MC Working Group Report

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Outline

1. Pre-CDR status and Working Group

2. MC introduction

   Motivation & history & Status & CEPC

3. Activities

   Seminars & Schools & Workshops

   Tool Development;

   Physics Potential

4. Next Steps

1. Pre-CDR status and Working Group

Pre-CDR: Monte Carlo Tools for future collider projects

Tongguang Cheng, Sergei Chekanov,Bo Feng, Bin Gong,Tao Han,Gang Li,Liang Li,Qiang Li,Zhao Li, Meenakshi Narain,Sanjay Padhi,Meade Patrick,Jimmy Proudfoot, Huilin Qu,Manqi Ruan,Dayong Wang,Jian-Xiong Wang,Kechen Wang, Liantao Wang,Yiwen Wen,Yongcheng Wu,Keping Xie,Qi-Shu Yan,Daneng Yang, Gao Yu,Bin Zhang,Jian-Hui Zhang, Xiao-Ran Zhao, Zhijie Zhao

- International Collaborations;
- Theorists and Experimentalists

Local MC working Groups

Coordinators: Jianxiong Wang (IHEP) and Qi-shu Yan (UCAS)

At present, we have 12 affiliations and 23 core members in total.

1. CCNU (Central China Normal University)

   Xin-Qiang Li

2. HBU (Hebei University)

   Tai-Fu Feng and Shu-Min Zhao

3. HZNU (Hangzhou Normal University)

   Qing-Jun Xu

4. IHEP (Institute of High Energy Physics, CAS)

   Yu Feng, BG, Zhao Li and Jian-Xiong Wang

5. PKU (Peking University)

   Qiang Li and Hua-Sheng Shao

6. SDU (Shandong University)

   Shou-Shan Bao, Hong-Lei Li, Shi-Yuan Li and Zong-Guo Si

7. SJTU (Shanghai Jiao Tong University)
   Jian-Hui Zhang
8. SYSU (Sun Yat-Sen University)
   Hong-Hao Zhang
9. UCAS (University of Chinese Academy of Science)
   Qi-Shu Yan and Xiao-Ran Zhao
10. USTC (University of Science and Technology of China)
   Lei Guo, Wen-Gan Ma and Ren-You Zhang
11. ZJU (Zhejiang University)
   Bo Feng
12. ZZU (Zhengzhou University)
   Guo-Li Liu

Roles	Core Members
Amplitude Computations(TH)	B. Feng,J.H.Zhang, Z.Li
Physics Study	Q.J. Xu[F]
H/W/Z, QCD/EW corrections	T.F. Feng, S.M. Zhao, X.Q. Li
FDC and ME generators	J.X. Wang, B. Gong, Y. Feng, Z. Li
TOOLKITS DEVELOPMENT	Q. LI, H.S. SHAO
QCD cor./Showering/Matching	Z.G. Si, S.Y. Li, S.S. Bao, H.L. Li
TOOLKITS & Physics Study	QY, X.R. ZHAO
TOOLKITS & Physics Study	L. Guo, R.Y. Zhang, W.G. Ma
Physics Study	G.L. Liu[F] H.H. Zhang

Contents

- e+e- and pp
- Parton level and fast simulation
- Tool: User friendly and high precision

