JAGIELLONIAN UNIVERSITY
IN KRAKÓW

WG2: Technical Benchmarks for Monte Carlo Generators

Alan Price on behalf of WG2
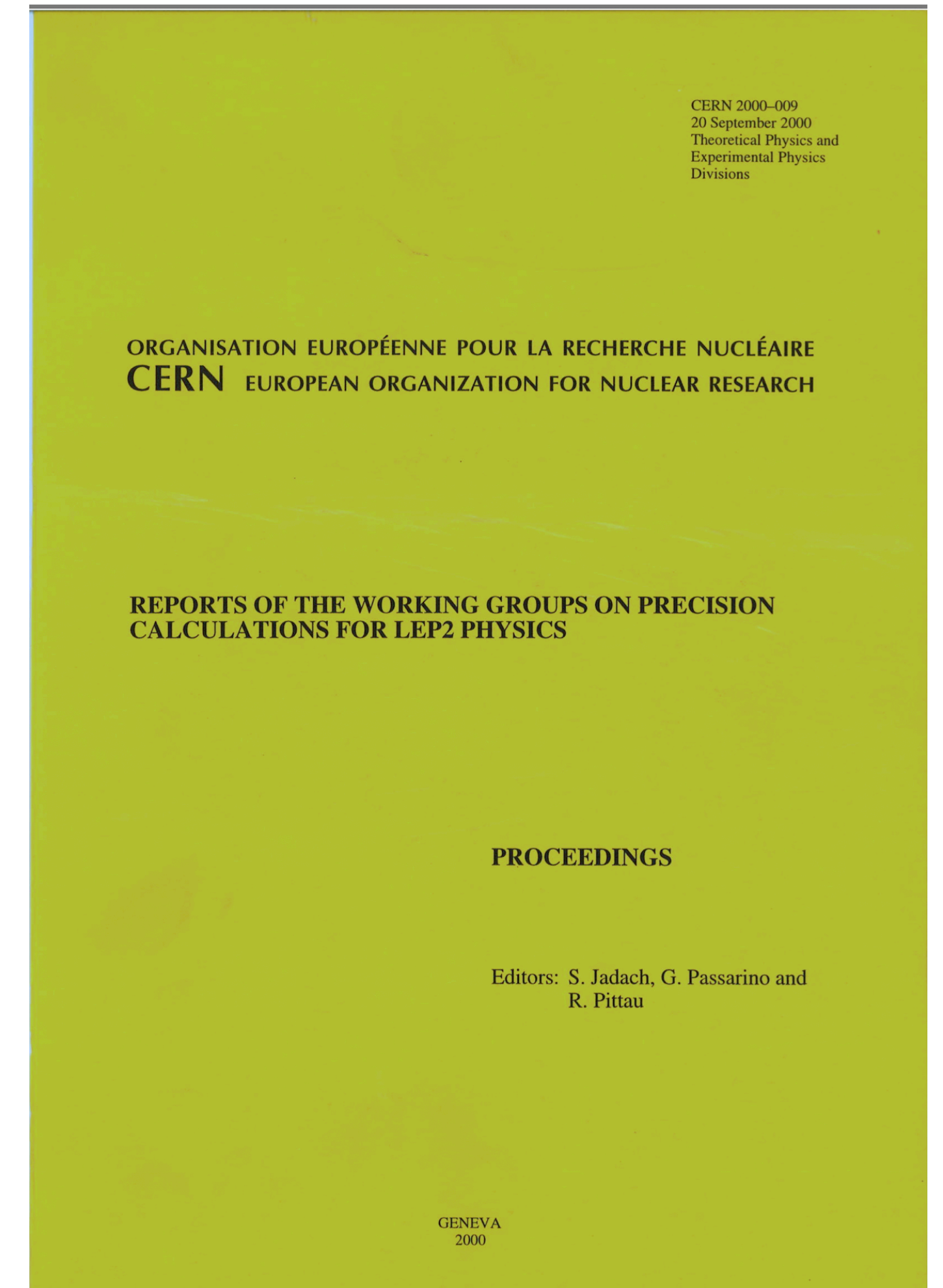**Patrizia Azzi, Fulvio Piccinini, and Dirk Zerwas**

