Data and MC modeling

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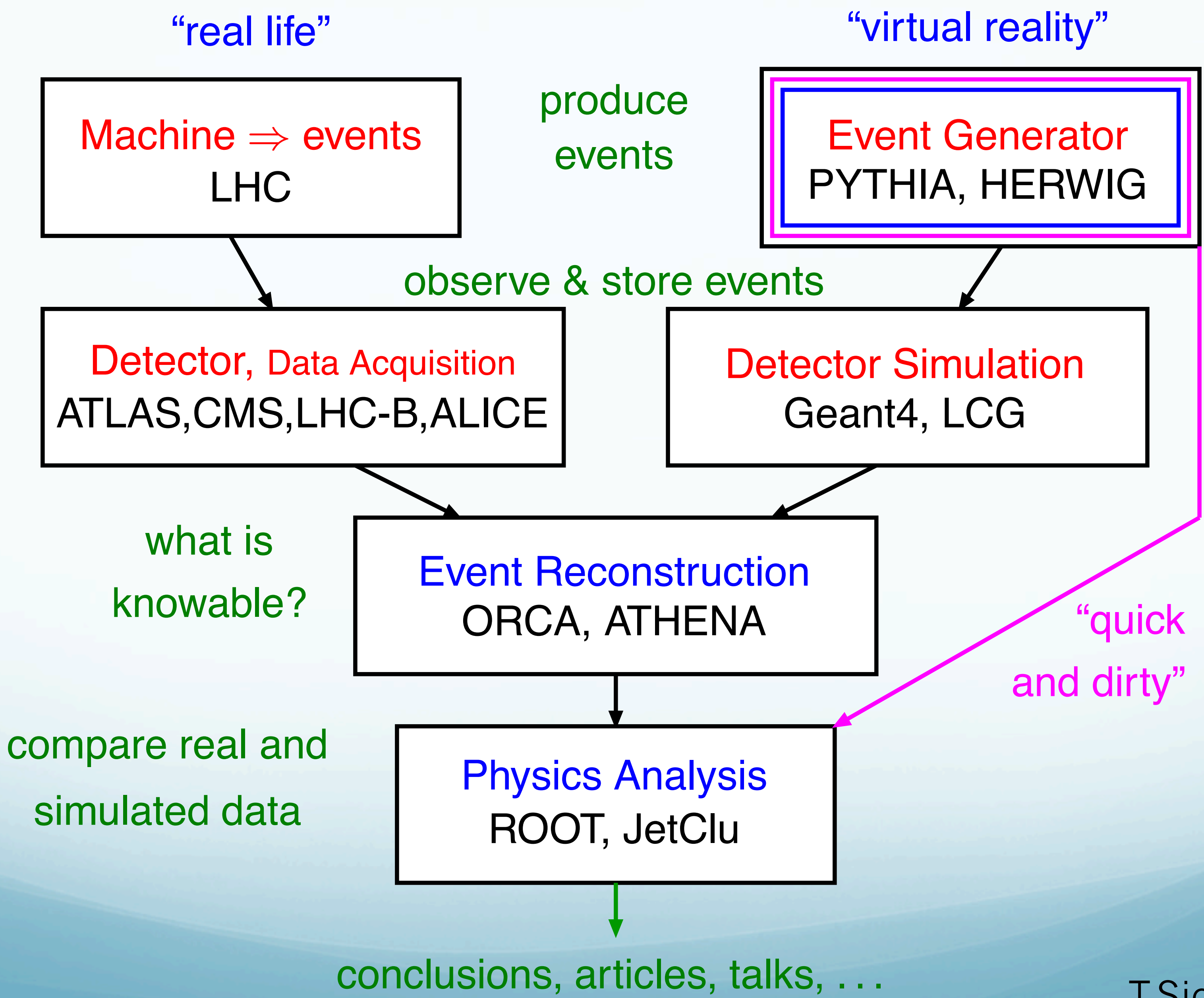
Event Generator Position



T.Sjoestrand

MC programs

General purpose generators:

Herwig, Herwig++, Pythia6, Pythia8, Sherpa

Matrix element generators:

NLO generators: MC@NLO, PowHeg

LO multi-leg generators: AlpGen, MadGraph

Minimum bias generators:

EPOS

Motivation

MC modeling has significant contribution to the systematic uncertainty of the precision measurements

This talk: MC modeling and constraints from data

Inclusive W and Z/g* cross section measurement

	A	$\delta A^{\rm pdf}_{\rm err}$	$\delta A^{\rm pdf}_{\rm sets}$	$\delta A_{\rm hs}$	$\delta A_{\rm ps}$	$\delta A_{\rm tot}$
			Electron channels			
W^+	0.478	1.0	0.7	0.9	0.8	1.7
W^-	0.452	1.5	1.1	0.2	0.8	2.0
$W^\pm$	0.467	1.0	0.5	0.6	0.8	1.5
Z	0.447	1.7	0.6	0.2	0.7	2.0
			Muon channels			
W^+	0.495	1.0	0.8	0.6	0.8	1.6
W^-	0.470	1.5	1.1	0.3	0.8	2.1
$W^\pm$	0.485	1.0	0.5	0.4	0.8	1.5
Z	0.487	1.8	0.6	0.2	0.7	2.0

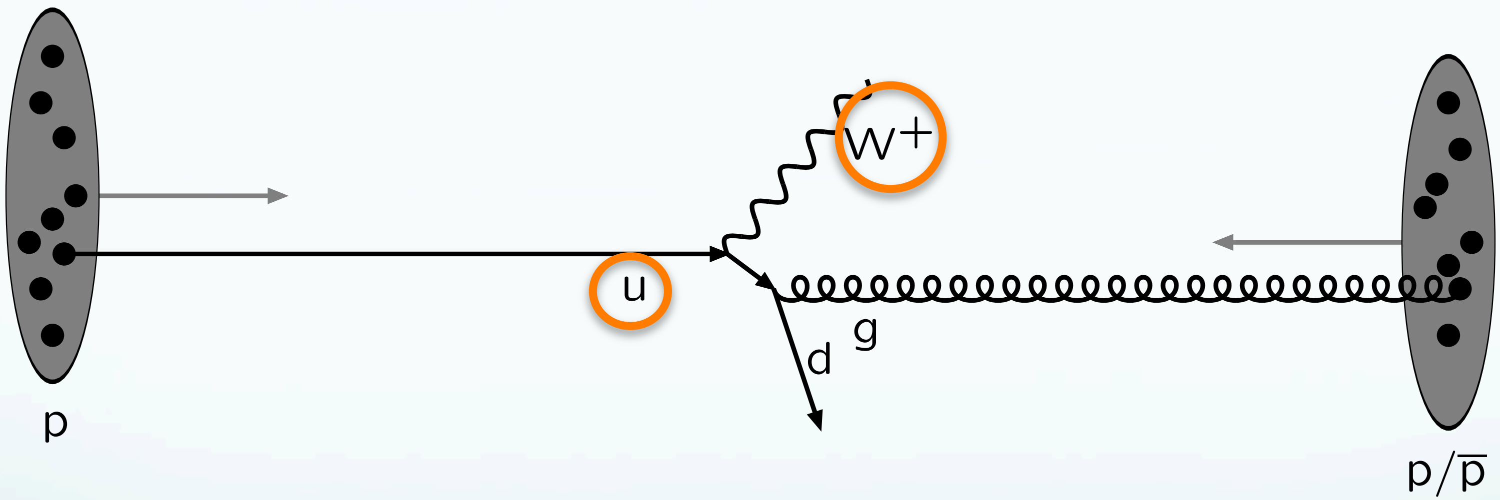
TABLE II. *Acceptance values (A) and their relative uncertainties (δA) in percent for W and Z production in electron and muon channels. The various components of the uncertainty are defined in the text. The total uncertainty (δA_{tot}) is obtained as the quadratic sum of the four parts.*