2. MC introduction

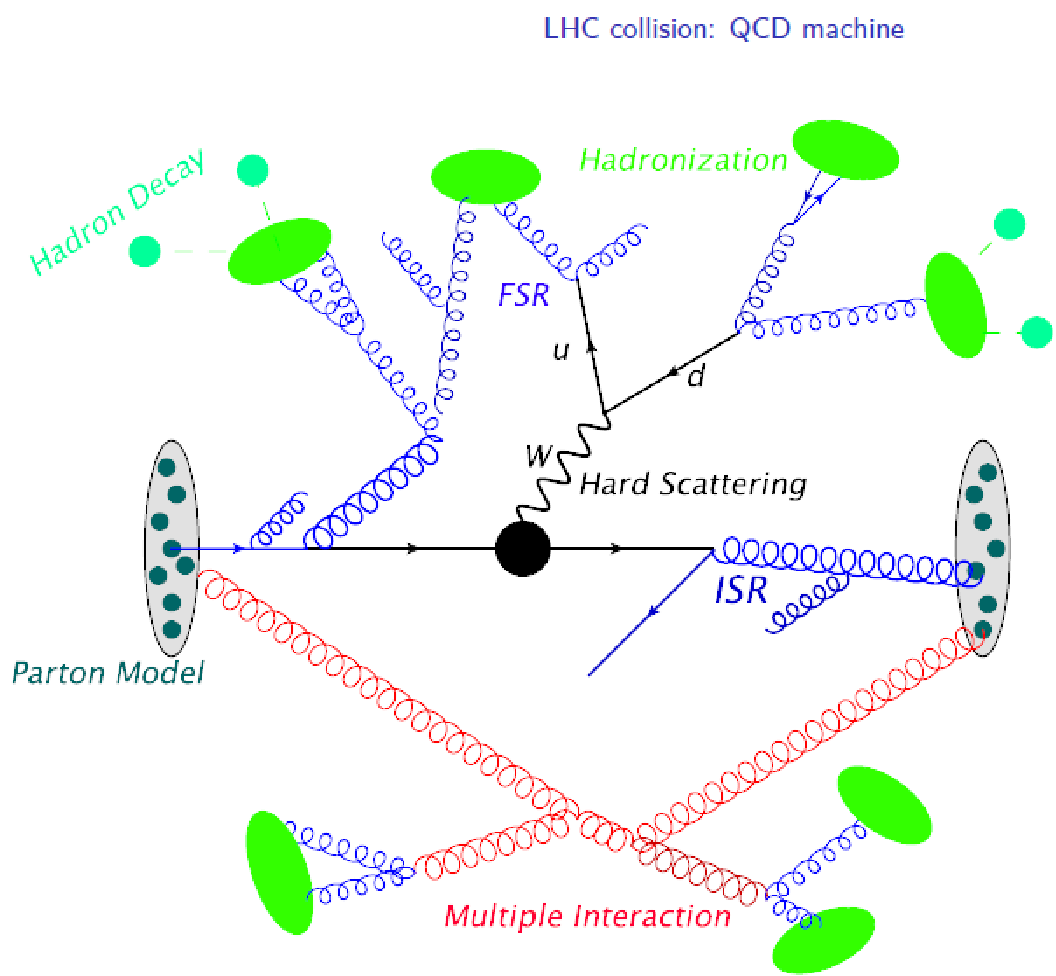
Motivation & history & Status & CEPC

MC Introduction

Matrix Element Generators in CMS

- LHE interface in CMSSW
- the CMS - ALPGEN Twiki Page
  - ALPGEN 2.13 7 TeV production summary
- the CMS - CompHEP Twiki Page
- the CMS - MadGraph Twiki Page
  - Madgraph 4.22 7 TeV production summary
  - Madgraph 5.1 7 TeV production summary
  - Madgraph 5.1 2012 8 TeV production summary
  - UPDATED Gridpack Production Documentation for MG5 1.5.11
  - NEW: Madgraph 5v1.5.11 13 TeV production summary
- the CMS - POWHEG Twiki page
  - POWHEG 7 TeV production summary
- CMS aMCatNLO Twiki Page
- CMS SherpaNLO Twiki Page
- CMS - BlackHat Twiki Page
- Proposal for a general handling of ME tools

Ingredients



pp: PDF
e+e-: Beam loss effects…

Hard Scattering:
LO, NLO, NNLO QCD, QED..

Parton Shower:
Pythia6/8, Herwig(++), Sherpa Dipole Shower

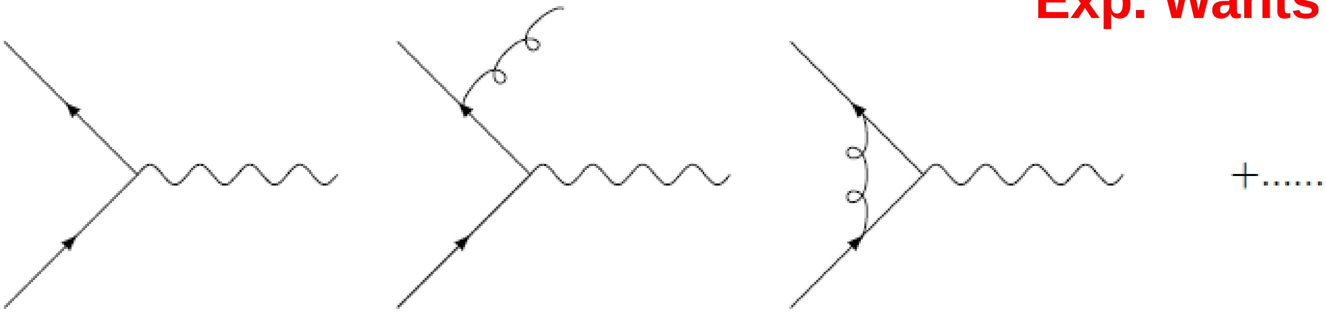
Hadronization:
String Model; Color Cluster

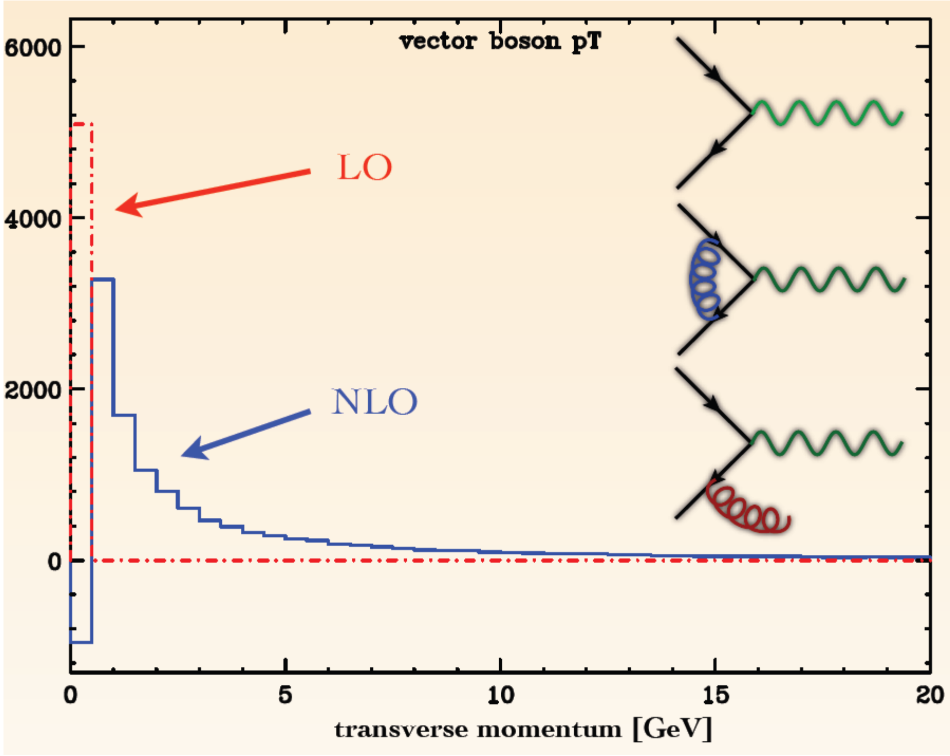
Detector Simulation:
PGS; Delphes

Tools on the market: Pythia, Herwig, aMC@NLO_Madragph, Sherpa, GoSam, Whizard……

MC Introduction

Exp. Wants Events!





