QCD for the LHC
A few illustrative figures...

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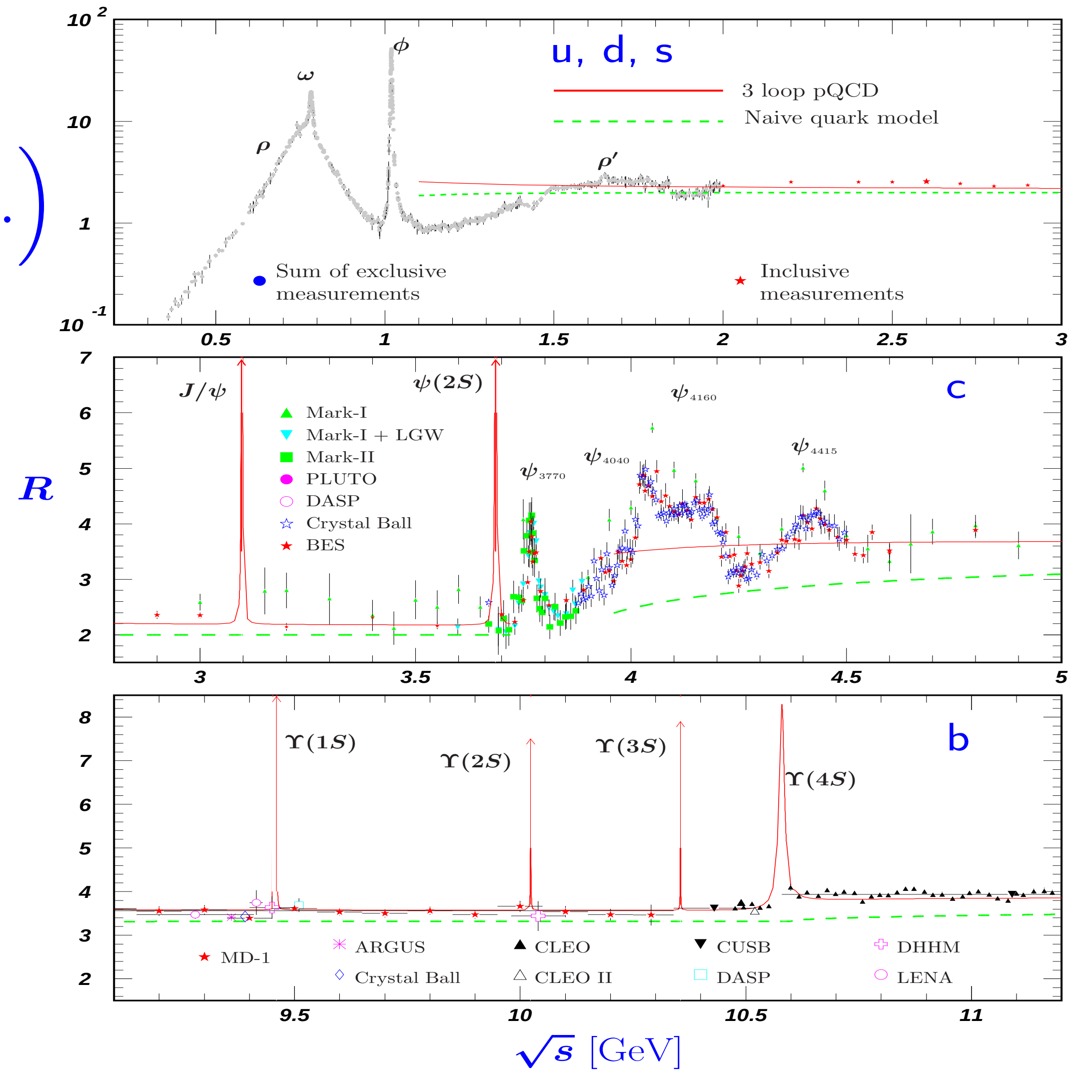
- e^+e^-
  - Measurements of jet cross-sections $\longrightarrow \alpha_s$
- DIS
  - Bjorken scaling, scaling violations, Global fits
- pp
  - Kinematics
  - PDF uncertainties and their impact
  - Jets: challenges, TEVATRON results

e^+e^-

$$R = \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)}$$
$$= \sum_q N_c e_q^2 \left(1 + \frac{\alpha_s}{\pi} + \ldots\right)$$

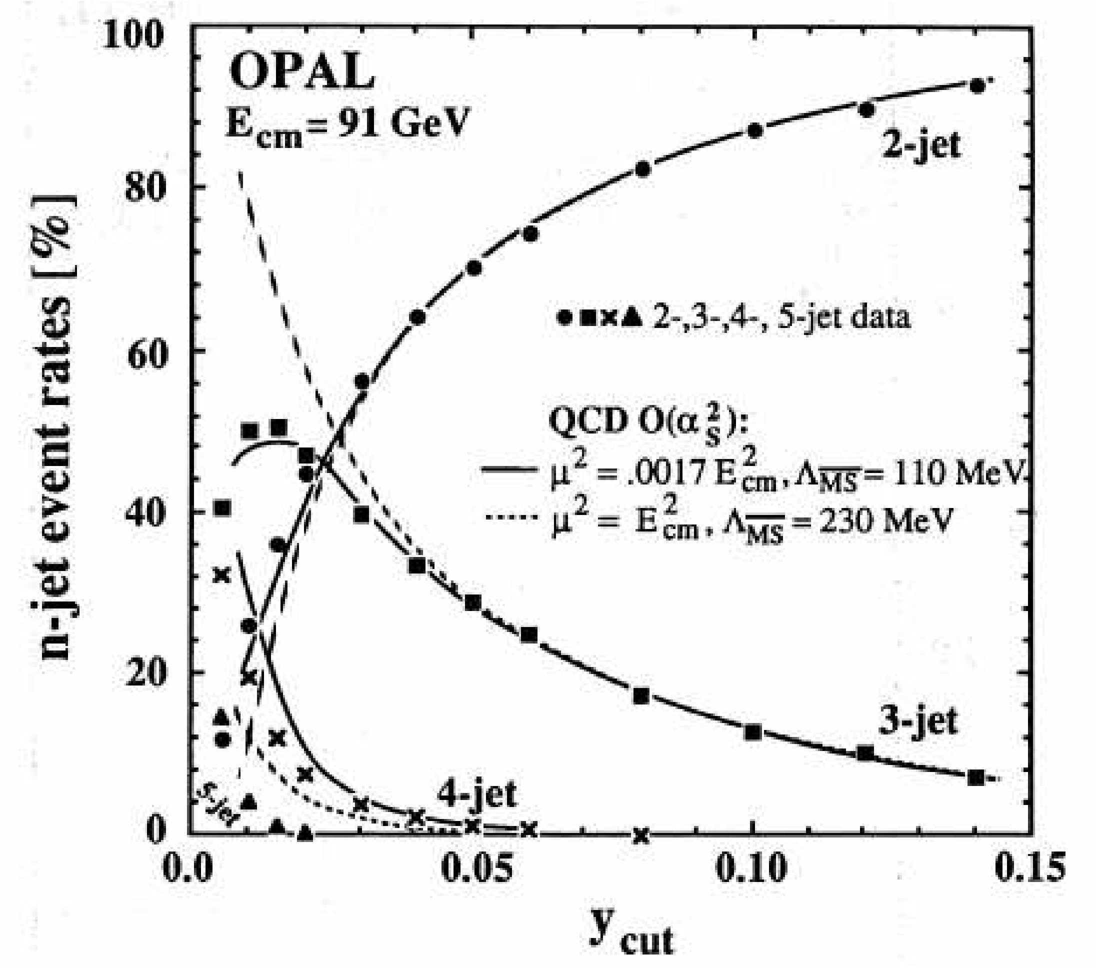


- u, d, s: $3\frac{4+1+1}{9} = 2$
- $+c$: $+3\frac{4}{9} \to= 10/3$
- $+b$: $+3\frac{4}{9} \to= 14/3$

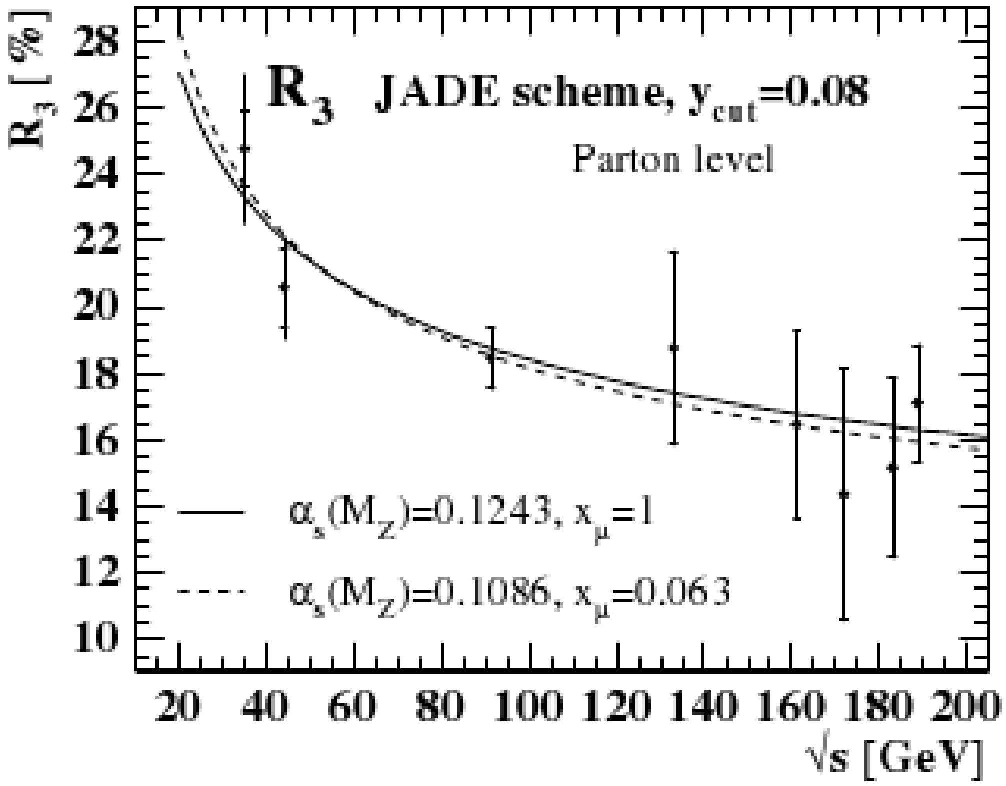
Note: threshold effects for $m \neq 0$

Fraction of jet multiplicities vs. $y_{\rm cut}$

OPAL collaboration, JADE algorithm

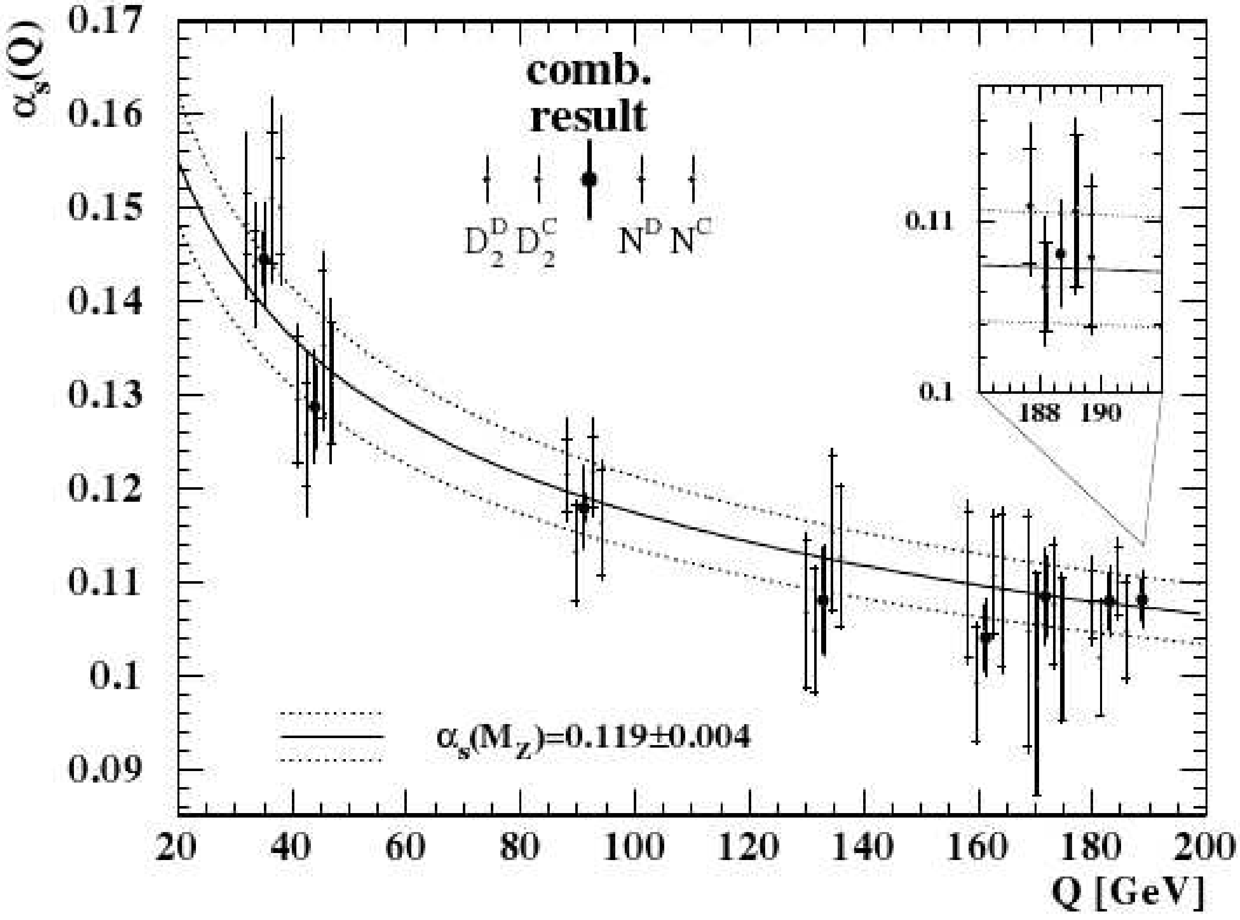


Evolution of the fraction of 3-jet events with colliding energy



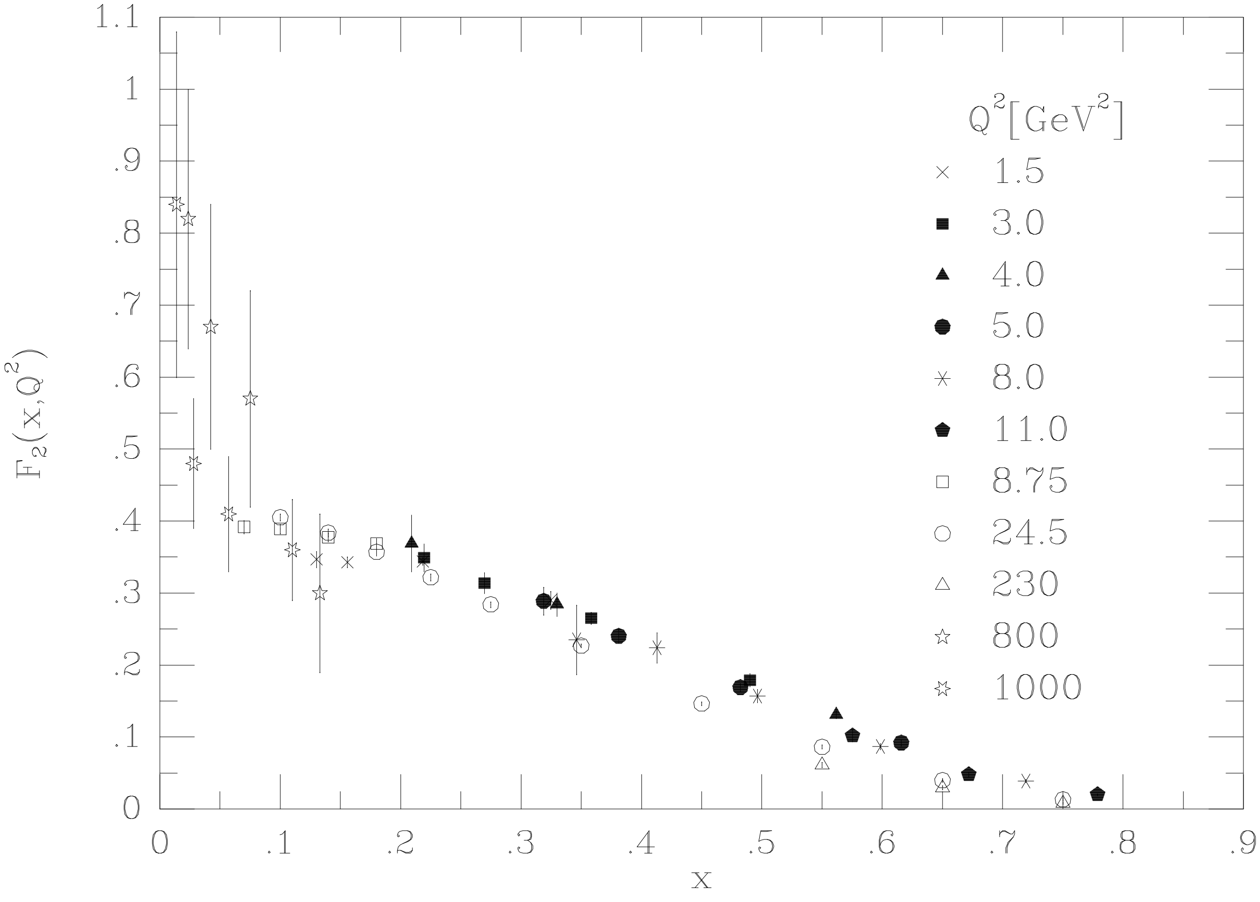
Note $R_3 = C\alpha_s$ i.e. direct measurement of α_s (at LO)

Extraction of α_s from the k_t and Cambridge jets



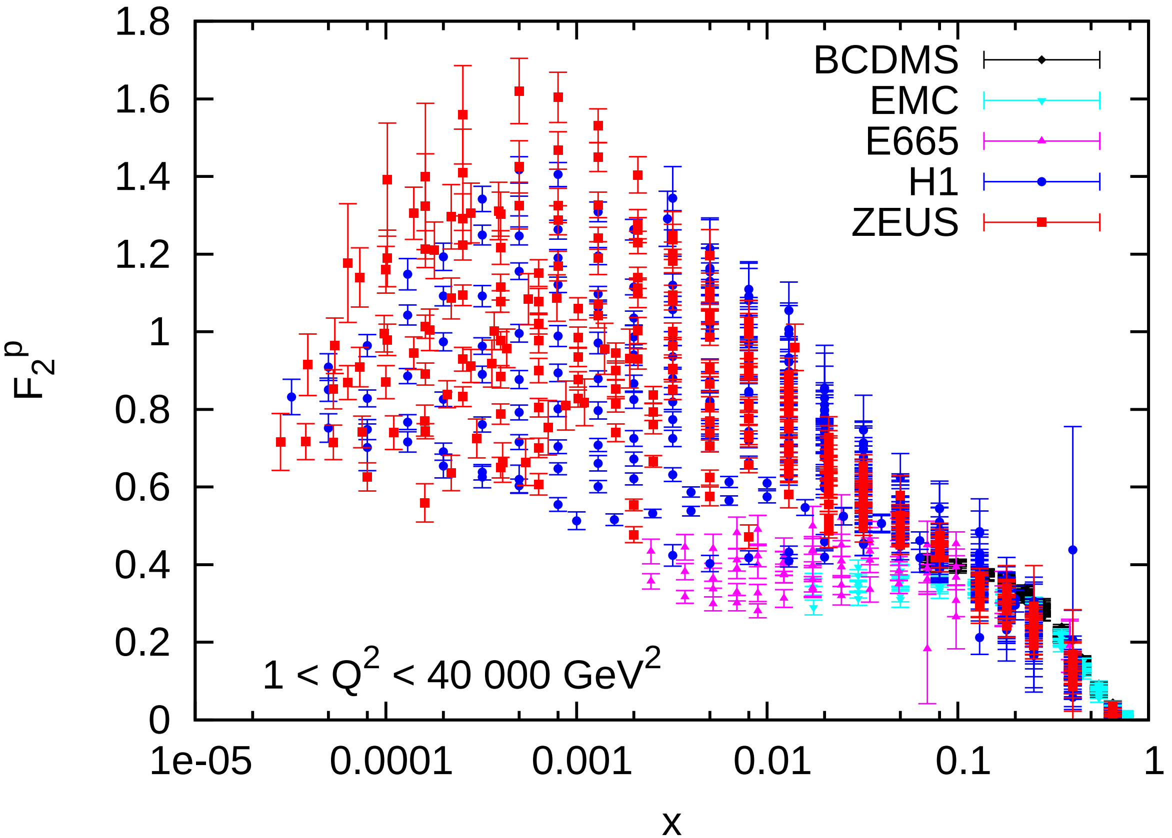
DIS

Bjorken scaling



Measurements from BCDMS, SLAC, NMC, H1 and ZEUS

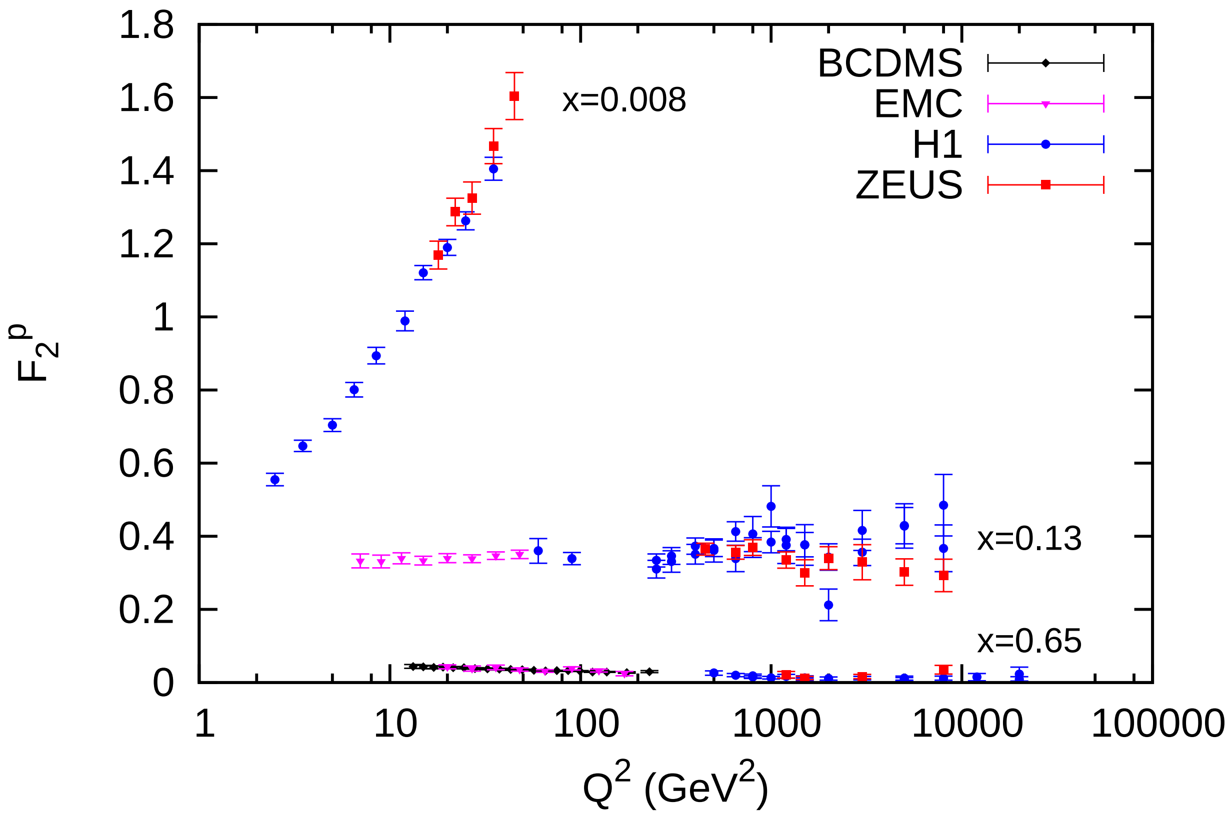
Scaling violations



HERA measurements ($\approx$ 1993-2007)