arXiv:1109.5141

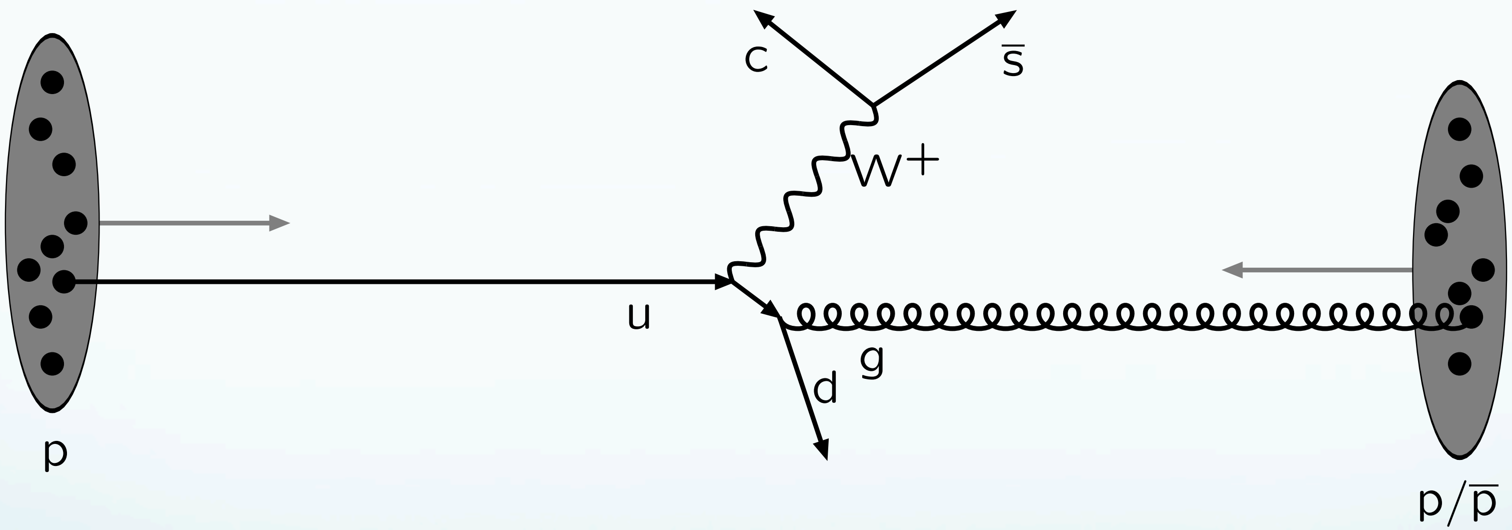
Taken from T.Sjoestrand

Structure of an event

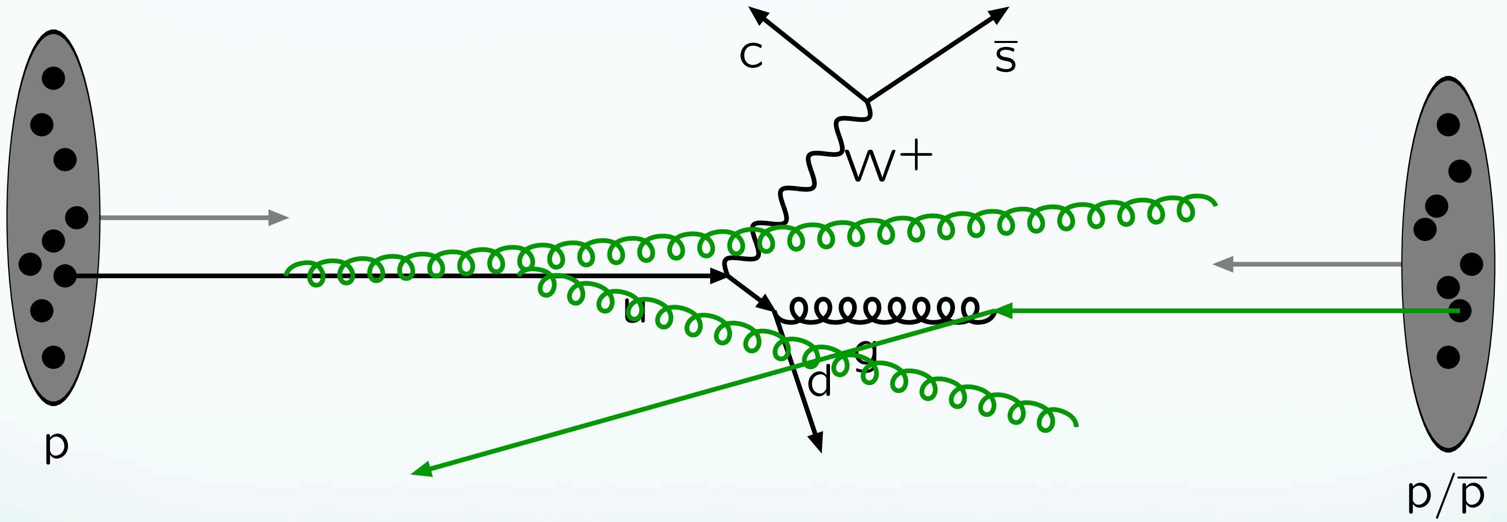
Incoming beams: parton densities



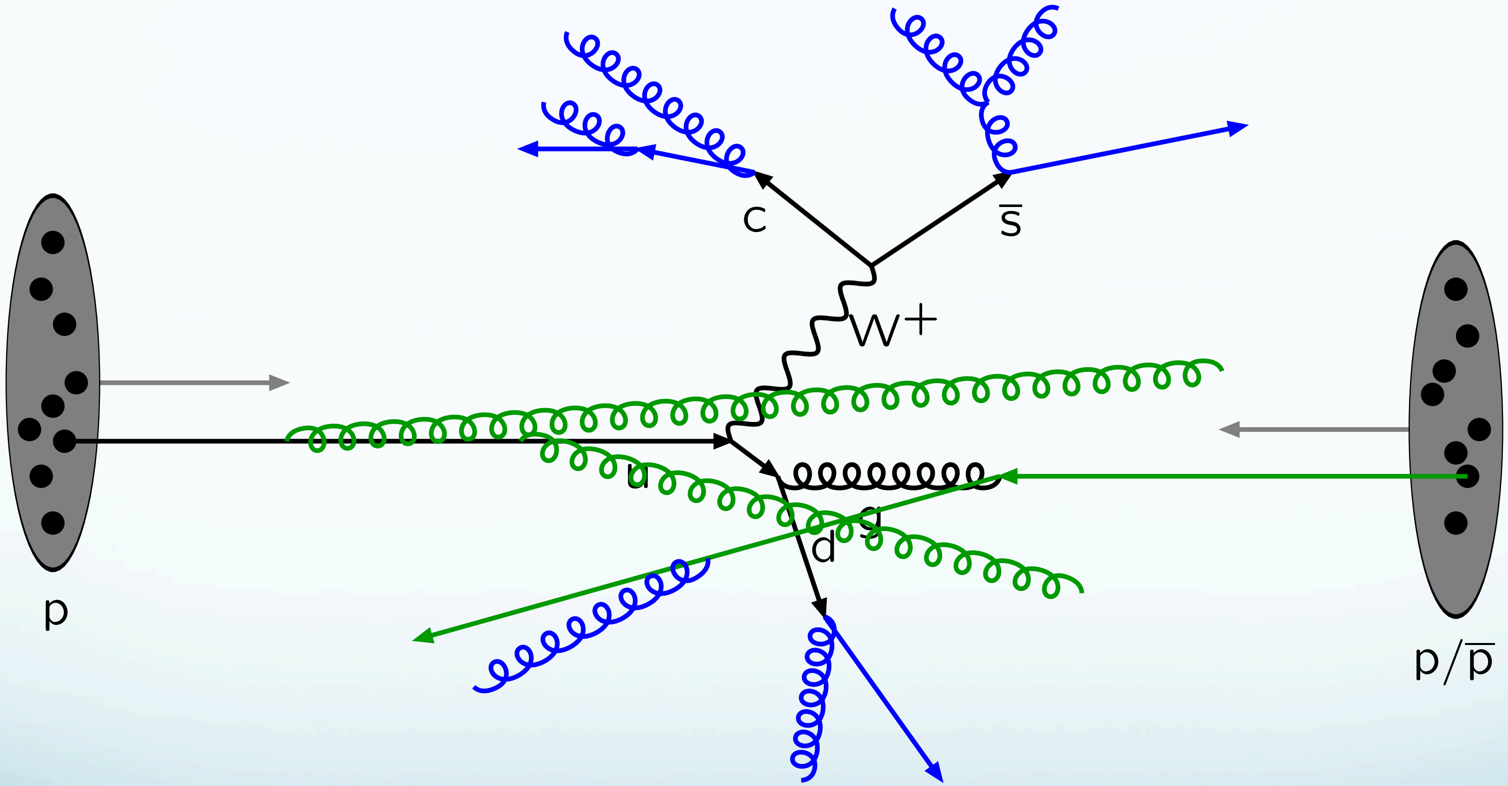
Hard subprocess: described by matrix elements
W,Z kinematics determined by constituent parton kinematics