Exclusive observables not described well in PQCD

Parton Shower
although approximation (~LL), work well in collinear and soft region; LHE events

Let's Combine them!

Be careful of: Double counting, matching scale dependence

Jet parton Matching as an example

ME-PS Matching (Shape)
e.g. Eur.Phys.J.C53:473,2008

CKKW MLM …

NLO PS Matching
(Shape & Normalization)

MC@NLO e.g. hep-ph/0204244
POWHEG e.g. arXiv:0709.2092
…

Multi-leg Multi-Loop Matching:
(Shape & Normalization)
Merging e.g. arXiv:1311.3634

Not meant to be exhaustive, see more
In arXiv:1203.6803

QCD Matrix Elements + Parton Showers

S. Catani[a*], F. Krauss[b], R. Kuhn[c,d] and B.R. Webber[b]

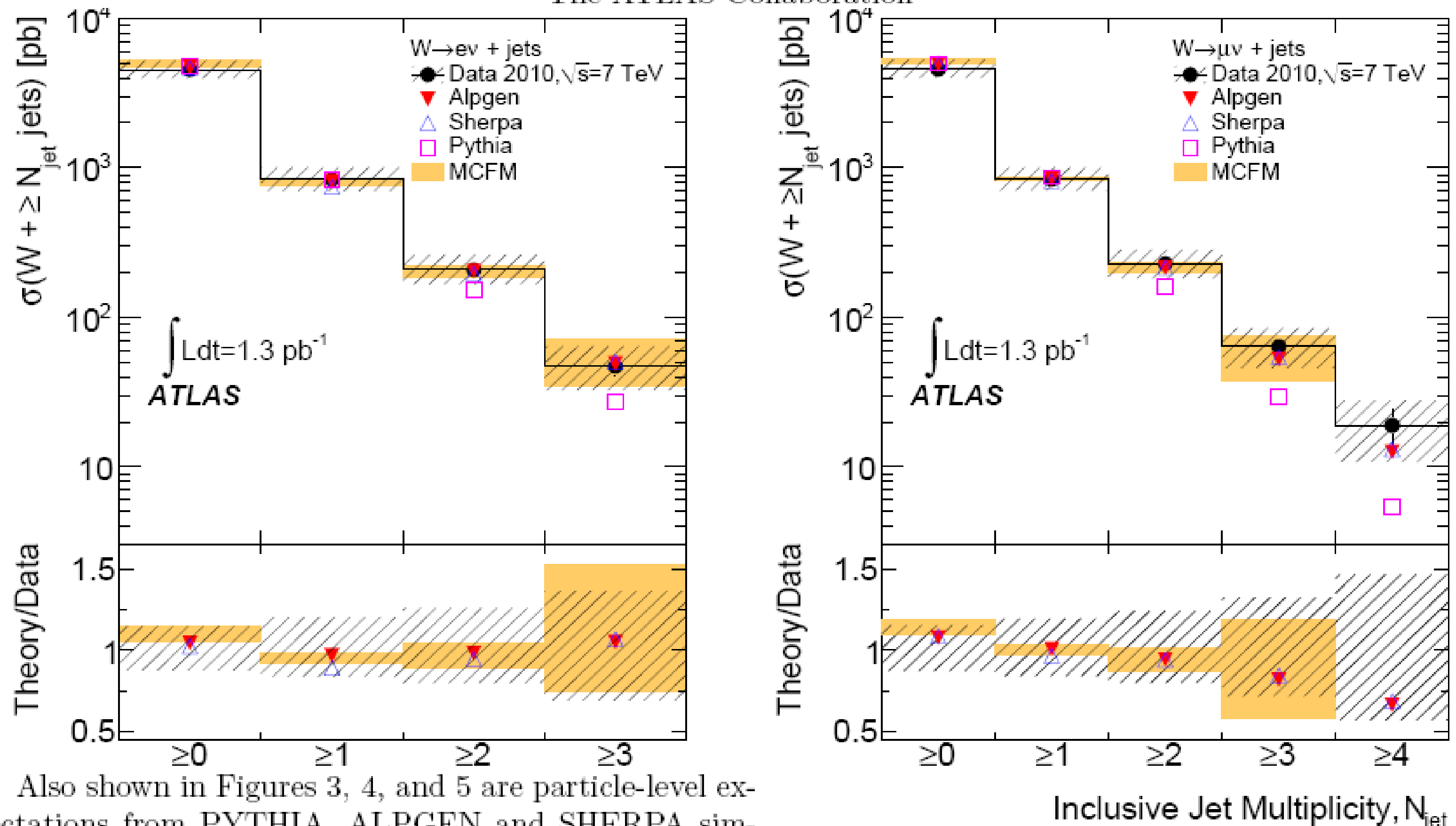
JHEP 0111:063,2001

ABSTRACT: We propose a method for combining QCD matrix elements and parton showers in Monte Carlo simulations of hadronic final states in e^+e^- annihilation. The matrix element and parton shower domains are separated at some value y_{ini} of the jet resolution, defined according to the k_T-clustering algorithm. The matrix elements are modified by Sudakov form factors and the parton showers are subjected to a veto procedure to cancel dependence on y_{ini} to next-to-leading logarithmic accuracy. The method provides a leading-order description of hard multi-jet configurations together with jet fragmentation, while avoiding the most serious problems of double counting. We present first results of an approximate implementation using the event generator APACIC++.