Content

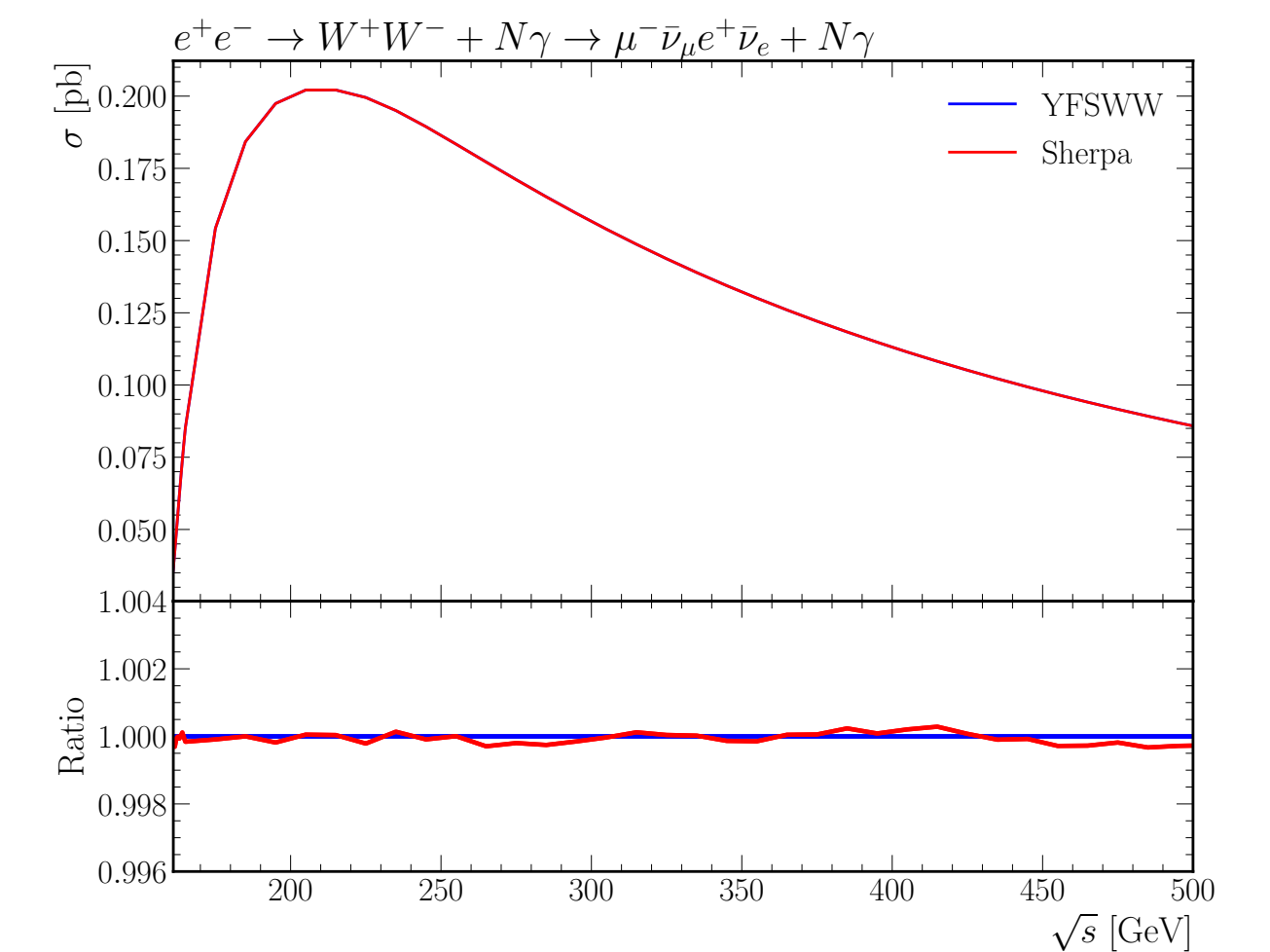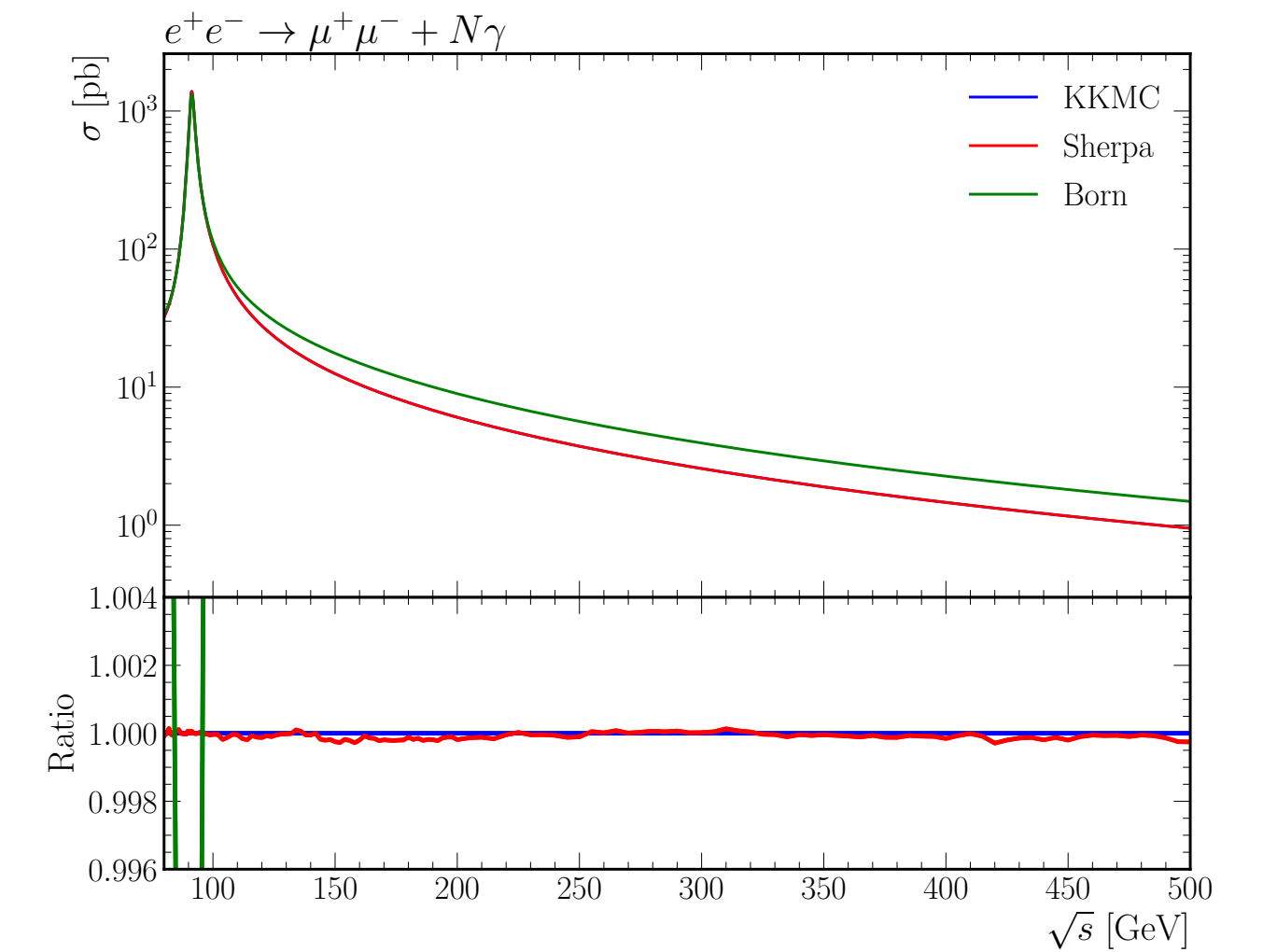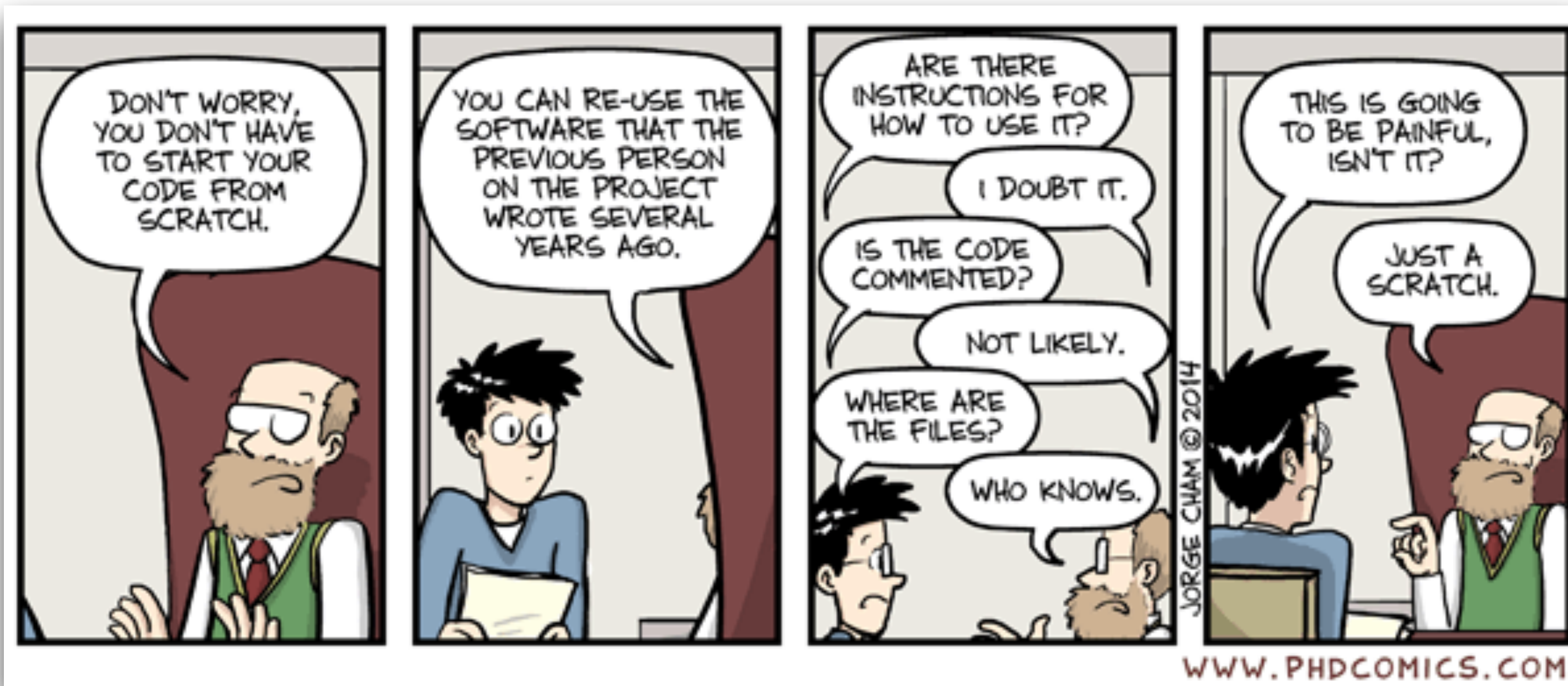❖Benchmark Aims

❖How to Benchmark

❖Future Plans and Outlook

Benchmark Aims

❖ Main goal is to provide a framework to perform *technical* test of MC generators for all possible future Higgs factories

❖ Identify possible deviations between generators

  ❖ Lead to discussions with WG1 and generator authors

❖ e+e- study has a long lifetime and MC will through many changes

  ❖ Need a benchmark or standard candle to compare to