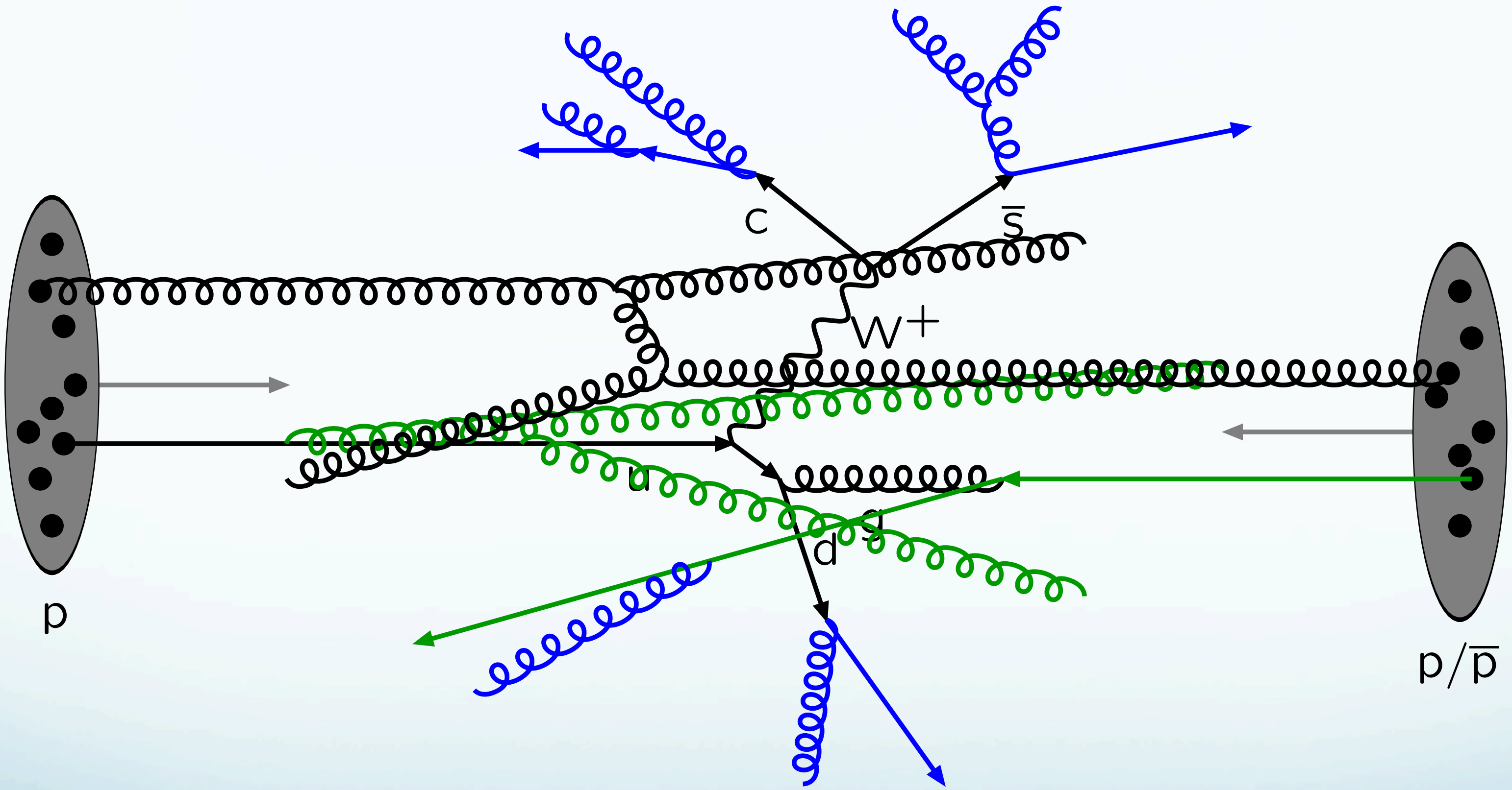
Resonance decays: correlated with hard subprocess



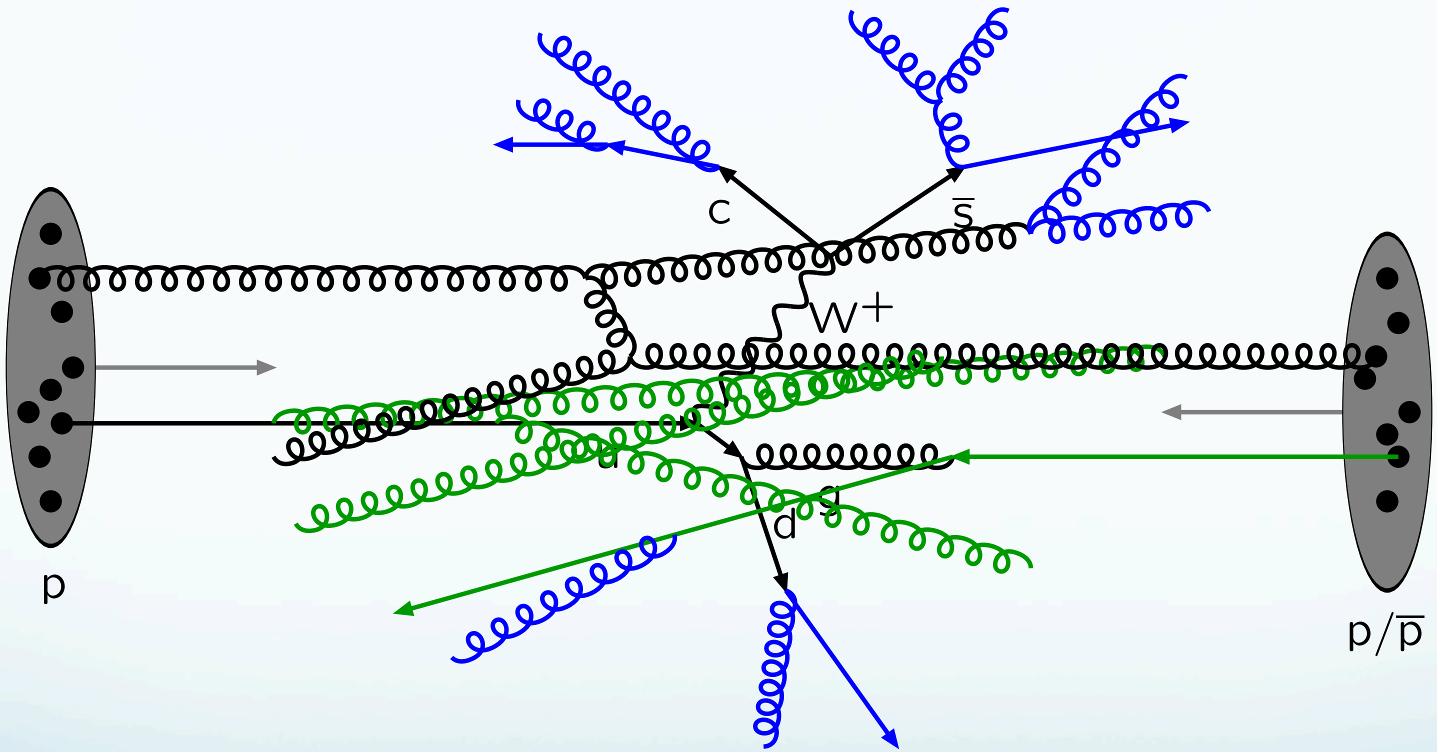
Initial-state radiation: spacelike parton showers
Radiation influences kinematics of the incoming partons



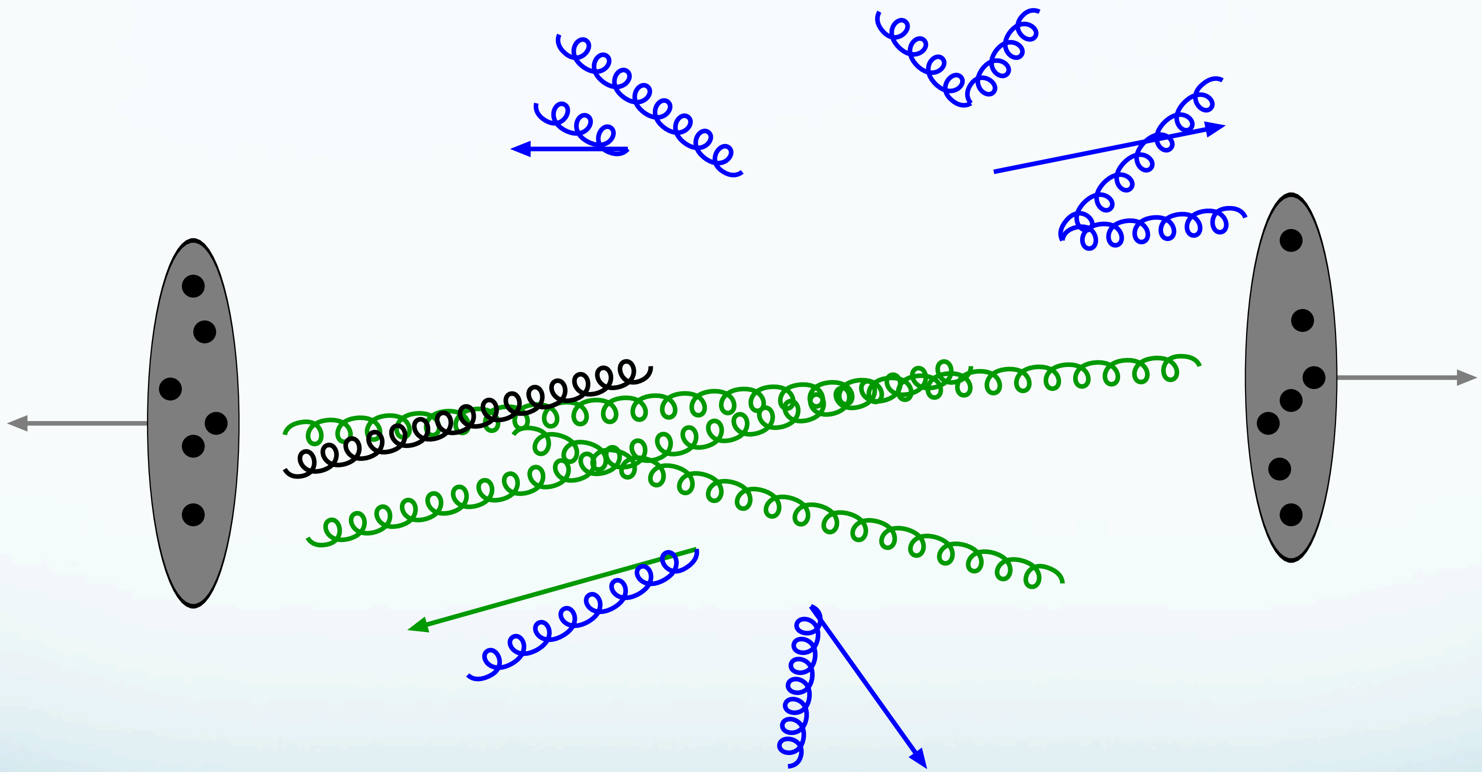
Final state radition: timelike parton showers



