MCnetITN activities Göttingen

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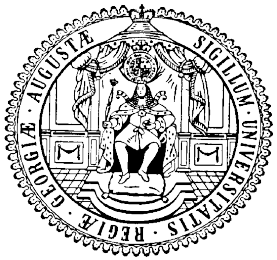


MCnetITN @ CERN

31/03/14

Göttingen node: links & personnel

Göttingen node

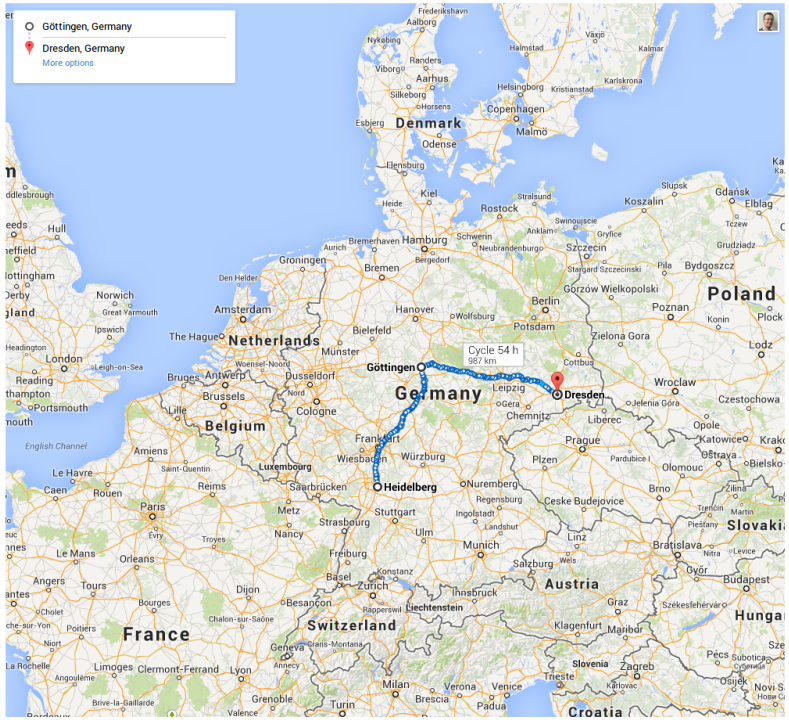
- Steffen Schumann: team leader
  (`Sherpa`, QCD, pheno)
- Erik Gerwick: PostDoc
- Danilo Paulikat: PhD
- Enrico Bothmann: PhD
- Piero Ferrarese: PhD

Heidelberg link

- Tilman Plehn: chair
  (Higgs, BSM, (s)Tops)

Dresden link

- Frank Siegert: PostDoc
  (ATLAS, `Sherpa`, `Rivet`)



Göttingen node: highlights so far

MCnet summer school 2013

- 5d school in Mariaspring/Göttingen
- joint with annual Terascale HA school
- focus on NLO QCD, merging, statistics

Sherpa collaboration meeting

- 3d get-together at MPI Munich
- including an NLO user forum

Short term student programme

- Nathan Hartland: PhD U Edinburgh
  (appointed Aug - Dec '13)
  development of MCgrid tool

Göttingen node: focal points

Matrix Element calculations

- New Physics: `Comix` & `FeynRules`
- uncertainty estimates for NLO calcs
  - ⇝ MCgrid [Hartland, Bothmann]
- phase-space integration
  - ⇝ $(\mathrm{MC})^3$algorithm

Parton Shower & Resummation

- Catani–Seymour dipole shower
  - ⇝ massive initial states [Paulikat]
- jet rates and scaling patterns
  - ⇝ analytic jet rates [Gerwick]
- analytic soft gluon resummation
  - ⇝ automation [Gerwick,Höche, Marzani]

Phenomenology

- QCD & New Physics
  - ⇝ event shapes, scaling [Ferrarese]