❖ "Lessons learned from LEP2"

See F. Piccinini **Talk**

2nd Topical Meeting on Generators

CERN 2000-009
20 September 2000
Theoretical Physics and
Experimental Physics
Divisions

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

REPORTS OF THE WORKING GROUPS ON PRECISION CALCULATIONS FOR LEP2 PHYSICS

PROCEEDINGS

Editors: S. Jadach, G. Passarino and R. Pittau

GENEVA
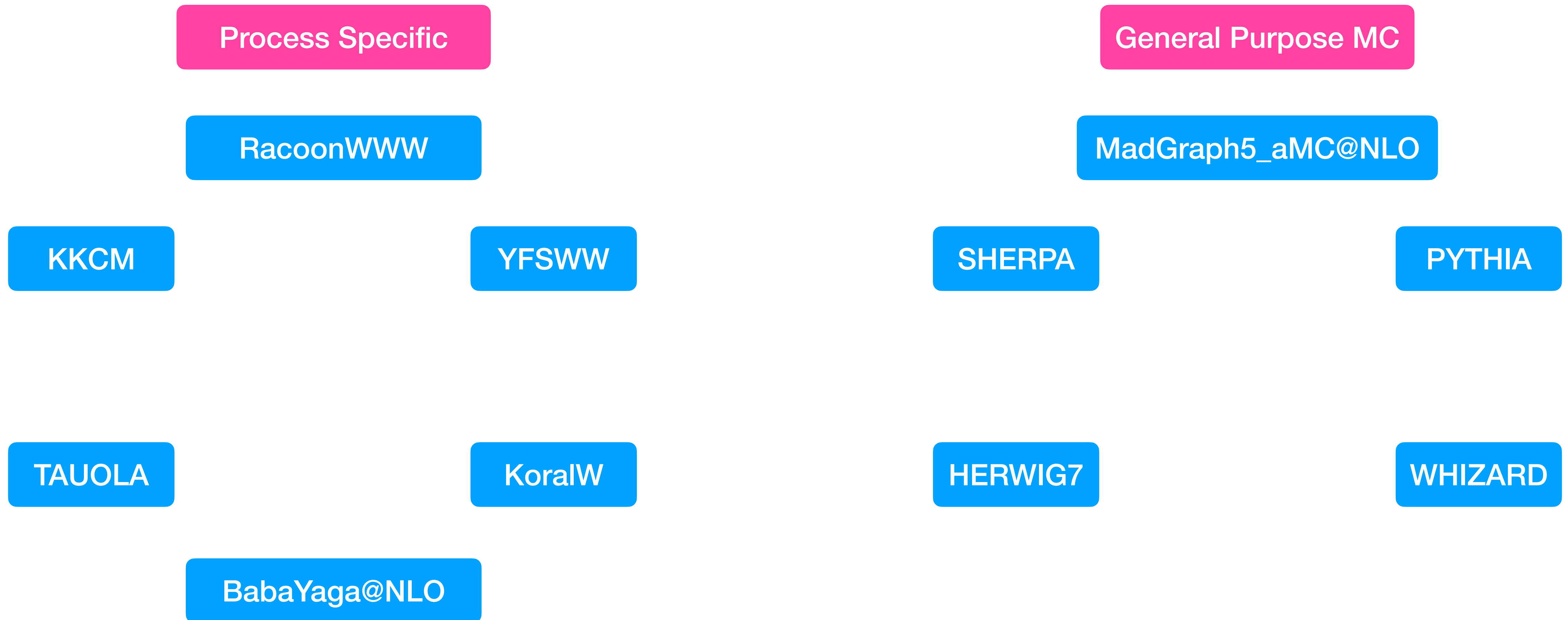2000

Motivation: Philosophy

❖ Generators are generally trying to simulate the same physics

❖ Why not have one **master** input card that will work for all MC?