ME-PS Matching@LHC

Measurement of the production cross section for W-bosons in association with jets in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

The ATLAS Collaboration



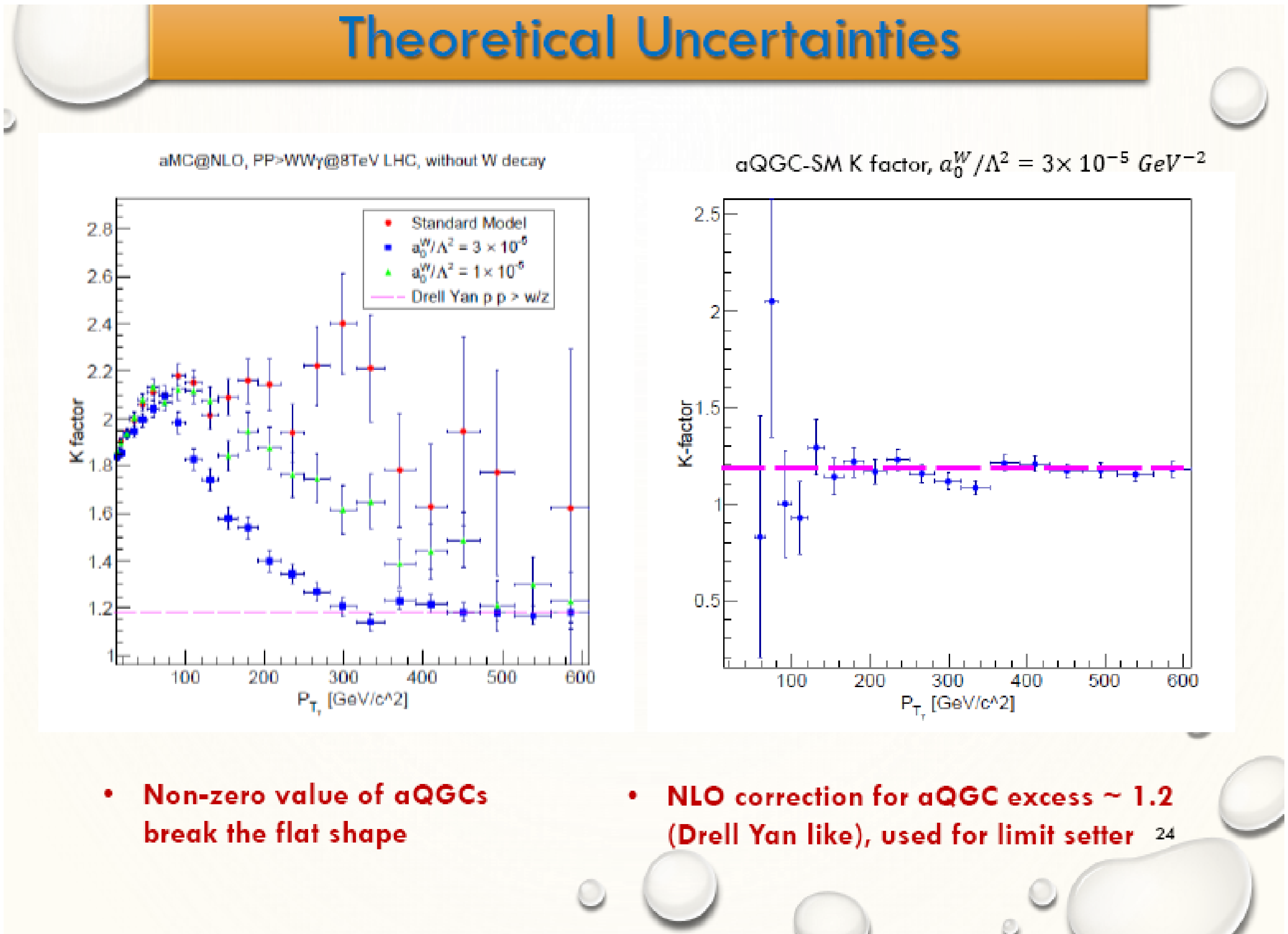
Also shown in Figures 3, 4, and 5 are particle-level expectations from PYTHIA, ALPGEN and SHERPA simulations as well as a calculation using MCFM v5.8 [35]. PYTHIA is LO, while ALPGEN and SHERPA match higher multiplicity matrix elements to a leading-logarithmic parton shower; these predictions have been normalised to the NNLO inclusive W production cross section. The version

arXiv:1012.5382

NLO PS Matching@LHC

aMC@NLO Used in Phys. Rev. D 90, 032008 (2014)

CMS WWγ+WZγ →lνjjγ for full Sim and K factors



Approved by Daneng Yang (PKU)

First Triple-V Measurement at the LHC

Motivations for our efforts

- As end users, you will not be able to know details of generators (you are unable to custom them).
- Current MC tools are not so powerful as you thought, new colliders bring new difficulties. (Gluon Fusion; QED matching; Multi-V emission; beam energy loss)
- Future high energy physics needs more powerful MC generators (two and even higher loops/more than 10 legs)
- We are not too far away, but will never catch up if we stop.