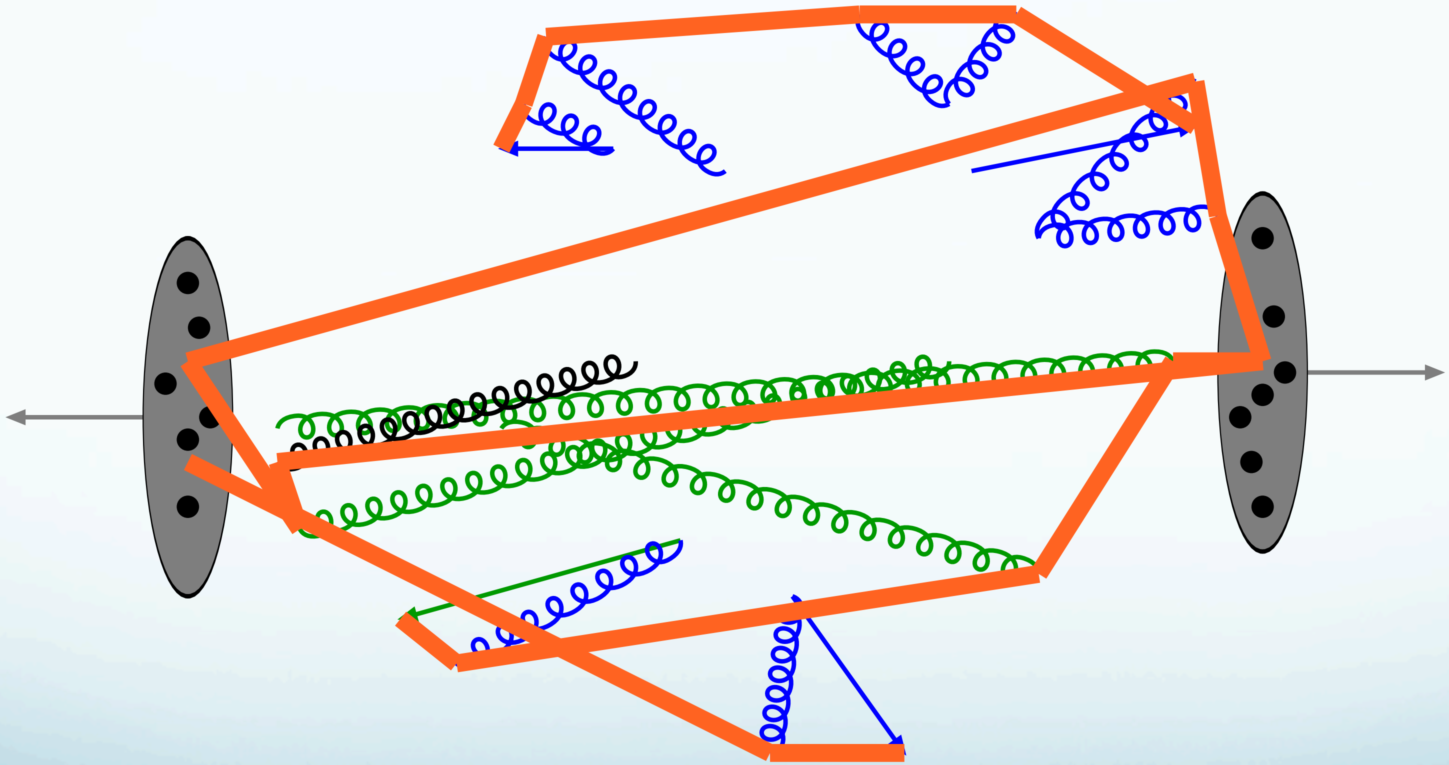
Multiple parton-parton interactions



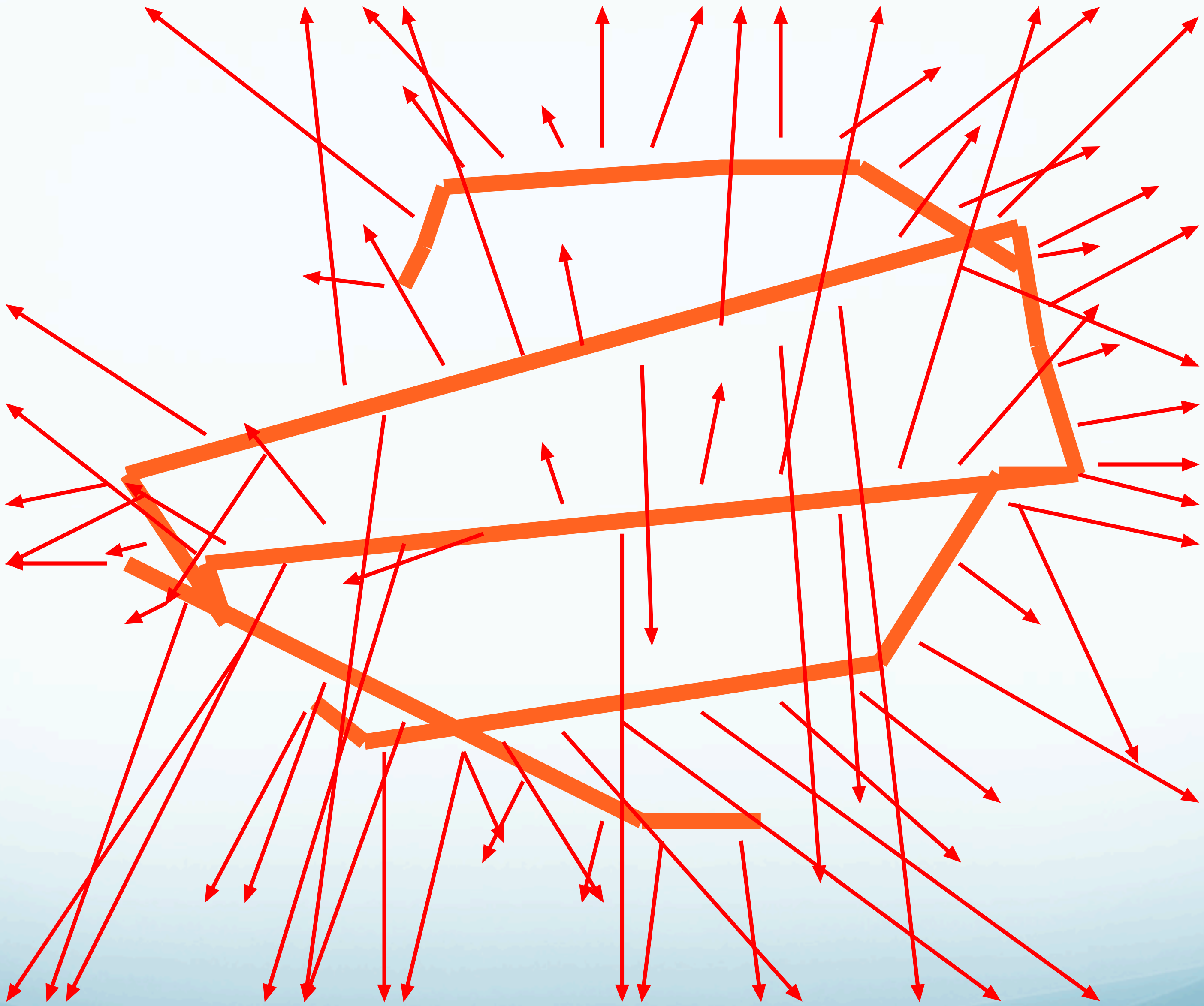
...with its initial- and final-state radiation



