio: 0.005 // 0.011 // 0.016 // 0.019
  - ➡ Not stable Branching Ratio (What?)

Result with auto-width

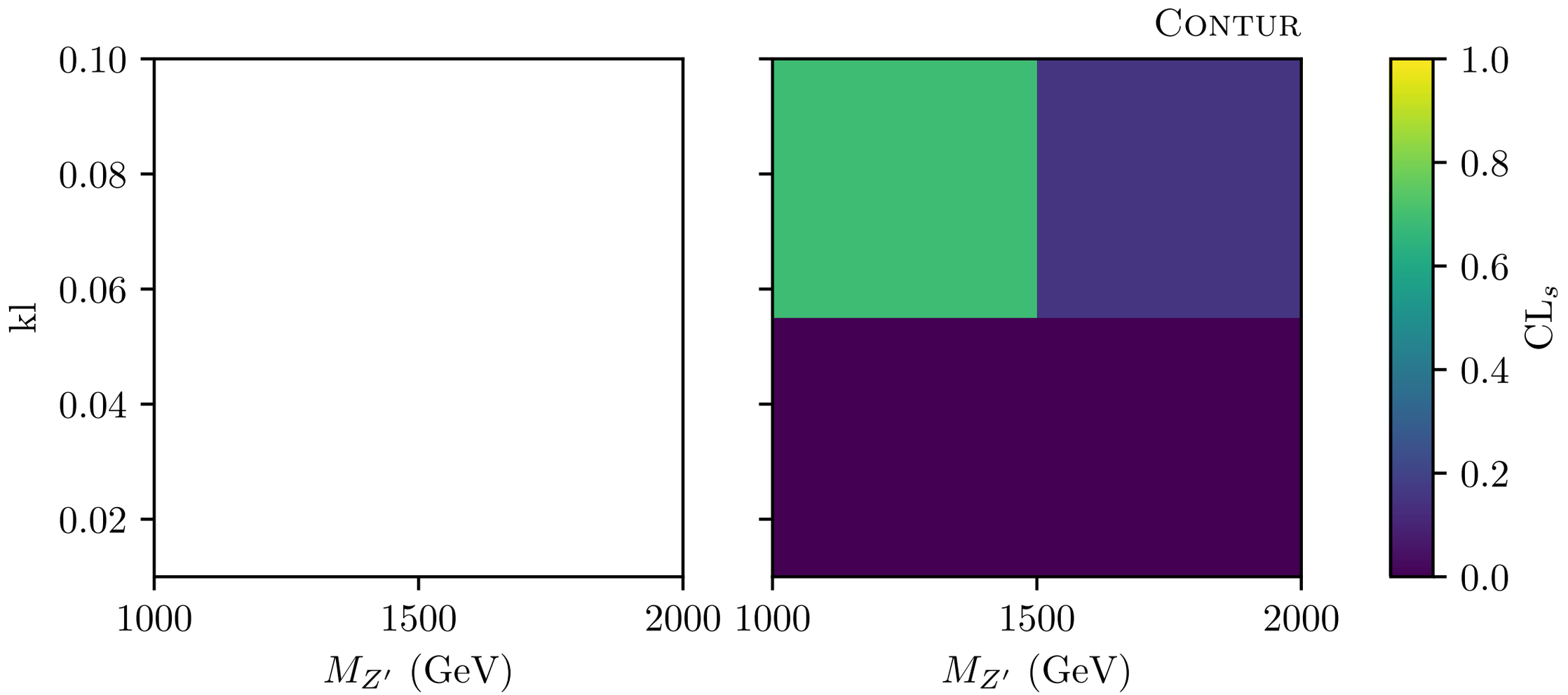
Available Results

Run	Collider	Banner	Cross section (pb)	Events	Data	Output	Action
run_01	p p 6500.0 x 6500.0 GeV	tag_1	175 ± 0.18 ± systematics	10000	parton madevent	LHE	remove run launch detector simulation
run_02	p p 6500.0 x 6500.0 GeV	tag_1	12.03 ± 0.012 ± systematics	10000	parton madevent	LHE	remove run launch detector simulation
run_03	p p 6500.0 x 6500.0 GeV	tag_1	1.981 ± 0.0017 ± systematics	10000	parton madevent	LHE	remove run launch detector simulation
run_04	p p 6500.0 x 6500.0 GeV	tag_1	0.4651 ± 0.00043 ± systematics	10000	parton madevent	LHE	remove run launch detector simulation