Uncertainty estimates with MCgrid

The MCgrid tool: motivation

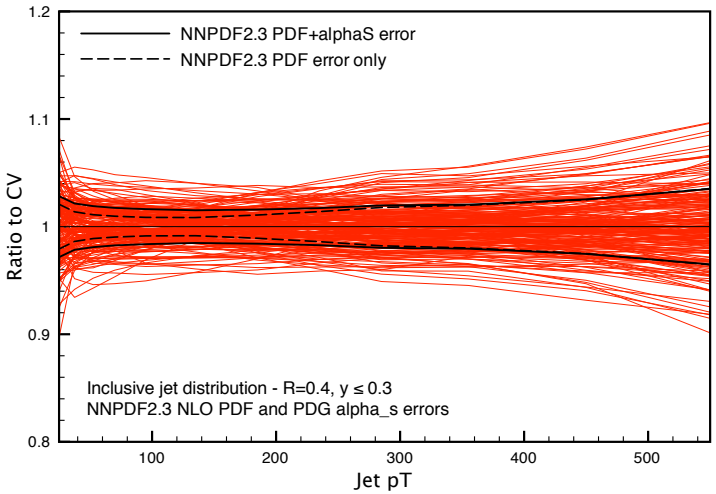
Enormous progress in NLO QCD calculations

- computations largely automated
  OLP: BlackHat, OpenLoops, NJet, GoSam, ...
  MC: MadGraph, Helac, Sherpa, Herwig++, ...
- large number of new calculations readily available

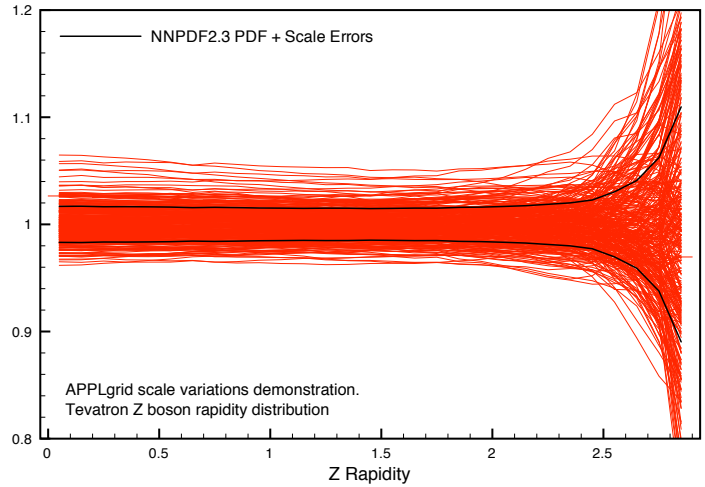
⇝ need to estimate theoretical uncertainties: α_S, μ_R, μ_F, PDFs

⇝ include results in PDF fits

inclusive jets @ LHC



Drell-Yan @ Tevatron

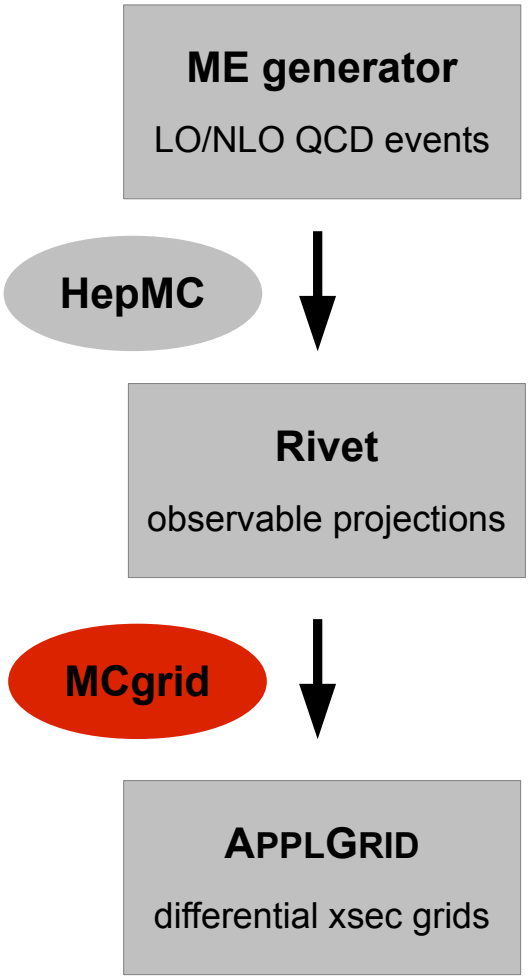


⇝ need for hundreds of repeated calculations

⇝ reweighting is the way to progress: event files *or* cross section grids

The MCgrid tool: implementation

projecting event weights on APPLGRID tables



- supply extra weights with HepMC event (like `Root` Ntuple record 1310.7439)
- `HepMC::WeightContainer`

- analysis plugin to Rivet
- sub-process identification
- initialize & fill APPLgrid objects