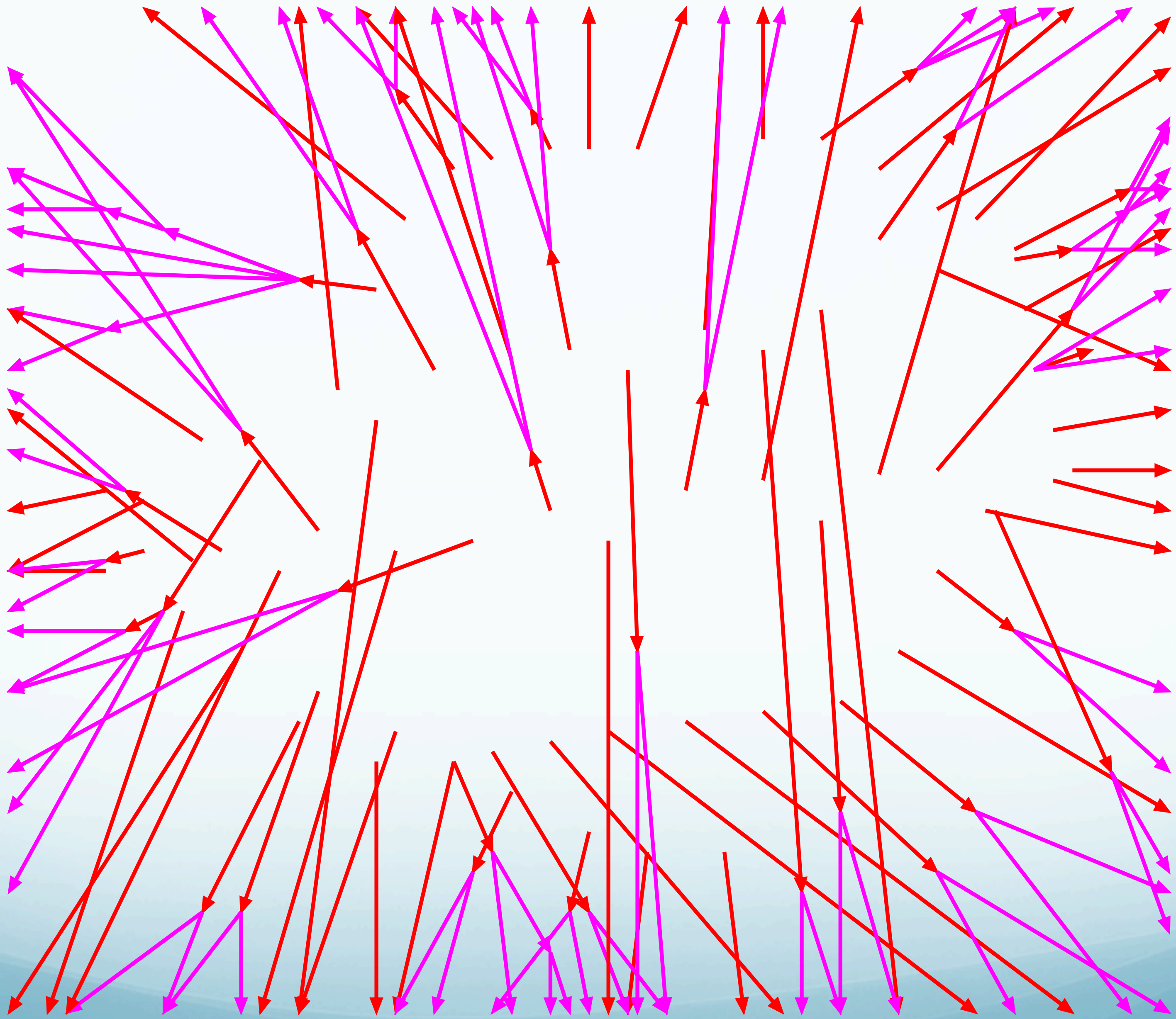
Beam remnants and other outgoing partons



Everything is connected by colour confinement strings
Not to scale: strings are of hadronic width

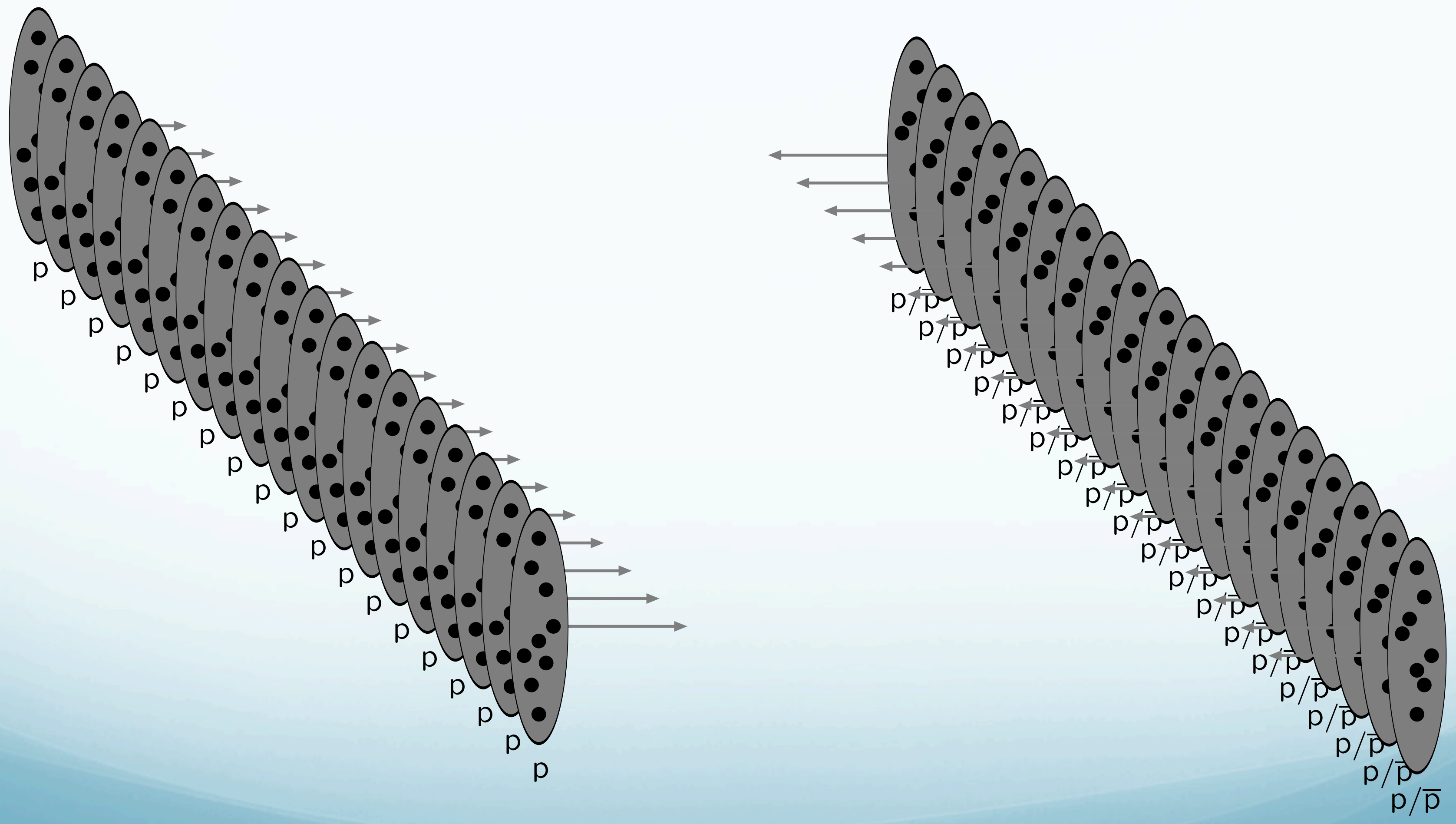


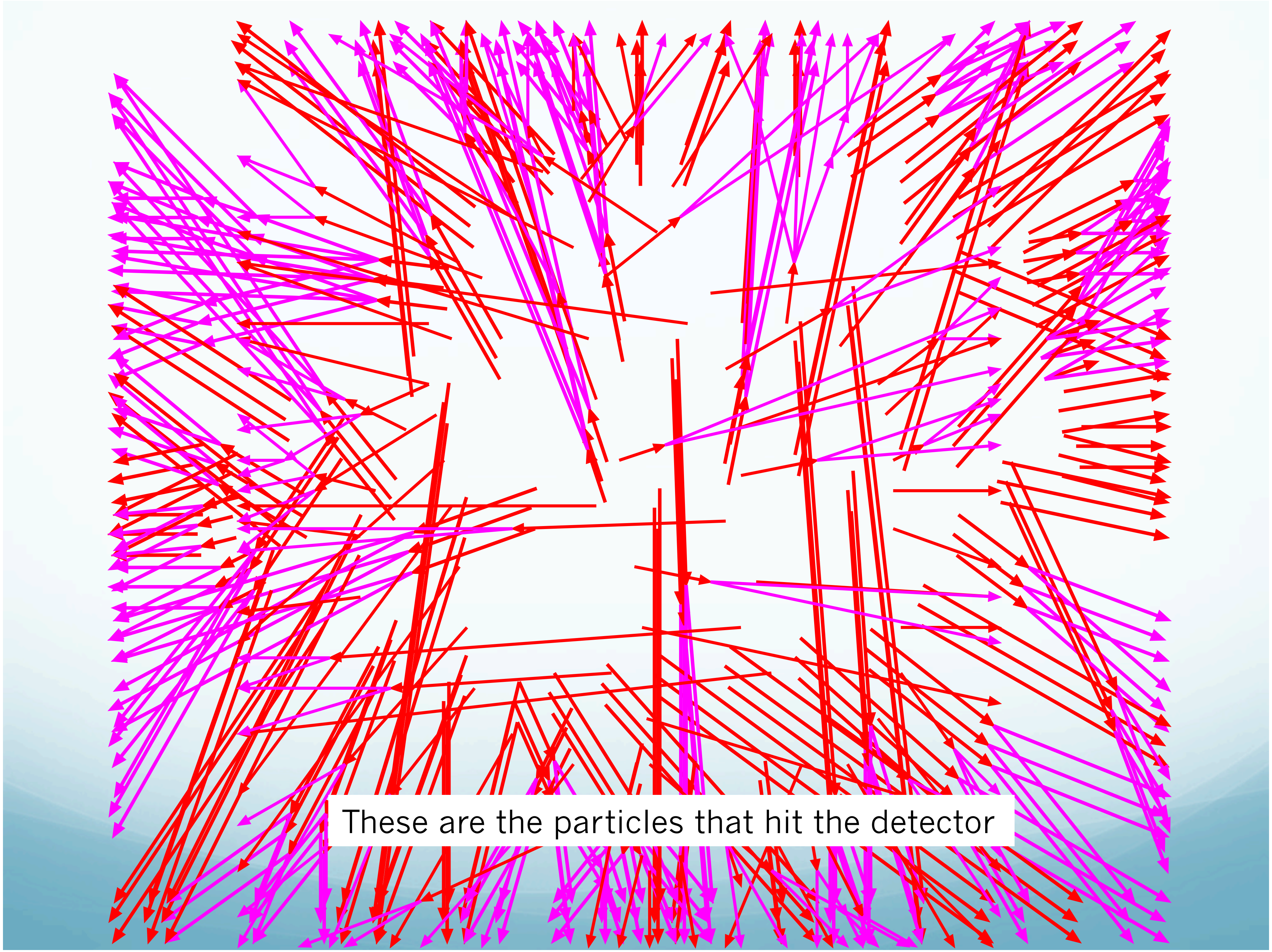
The strings fragment to produce primary hadrons