run_05	p p 6500.0 x 6500.0 GeV	tag_1	5.647 ± 0.0055 ± systematics	10000	parton madevent	LHE MA5_report_analysis1	remove run launch detector simulation
run_06	p p 6500.0 x 6500.0 GeV	tag_1	0.3729 ± 0.00036 ± systematics	10000	parton madevent	LHE MA5_report_analysis1	remove run launch detector simulation
run_07	p p 6500.0 x 6500.0 GeV	tag_1	0.06119 ± 6.5e-05 ± systematics	10000	parton madevent	LHE MA5_report_analysis1	remove run launch detector simulation
run_08	p p 6500.0 x 6500.0 GeV	tag_1	0.01444 ± 1e-05 ± systematics	10000	parton madevent	LHE MA5_report_analysis1	remove run launch detector simulation

Main Page

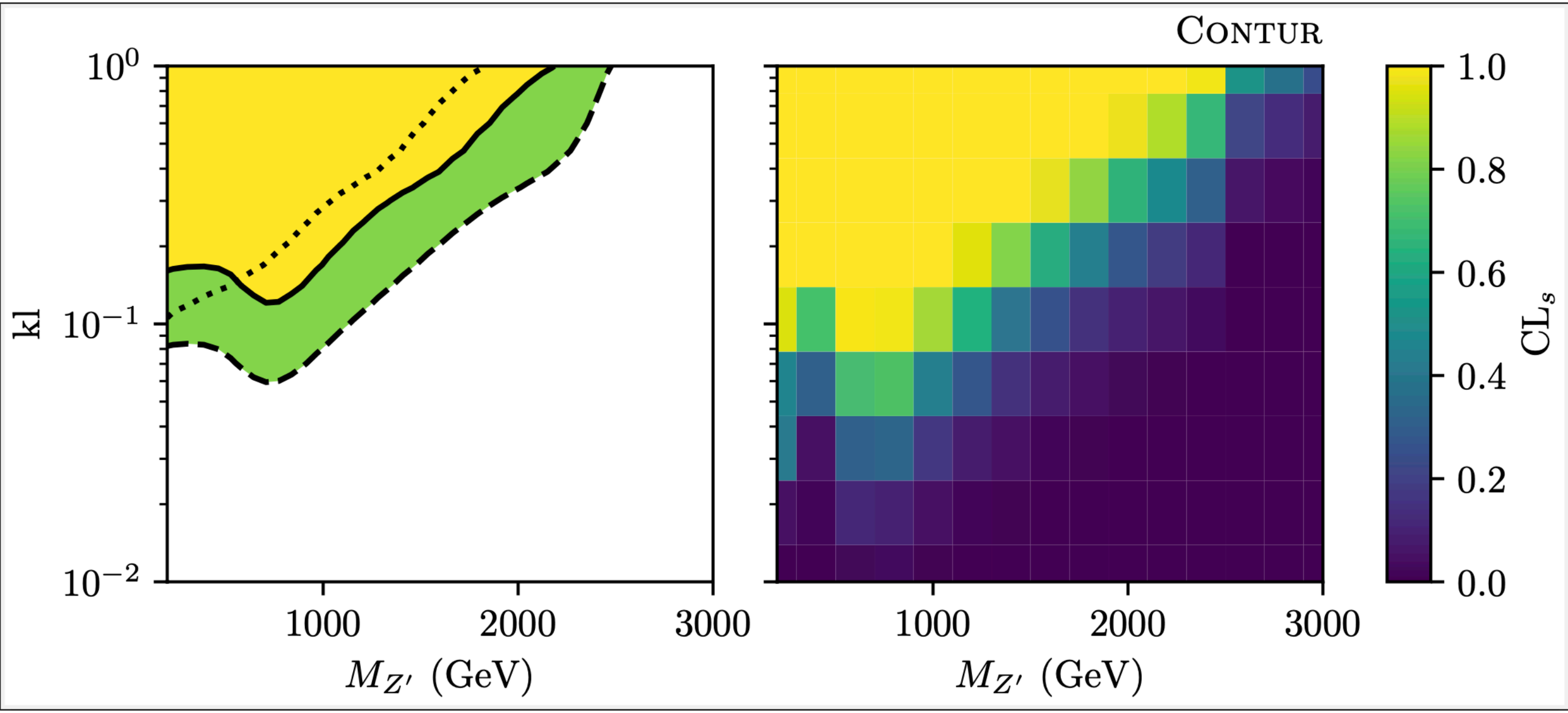
- Ratio: 0.032 // 0.031 // 0.030 // 0.031
  - ➡ Stable Branching Ratio (Good)