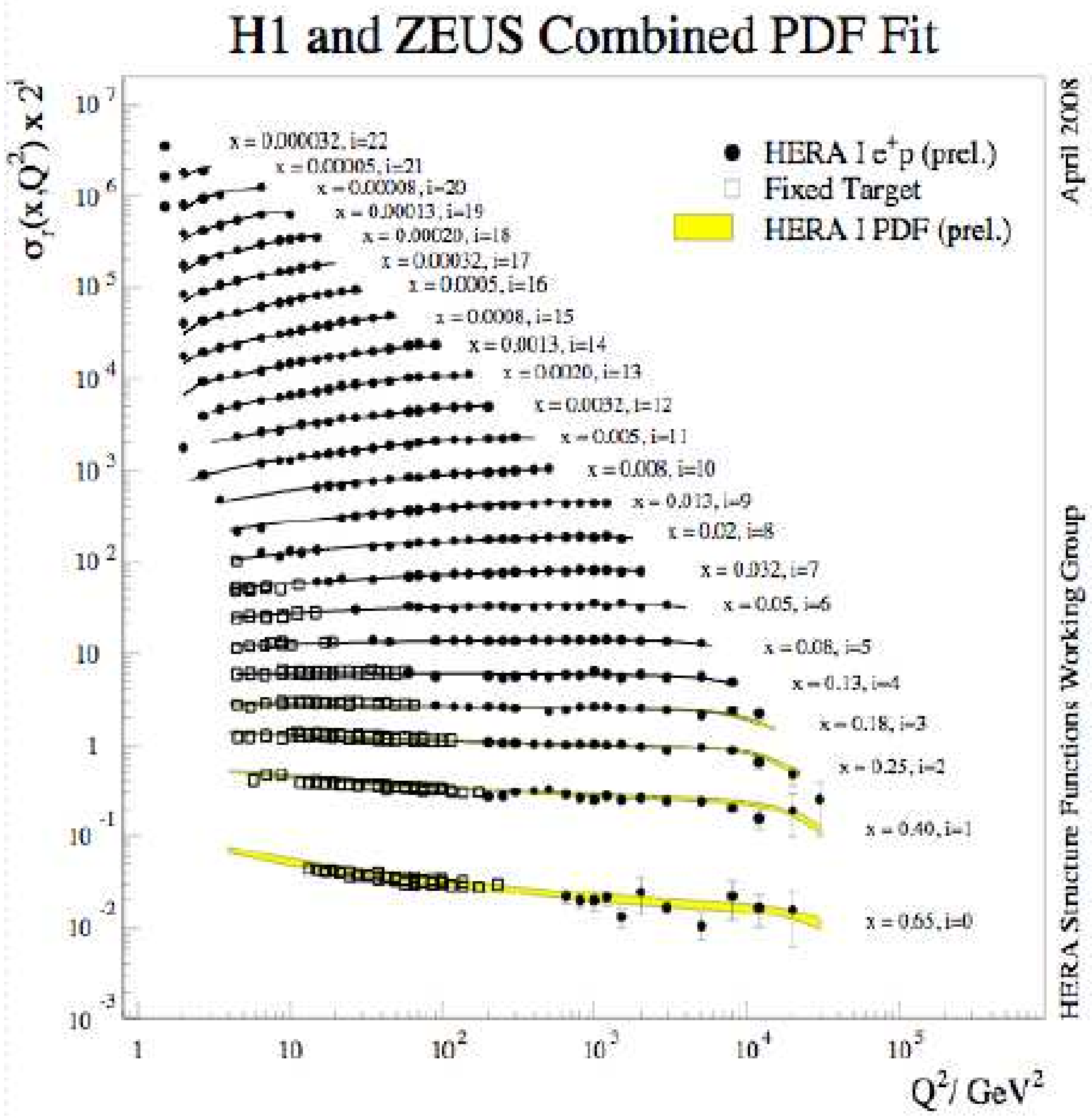
Note the $\log(x)$ scale

A closer look at the Q^2 dependence for 3 bins in x



- decreasing at large x
- (strong) rise at small x

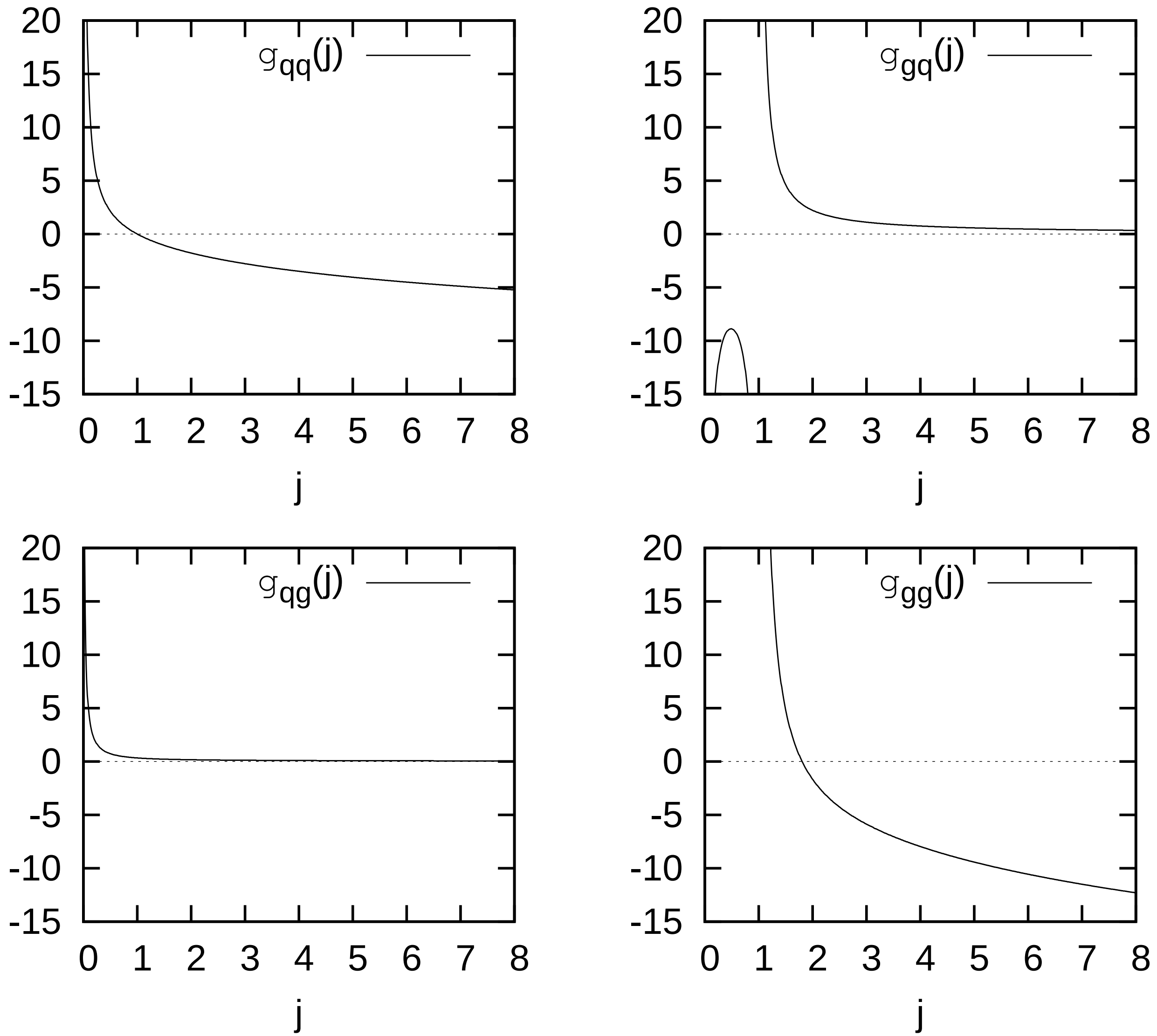
Remarkable agreement with DGLAP Global Fits



Here: prelim. HERA fit, prelim. HERA combined measurements

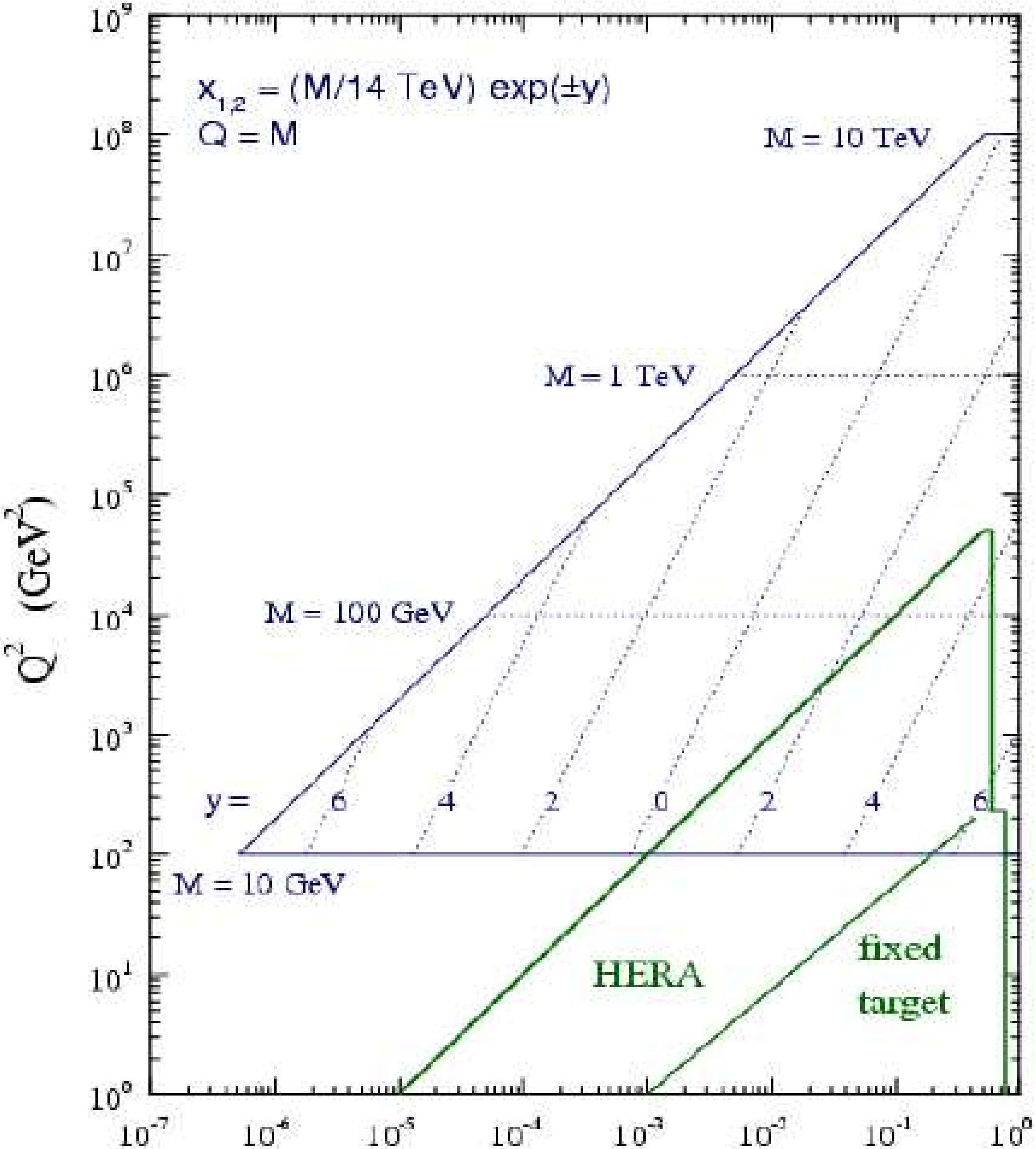
LO DGLAP anomalous dimensions

- Pole at $j = 1$ for gq and gg
- $\log(j)$ at $j \gg 1$ for qq and gg
- $\gamma_{qq}(1) = 0$

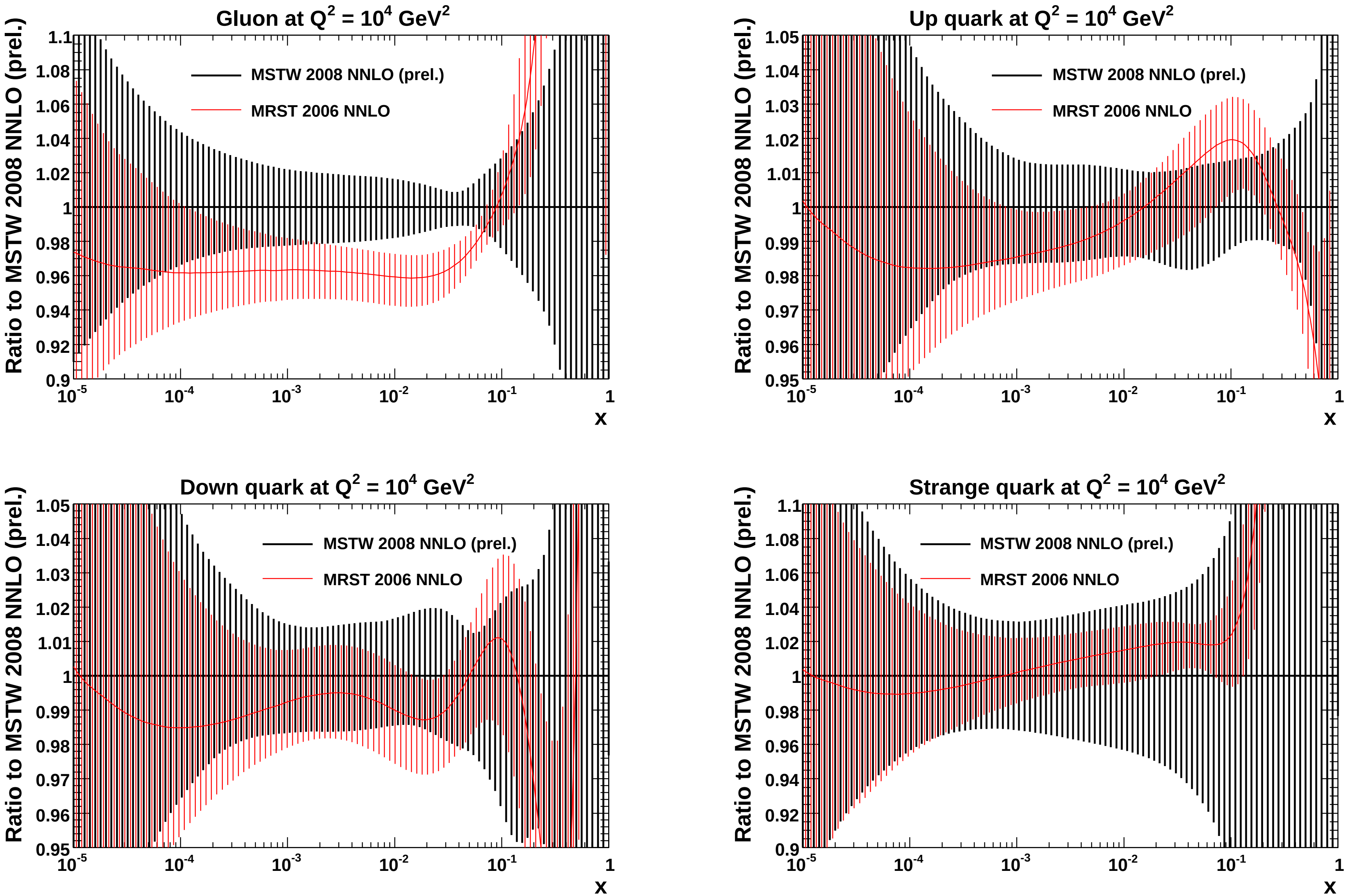


pp

Kinematics reached at the LHC

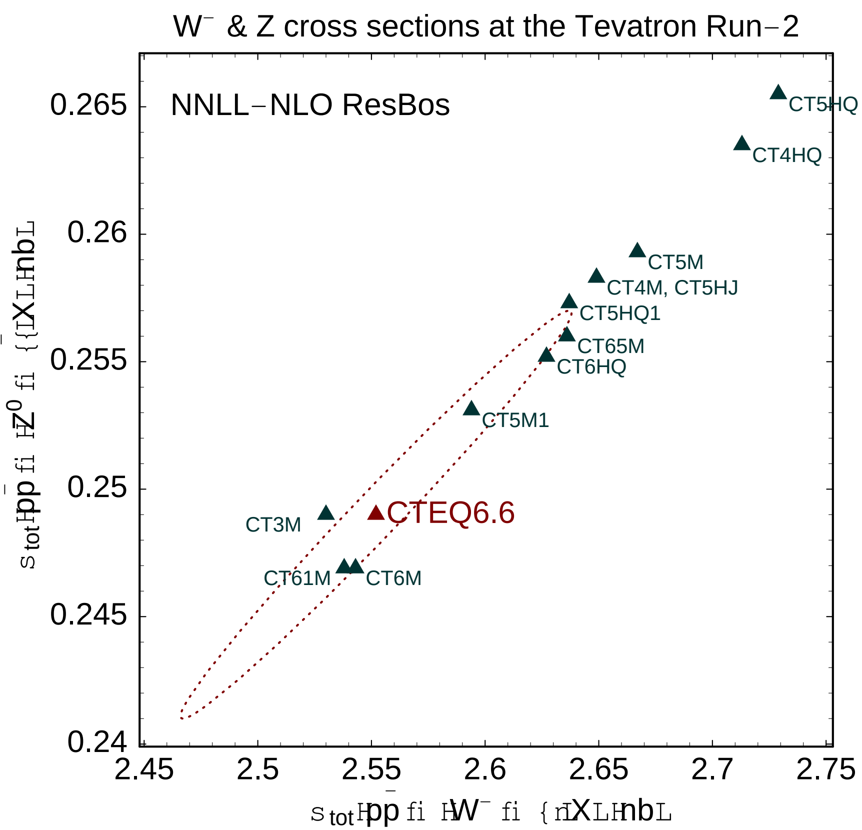


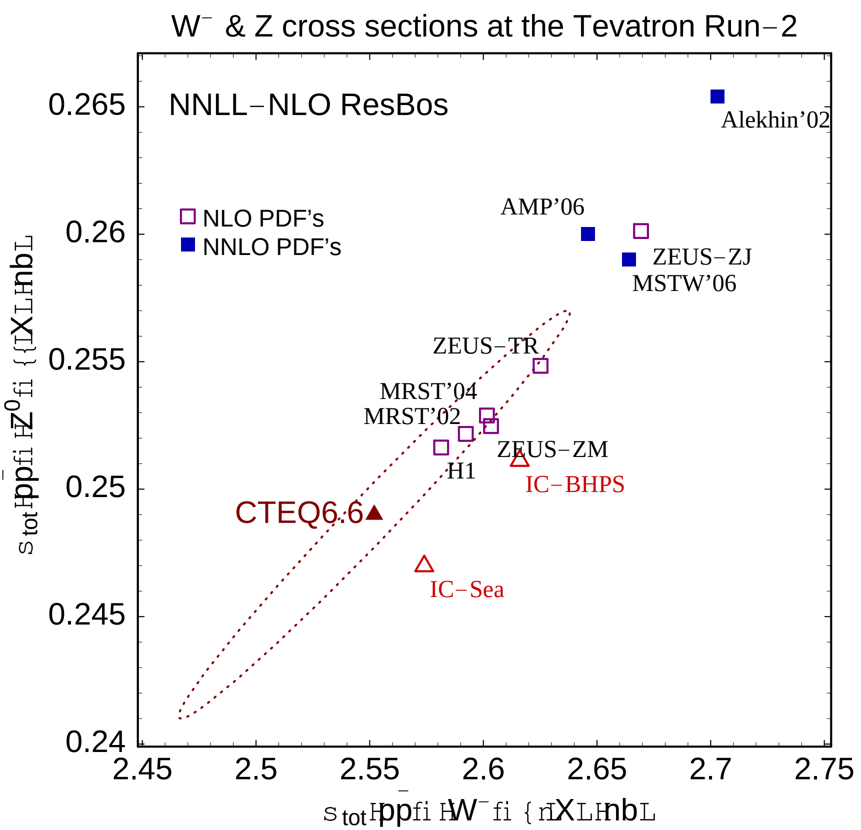
PDF uncertanities (here: prelim. MSTW & MRST 2006)