3. Activities

Seminars & Schools & Workshops
Tool Development;
Detector R&D;
Physics Potential

WG Activities

egroup: CEPC-100pp@cern.ch

Video Meeting

June 2014

- 27 Jun 100 TeV Generator - Fast Simulation Discussion (13th)
- 27 Jun CEPC Calorimeter Group Meeting (11th) (protected)
- 25 Jun Simulation & Physics Analysis Meeting
- 20 Jun 100 TeV Generator - Fast Simulation Discussion (12th)
- 18 Jun CEPC physics+detector regular meeting
- 13 Jun 100 TeV Generator - Fast Simulation Discussion (11th)
- 13 Jun CEPC Calorimeter Group Meeting (10th) (protected)
- 11 Jun Simulation & Physics Analysis Meeting
- 06 Jun 100 TeV Generator - Fast Simulation Discussion (10th)

Schools & Workshops

- **MadGraph 2013 Spring School, May 2013, Beijing**
- **HEP Computing Mini-Workshop, Nov.27-30, 2013, CHEP, PKU**
- **Lectures/Tutorials by Whizard authors, Aug, 2014**
- **Preparing for MC4BSM 2016 and others**

KITPC Platform: Activities

Speakers	date	topics
Qiang Li (PKU)	8/March	Jet/Parton Matching
Zhao Li (IHEP)	10/April	IR Regularization: Paradise and Purgatory
Hua-Sheng Shao (cern/PKU)	8/May	Automation of Next-to-leading Order Computations with MadGraph5_aMC@NLO
Jian-Hui Zhang (SHJTU)	12/June	Recent developments in computing loop amplitudes
Bing Gong (IHEP)	4/July	Current status and future development of FDC
Zhao Li (IHEP)	22/August	Symbol: a new toy?

Supported by KITPC and KITPC Contact person: Z.X. Zhang and J. Shu

Computing Resources

ITP Cluster: >4000 CPU and >40T

PKU Farm: O(100) CPU and 20T storage

THU Farm: O(100) CPU and 10T storage

……

Snowmass 100TeV Sample Recycle:
http://uaf-2.t2.ucsd.edu/~spadhi/Snowmass/Beijing/data

Our aims

At the early stage of CEPC, to provide important information for detector designs; to explore the event shape of the SM; to explore the physics potential at future colliders

To develop High Precision MC toolkits and general purposed MC generators for data analysis

To train regional users and foster next generation of MC authors; to strength connections with the other MC working groups in the world

Tool Developments: FDC

(Jianxiong Wang, Bin Gong, Zhao Li)

FDC (Feynman Diagram Calculation) Project has been continued for more than twenty years, with much contributions in quarkonium physics; FDC-MSSM: extended to implement SUSY models……

- middle-term aim: develop a MC generator at one-loop level (something like Madgraph5 but capable of more legs)
- long-term aim: develop an even higher precision MC generator (capable of two/higher loops), at least fulfil the need of Z&H factory/CEPC/SPPC
- The generator will be developed based on FDC package, which is already a NLO ME generator
- The first step of the plan is to improve current FDC package.

Multi-Higgs Box

(Q. S. Yan, X. R. Zhao, Z. J. Zhao, Q. Li,)

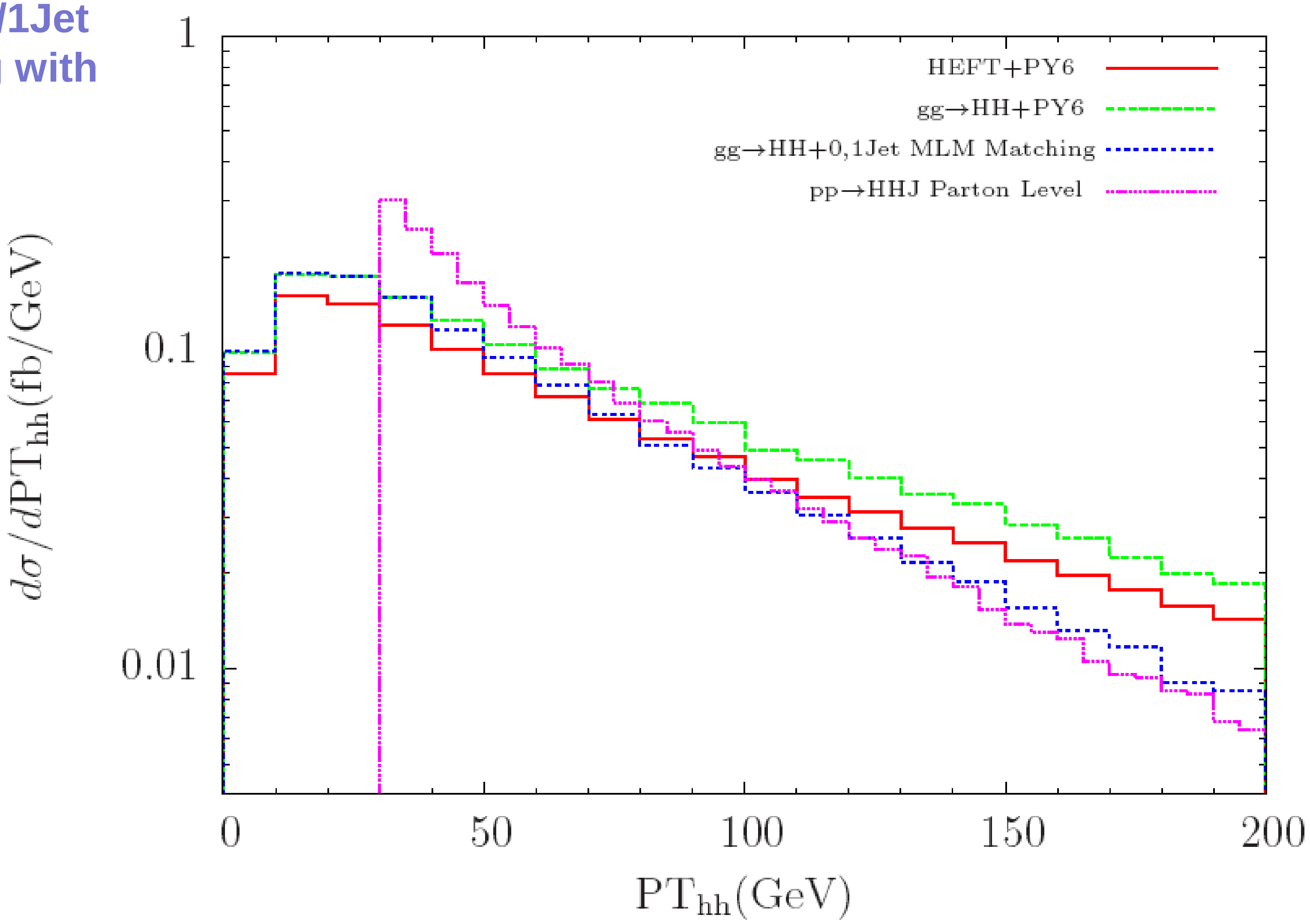
Di- and Tri- Higgs productions are crucial for Higgs self-coupling measurement; However, in current MC tool, Gluon-Fusion processes are not supported well