Excercise 5: Contour Exclusion



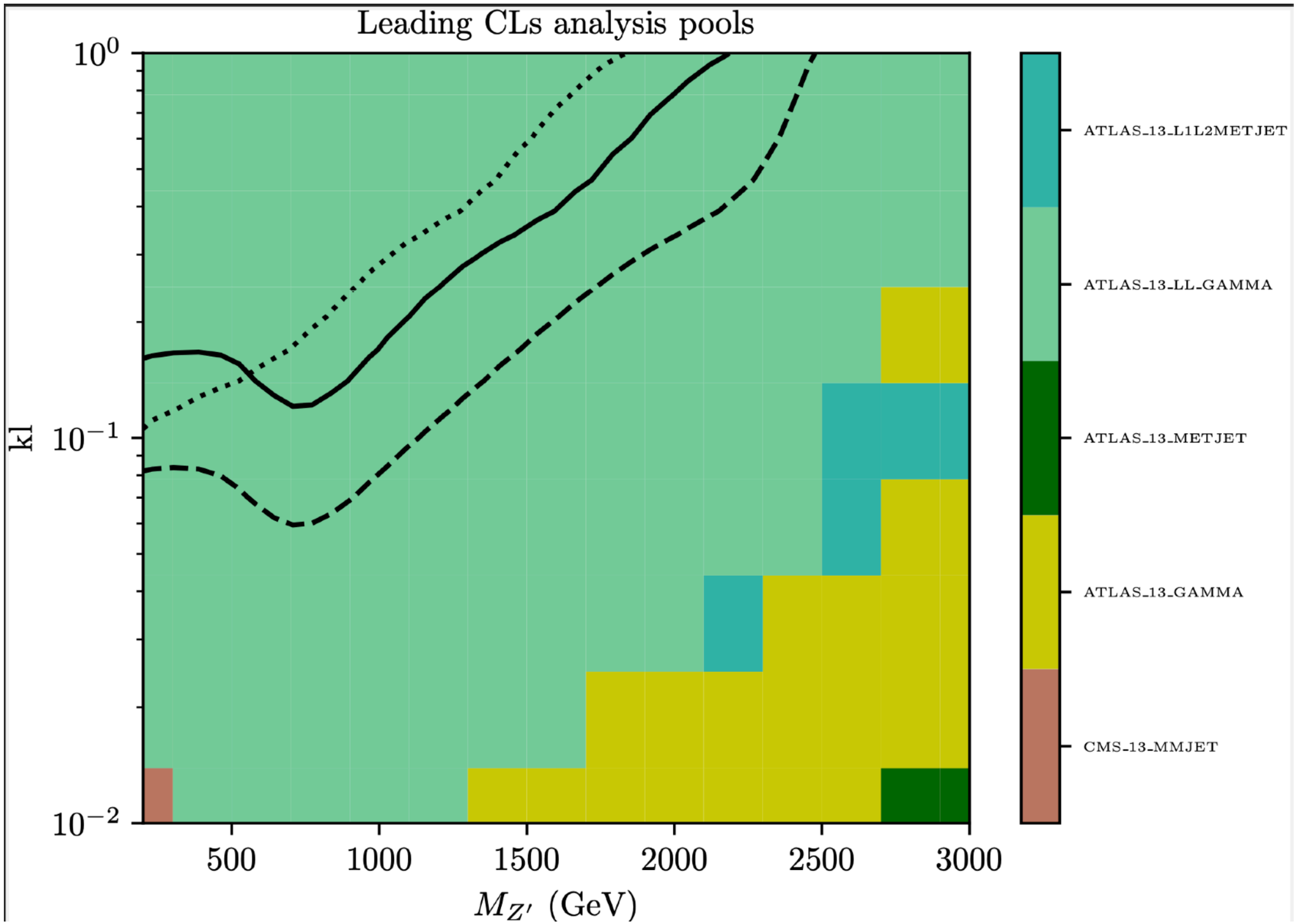
- Contur plot not really interesting
  - ➡ Too few events
  - ➡ Too few points in the grid