➡ Authors are unlikely to change or decide on a common input!

❖ Have python module which will create generator specific runcards from one master input

❖ This will help improve reproducibility and hopefully reduce input errors

❖ Preserve the "LEP era" MC, who may not have active authors on the timeline of a Higgs Factory

Monte Carlo Tools

Process Specific

General Purpose MC

RacoonWWW

MadGraph5_aMC@NLO

KKCM

YFSWW

SHERPA

PYTHIA

TAUOLA

KoralW

HERWIG7

WHIZARD

BabaYaga@NLO

See Carlo Calame **Talk**

Monte Carlo Tools

Process Specific

RacoonWWW

KKCM

YFSWW

TAUOLA

KoralW

BabaYaga@NLO

❖ Well validated against e^+e^- data

❖ Most benchmarked for LEP

❖ New versions released

➡ Benchmarked by authors

❖ Good Standard candles to compare against

❖ Some still state of the art

Monte Carlo Tools

❖ Well validated in LHC environment

❖ Compared against LEP date e.g tuning

❖ Some detailed validatiation already done for e^+e^-

  ❖ Whizard vs Madgraph **Pia Bredt Thesis**

  ❖ Sherpa YFS vs LEP YFS **AP Thesis**

General Purpose MC

SHERPA

PYTHIA

HERWIG7

WHIZARD

MadGraph5_aMC@NLO

MC Contacts

❖ **Herwig7**: Simon Plaetzer

❖ **Madgraph5_aMC@NLO**: Stefano Frixione

❖ **Pyhtia**: Ilkka Helenius

❖ **Sherpa**: Daniel Reichelt

❖ **Tauola** et al: Zbigniew Was

❖ **Whizard**: Juergen Reuter

❖ **Powheg**: Emanuele Re

❖ **BabaYaga**: Carlo Carloni Calame

❖ **Geneva**: Simone Alioli

❖ **Guinea Pig**: Daniel Schulte

❖ **CIRCE**: Thorsten Ohl

❖ Point of first contact for the benchmark study

❖ Regular contact with authors outside of ECFA

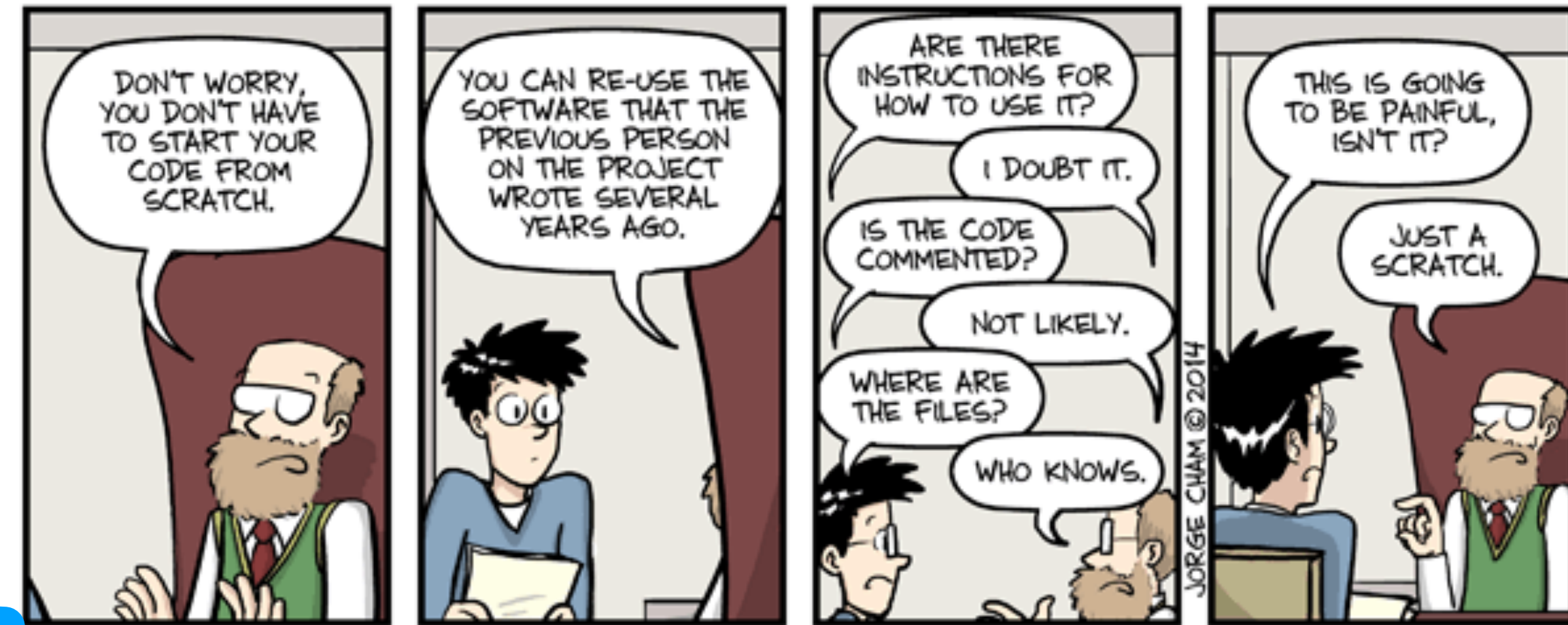# How to Benchmark?

Reproducibility

Paper

Reproducible with
some effort

**+ Run-card**

Easily
Reproduced

+ Analysis Files

Easily Reproduced

And trivially to validate

Reproducibility

❖ Provide **"Add-on"** to Key4Hep framework

❖ Should be simple enough that:

    ❖ New process can be easily added

    ❖ MC authors can update interfaces if needed

❖ Keep some public event records

    ❖ Juggle usefulness vs Storage

❖ More dedicate test for new generator releases

We already have a sophisticated software system!
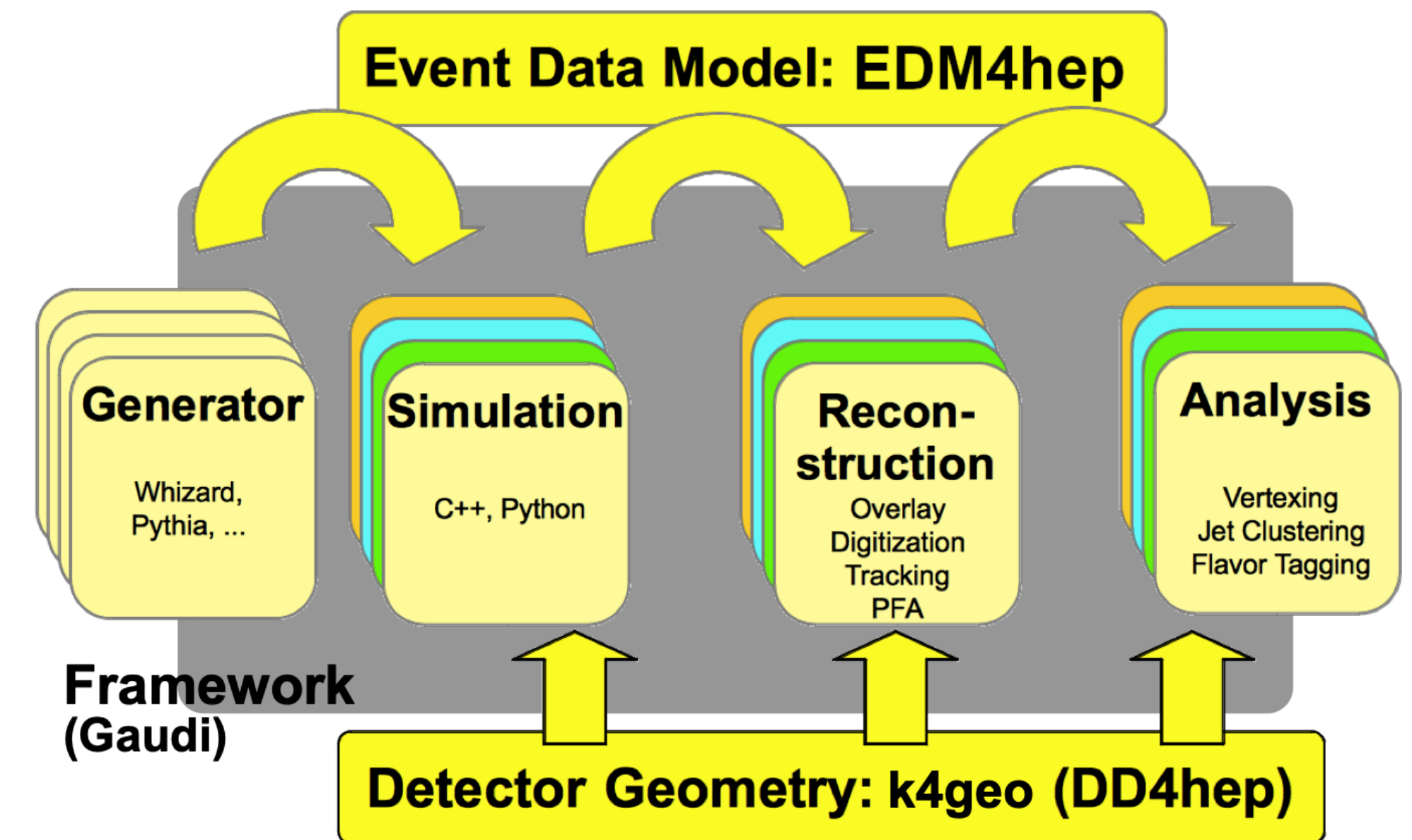
See Juraj Smieško **Talk**