Typically a few %, larger at small and large x, especially the

Predictions for the W and Z cross-section: 1. Tevatron

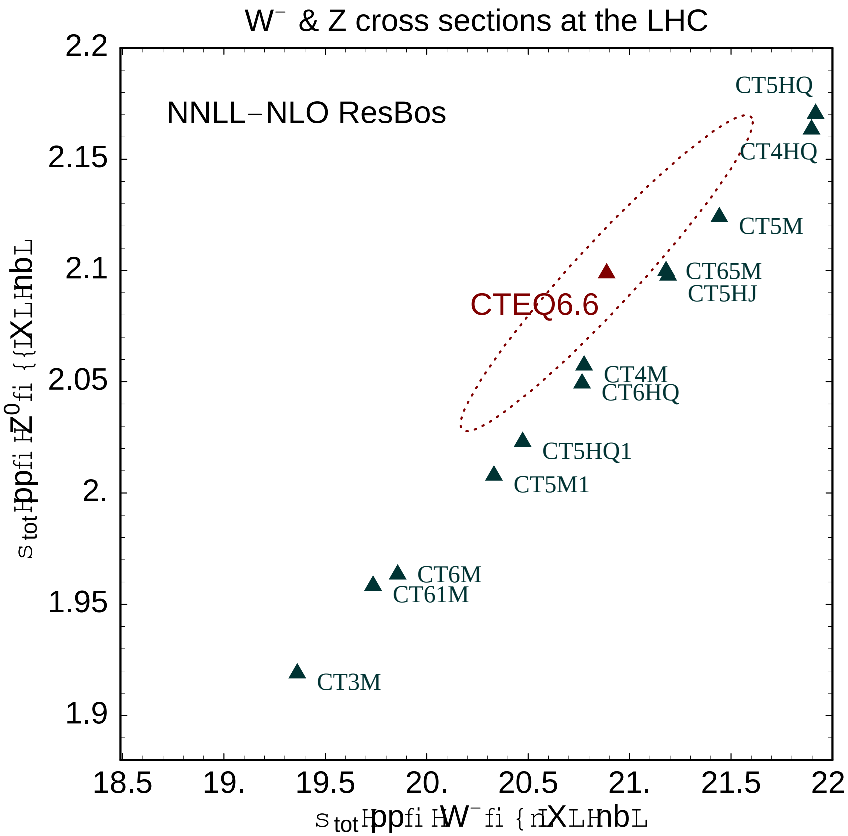


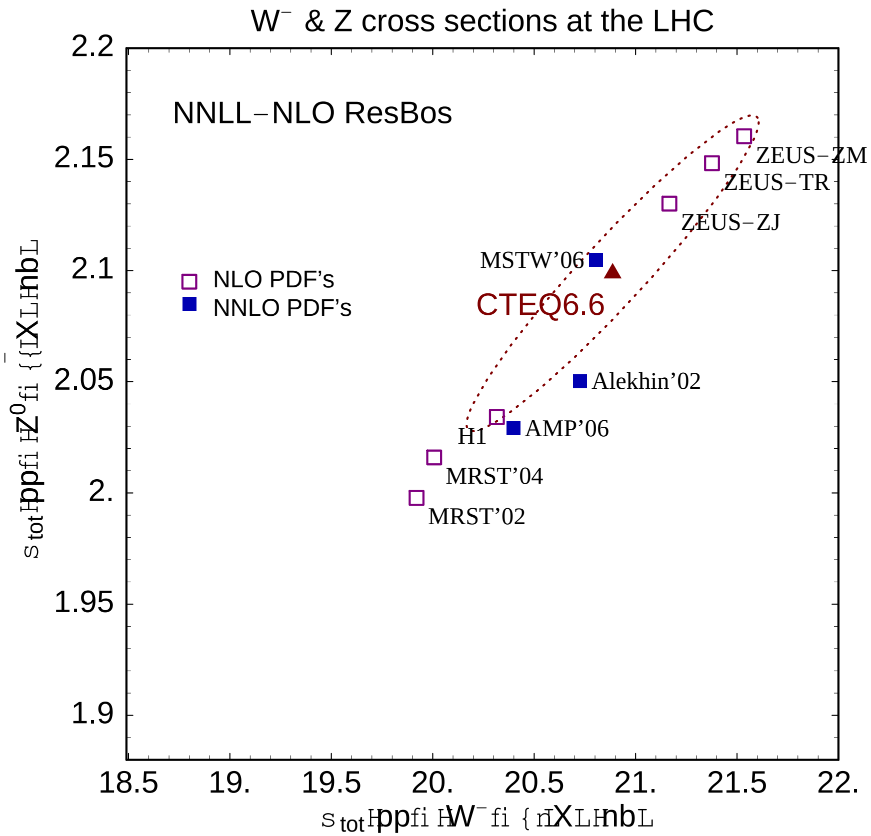


Non-begligible effect

Beyond the uncertainties contained in 1 PDF set

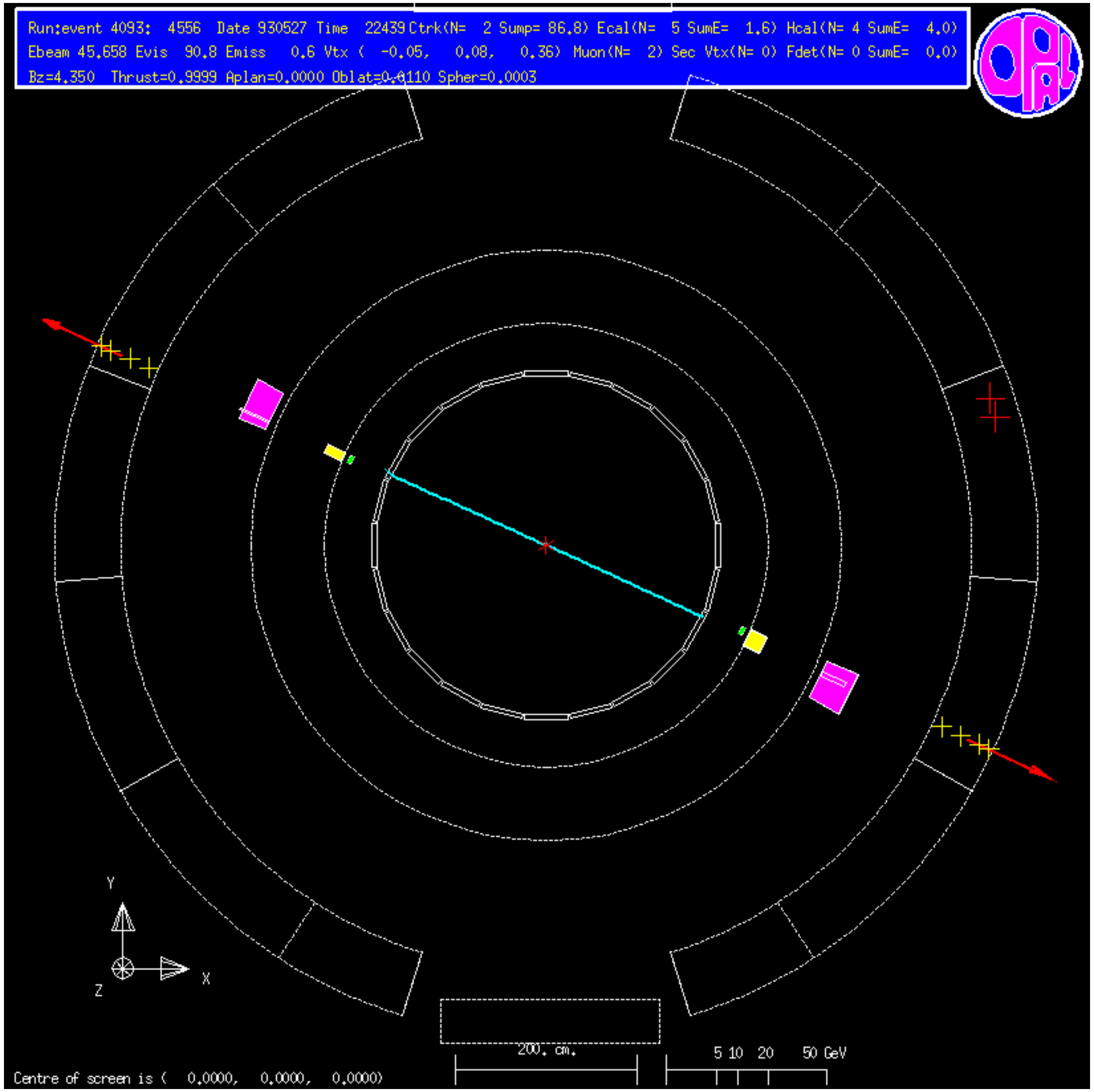
Predictions for the W and Z cross-section: 2. LHC