We are preparing a Multi-Higgs Box:

- Include Di- and Tri- Higgs GF and VBF and V-associated production process, able to generate LHE events;
- Make it Suitable for BSM: 2HDM, Composite Higgs…;
- Implement HH+1Jet and the 0/1Jet matching;
- Implement VBF HH NLO PS matching;
- Perform Physics studies

Matched predictions for Higgs pair production
Q.Li, Qi-Shu Yan, Xiaoran Zhao Phys. Rev. D 89, 033015 (2014)

GF HH+0/1Jet matching with Pythia



Benchmark processes for CEPC/SPPC

- CEPC simulations
  - Beams [Radiation, Matter-Beam interaction, Beams distribution functions]
  - Higgs Production with polarised and unpolarised beams
  - Z+ γ (s)
  - WW/ZZ, TGC measurements
  - multi-vector boson scattering and QGC measurements

- Eventshape of the SM at 100 TeV Collisions
  - Jets, boosted W/Z/H/top
  - W/Z's, multi-vector boson final states
  - Single Top and multi-top
  - Higgs boson, multi-Higgs bosons
  - VBF
  - $t\bar{t}H$, $t\bar{t}HH$, $t\bar{t} \to HH$

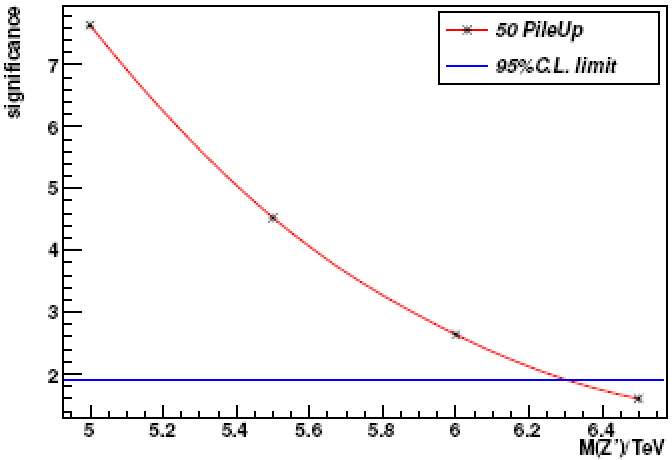
Benchmark processes for CEPC/SPPC

– Bench new physics processes at 100 TeV collisions
  * Spin Zero particle search: new Higgs bosons (neutral, charged, multi-charged), stop/sbottom quark, sleptons
  * Spin 1/2 particle search: new quarks, new leptons, charginos
  * Spin 1 particle search: W'/Z', KK W/Z
  * Spin 3/2 particle search: Gravitino
  * Spin 2 particle search: KK gravitons
  * Dark matter search at colliders

Z prime search at SPPC (Keping Xie, Q.Li)

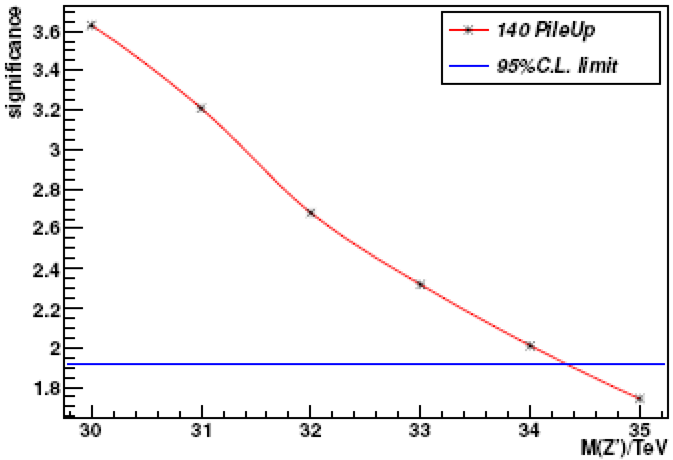
Sequential Standard Model Z' decay into $\mu^+\mu^-$