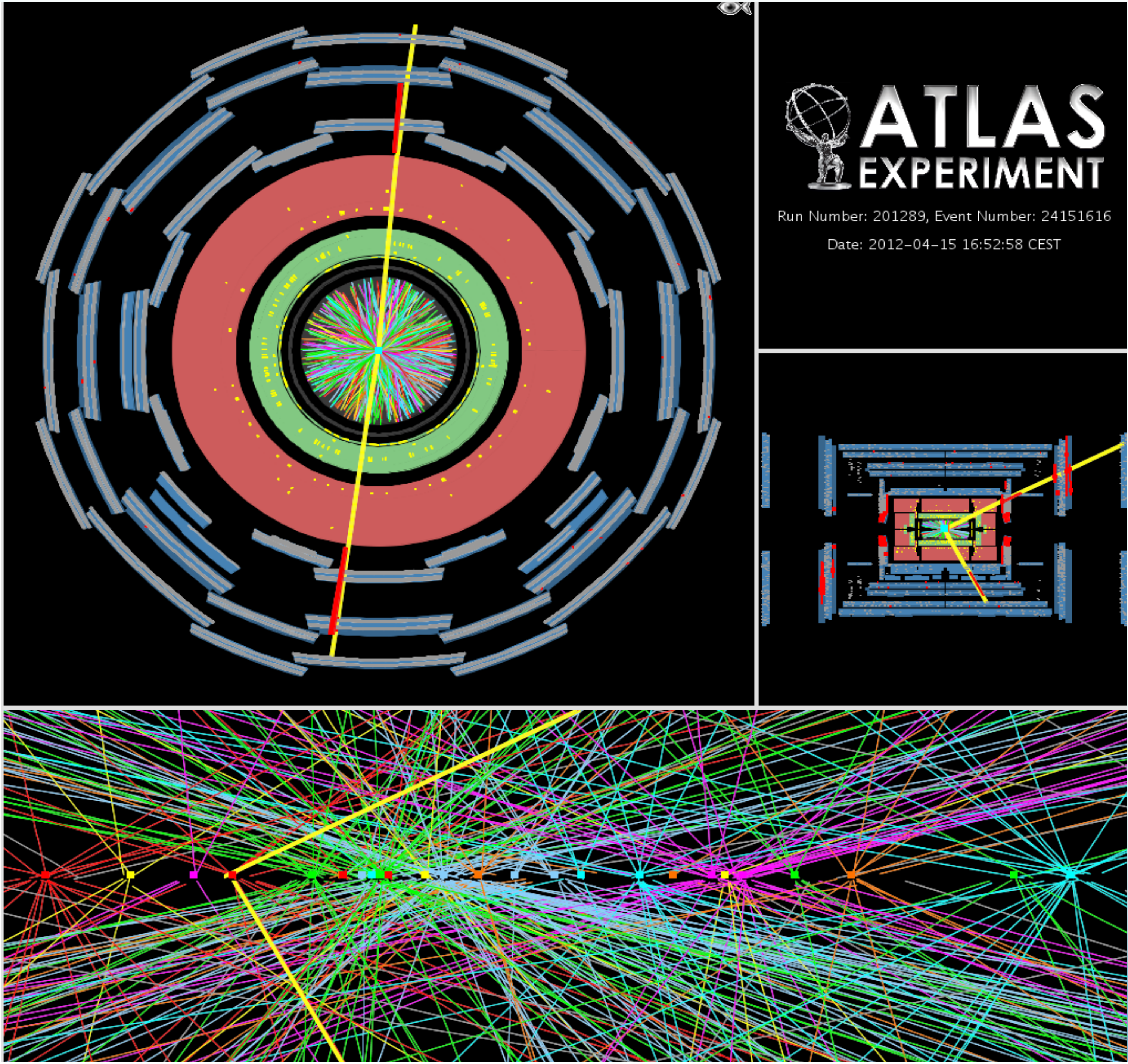


Many hadrons are unstable and decay further

Multiple proton-proton collisions simultaneously




These are the particles that hit the detector



Z->mumu Event with 25 pile-up events

Outline

- MC programs overview
- Parton shower models
- Hadronisation models
- Underlying event models
- Minimum bias models for pile-up simulation

Multi-purpose
MC generators:
PYTHIA6, PYTHIA8,
fHERWIG, HERWIG++,
(Sherpa)

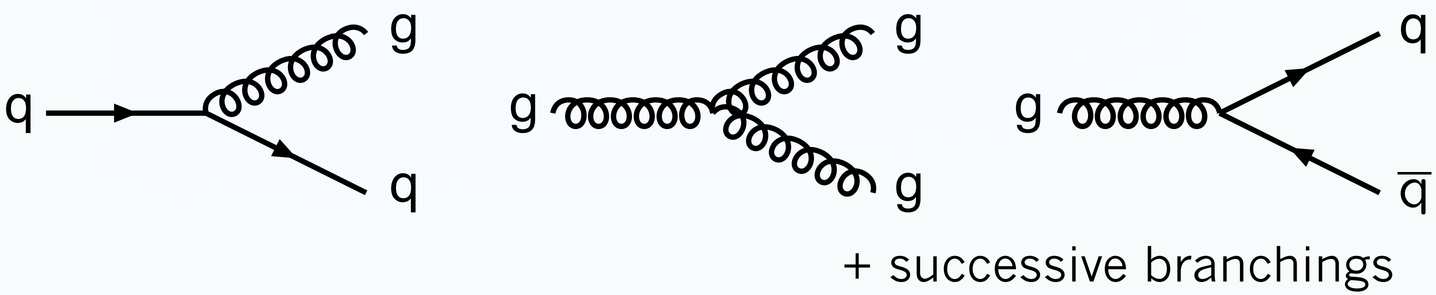
ME Generation	NLO Generators:MC@NLO, PowHeg, aMC@NLO, .. Multileg Generators: AlpGen, MadGraph
Parton Shower	Evolution variable: Pythia: Q2 (old), pt (new) Herwig: angle
Multi-parton interaction	Pythia6, Pythia8, HERWIG+JIMMY,HERWIG++
Beam Remnants	
Hadronisation	Pythia: Lund String fragmentation Herwig: Cluster fragmentation
Particle decay	Taula, EvtGen

Standard MC Tunes

- Pythia6, pt ordered shower:
  - S0, Perugia0, Perugia2010, Perugia2011
  - MC09, AMBT1, AUET2b, AMBT2b ATLAS
  - Z1, Z2 CMS
- Pythia6, Q2 ordered shower:
  - Tune A, DW, D6T, D6, ProQ2
- Pythia8:
  - C2,c4 (authors tunes) , AM1, AM2 ...(ATLAS tunes)
- fHerwig:
  - Tune A1, A2,..
- Herwig++:
  - UE tunes (default)
- Sherpa: tunes are incorporated in the default values that change with the release

Tune pre-LHC
Tune with LHC data

Parton Shower Models



- PYTHIA - many modeling options:
  - PYTHIA6: Q2 shower, pT ordered shower
  - PYTHIA8: pT ordered shower
  - Further modeling options within the shower modeling, e.g. maximal allowed virtuality for emitted parton (wimpy, power shower)
- Herwig:
  - C++ version (new) Herwig++, fortran version (old) fHerwig
  - Both angular ordered, but slight differences in the ordering variable
- Sherpa:
  - Parton shower used with Sherpas ME
- Tuneable and/or model parameters:
  - Shower cut-off at collinear or soft limit
  - Alpha_s evaluation scale
  - Maximal allowed virtuality of radiated parton for ISR