Input

❖ Think about reproducibility!

    ❖ With such a long timeline for lepton colliders
       results should be easily reproduced

❖ Develop in house tool that will automatically:

    ❖ Run all MC from one input card, allows for easy setting
      of global parameter

    ❖ Collect and compare final results e.g Cross-sections

    ❖ Allow for easy comparison of differential distributions

    ❖ Tricky but possible for technical checks

```
Generators:
  - Sherpa
  - Whizard
  - Madgraph
  - KKMC
  - Pythia

OutputFormat: hepmc3
OutDir: Run-Cards
Events: 10000
EventMode: unweighted

SqrtS: 91.2
Model: SM
ISRMode: 0

Processes:
  Muon:
    Final: [13, -13]
    Order: [2,0]

  Tau:
    Final: [15, -15]
    Order: [2,0]

Sherpa:
  Run:
    EW_SCHEME: 3


ParticleData:
  23:
    mass: 91.1876
    width: 2.4952
```

Output

❖ For all generators we should aim for a consistent output

    ❖ At top-level, tables of cross-sections, differential distributions

❖ Store all outputs in a systematic way

❖ Tricky but possible for technical checks

❖ Long term storage of event files and make them publicly available

```
Generators:
  - Sherpa
  - Whizard
  - Madgraph
  - KKMC
  - Pythia

OutputFormat: hepmc3
OutDir: Run-Cards
Events: 10000
EventMode: unweighted

SqrtS: 91.2
Model: SM
ISRMode: 0

Processes:
  Muon:
    Final: [13, -13]
    Order: [2,0]

  Tau:
    Final: [15, -15]
    Order: [2,0]

Sherpa:
  Run:
    EW_SCHEME: 3

ParticleData:
  23:
    mass: 91.1876
    width: 2.4952
```

Output

❖ k4GeneratorsConfig also provides event format conversion

❖ Supports both LHEF and HEPMC conversion to EDM4HEP format

❖ After conversations with the HEPMC authors it is envisioned that this conversion will take place within HEPMC. This will allow MC to generate EDM4HEP without a dedicated interface

❖ Thanks to Dirk Zerwas!

```
Generators:
  - Sherpa
  - Whizard
  - Madgraph
  - KKMC
  - Pythia

OutputFormat: hepmc3
OutDir: Run-Cards
Events: 10000
EventMode: unweighted

SqrtS: 91.2
Model: SM
ISRMode: 0

Processes:
  Muon:
    Final: [13, -13]
    Order: [2,0]

  Tau:
    Final: [15, -15]
    Order: [2,0]

Sherpa:
  Run:
    EW_SCHEME: 3

ParticleData:
  23:
    mass: 91.1876
    width: 2.4952
```

What to Benchmark?

❖ We will consider all **process** of interest to all **colliders** at all relevant **energies**

❖ Add your favourite process to our living, evolving document **here**

❖ If two or more MC support a feature it should be benchmarked

❖ E.g Coulomb correction in W+W- production. Not present in all generators

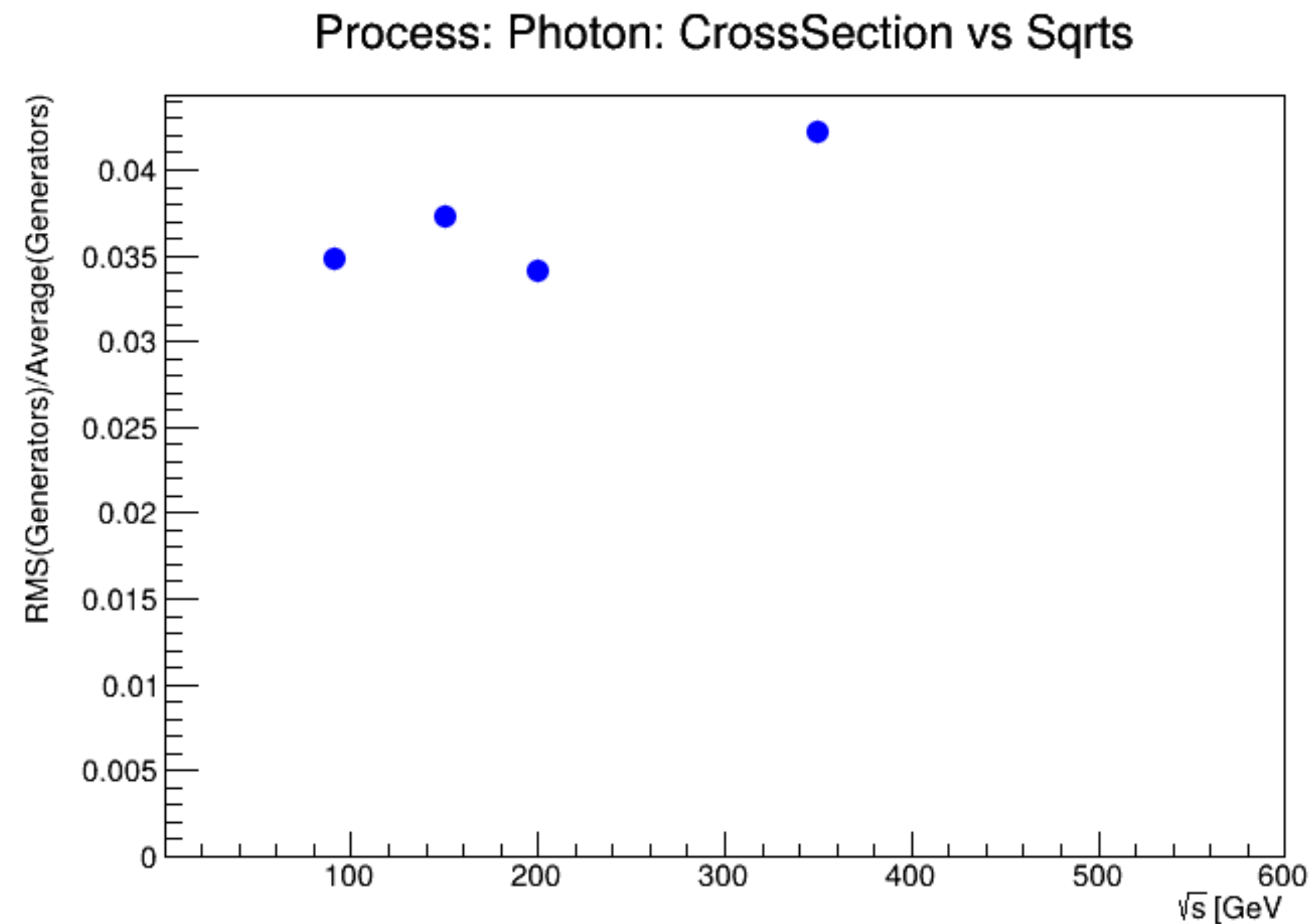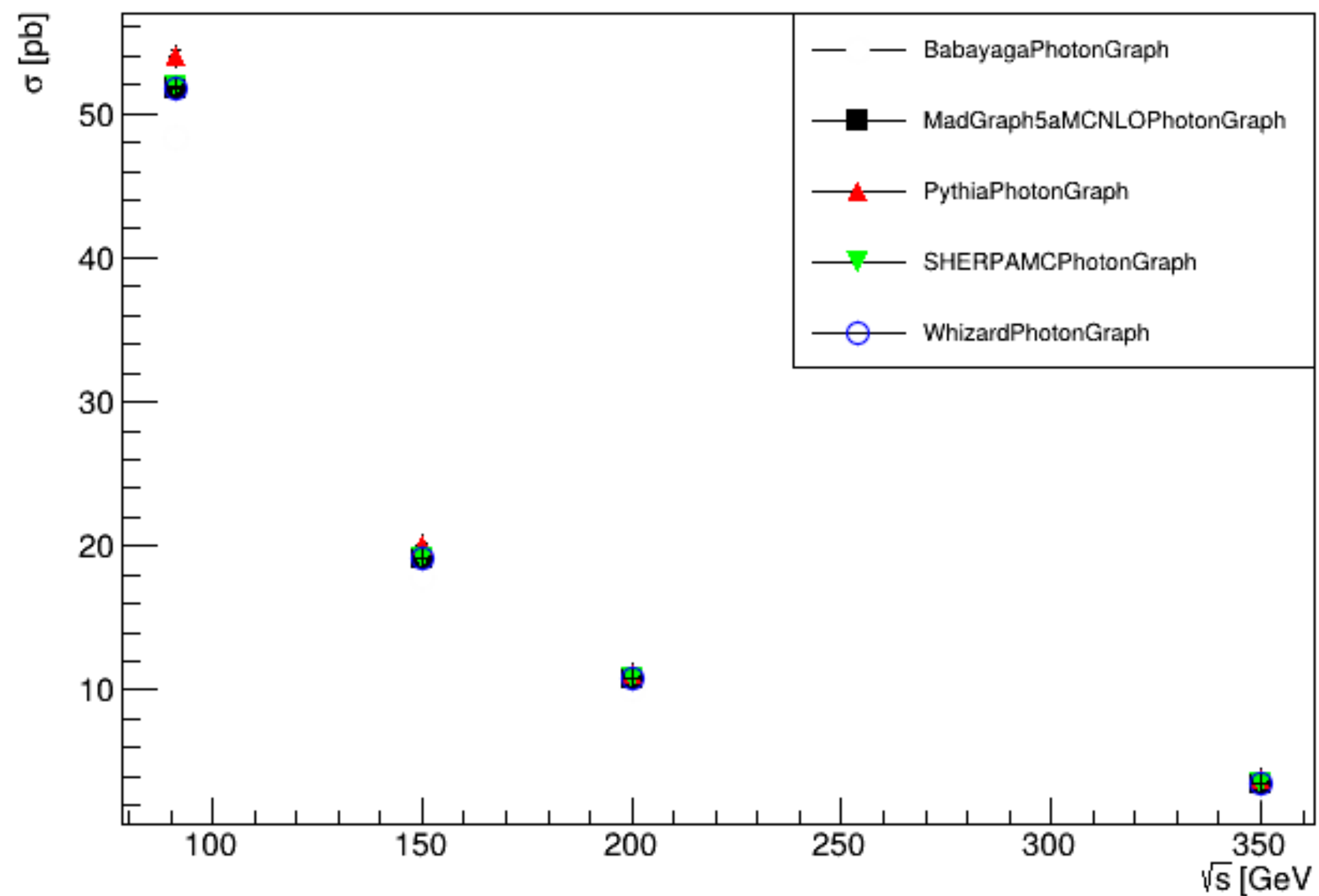We have input cards for all relevant $2 \rightarrow 2$ processes