Del Debbio, Hartland, S. arXiv:1312.4460

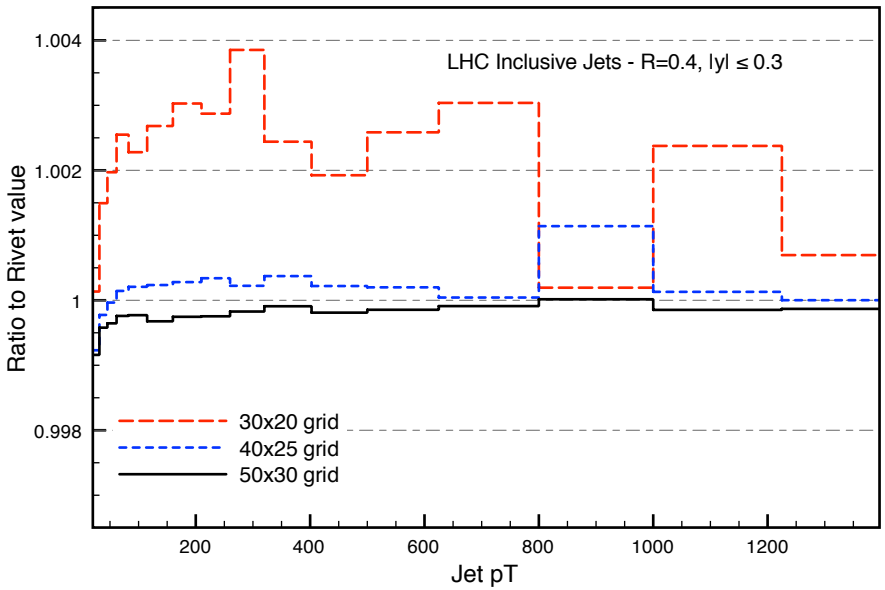
`http://mcgrid.hepforge.org/`

The MCgrid tool: validation

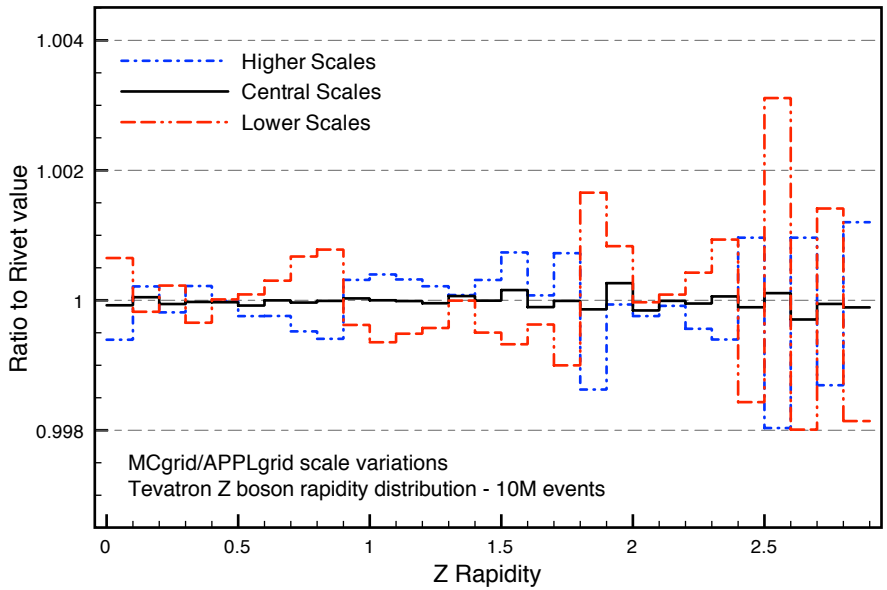
Reproduction of input cross section & scale variations

- test coarser and finer grid binning in x & Q^2
- scale variations via APPLGRID compared to direct calc