CMS Detector



(a) $\sqrt{s} = 14TeV, \mathcal{L} = 300fb^{-1}$

Snowmass Detector:
Simple Combined CMS+ATLAS



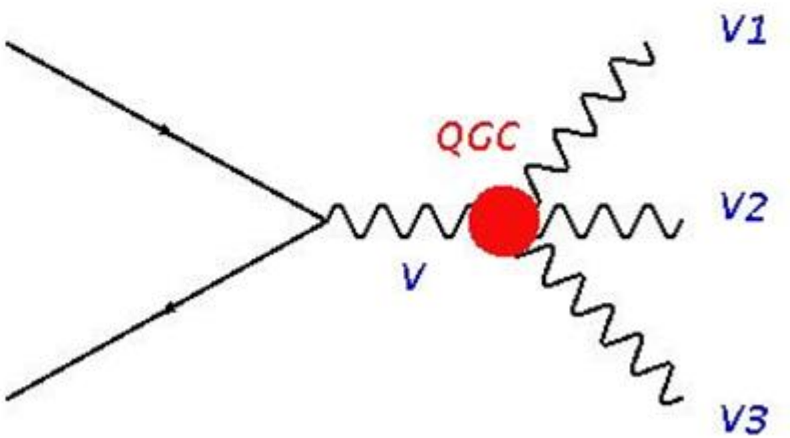
(b) $\sqrt{s} = 100TeV, \mathcal{L} = 1000fb^{-1}$

95% CL exclusion limit on Z'_{SSM} 6.3/34.3TeV

Triple W at pp collider Yiwen Wen et.al.

Rare processes, Crucial test of the SM
Sensitive to anomalous Quartic Gauge Couplings

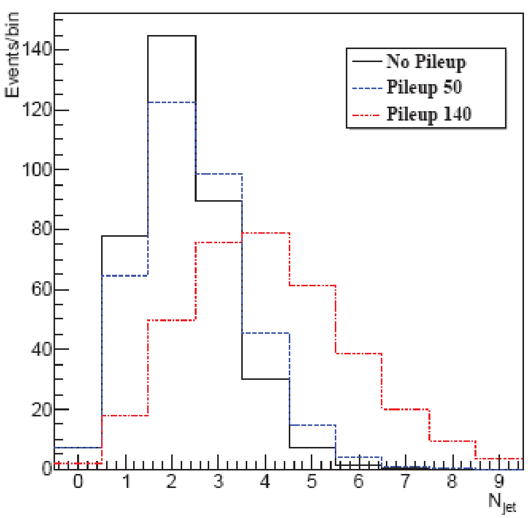
MadGraph+Pythia+Delphes
8/14/100TeV pp collider
CMS Sim Card
Snowmass 100TeV Card



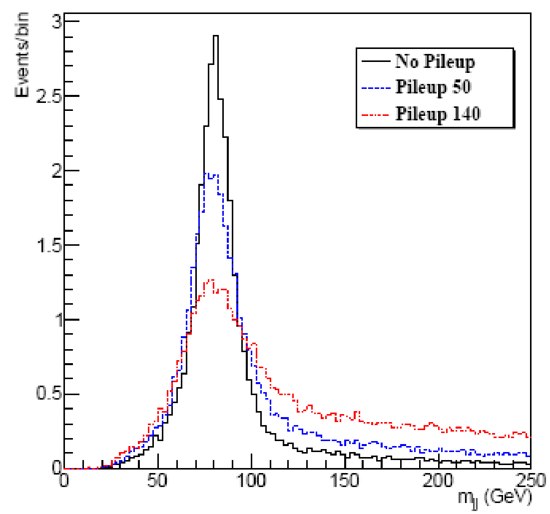
1. Pure leptonic $W^{\pm}W^{\pm}W^{\mp} \to 3l$+MET **Checked with Snomass** **arXiv:1309.7452**
2. Same-sign dileptons + 2 jets: $W^{\pm}W^{\pm}W^{\mp} \to l^{\pm}l^{\pm}jj$+MET

Processes	Cross section[fb]	Events			
		Pileup 50		Pileup 140	
		cut-based	BDT	cut-based	BDT
WWW	26	6465	12156	7794	13485
$t\bar{t}W$	7684	35961	65928	60396	100047
$WWjj$	535	30507	41124	71610	75708
$WZjj$	16250	209820	437775	429195	693225
Significance		12.3	16.4	10.4	14.4

semileptonic decay channel $\sqrt{s} = 100$ TeV and integrated luminosity of 3000 fb^{-1}.



(a) Number of jet



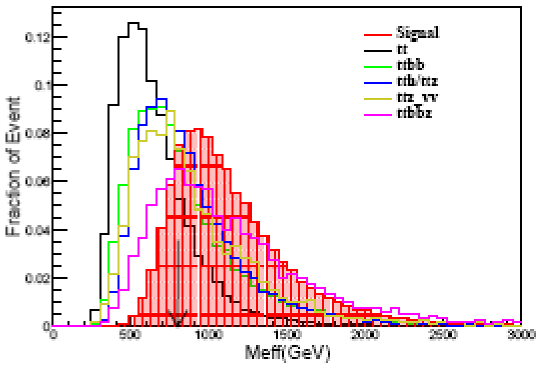
(b) The invariant mass of the two leading jet

Figure 4. Distribution of signal process $l^{\pm}\nu l^{\pm}\nu jj$ in different pileup scenarios at 14 TeV LHC