We seeing excellent agreement in most cases, one or two effects (<5%) that requires more detailed study
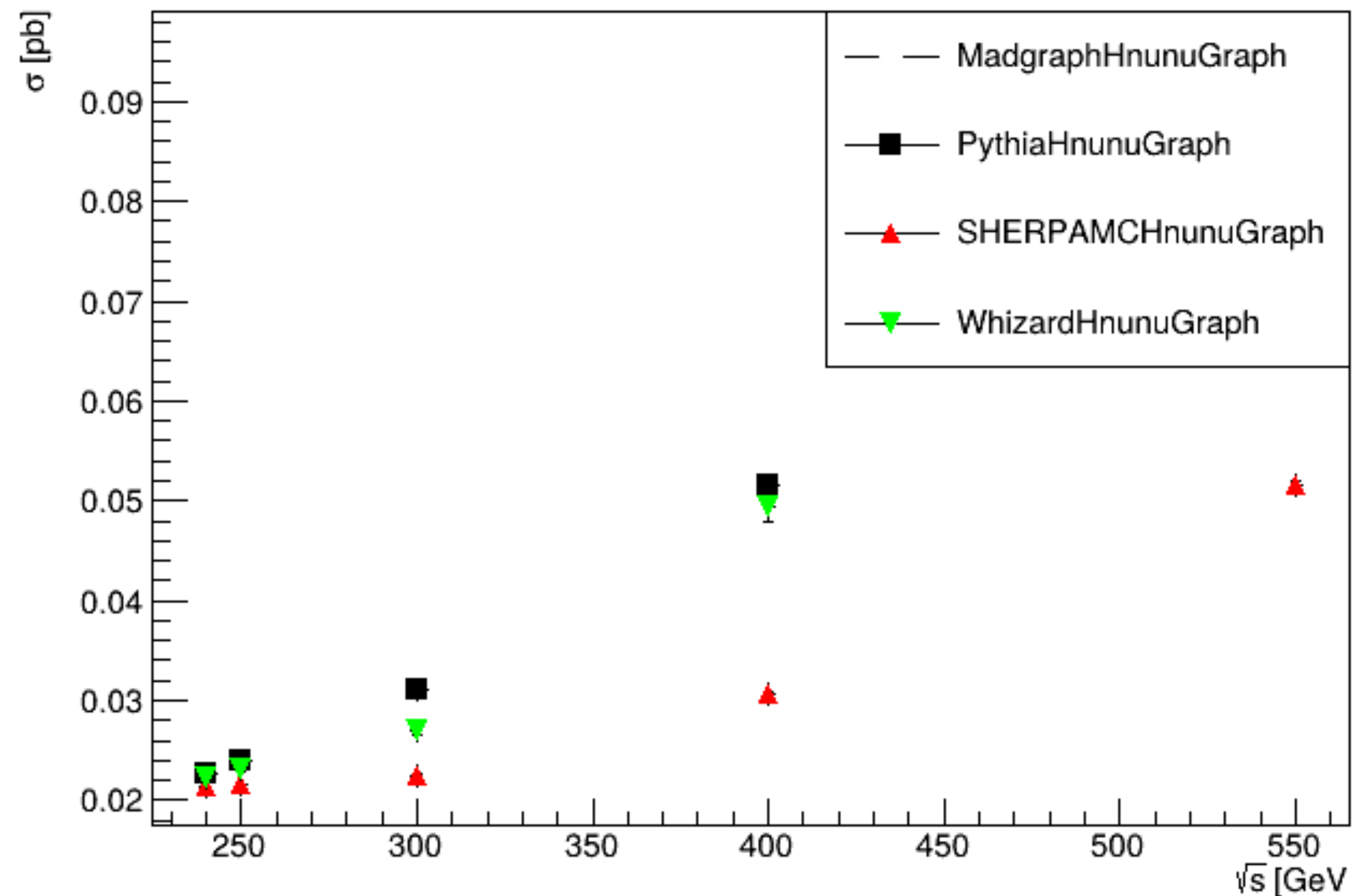
Differential distributions are also in good agreement
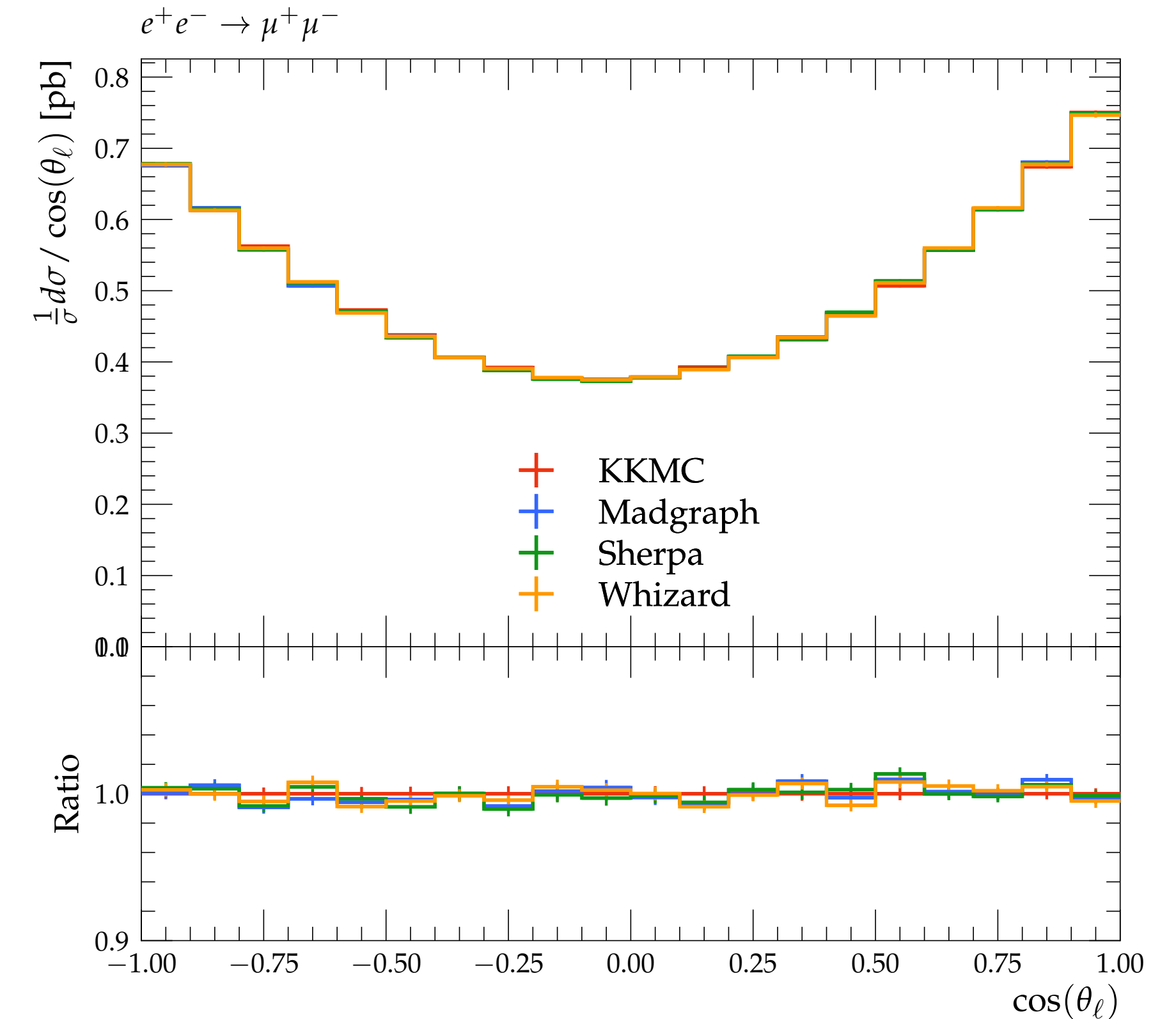
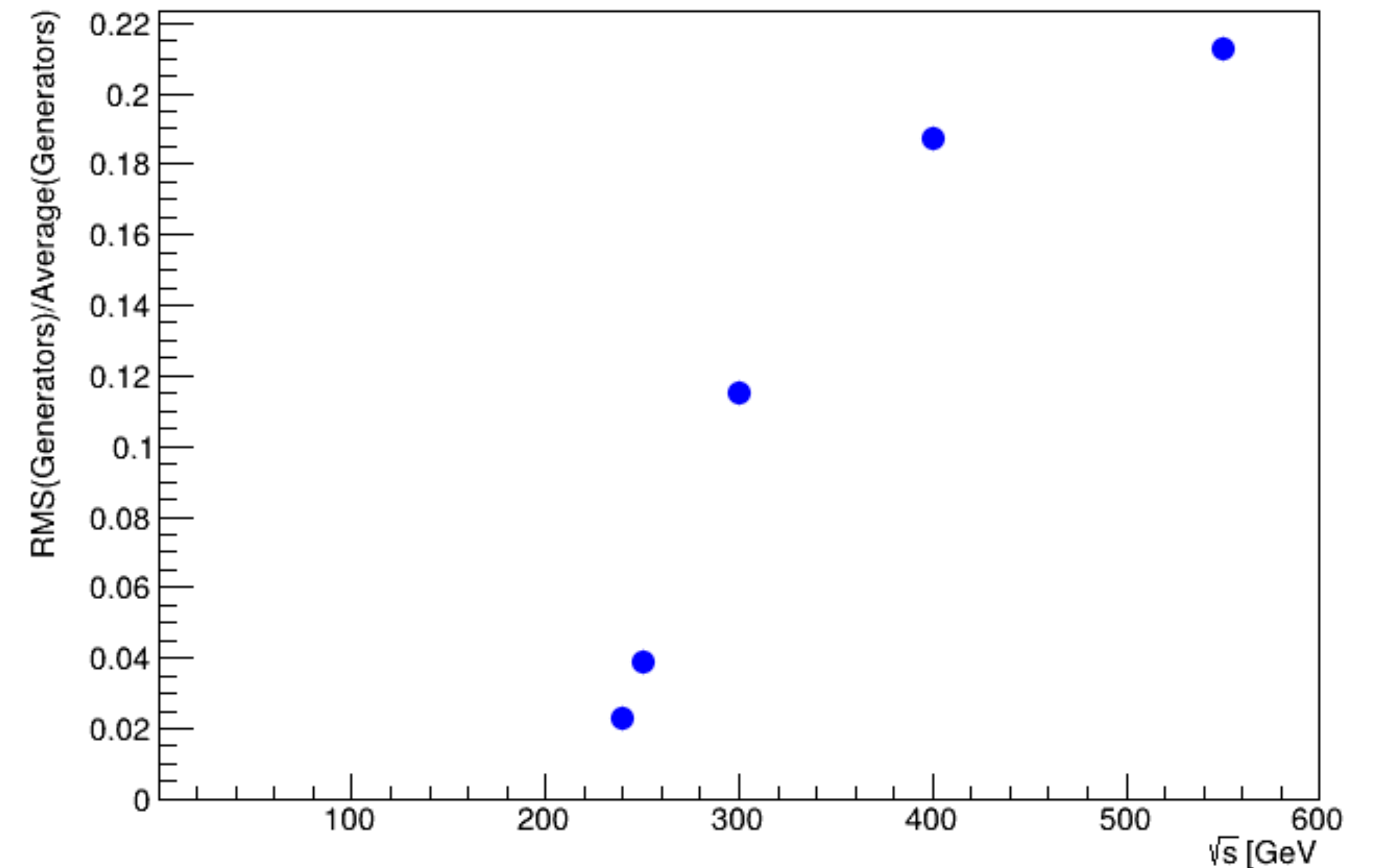$$e^+e^- \to \gamma\gamma$$