inclusive jets @ LHC



Drell-Yan @ Tevatron



⇝ reproduction of input cross section at permille accuracy ✓

⇝ scale dependence determination agrees within permille level ✓

⇝ cross section re-evaluation within *ms* ✓

Markov-Chain methods for phase-space generation $(\mathrm{MC})^3$

$(\mathrm{MC})^3$: motivation

Inputs to multijet matrix element generation

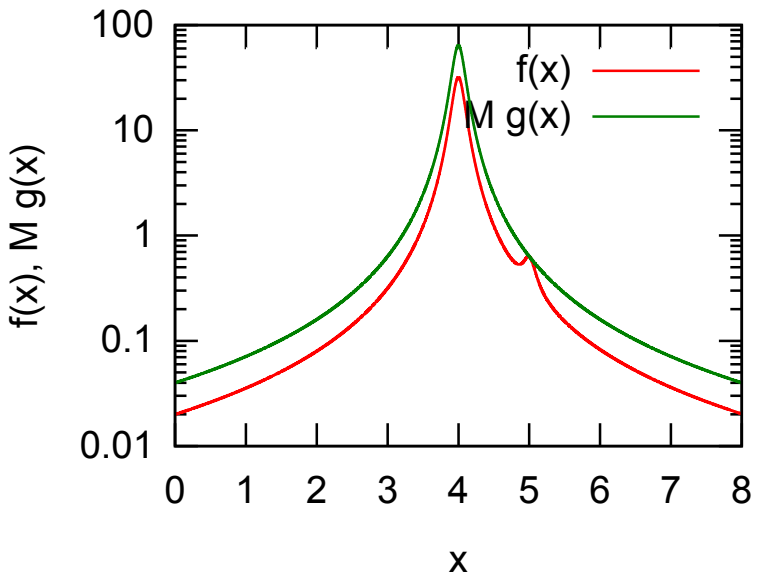
- fast amplitude evaluation: compact expressions, optimal re-use of subterms
  - $\rightsquigarrow$ symbolic identification of common terms in Feynman graphs
  - $\rightsquigarrow$ recursive algorithms [`Comix`, `Helac`]
- efficient phase-space generator: fast, high unweighting efficiency
  - $\rightsquigarrow$ Multi-Channel Importance Sampling [`Comix`, `Amegic`, `MadGraph`, `Helac`]
  - $\rightsquigarrow$ Vegas derivates [`Alpgen`, `Whizard`]

Multi-Channel Importance Sampling

- find proposal $g(x) = \sum_k \alpha_k g_k(x)$ close to target $f(x)$, $\sum_k \alpha_k = 1$
- sample $\{x_i\}$ from g (weighted event)
- accept/reject event with $P(x_i) = \frac{f(x_i)}{M g(x_i)}$

✓ incorporates prior knowledge of target

✗ struck by mismodelling of target function



$(\mathrm{MC})^3$: motivation

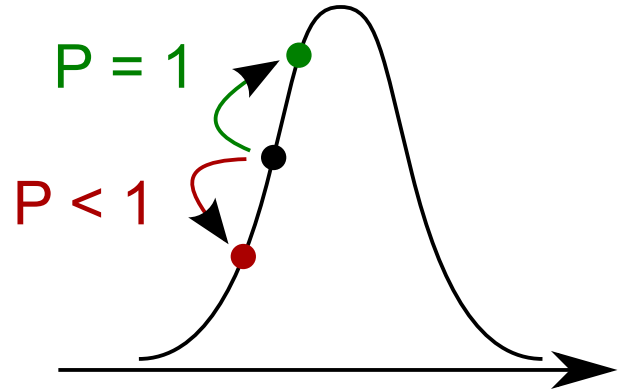
Markov-Chain Monte Carlo with limiting distribution f(x)

- Metropolis-Hastings transition kernel

$$\mathcal{K}_{MCMC}(y|x) = g_{MCMC}(y|x)\ \alpha(y|x)$$

$$\alpha(y|x) = \min\left(1, \frac{f(y)\ g_{MCMC}(x|y)}{f(x)\ g_{MCMC}(y|x)}\right)$$

- generate proposal state y according to $g(y|x)$
- accept state y with probability $P(y) = \alpha(y|x)$



✓ efficiency adjustable

✓(✗) no knowledge of target needed (incorporated)

✗ high correlations for multi-modal $f(x)$

↪ widely used in statistical physics, parameter fits & scans in HEP

↪ phase-space generation: need to map out peaks and reduce auto-correlation

$(\mathrm{MC})^3$: Multi-Channel meets Markov-Chain Monte Carlo

The $(\mathrm{MC})^3$ algorithm

- linear combination of two Markov transition kernels: the $(\mathrm{MC})^3$ kernel