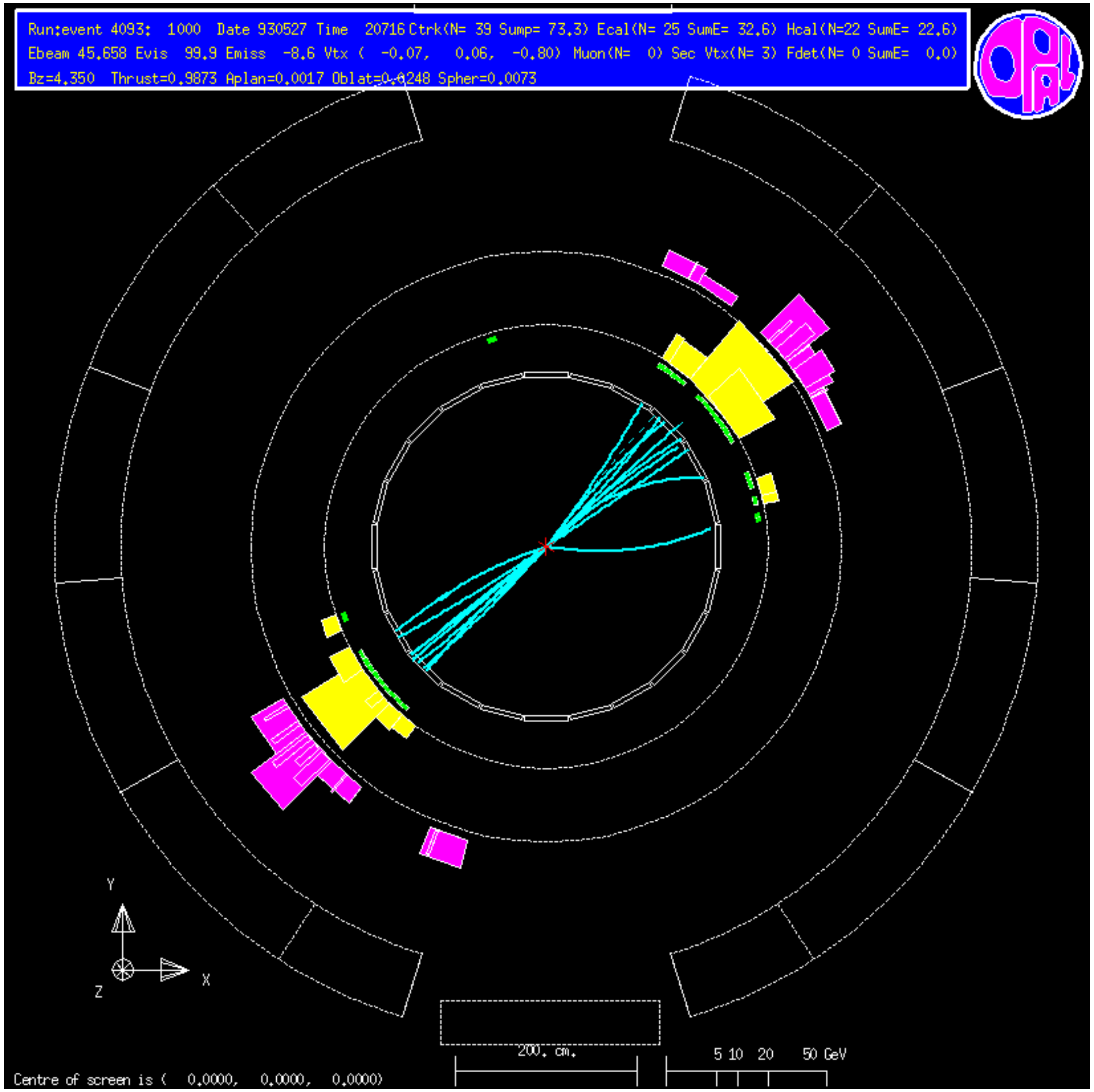


Non-begligible effect
Beyond the uncertainties contained in 1 PDF set

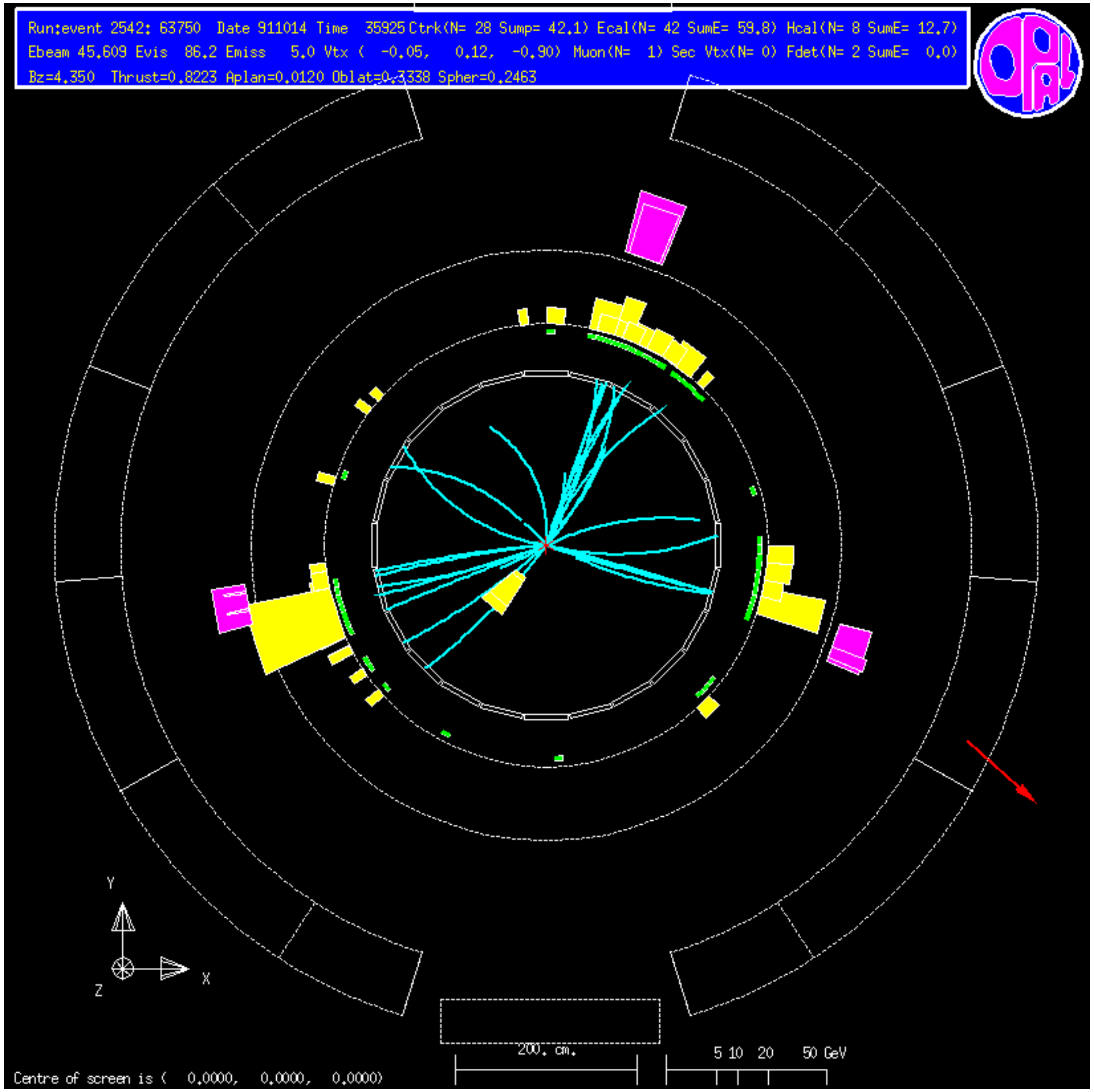
Typical $e^+e^- \to \mu^+\mu^-$ event



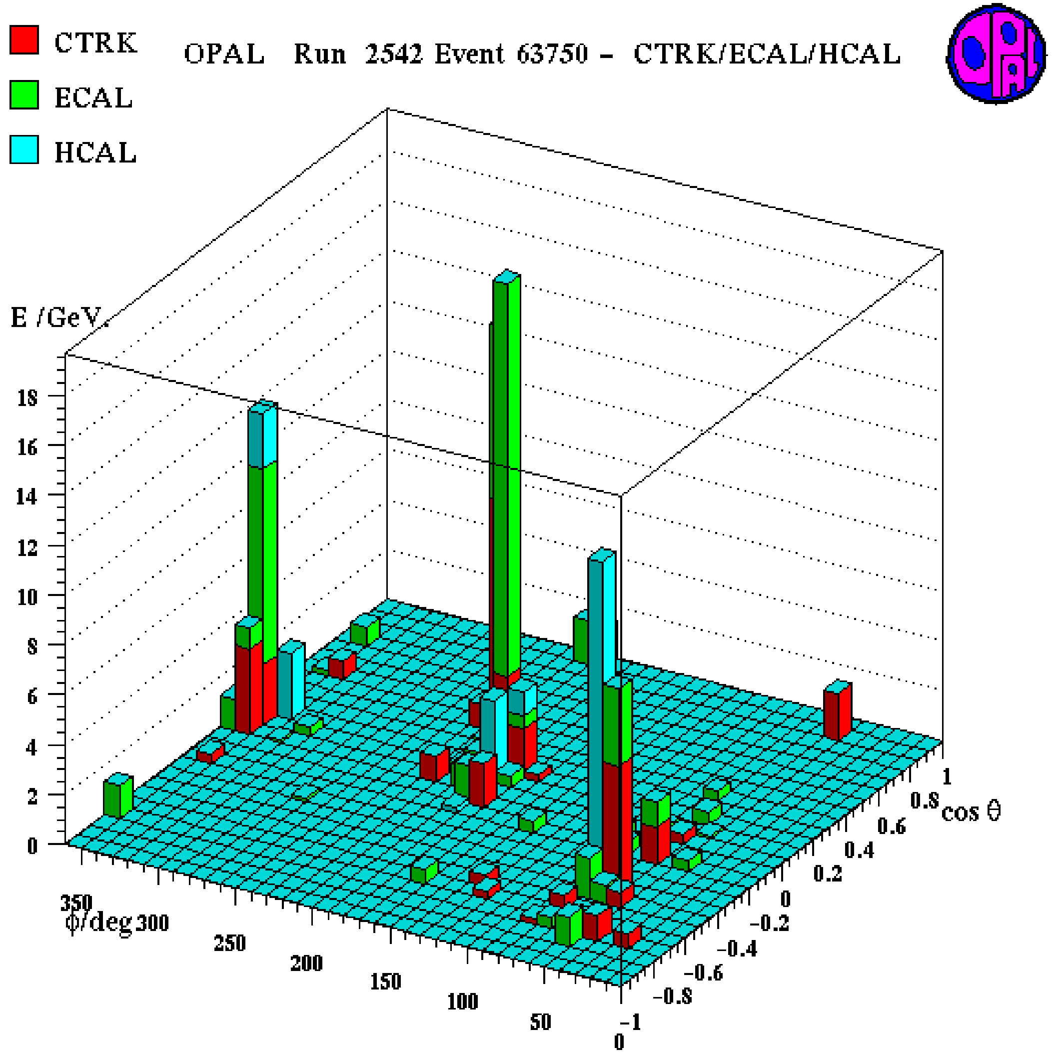
Typical $e^+e^- \to$ 2 jets event



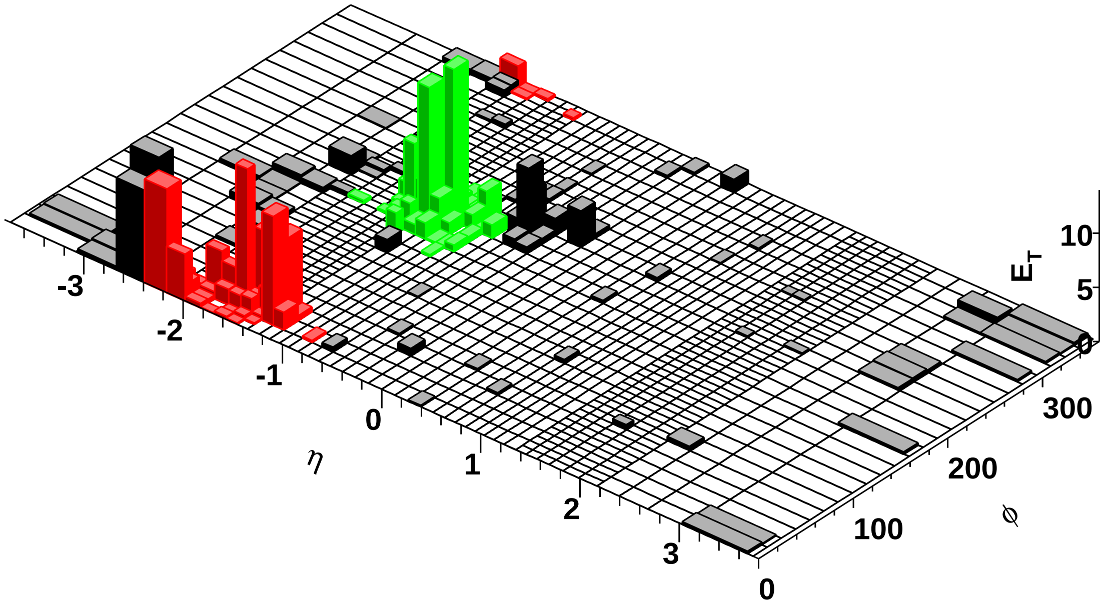
Typical $e^+e^- \to$ 3 jets event



Typical $e^+e^- \to$ 3 jets event

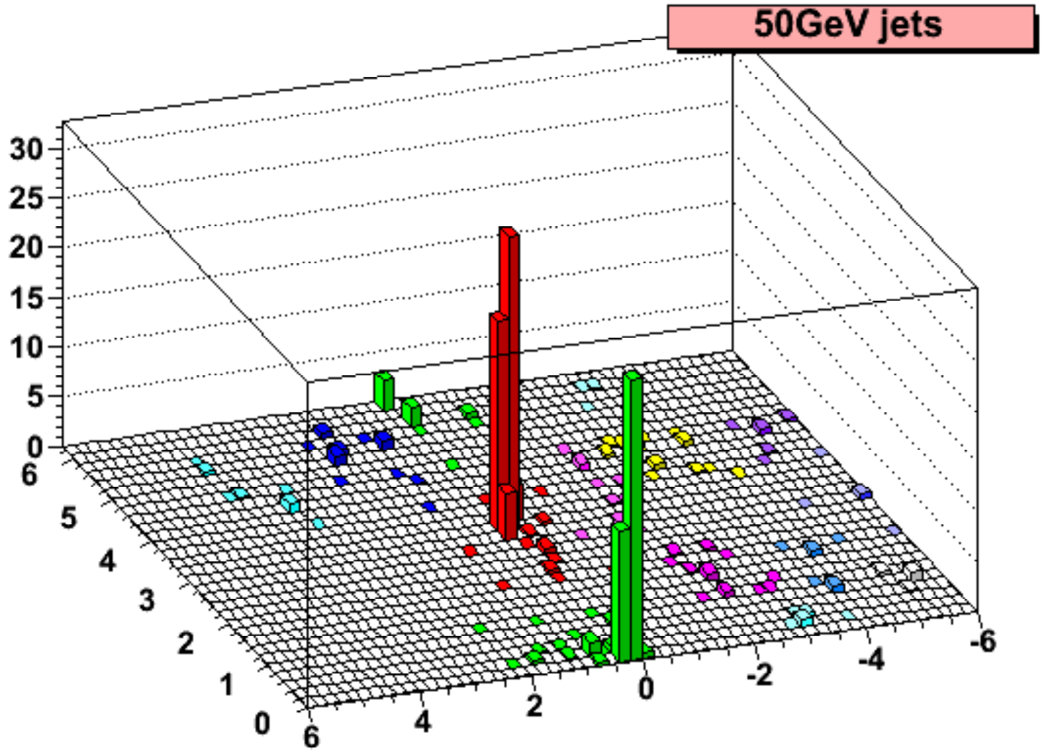


Typical $pp \rightarrow$ jets event at the TEVATRON



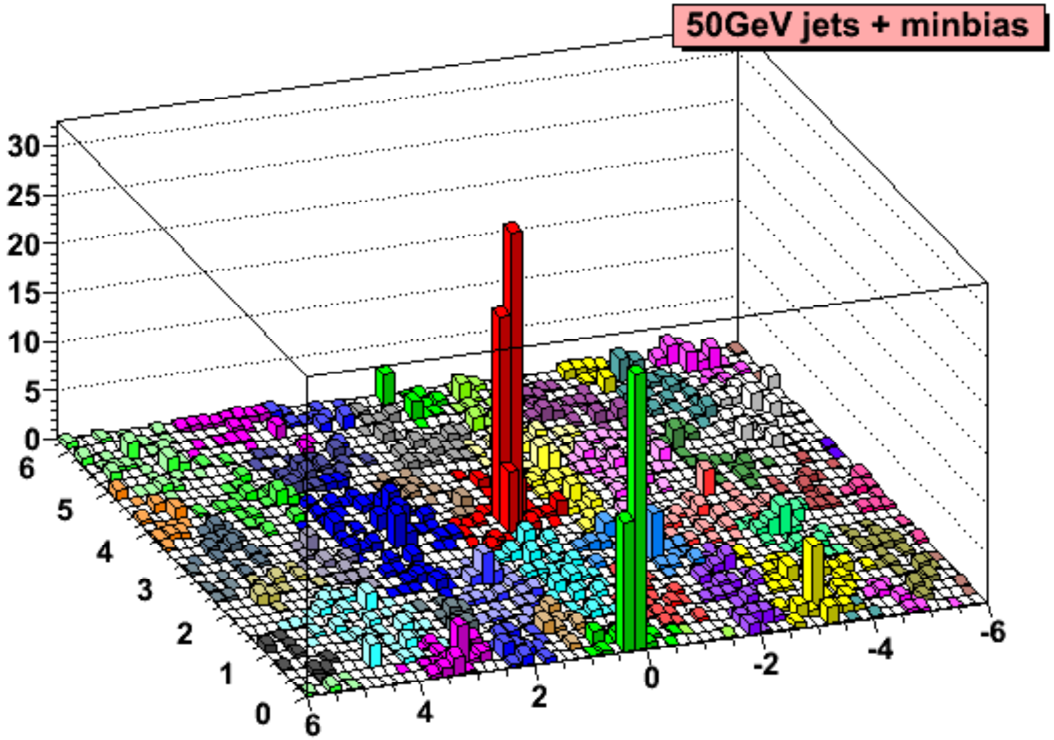
$$\sim 300 - 400 particles$$

Typical $pp \rightarrow$ jets event at the LHC



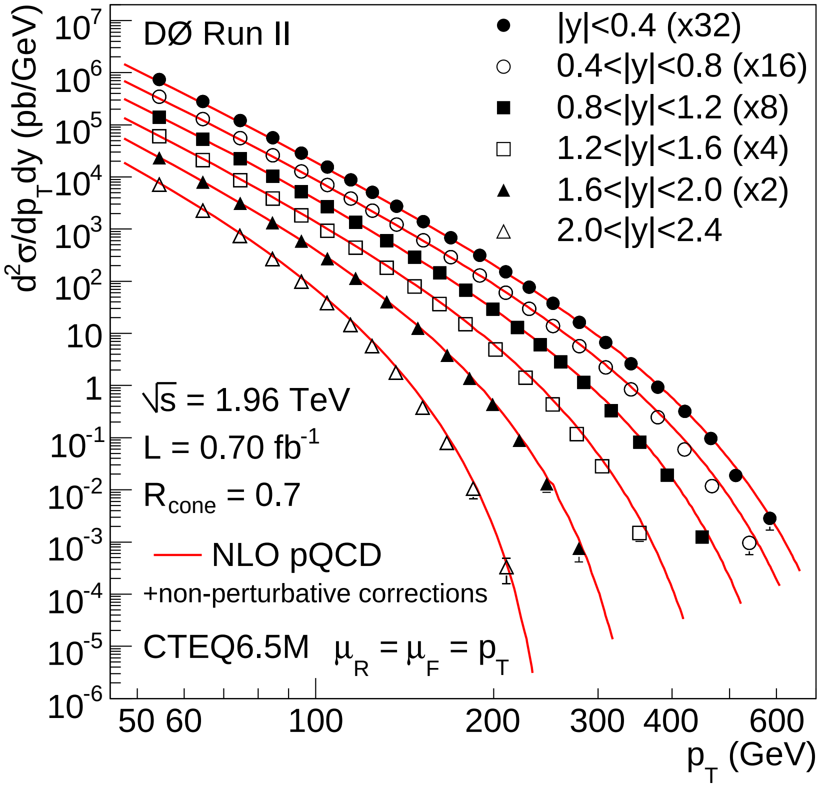
$$\sim 300 - 400 particles$$

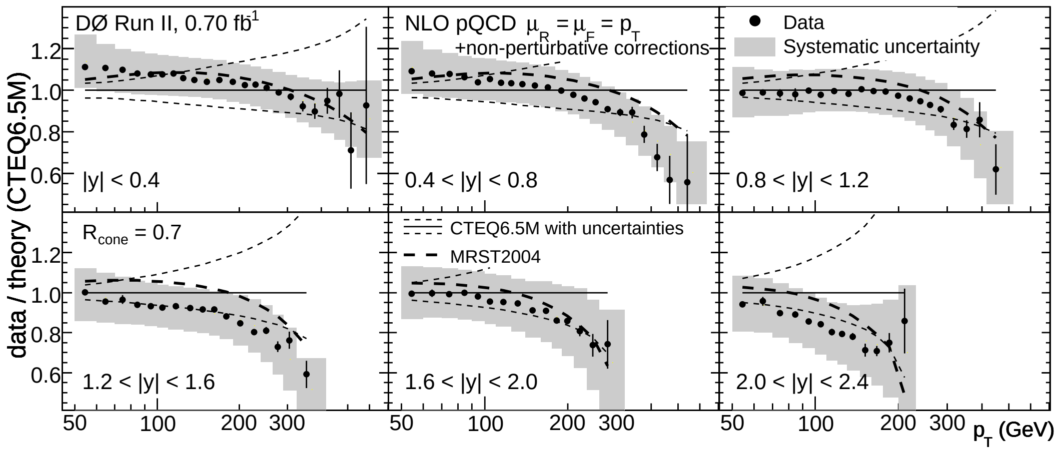
Typical $pp \to$ jets event with pileup



$$\sim 3000 particles$$

D0 measurements of inclusive cross-section

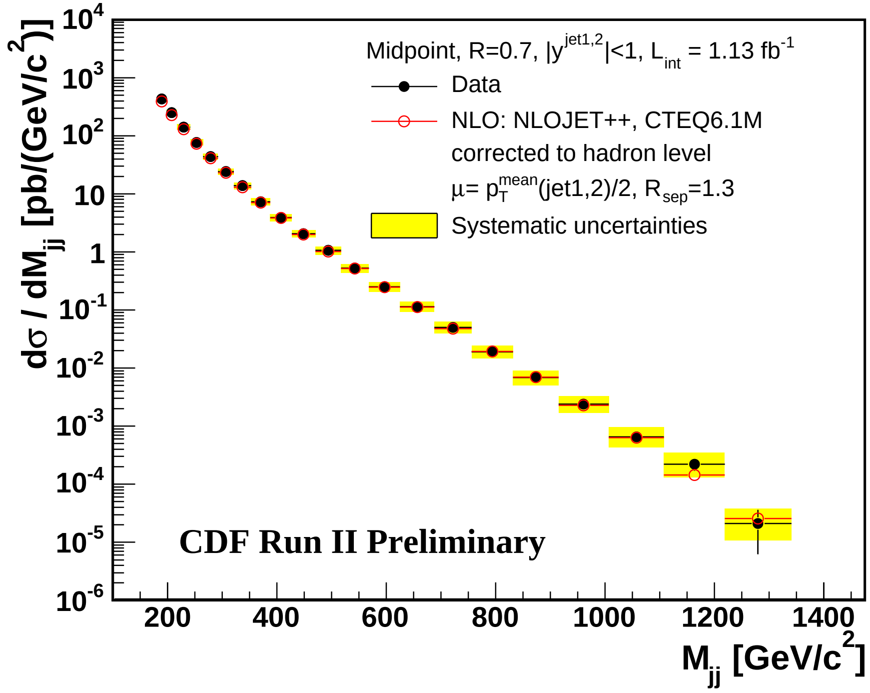


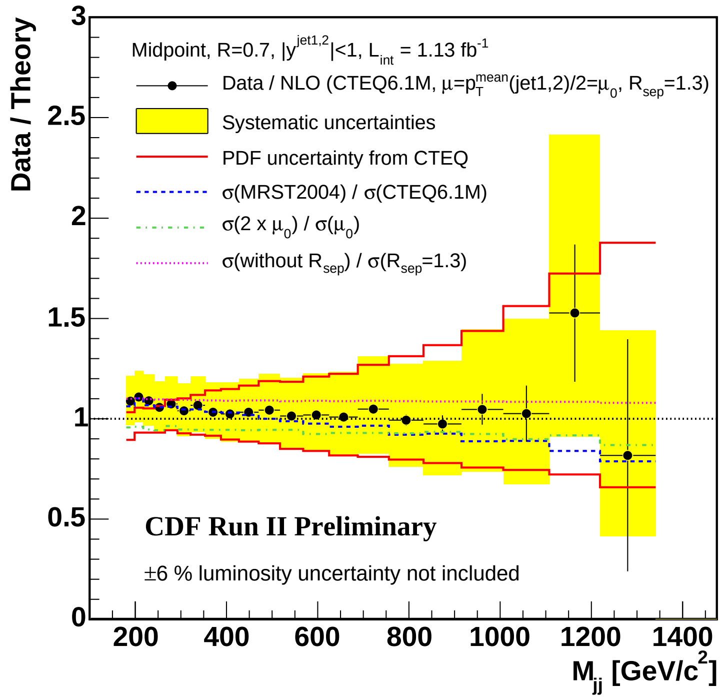


good agreement with NLO QCD predictions

Note that error(PDF) $\approx$ error(data)

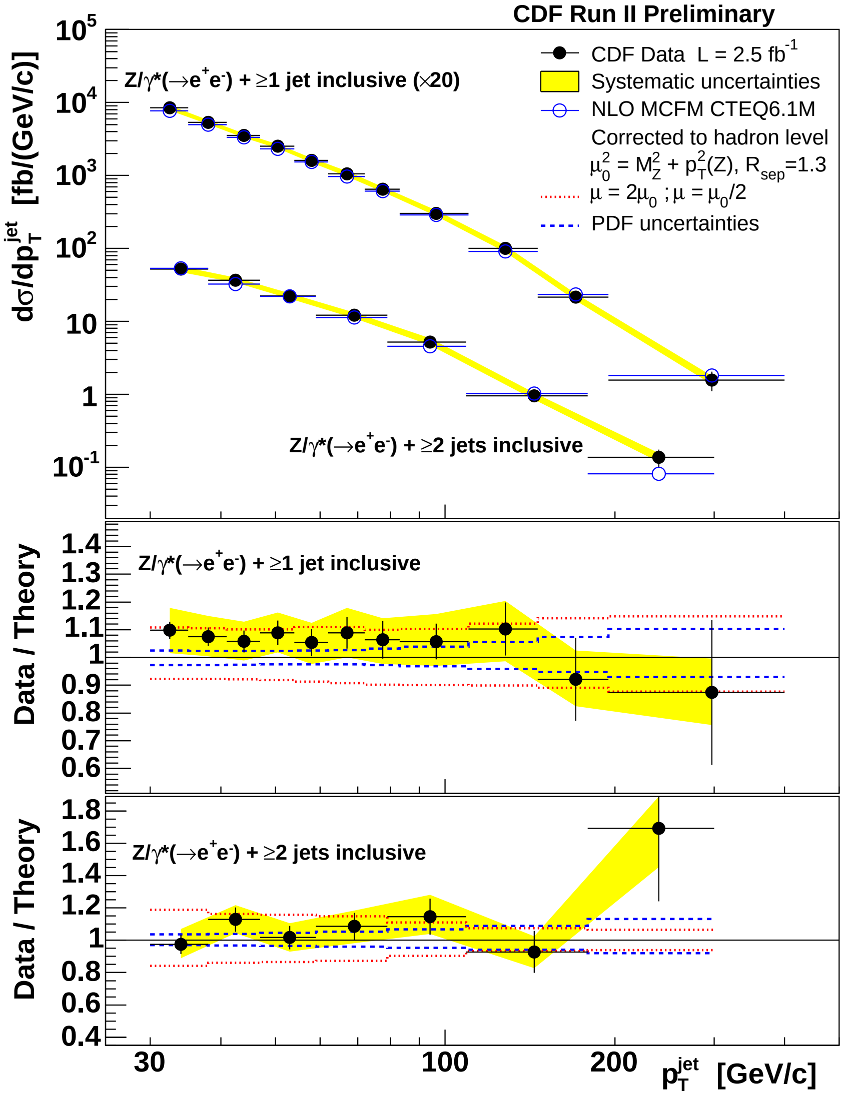
CDF measurements of dijet cross-section (prelim.)

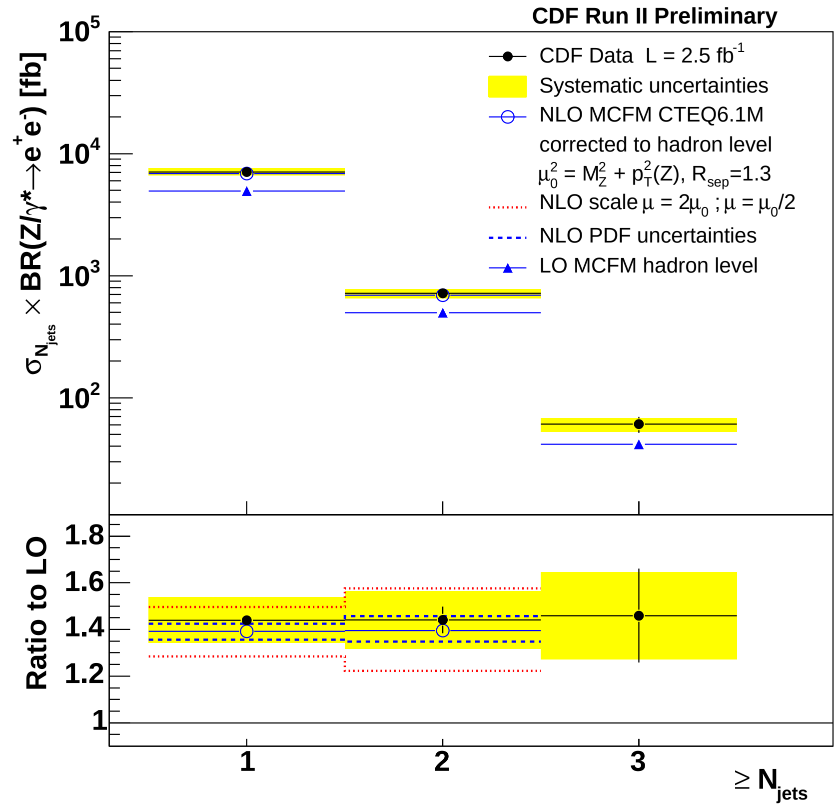




good agreement with NLO QCD predictions

CDF measurements of Z+jets cross-section (prelim.)



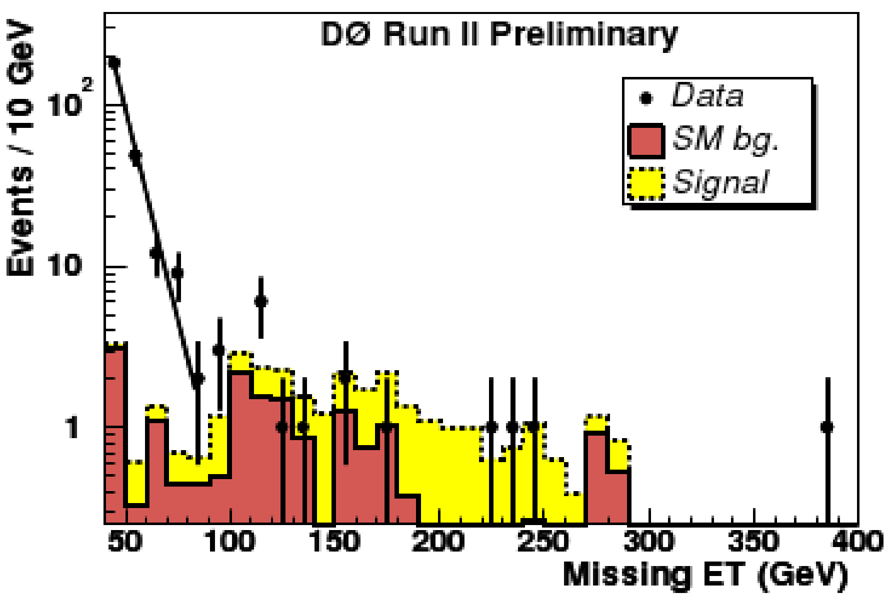


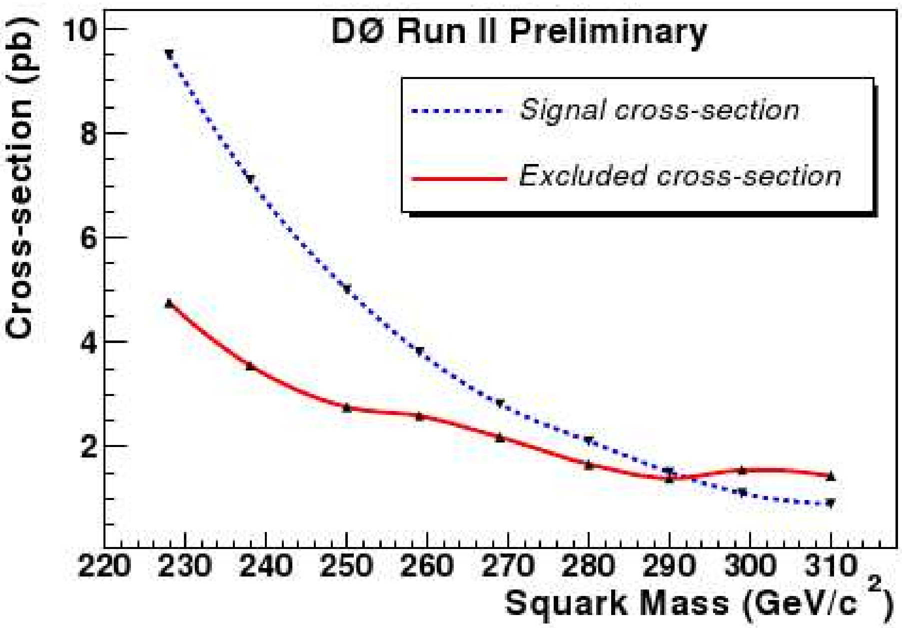
good agreement with NLO QCD

BUT Z+2j at with MidPoint
at NLO is dangerous

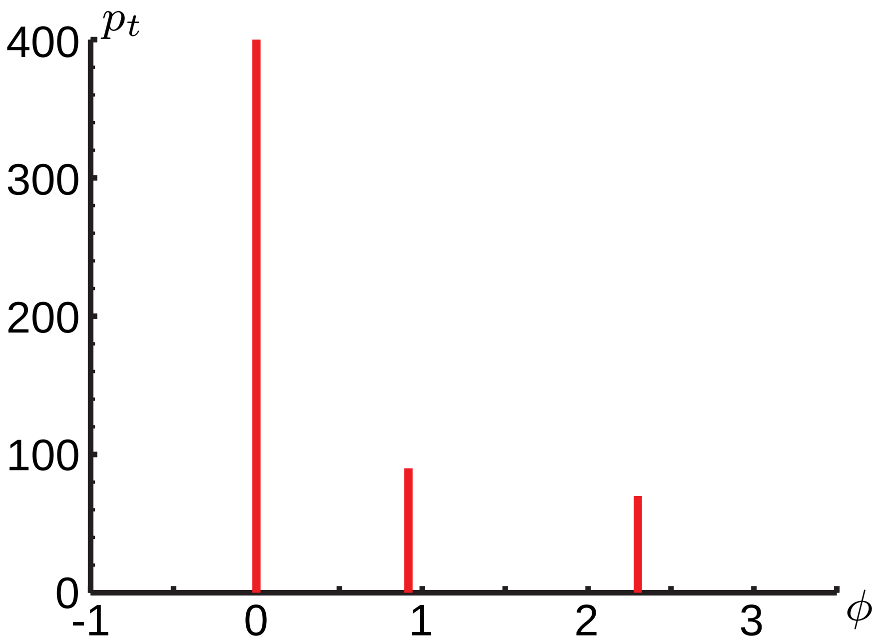
D0 SUSY searches (prelim.)