Thanks to Dirk Zerwas for the plots

$$e^+e^- \rightarrow H\nu\bar{\nu}$$

Issue with Sherpa's Z width setting, Resolved now

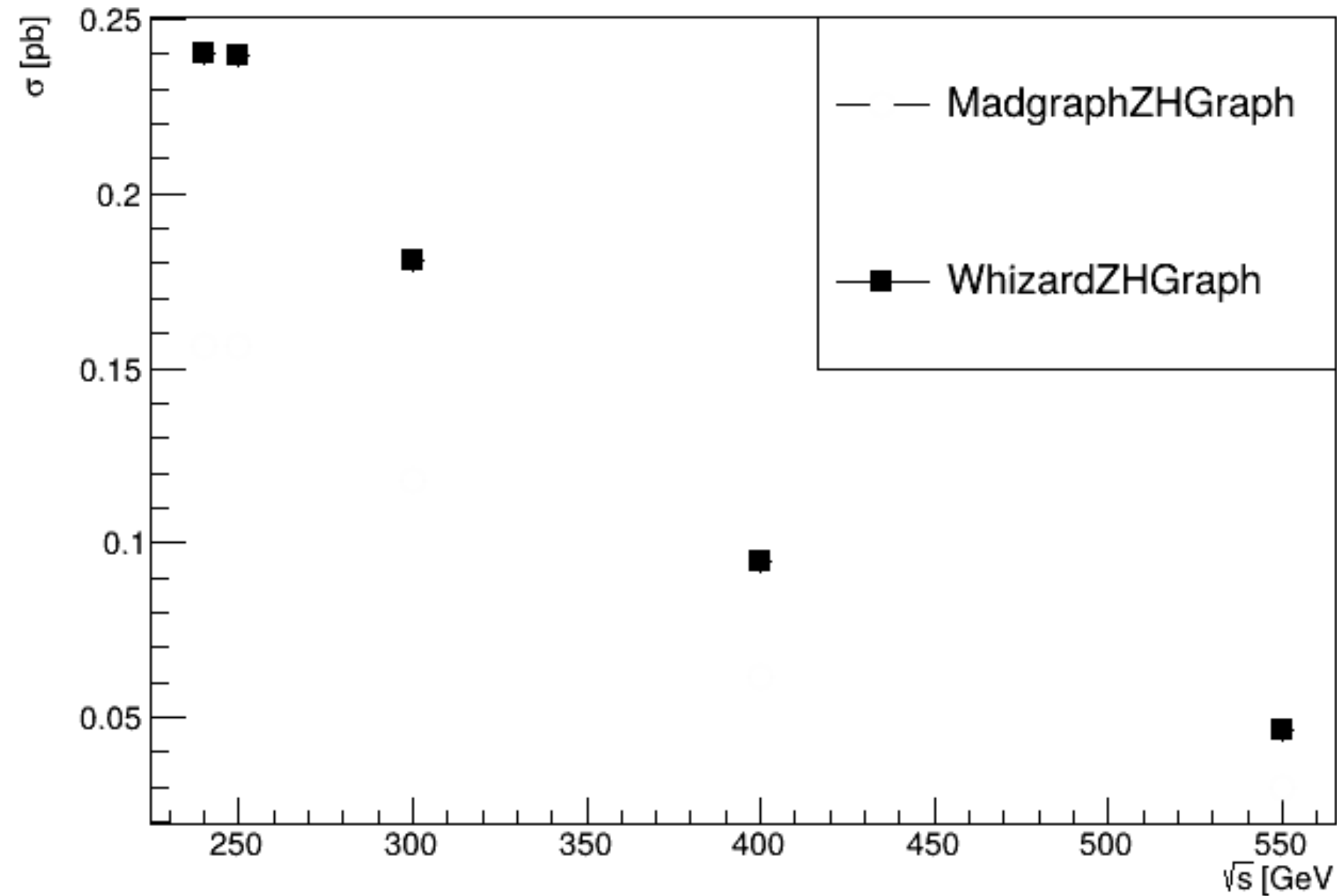

Thanks to Dirk Zerwas for the plots
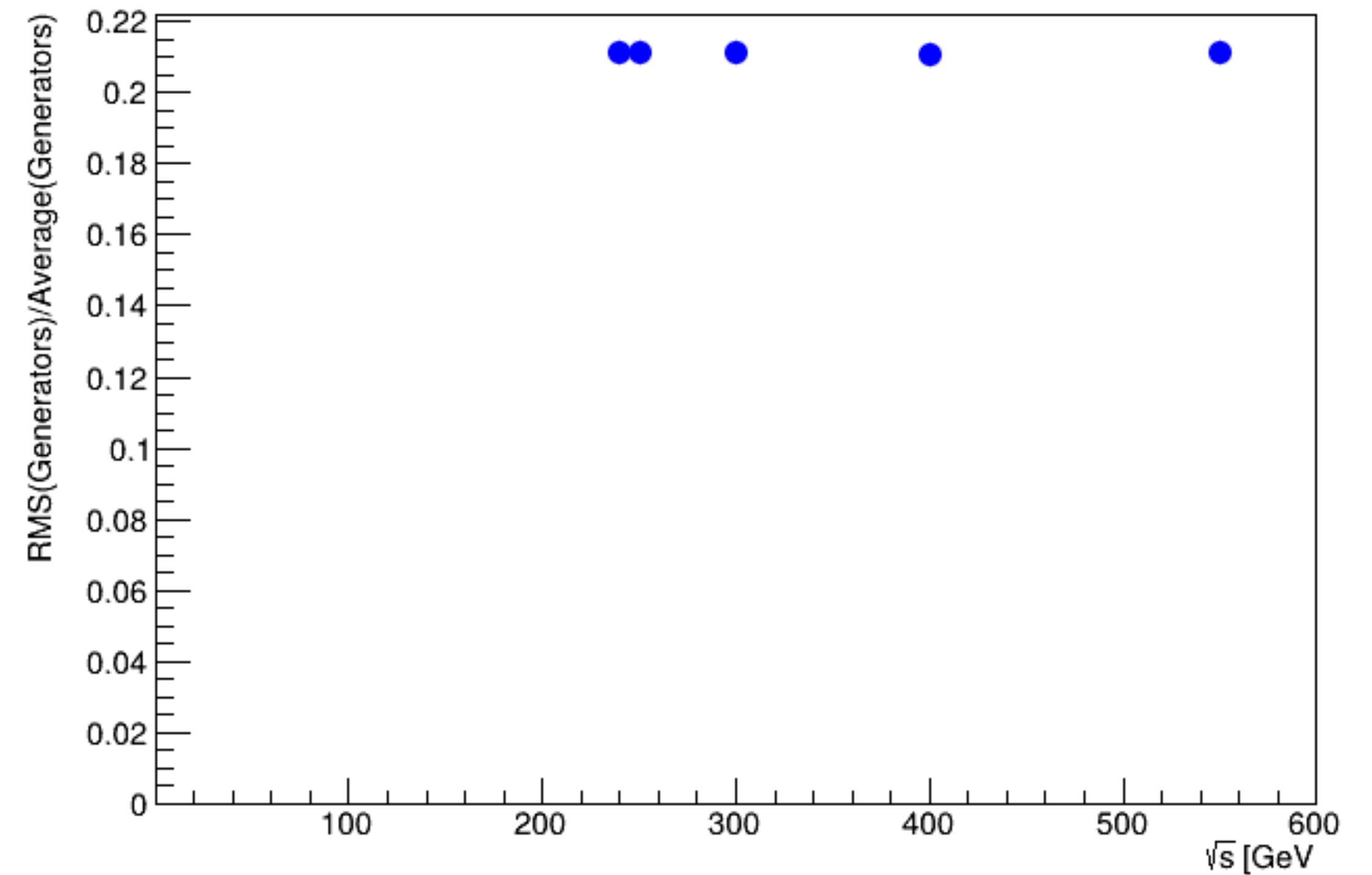
$$e^+e^- \rightarrow HZ$$