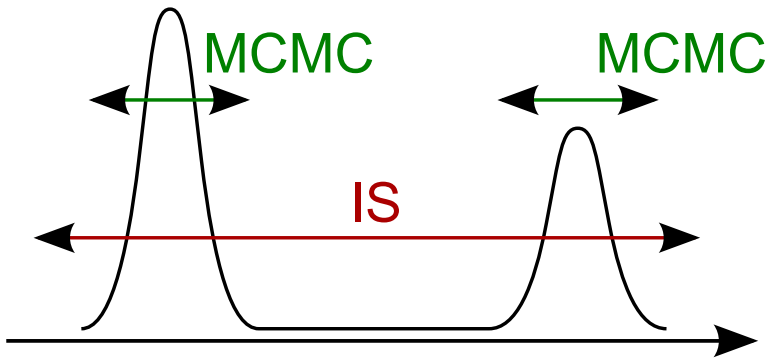
$$\mathcal{K}_{(\mathrm{MC})^3}(y|x) = \beta\, \mathcal{K}_{IS}(y|x) + (1-\beta)\, \mathcal{K}_{MCMC}(y|x)$$

$$\mathcal{K}_{MCMC}(y|x) = g_{MCMC}(y|x)\ \min\left(1,\ \frac{f(y)g_{MCMC}(x|y)}{f(x)g_{MCMC}(y|x)}\right) \qquad \mathcal{K}_{IS}(y|x) = g_{IS}(y)\ \min\left(1,\ \frac{f(y)g_{IS}(x)}{f(x)g_{IS}(y)}\right)$$

$\rightsquigarrow$ f limiting distribution of $\mathcal{K}_{MCMC}$ & $\mathcal{K}_{IS} \Rightarrow f$ target of $\mathcal{K}_{(\mathrm{MC})^3}$

$(\mathrm{MC})^3$ parameters

- multi-channel weights α_k
- proposal width g_{MCMC}
- mixing parameter β



$(\mathrm{MC})^3$ features

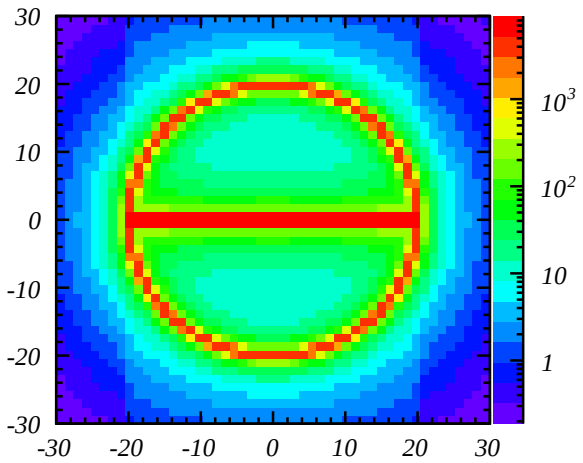
- ✓ incorporate knowledge about multi-modal target
- ✓ compensate inexact modelling of target f by g_{IS}
- ✗ residual correlation effects

$(\mathrm{MC})^3$: toy example I

target function

- Θ-shaped analytic function

$\rightsquigarrow$ two channels $g_{IS,k}$: circle & line



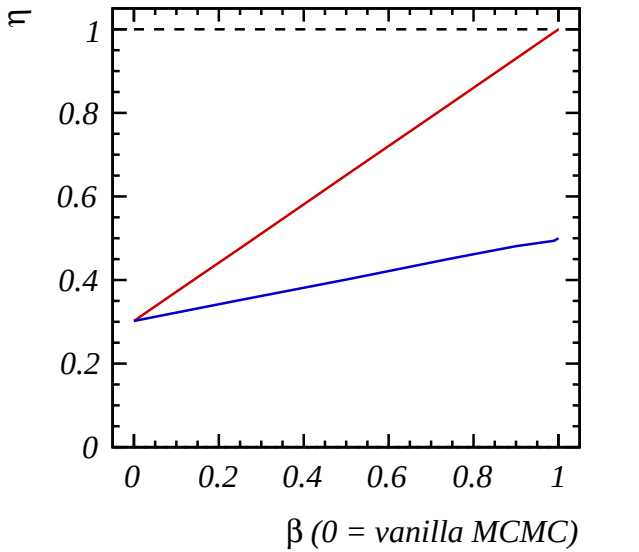
$(\mathrm{MC})^3$ setups

- $\ominus$ IS kernel $\mathcal{K}_{IS}$ with full knowledge
- $\bigcirc$ IS kernel with circle only
  (lacks peaked structure)