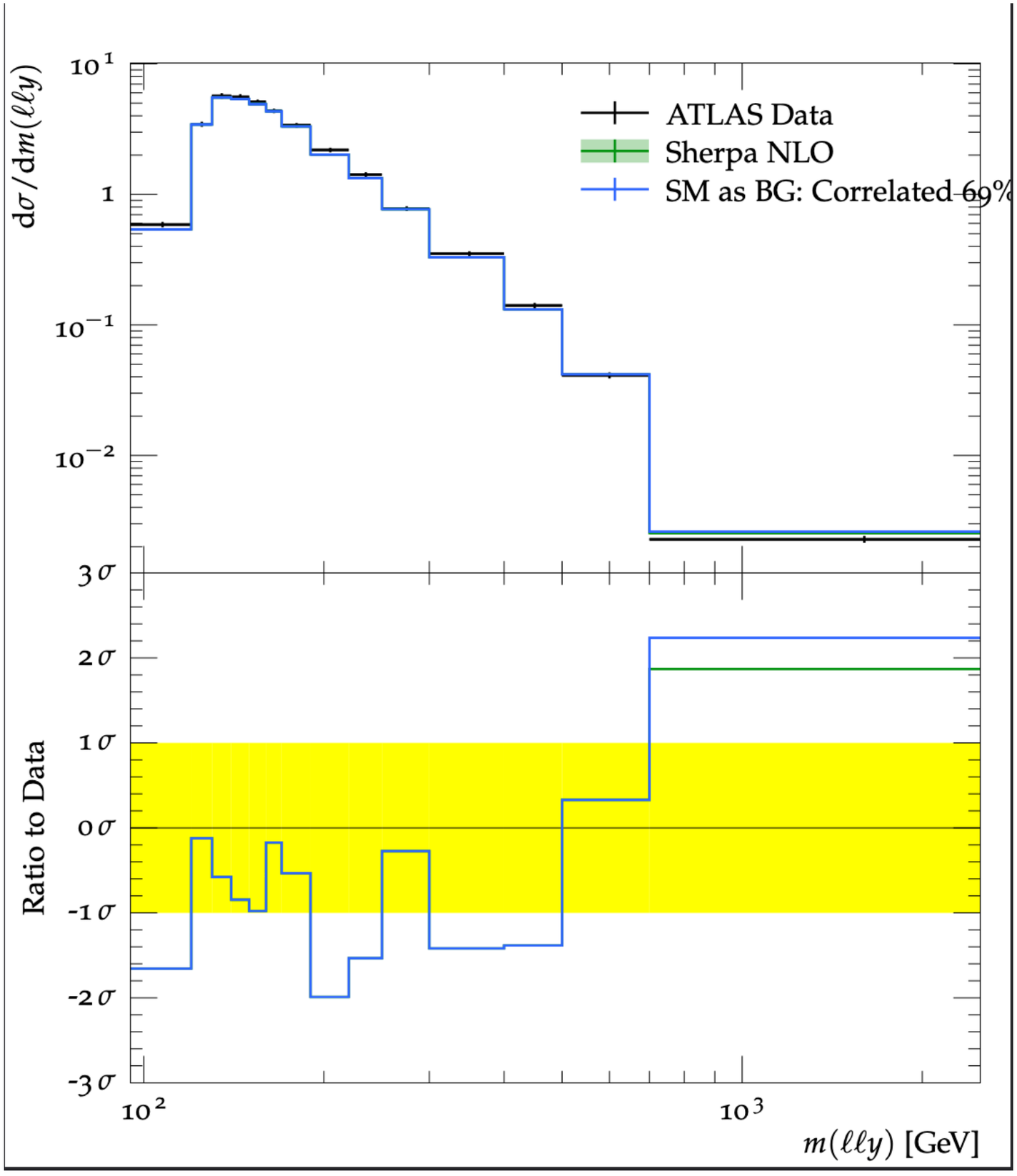
Excercise 5: Contour Exclusion



Excercise 5: Contour Exclusion

- Which analysis is the most sensitive?




ATLAS Data
Sherpa NLO
SM as BG: Correlated 69%
$d\sigma/dm(\ell\ell y)$
10^1
1
10^{-1}
10^{-2}
3σ
2σ
1σ
0σ
-1σ
-2σ
-3σ
Ratio to Data
10^2
10^3
$m(\ell\ell y)$ [GeV]