"Feature like check" Polarised Cross-Section from both Madgraph and Whizard

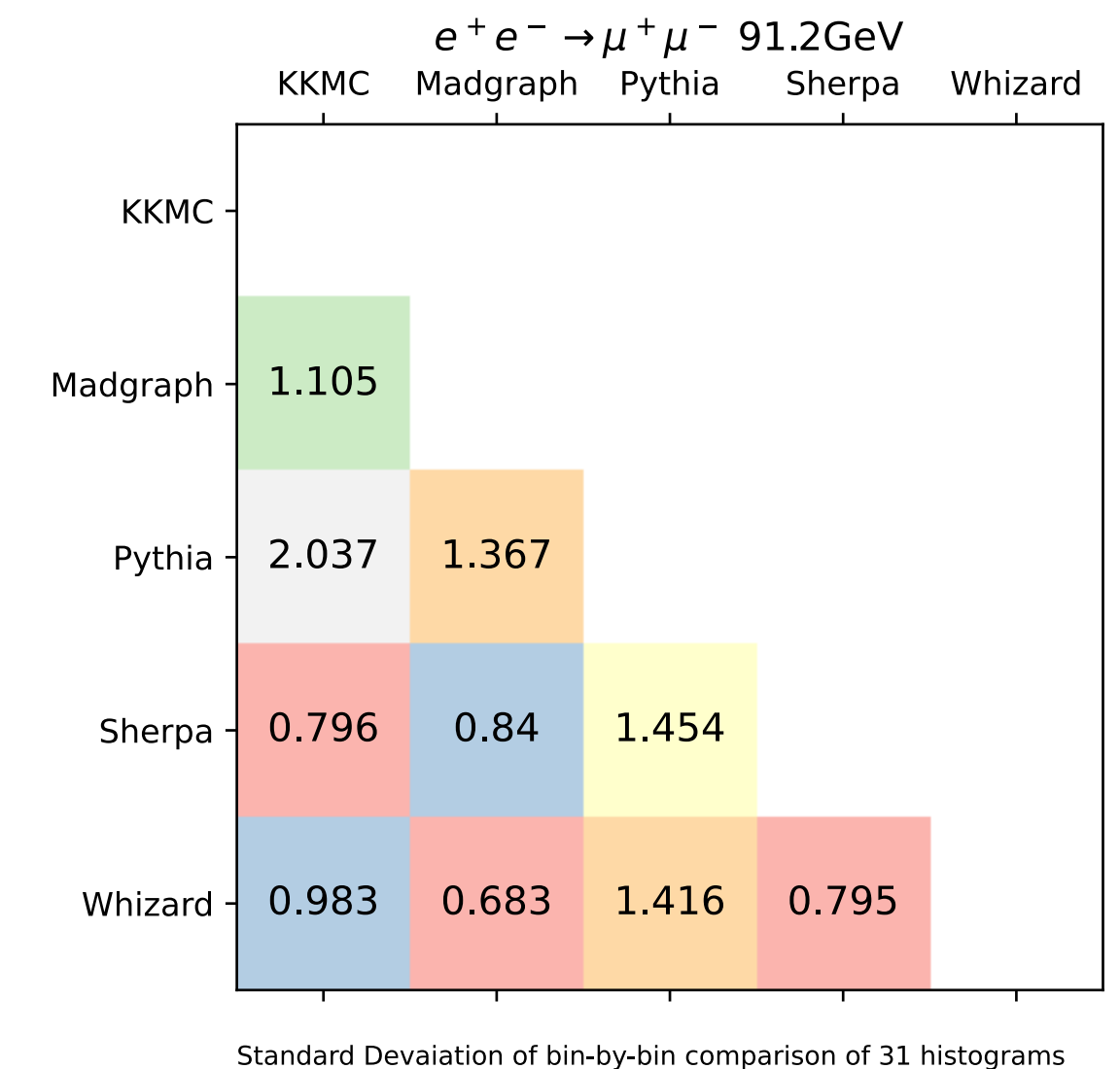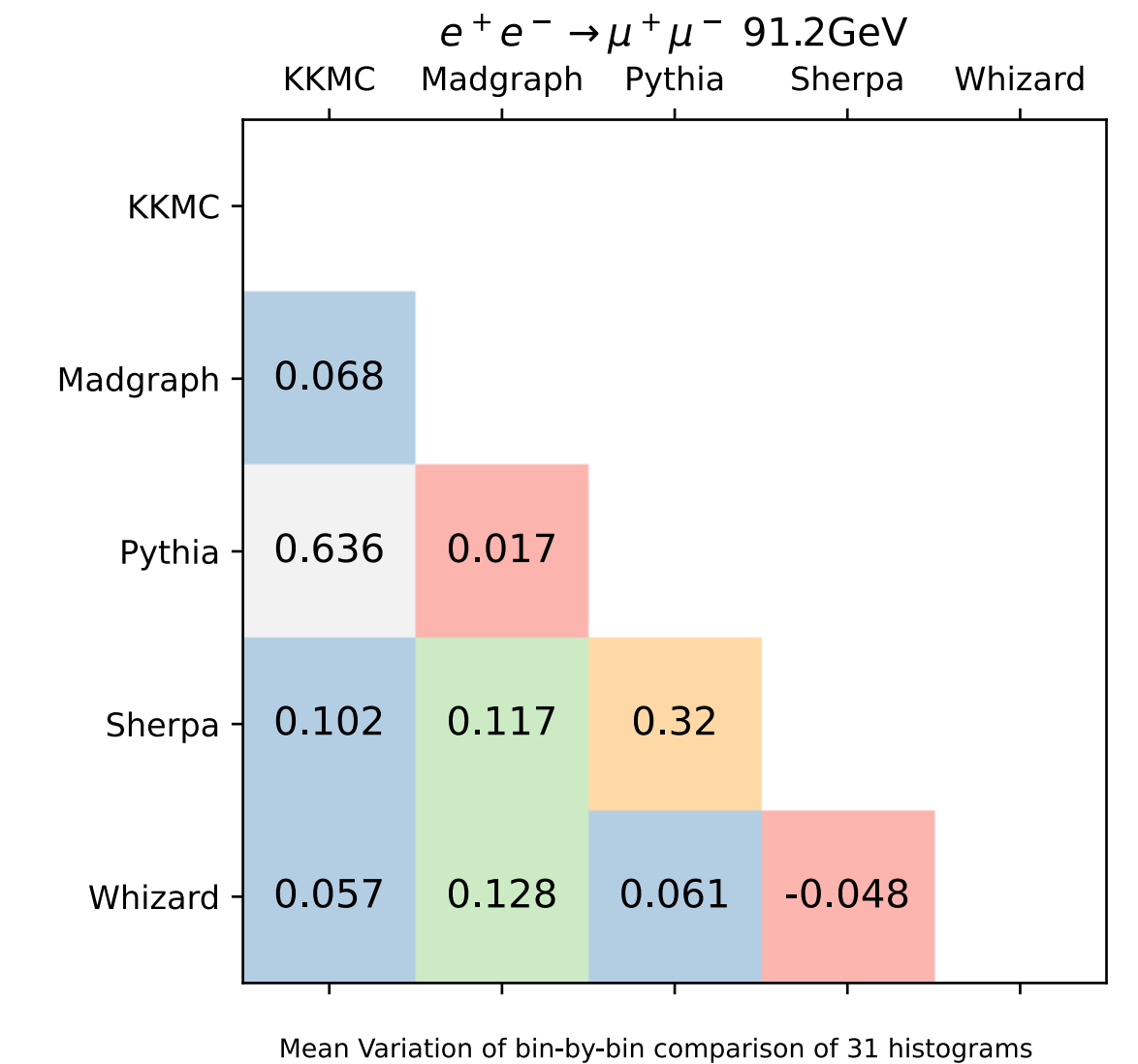Sherpa3 also supports Polarisation and will be included here also
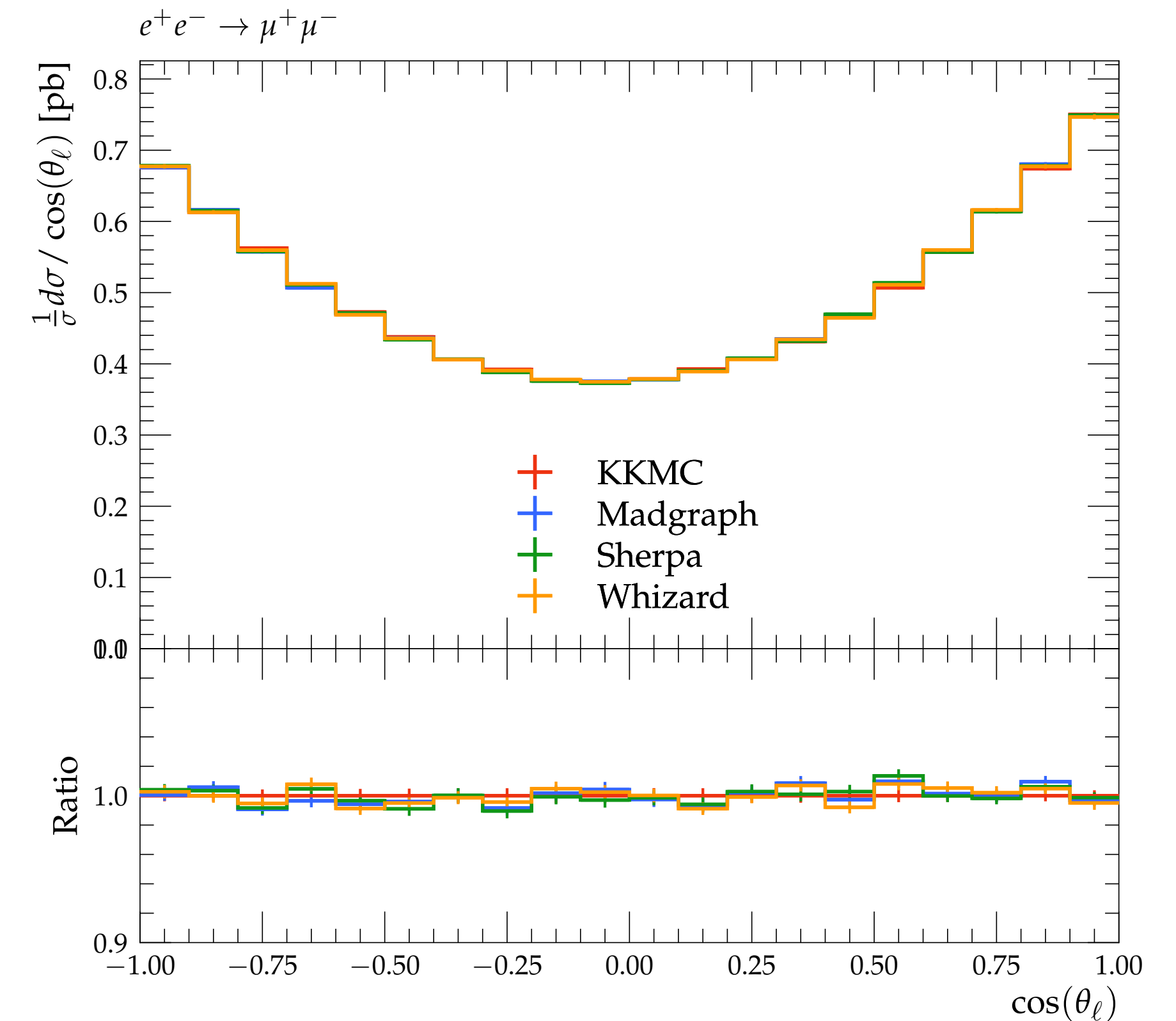

Thanks to Dirk Zerwas for the plots

ECFA Report: What to contribute?

❖ Tables of Cross-Sections are envisioned, so future researches can quickly cross-check

❖ Some key differential distributions will also be include but too many can be overwhelming

❖ Use statistical methods to perform bin-by-bin analysis between all generators to make summary plots

❖ Close contact with the generator editors, Carlo Calame , Juergen Reuter, and Marco Zaro

$e^+e^- \rightarrow \mu^+\mu^-$ 91.2GeV

	KKMC	Madgraph	Pythia	Sherpa	Whizard
KKMC					
Madgraph	0.068				
Pythia	0.636	0.017			
Sherpa	0.102	0.117	0.32		
Whizard	0.057	0.128	0.061	-0.048	

Mean Variation of bin-by-bin comparison of 31 histograms

$e^+e^- \rightarrow \mu^+\mu^-$ 91.2GeV

	KKMC	Madgraph	Pythia	Sherpa	Whizard
KKMC					
Madgraph	1.105				
Pythia	2.037	1.367			
Sherpa	0.796	0.84	1.454		
Whizard	0.983	0.683	1.416	0.795	

Standard Devaiation of bin-by-bin comparison of 31 histograms

```
Generators:
  - Sherpa
  - Whizard
  - Madgraph
  - KKMC

OutputFormat: hepmc3
OutDir: Run-Cards
Events: 10000000
EventMode: weighted

SqrtS: 91.2
Model: SM

Processes:
  Muon91.2:
      Final: [13, -13]
      Order: [2,0]
      ISRMode: 0

Selectors:
  Process:
    Muon91.2:
      PT:
        Max: 45.6
        Min: 5
        Flavour: [-13,13]
```


Key4Generators is now at the "hit the button" stage