$(\mathrm{MC})^3$ efficiencies

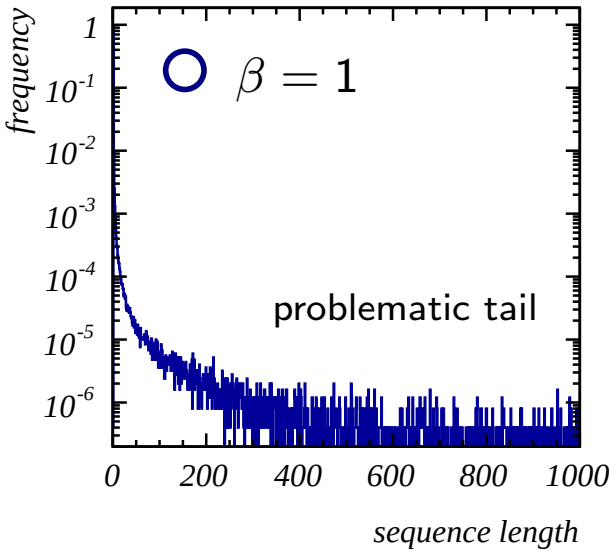
- acceptance scales linearly with β
- best performance for $\beta = 1$ when
  full knowledge $\ominus$ or circle only $\bigcirc$
  (importance sampling: $\eta = 1$ and $\eta = 10^{-4}$)

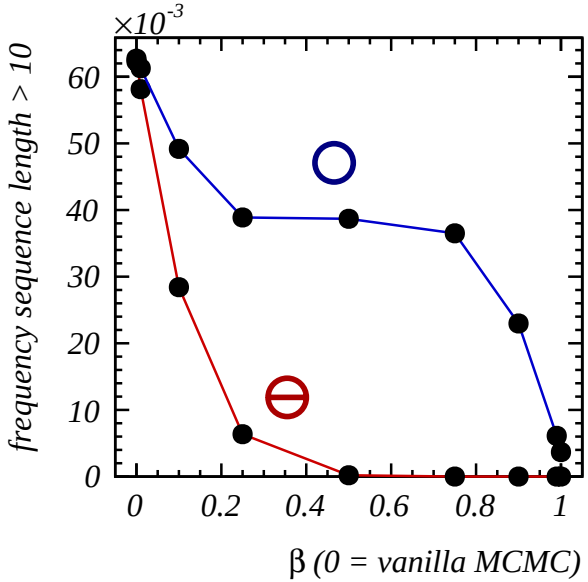
$\rightsquigarrow$ improved for poorly mapped target, but ...

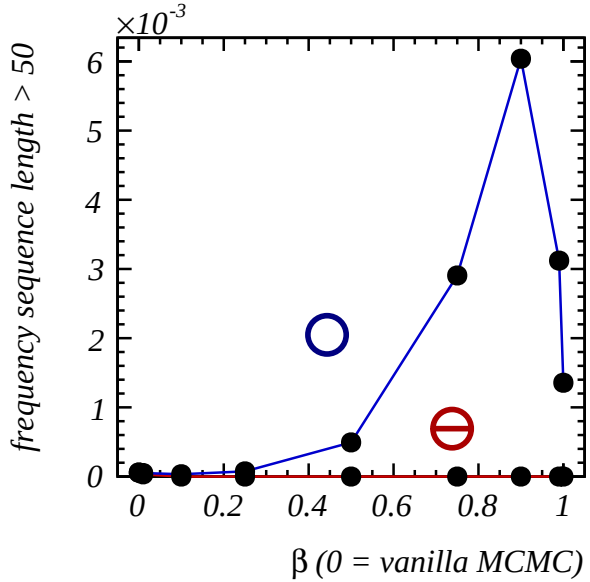


$(\mathrm{MC})^3$: toy example II

Sequence length: number of succeeding identical points in the Markov chain







full knowledge setup ⊖

- best performance for $\beta \to 1$
- no correlation issues expected

circle only setup ○

- problematic tail for $\beta = 1$
- reduced sequence lengths for admixture of MCMC

↪ find most suitable value for β

↪ introduce lag $l > 1$ and accept only every l^{th} point, mix chains

Summary & Outlook

MCgrid: projecting NLO cross sections on grids

- fast uncertainty evaluation, incorporate NLO in PDF fits

↪ attempt to include resummation/parton shower effects [Hartland, Bothmann]

$(\mathrm{MC})^3$: Multi-Channel improved Markov-Chain Monte Carlo

- improved unweighting efficiency, residual auto-correlation

  [Kröninger, Willenberg, S. to appear]

↪ implement as phase-space generator for `Sherpa`