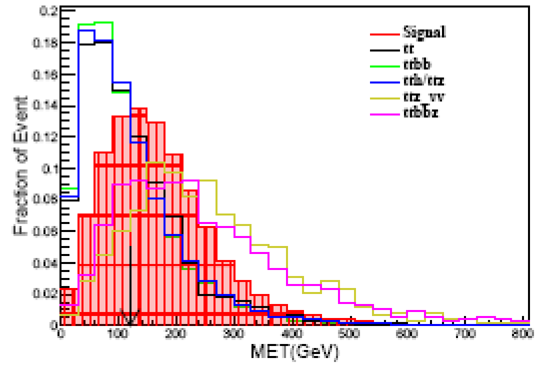
Sbottom Searches

Yong-Chen Wu, Shu-Fang Su, Tao Han, Bin Zhang

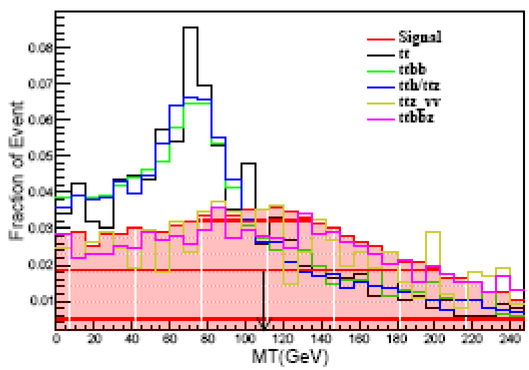
sbottom pair production via $4b + 2j + \ell +$ missing energy



(a) M_{eff}



(b) $\not{E}_T$



(c) M_T

100 TeV pp collider

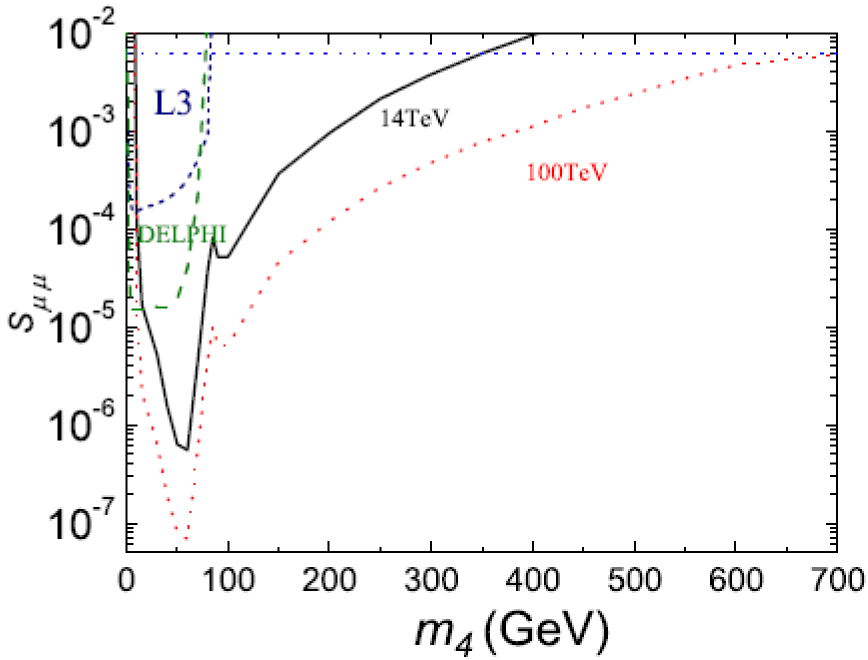
Process	No-Cuts	Cut1	Cut2	Cut3	Cut4
Signal	400000	72562	60516	40111	11938
fb	3293(153.7)	597.37	498.20	330.21	98.28(93.6)
ttbar	2000000	9784	2074	853	39
fb	7181000(47.9)	35129.5	7446.7	3062.7	140.03(143.9)
ttbb	400000	16245	7039	2675	173
fb	341200(88.4)	13856.9	6004.3	2281.8	147.6(182.1)
tth/ttz	400000	42190	20790	8189	382
fb	8387(68.9)	884.62	435.9	171.7	8.01(86.0)
ttbbz	80000	4261	3057	2448	734
fb	155.8(158.8)	8.30	5.95	4.77	1.43(136.2)
ttz_vv	400000	2560	1283	1104	352
fb	2524(74.3)	16.15	8.10	6.97	2.22(61.0)
$S/\sqrt{B}$	$L = 100 fb^{-1}$	26.74	42.26	44.41	56.81(7.5)

cut1: 3 b-jets tagging cut2: $M_{eff} \geq 800$ GeV
cut3: $\not{E}_T \geq 120$ GeV cut4: $M_T \geq 110$ GeV

Table 3: The significance and cut efficiencies are displayed for both signal and background events. The numbers in red is the ratio compared with the case at LHC 14 TeV.

Exotic Lepton Detection

Bin Zhang



2σ sensitivity for $S_{\mu\mu}$ versus m_4 at the LHC or 100TeV collider with 100 fb^{-1} integrated luminosity.

100TeV *pp* collider has strong ability to test massive Majorana neutrinos (can detect the mass less than 800 GeV).

Summary

1. Regional MC group is necessary for future HEP
2. It is a long-term and highly non-trivial task to develop MC generators. We need more people in various fields.
3. At present, main task of MC tools working group is to provide powerful tools for other sub-working groups to develop CDR/TDR. We need various activities to train young talents in order to complete the task.
4. The middle-term and long-term aim is to develop high precision general-purpose MC generators for Z&H factories and CEPC/SPPC.

Thank you!