If $m_0 < m_{1/2}$, $\tilde{q} \to q\chi_1^0$ i.e. for a pair production, at least 2 jets (not back-to-back) + missing E_T

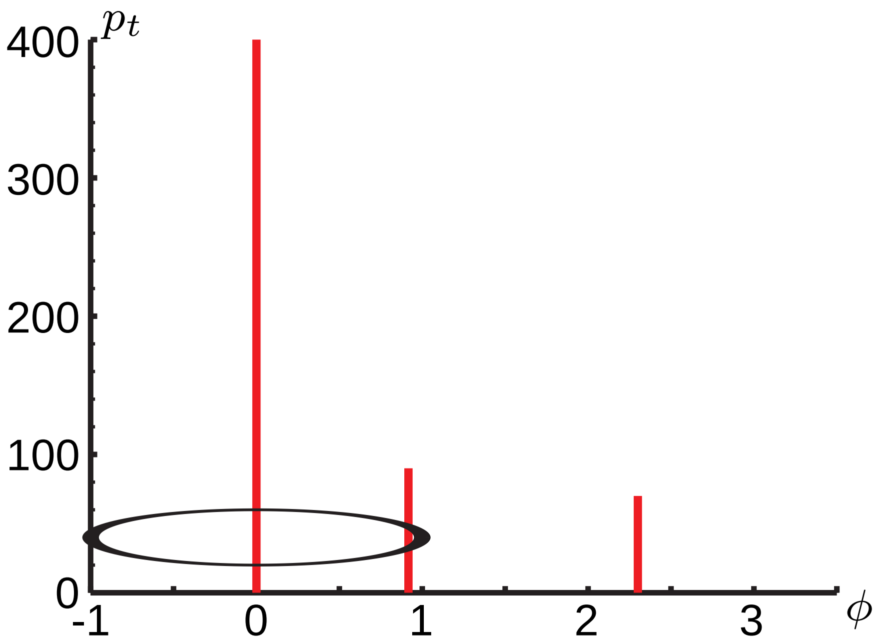




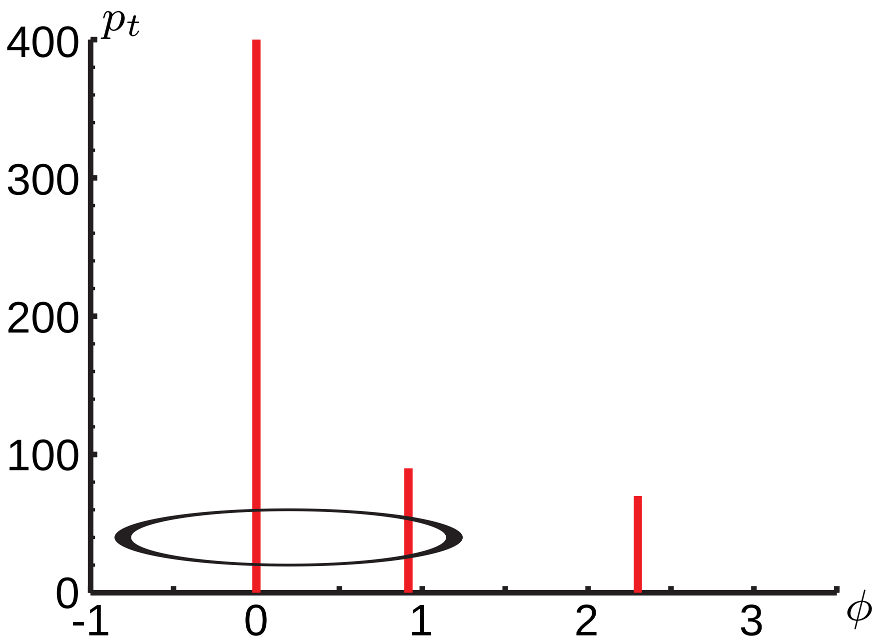
Red: upper limit on the data
Blue: theoretical expectations