Final state radiation

- LEP e+e→Z->q q̄ events best to tune FSR since no ISR or MPI
- All shower models tuned at LEP, e.g. jet resolution

$$y_{ij} = \frac{2\min(E_i^2, E_j^2)(1-\cos\theta_{ij})}{E_{\text{vis}}^2},$$

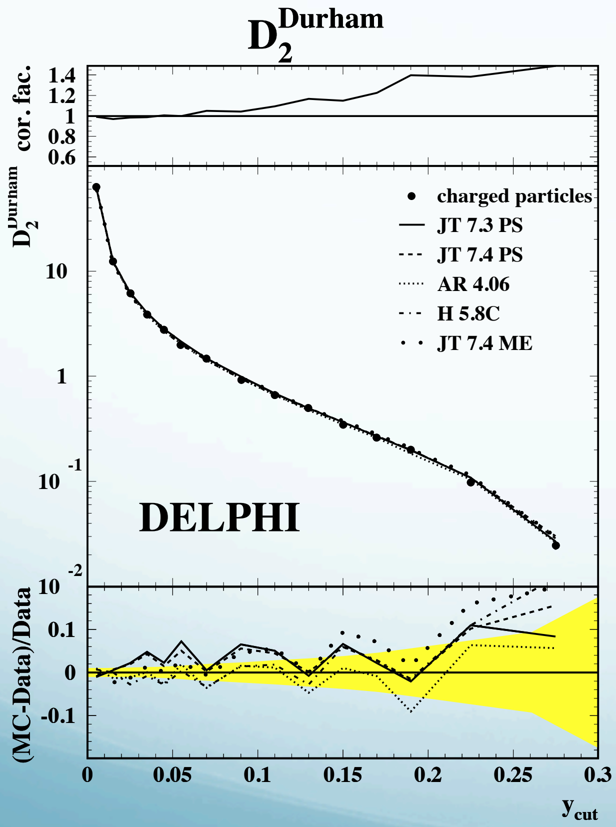
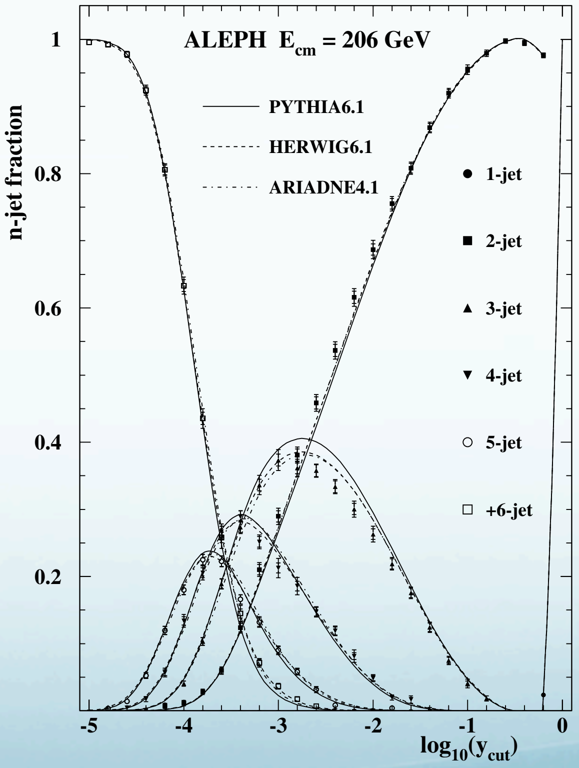
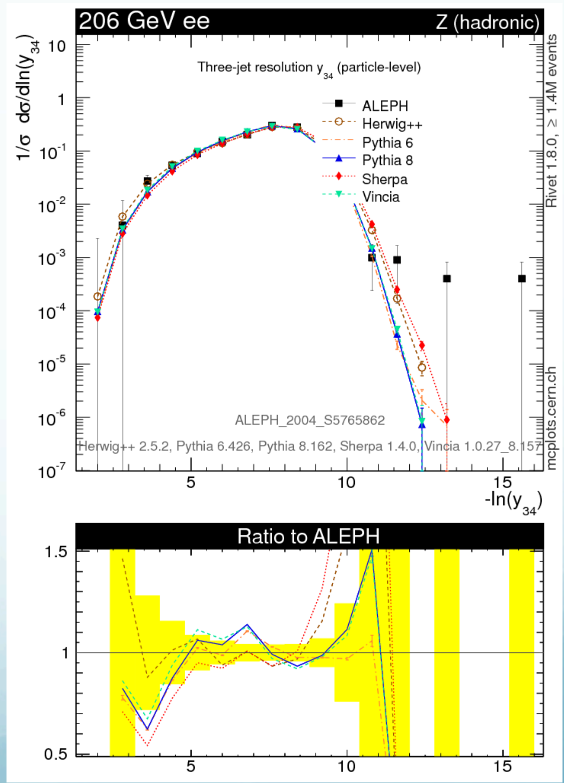


Fig. 15. Differential 2-jet rate for the Durham Algorithm, D_2^{Durham}

Z. Phys. C 73, 11–59 (1996)

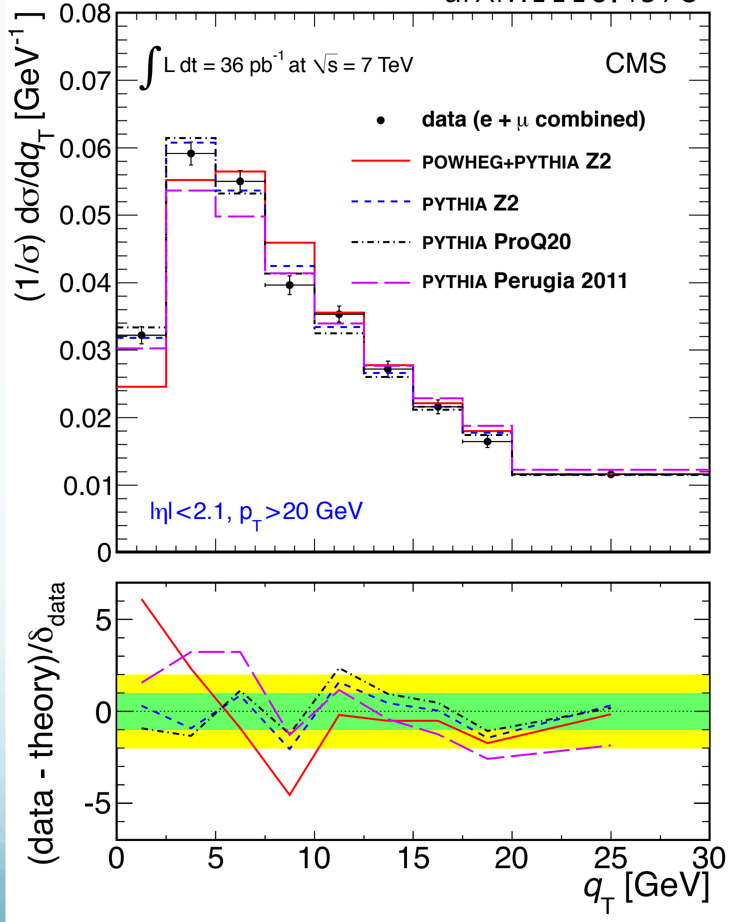


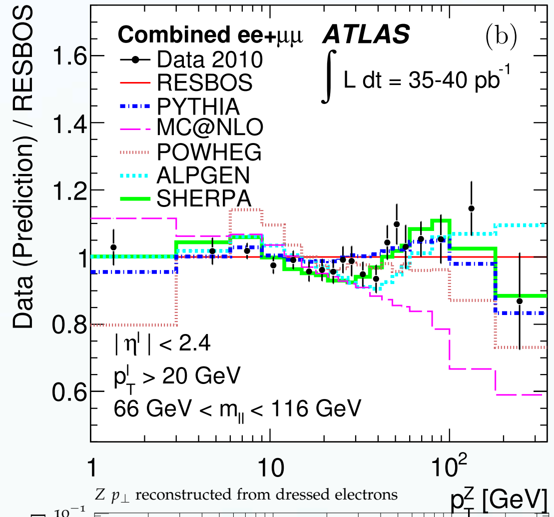


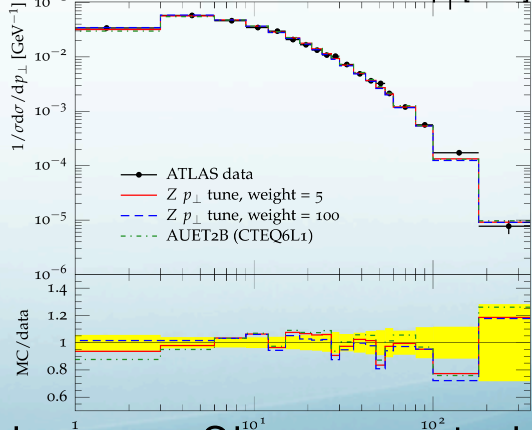
Initial state radiation (1)