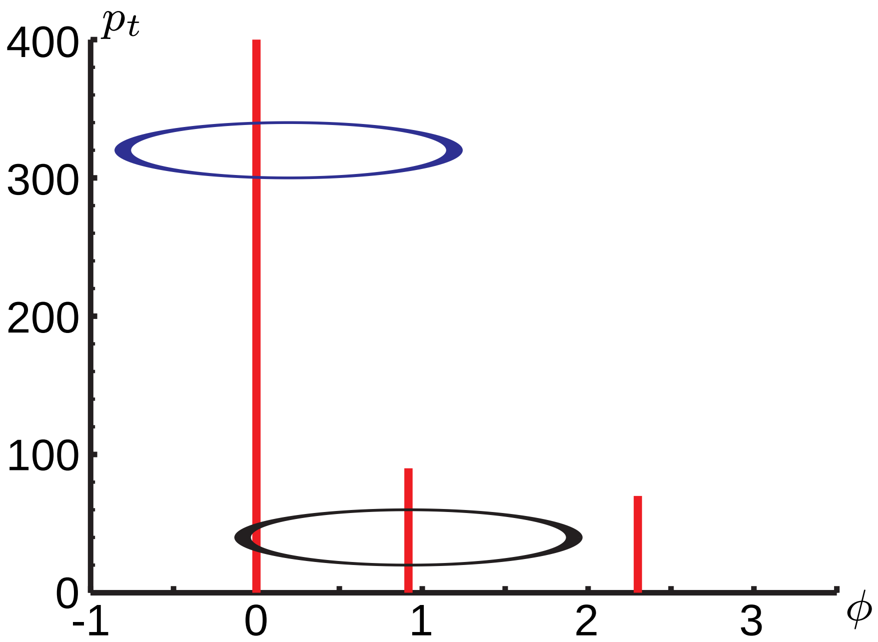
3-particle event — MidPoint clustering



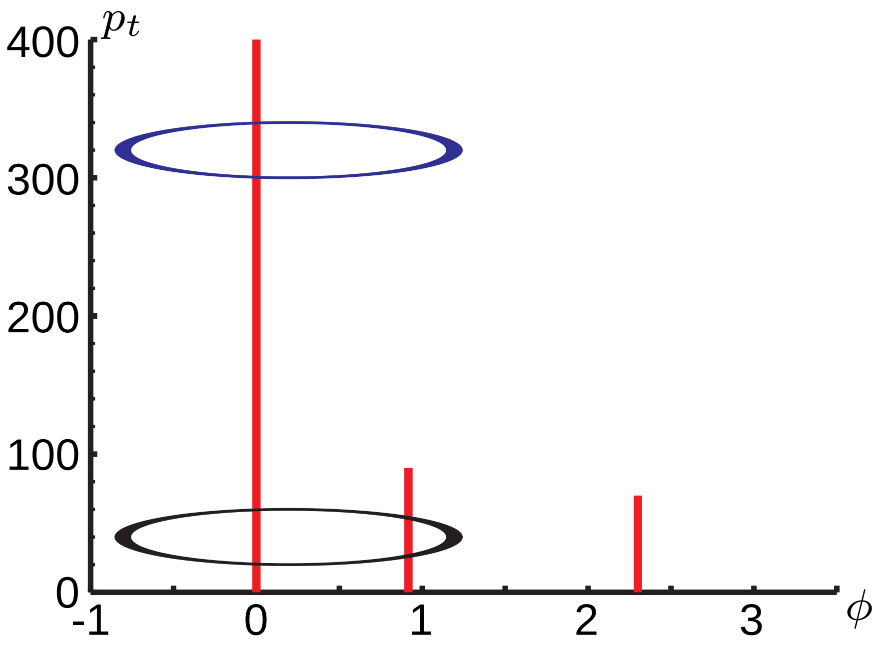
1st seed



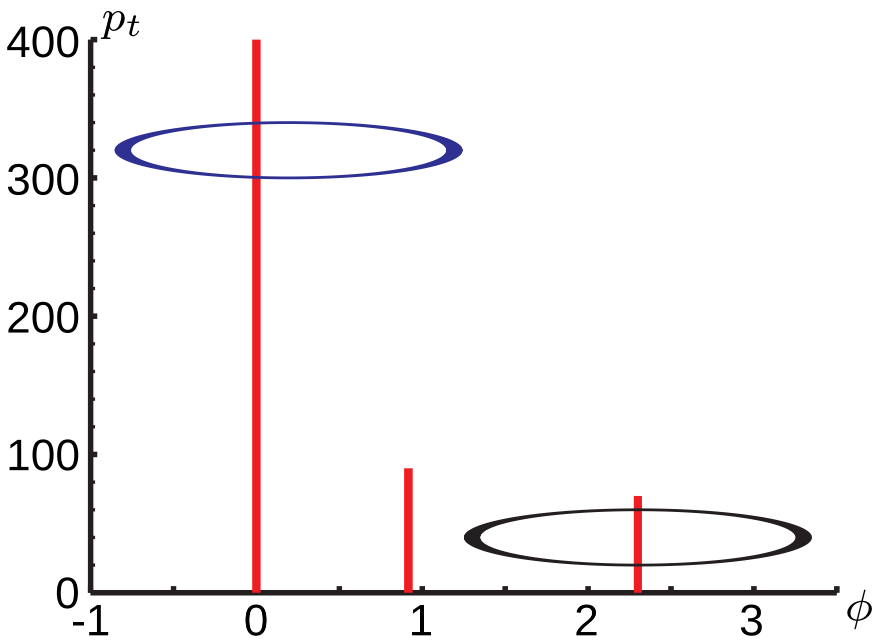
iterate



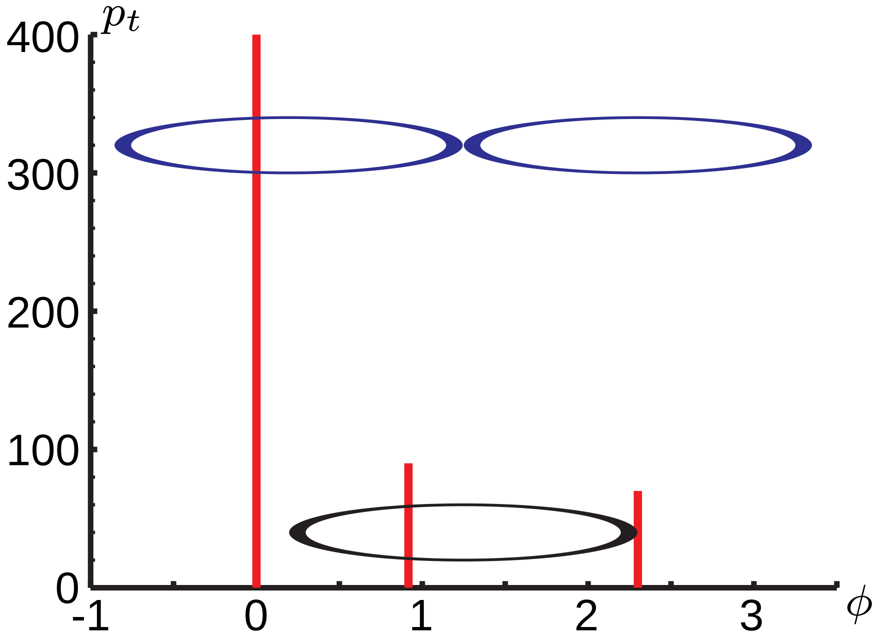
stable; 2nd seed



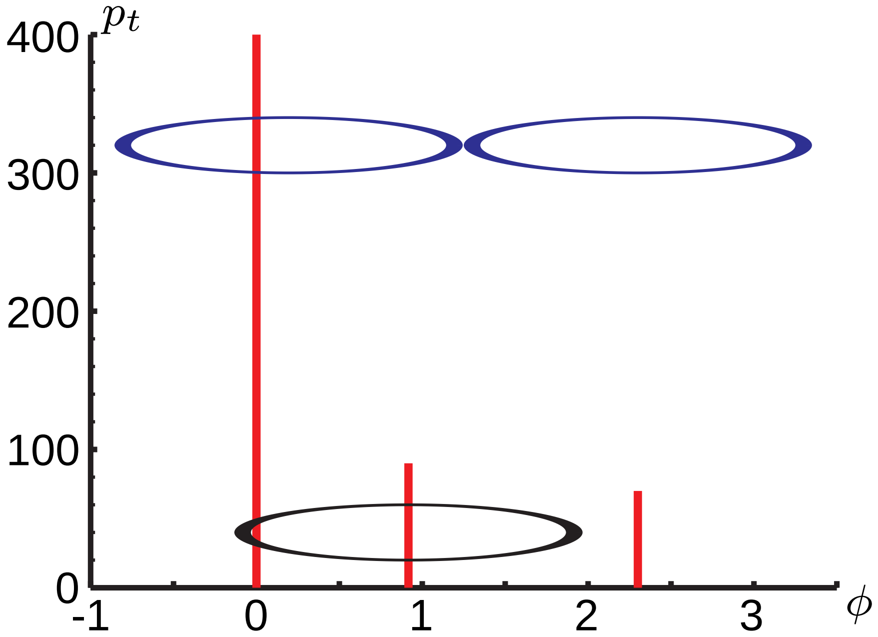
iterate



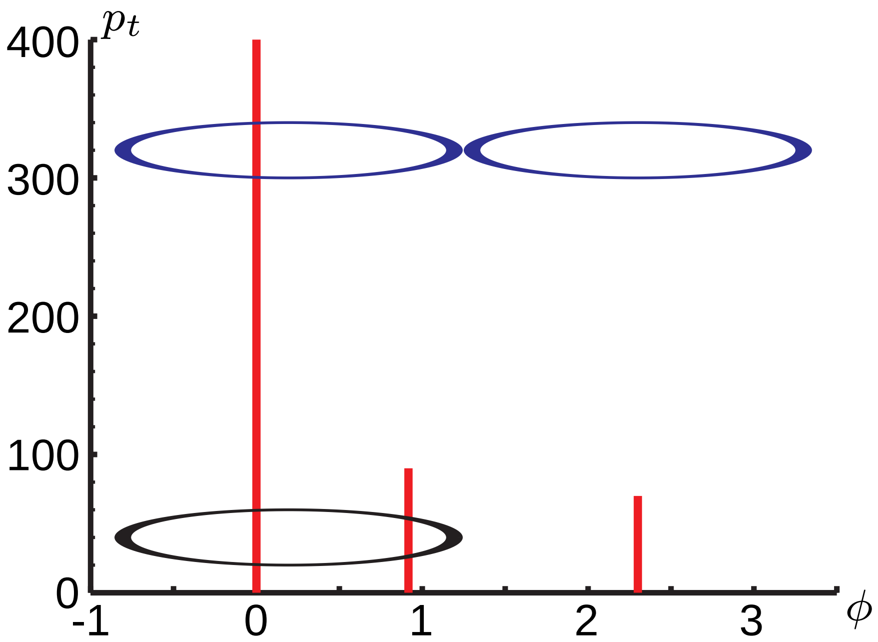
stable; 3rd seed



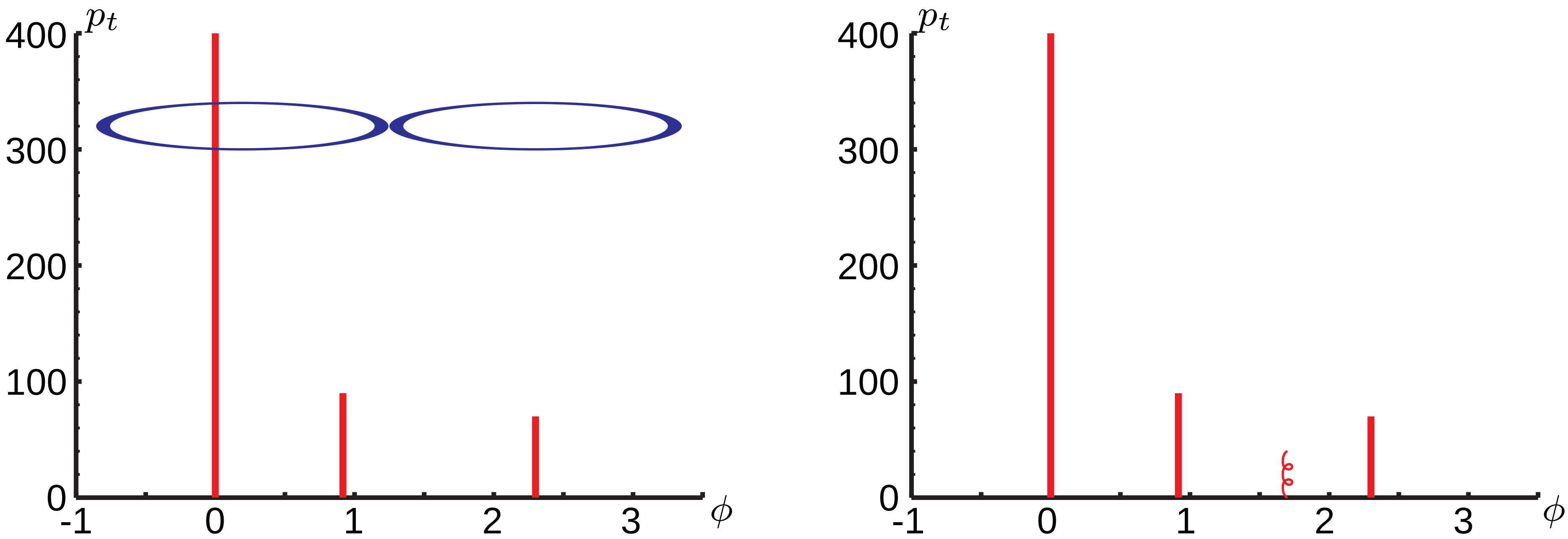
stable; midpoint seed



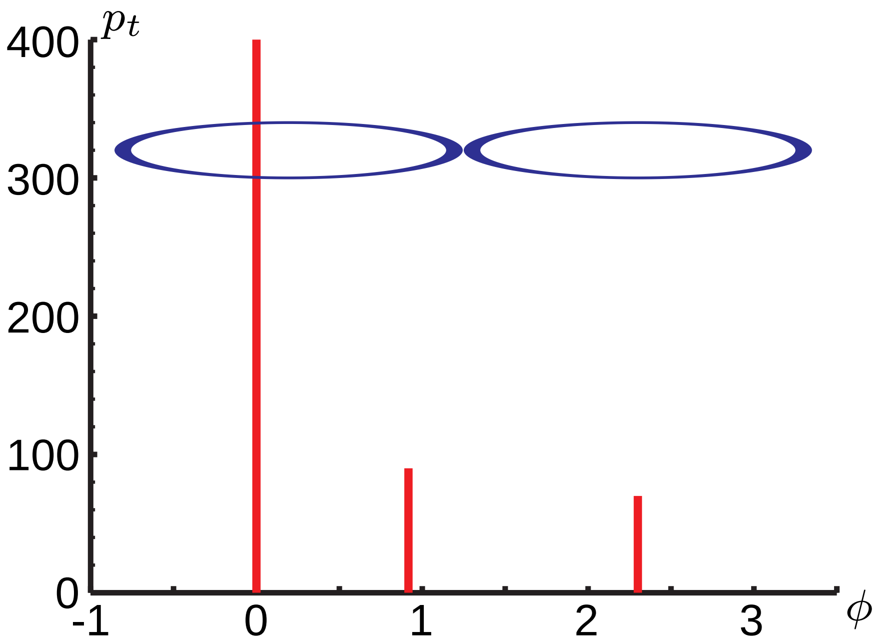
iterate

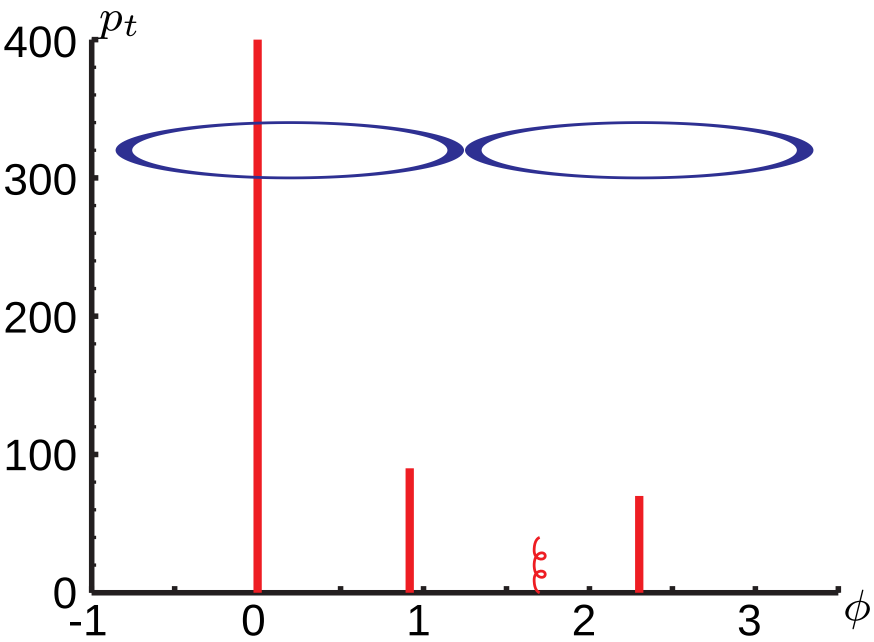


iterate

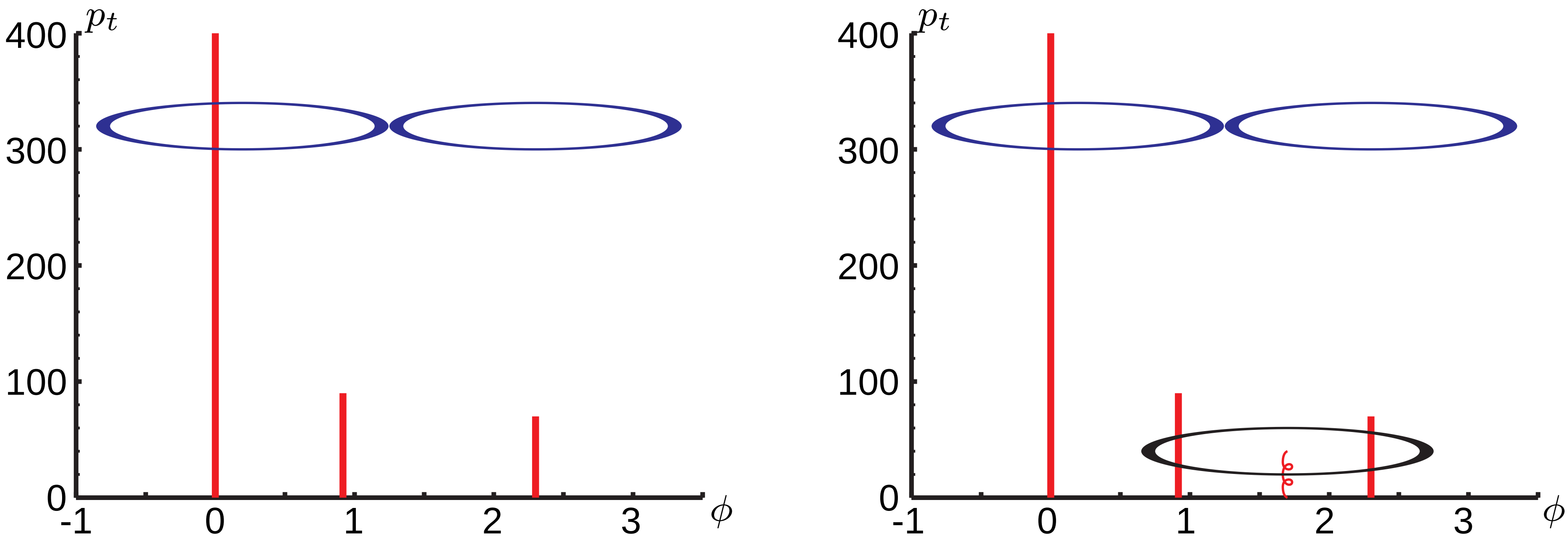


add an infinitely soft particle

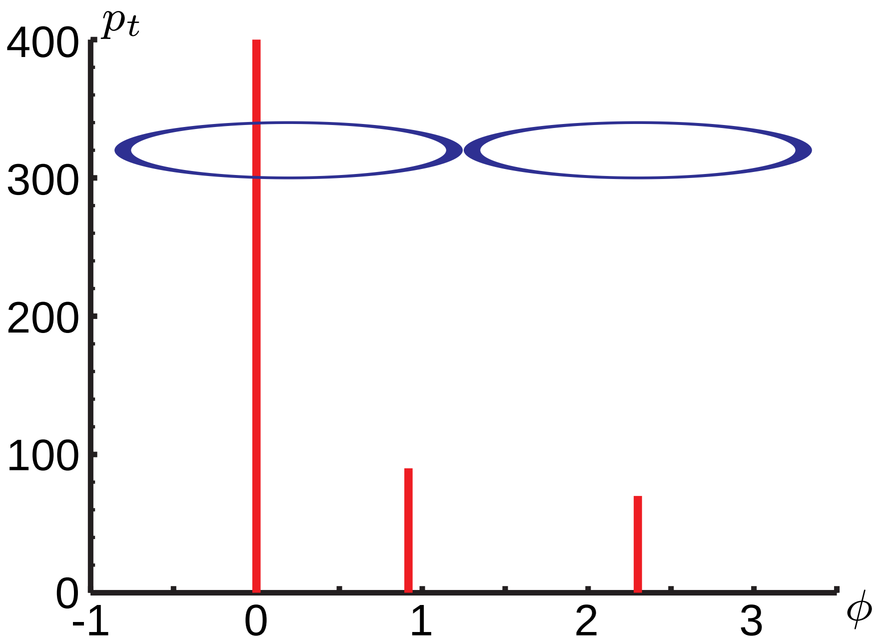


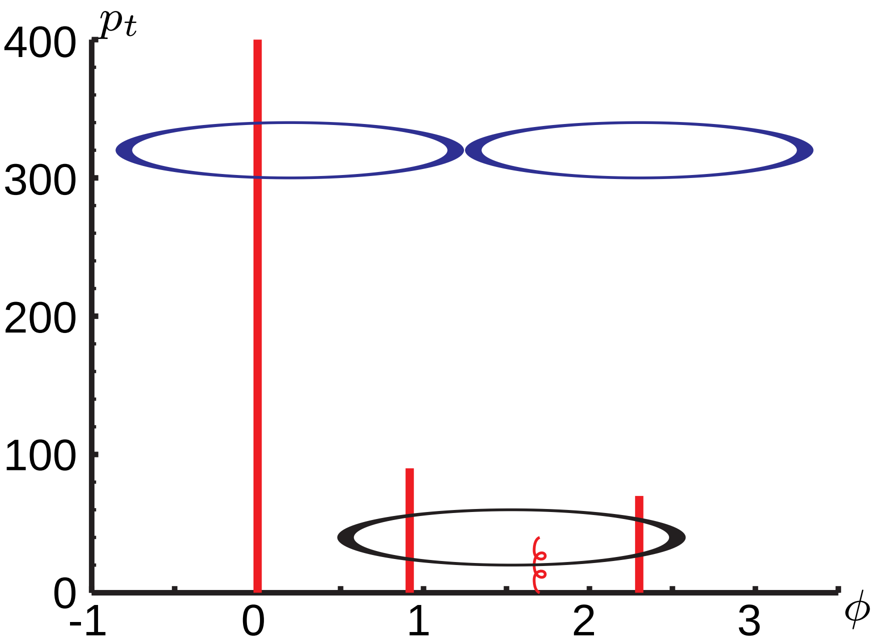


3 hard seeds + midpoint seed $\longrightarrow$ 2 stable cones

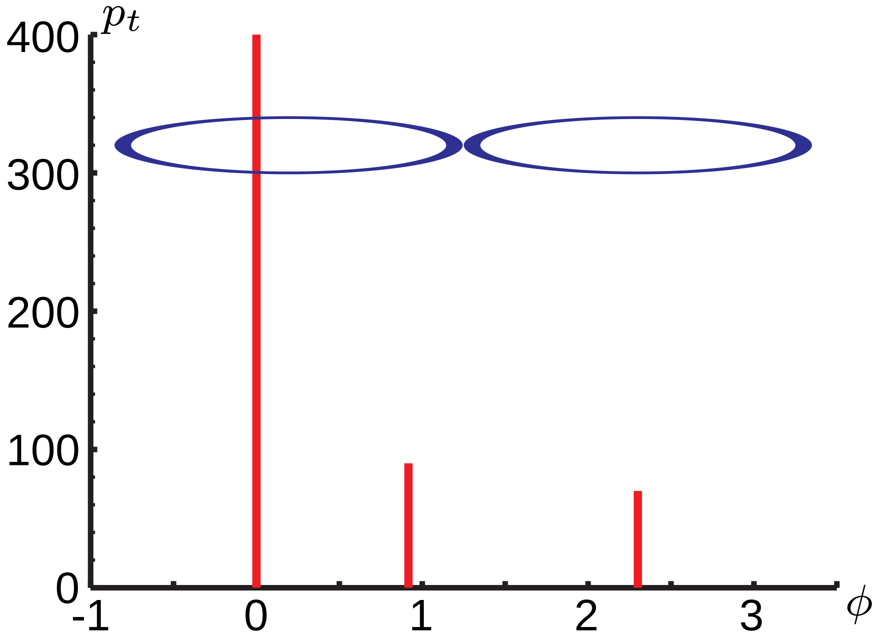


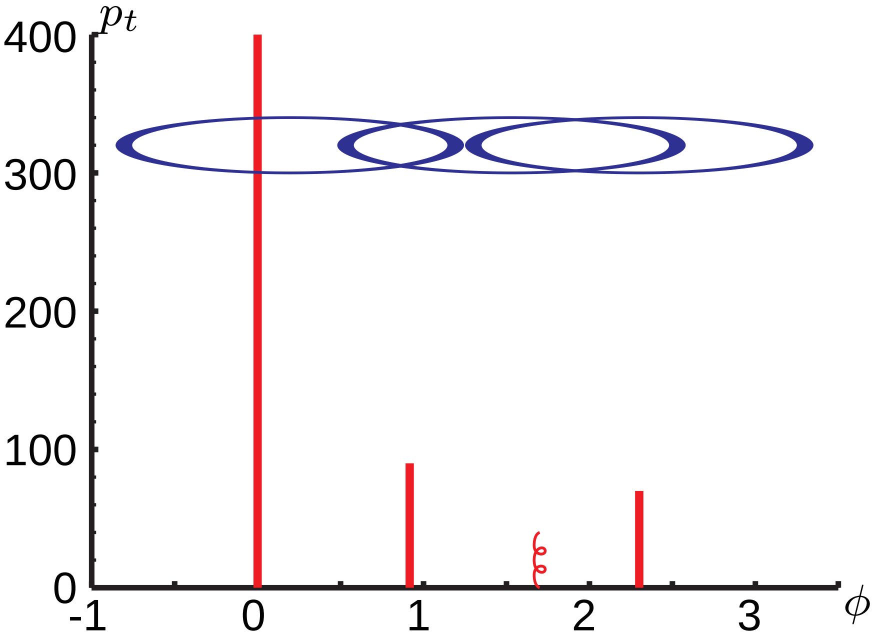
new seed!





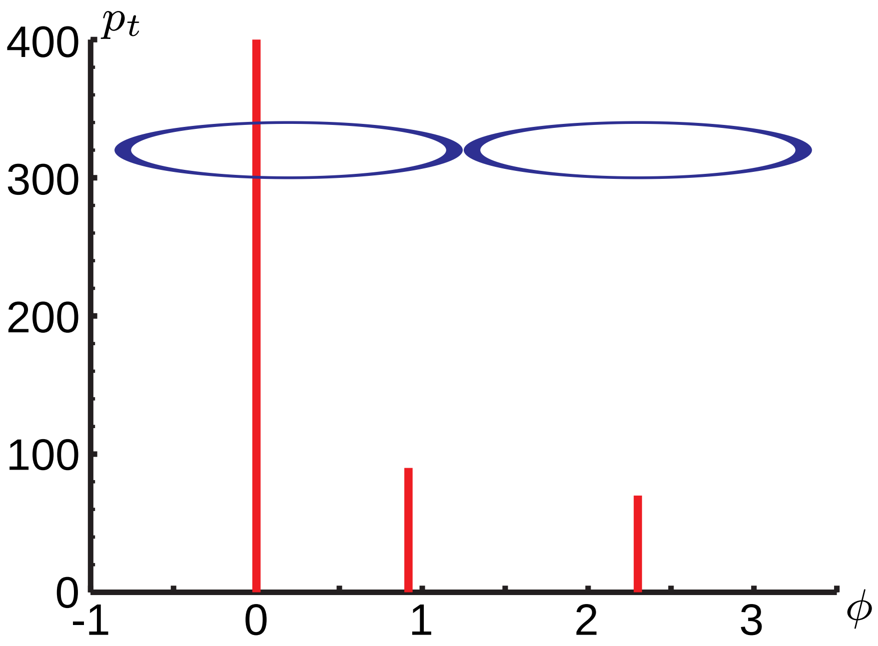
iterate

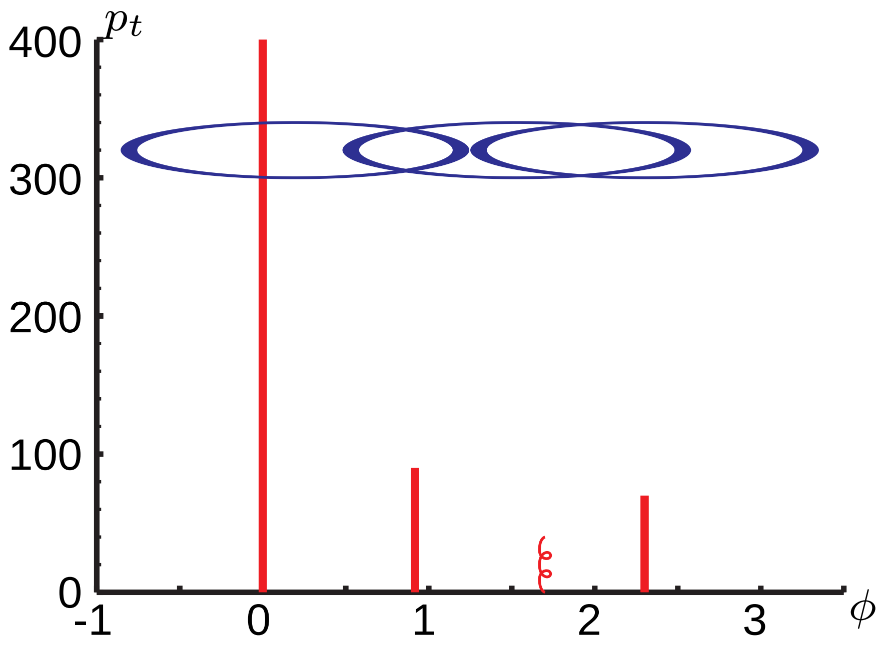




Stable cones:

Midpoint: {1,2} & {3} {1,2} & {3} & {2,3}



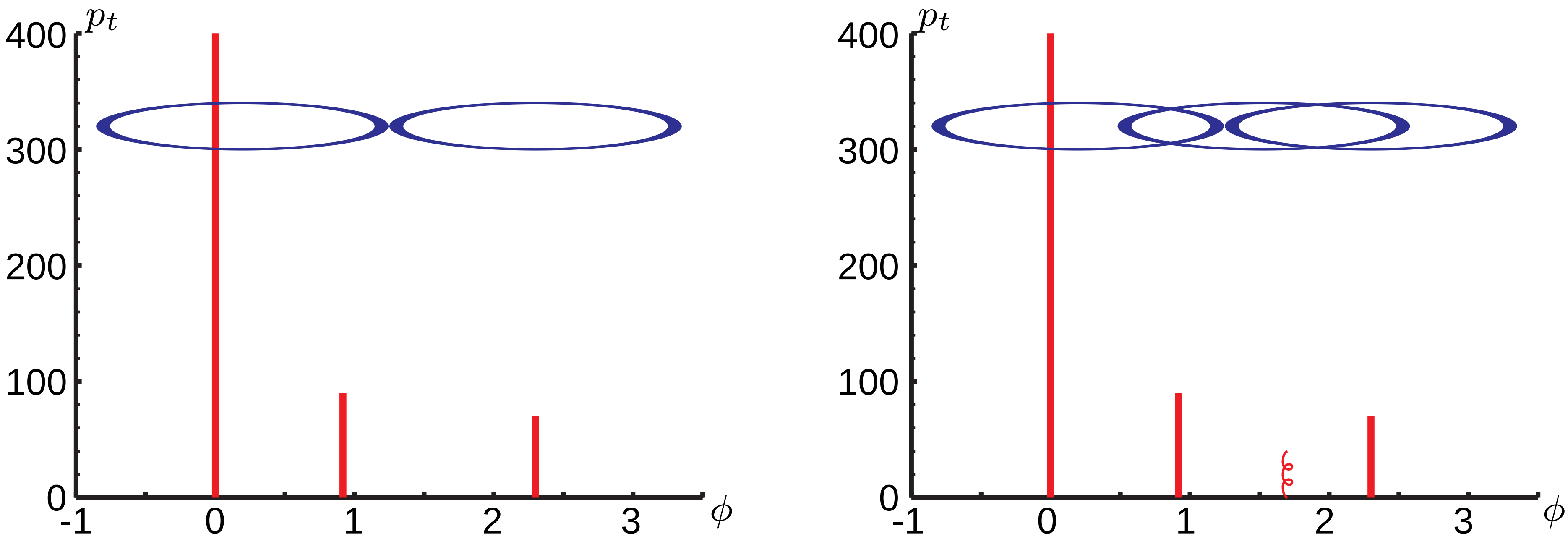


Stable cones:

Midpoint:	{1,2} & {3}	{1,2} & {3} & {2,3}

Jets: ($f = 0.5$)

Midpoint:	{1,2} & {3}	{1,2,3}

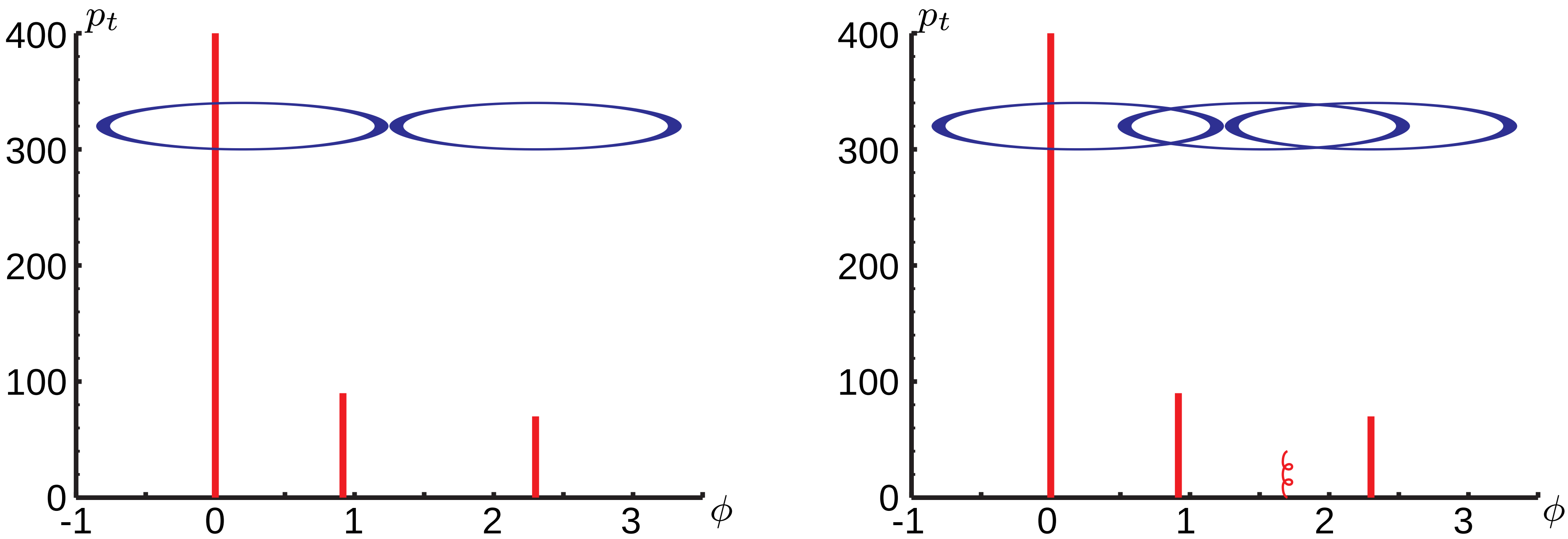


Stable cones:

Midpoint:	{1,2} & {3}	{1,2} & {3} & {2,3}
Seedless:	{1,2} & {3} & {2,3}	{1,2} & {3} & {2,3}

Jets: ($f = 0.5$)

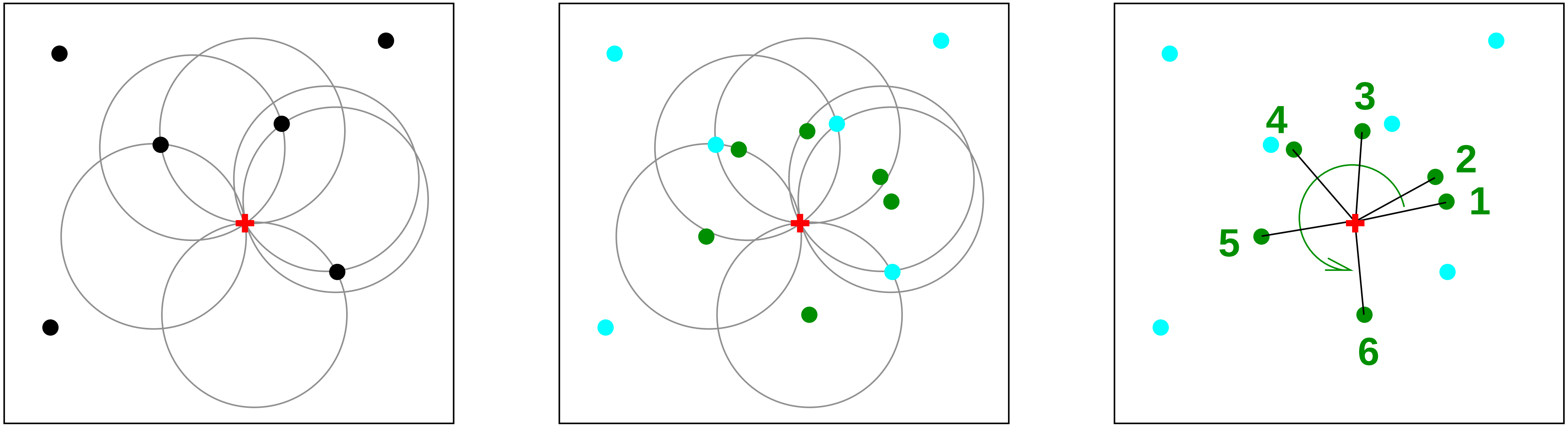
Midpoint:	{1,2} & {3}	{1,2,3}
Seedless:	{1,2,3}	{1,2,3}



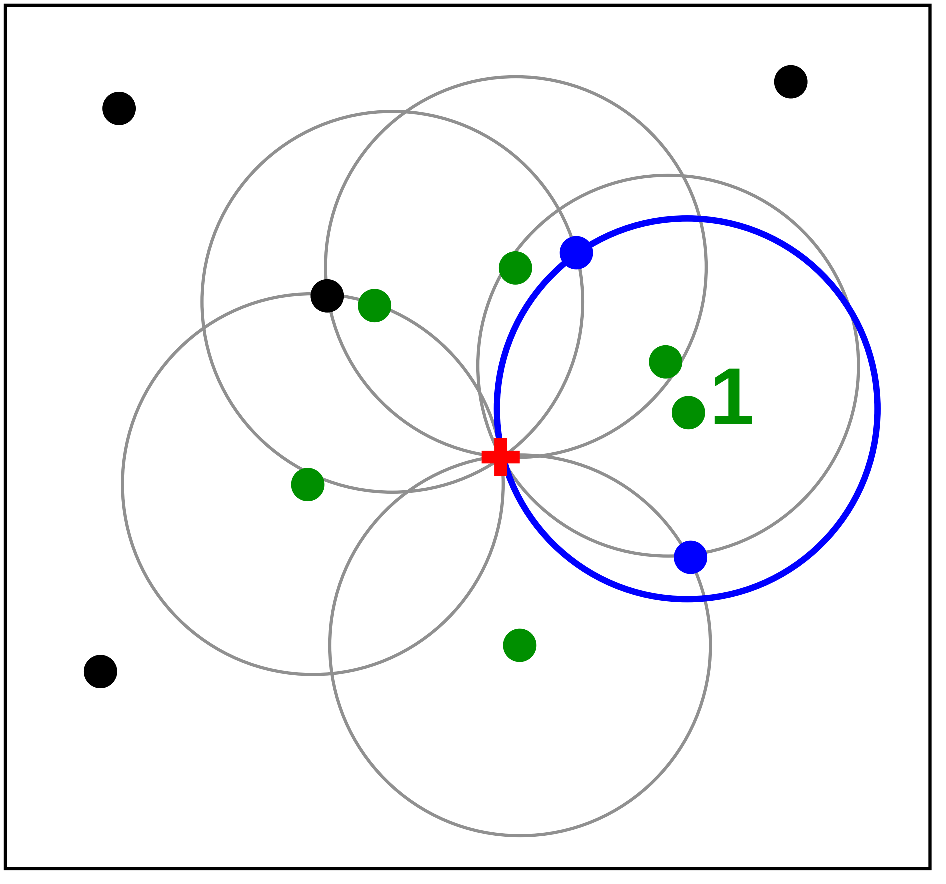
Stable cones:		
Midpoint:	{1,2} & {3}	{1,2} & {3} & {2,3}
Seedless:	{1,2} & {3} & {2,3}	{1,2} & {3} & {2,3}
Jets: ($f = 0.5$)		
Midpoint:	{1,2} & {3}	{1,2,3}
Seedless:	{1,2,3}	{1,2,3}

Stable cone missed $\longrightarrow$ IR unsafety of the midpoint algorithm

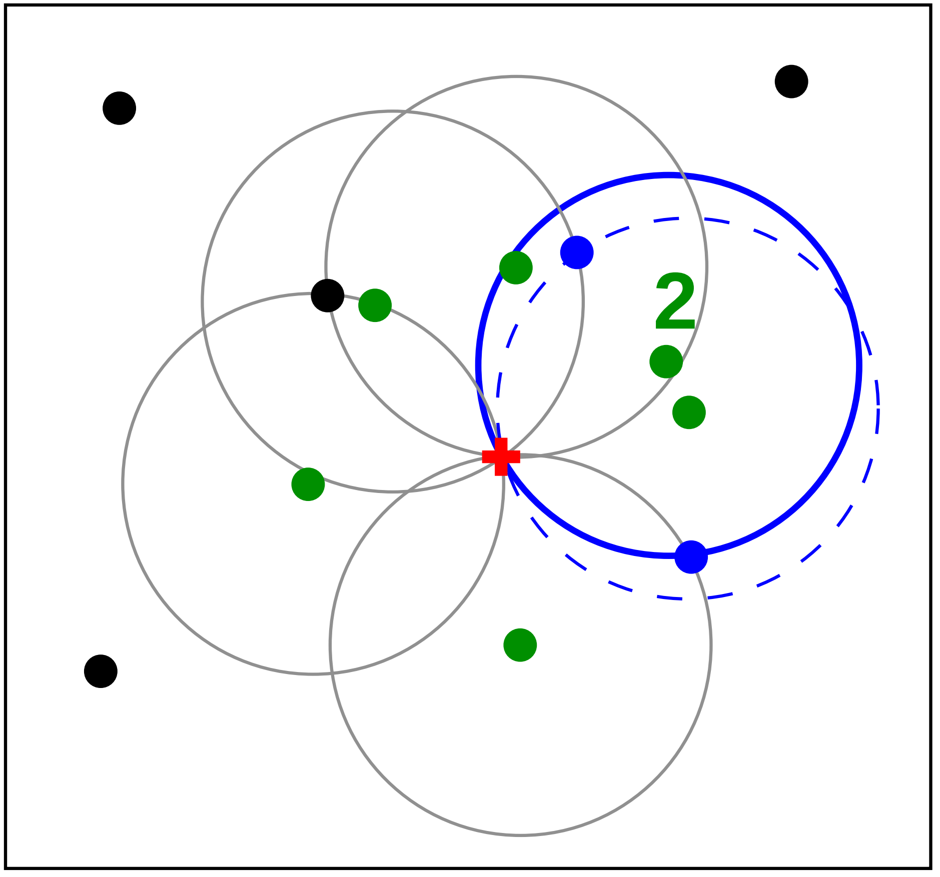
SISCone: traversal order for enclosures around a particle



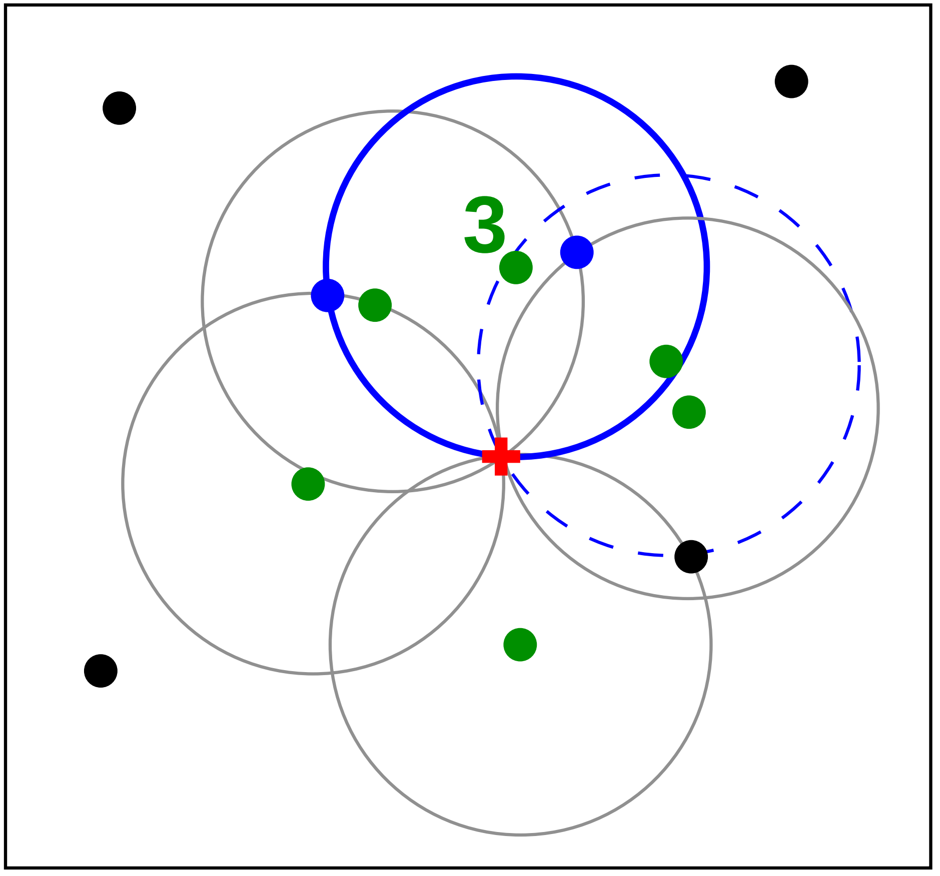
SISCone: traversal order for enclosures around a particle



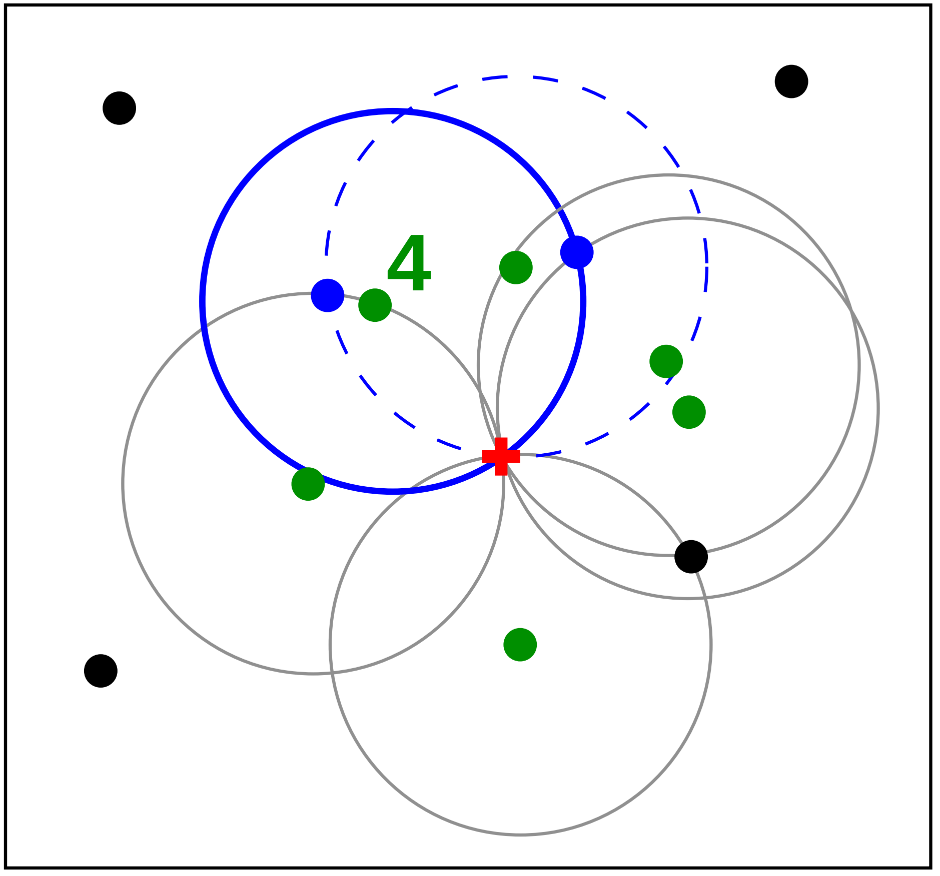
SISCone: traversal order for enclosures around a particle



SISCone: traversal order for enclosures around a particle



SISCone: traversal order for enclosures around a particle



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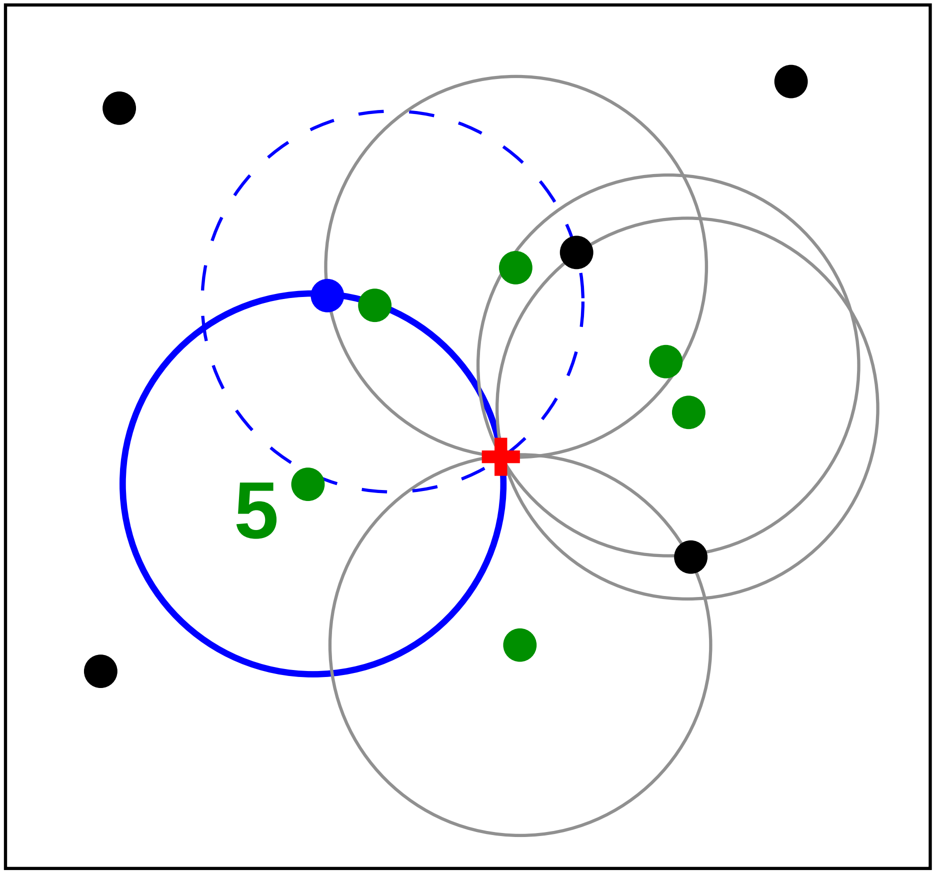
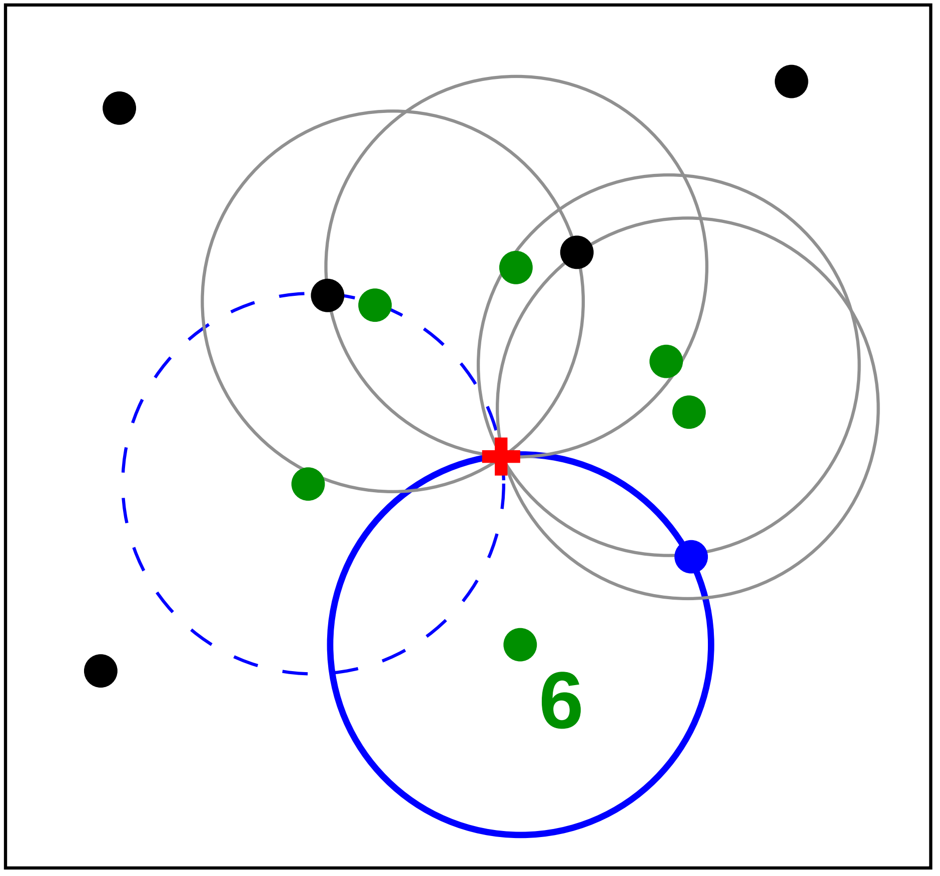
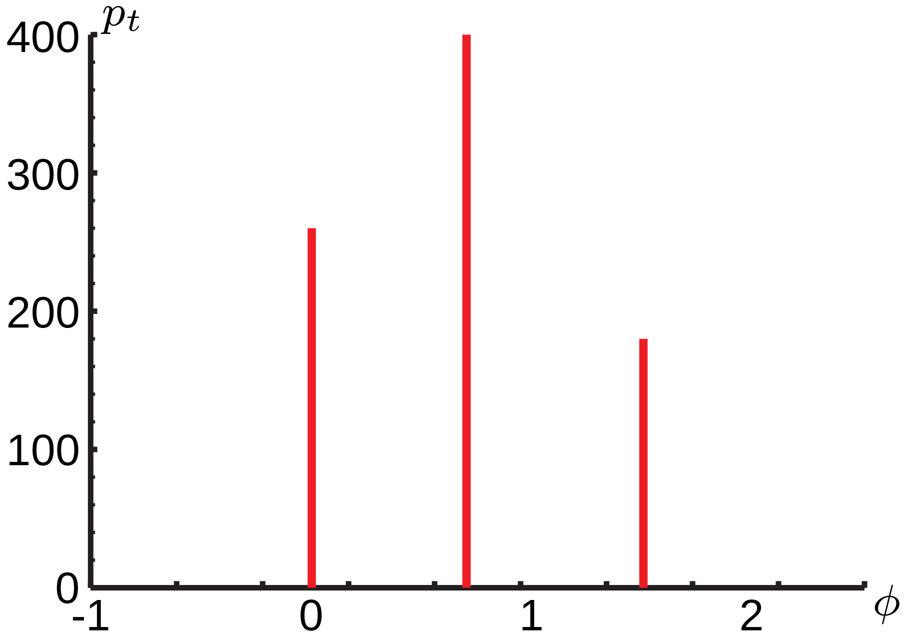
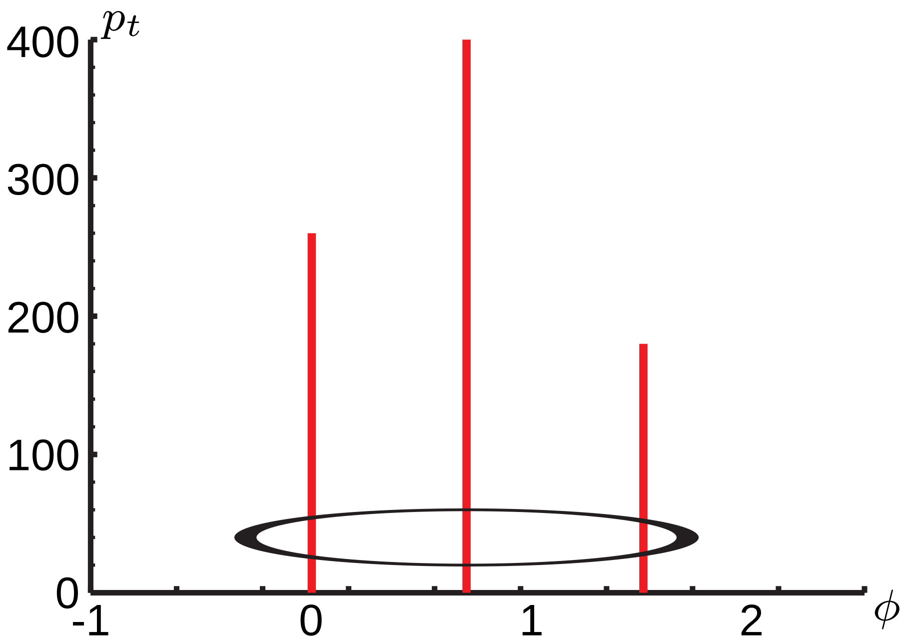


SISCone: traversal order for enclosures around a particle

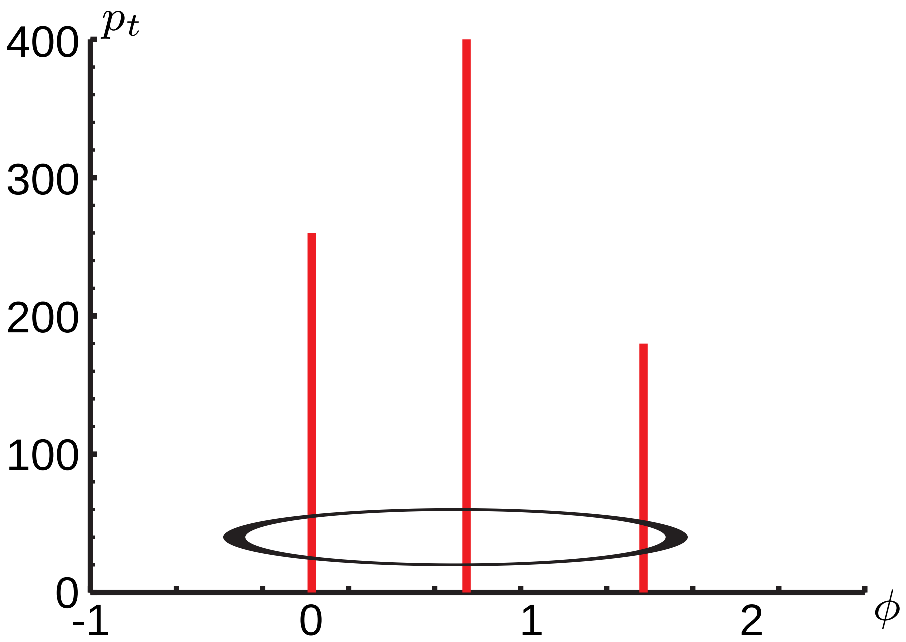




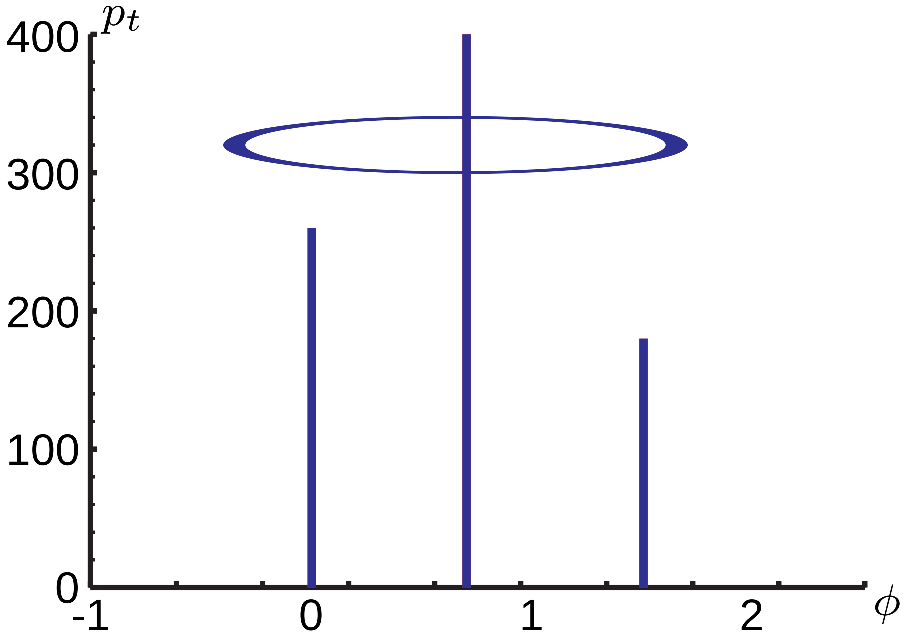
3-particle event — CMS Iterative Cone



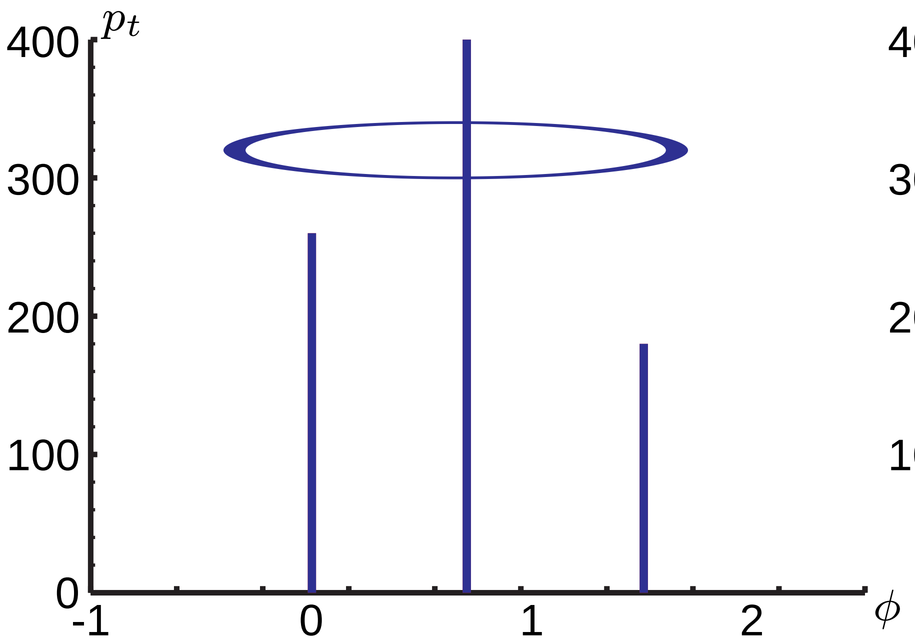
hardest seed

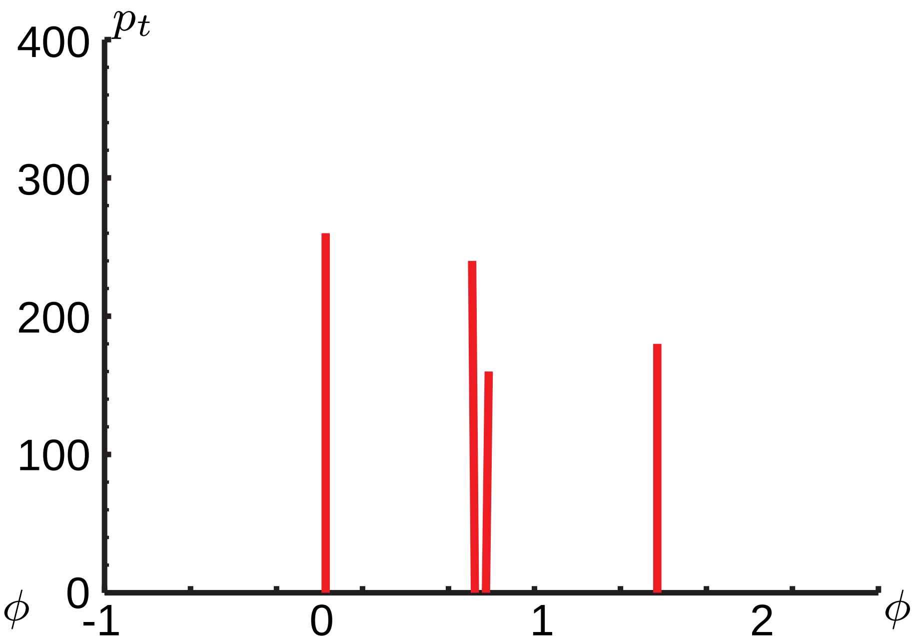


iterate

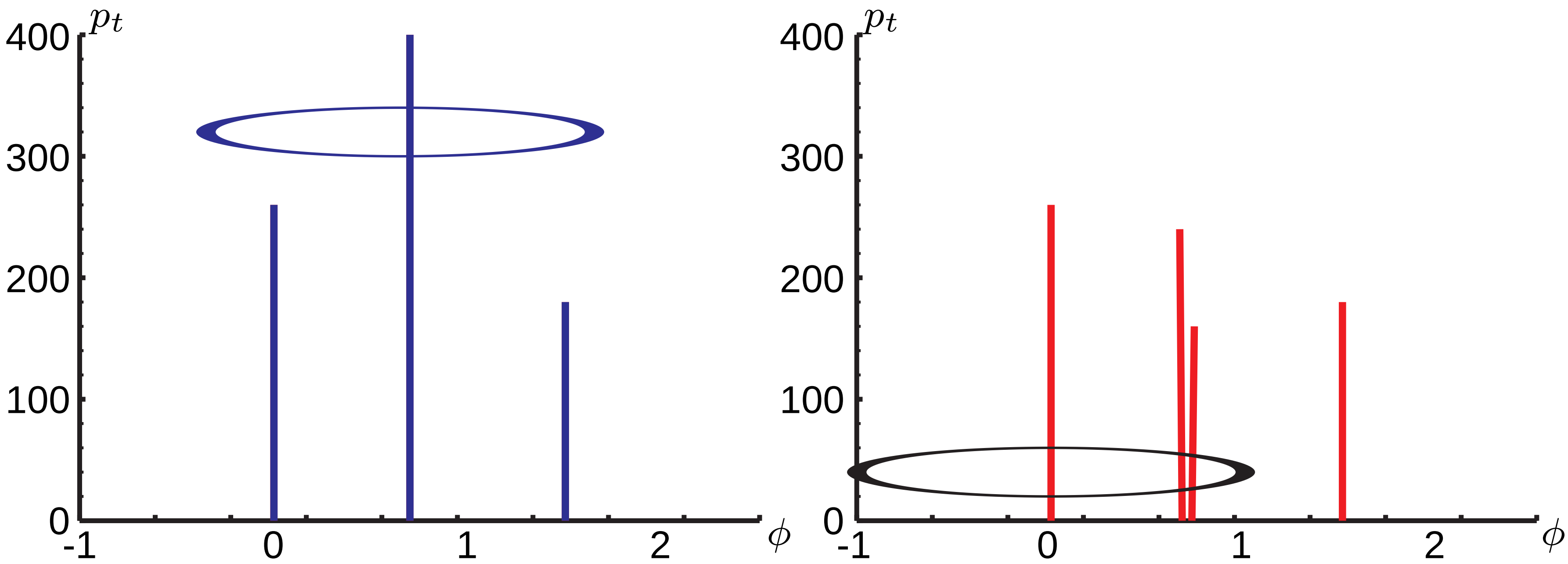


stable $\Rightarrow$ 1 jet

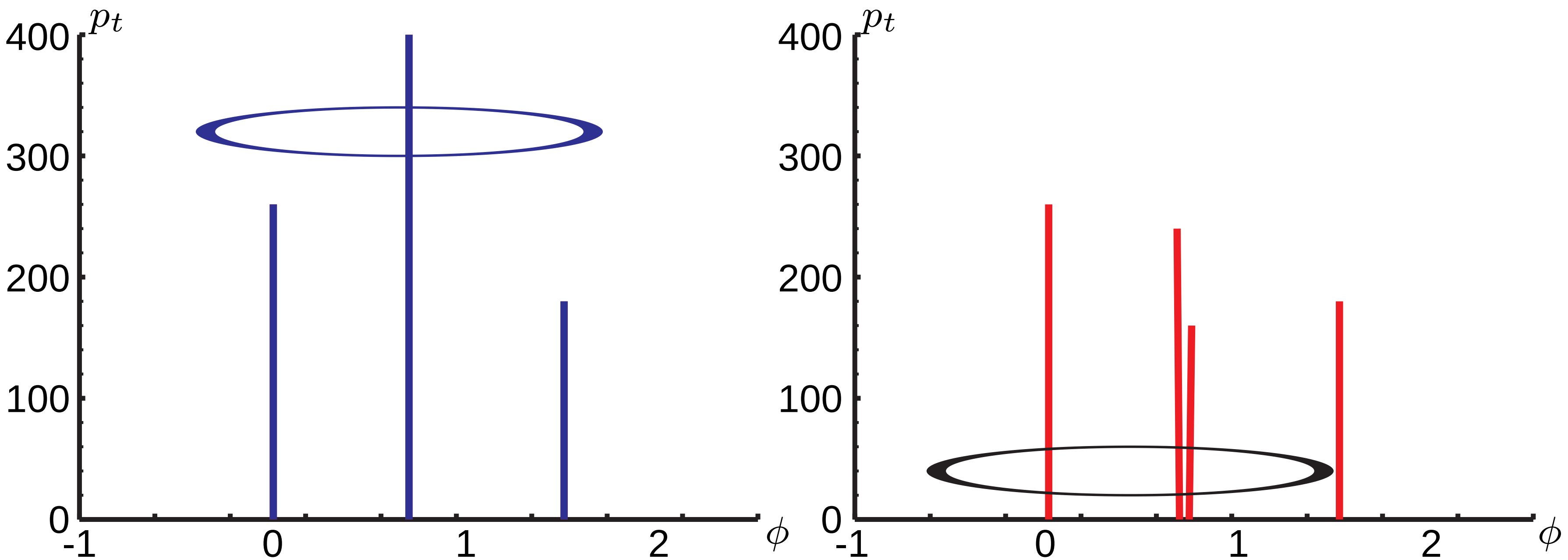




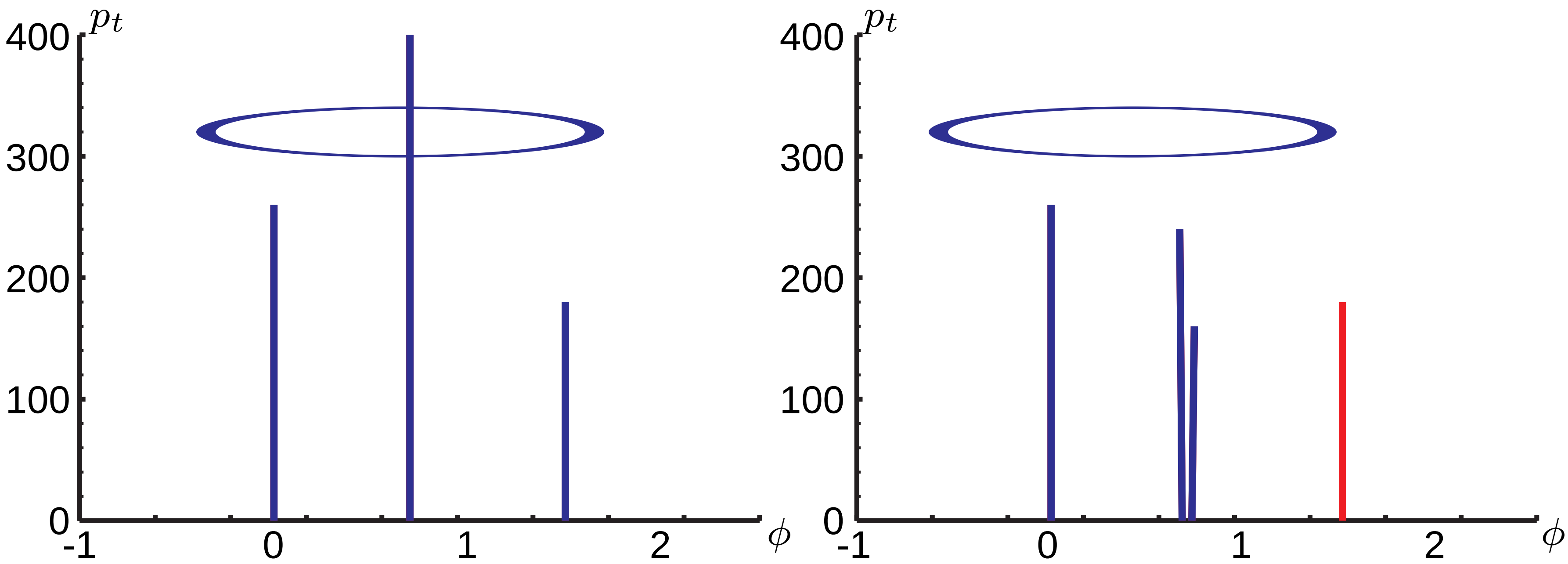
Collinear splitting



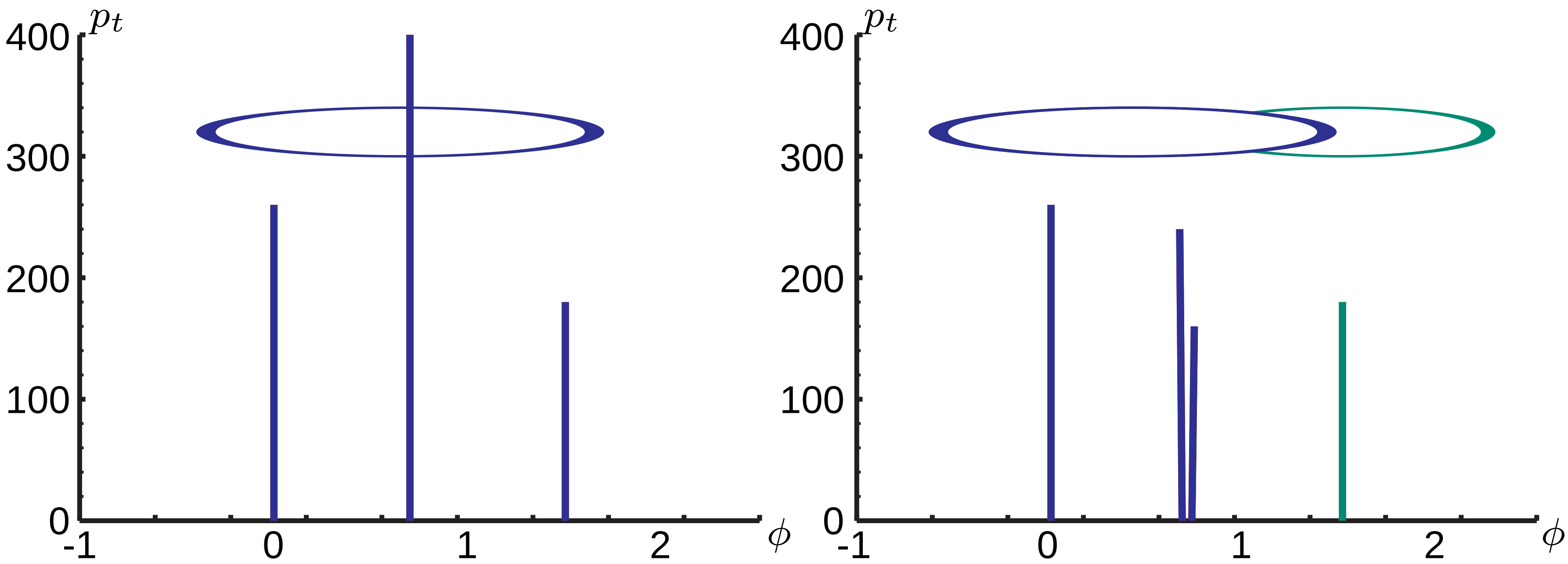
hardest seed



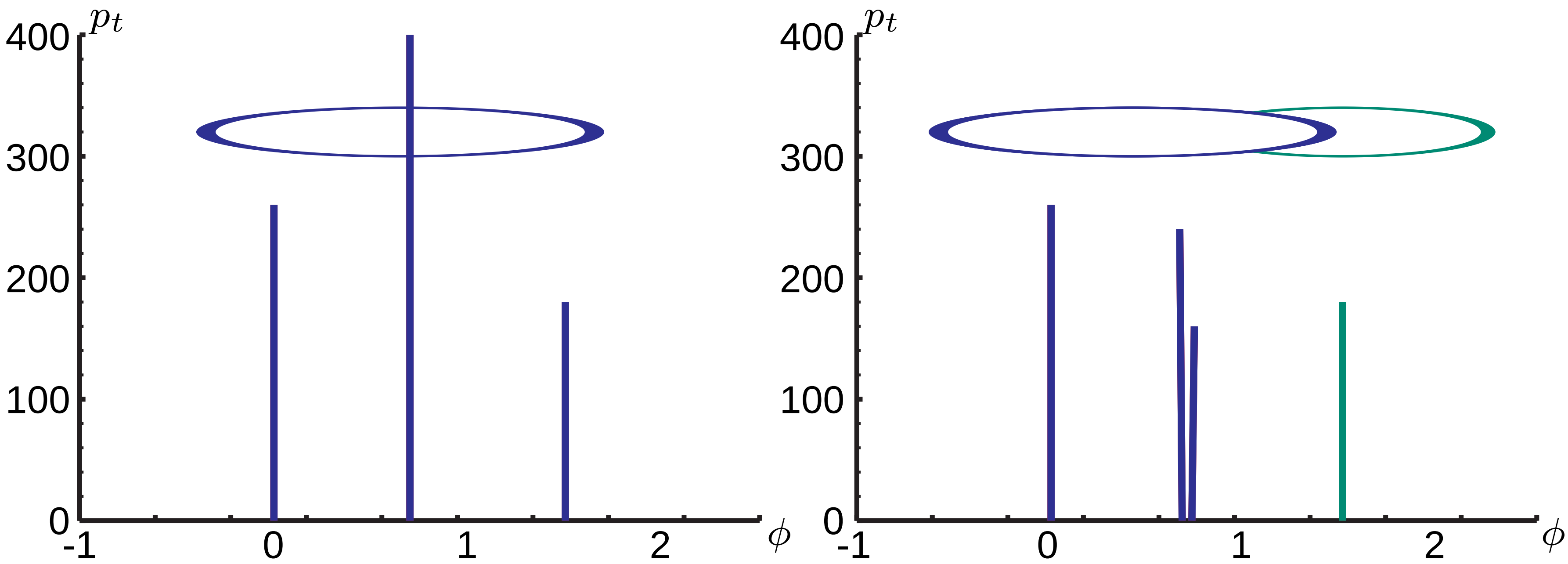
iterate



stable $\Rightarrow$ 1st jet



remaining particle stable $\Rightarrow$ 2nd jet



- Before collinear spliting: 1 jet
- After collinear spliting: 2 jets

$\longrightarrow$ **collinear unsafety of the iterative cone algorithm**