- only effects hadron colliders (ep, pp, pp)
- DY ideal case for ISR model test since it has no FSR
- ISR adds pt to the Z: test collinear and soft shower limit at low Zpt

arXiv:1110.4973



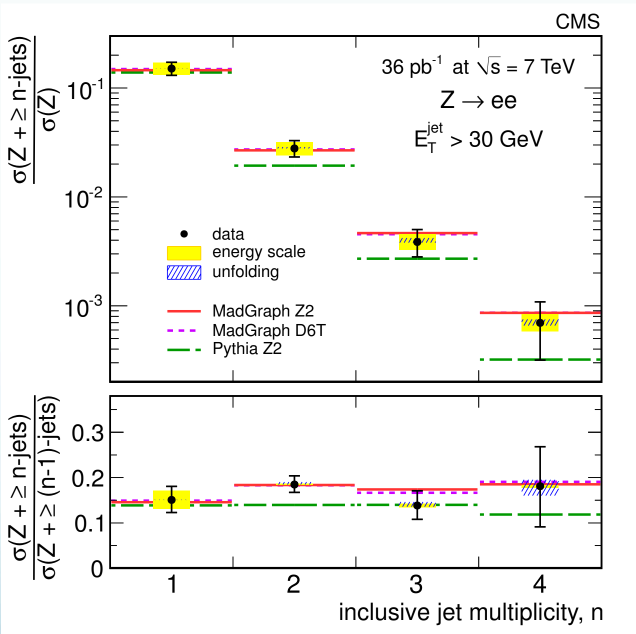


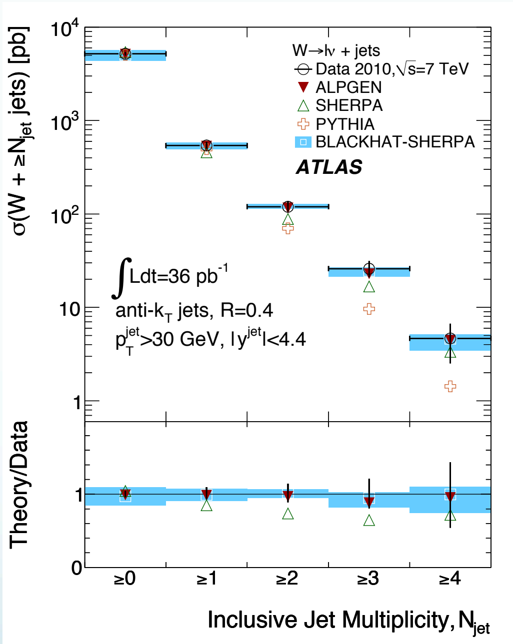


Good description of Z pt with Pythia showers, Sherpa up to high Zpt – problems using NLO generators

ISR – hard radiations

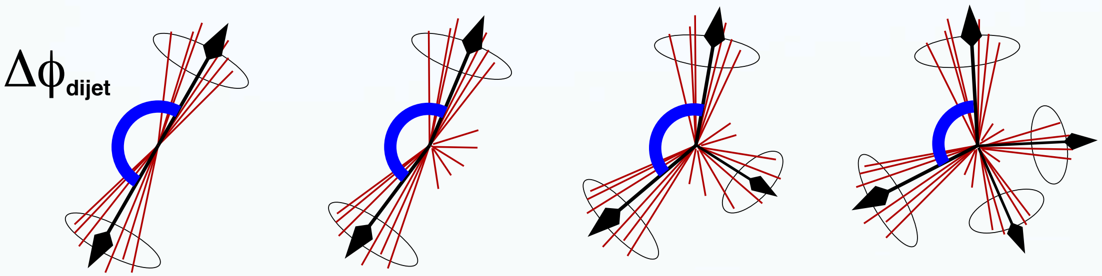
...and hard ISR emissions at high pt end and in additional observed jets

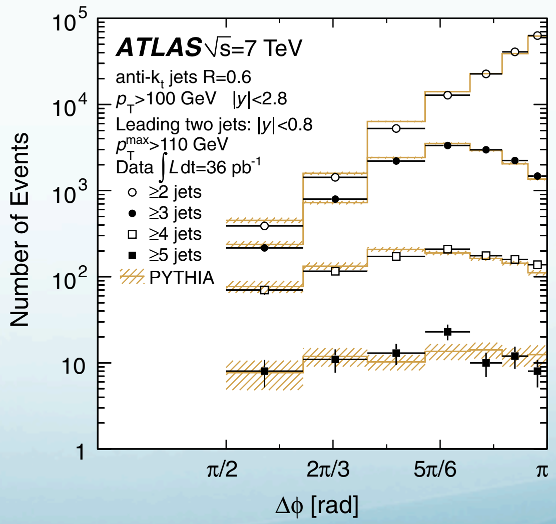




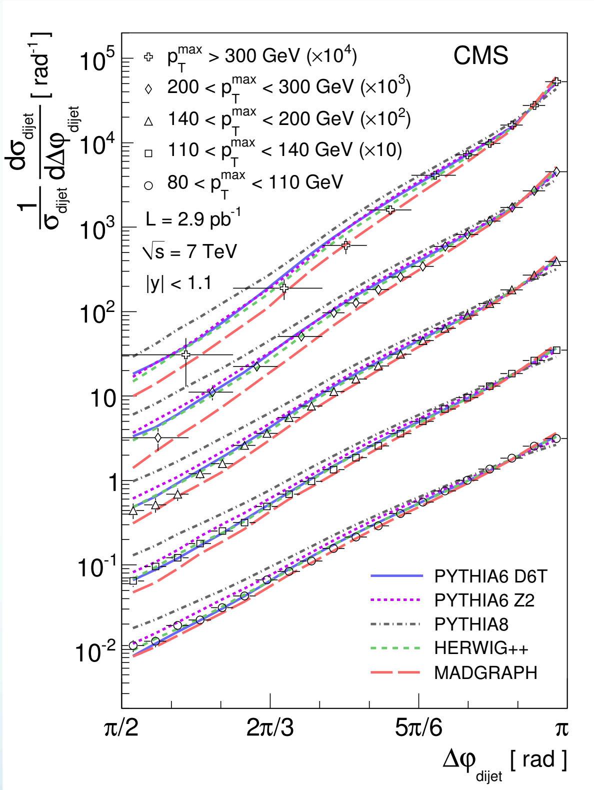
Current pythia shower implementations are not able to correctly describe the hard emissions

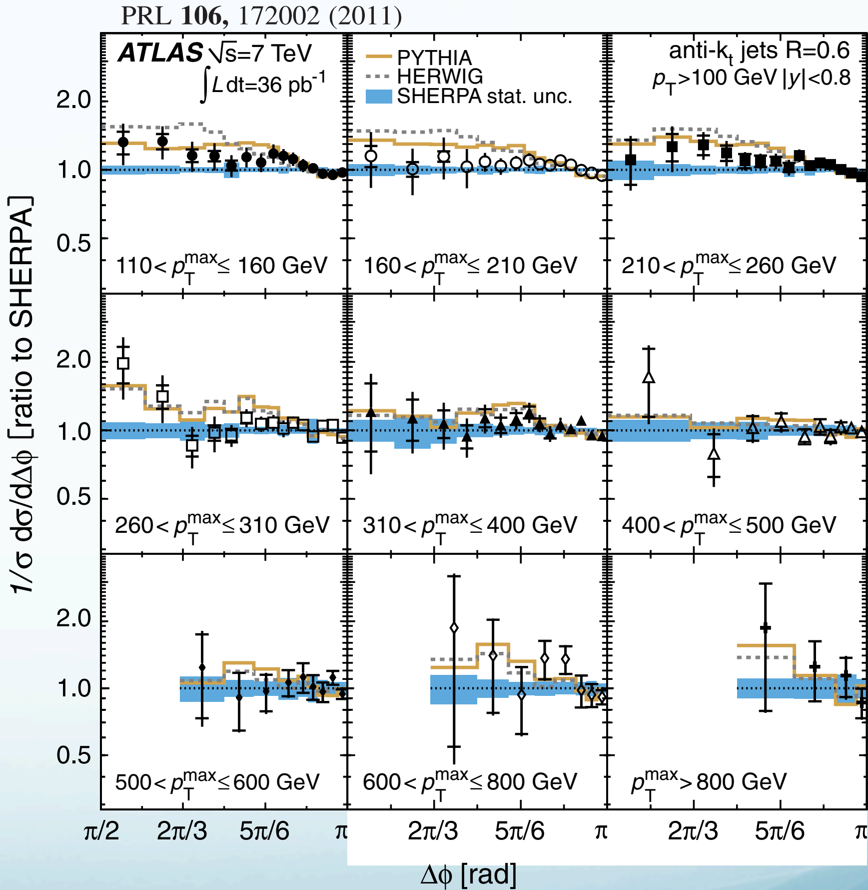
Initial state radiation (2)
max.parton virtuality





Initial state radiation (2)
max.parton virtuality

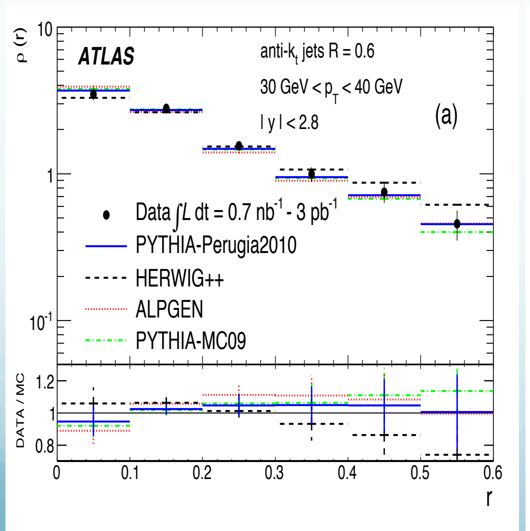


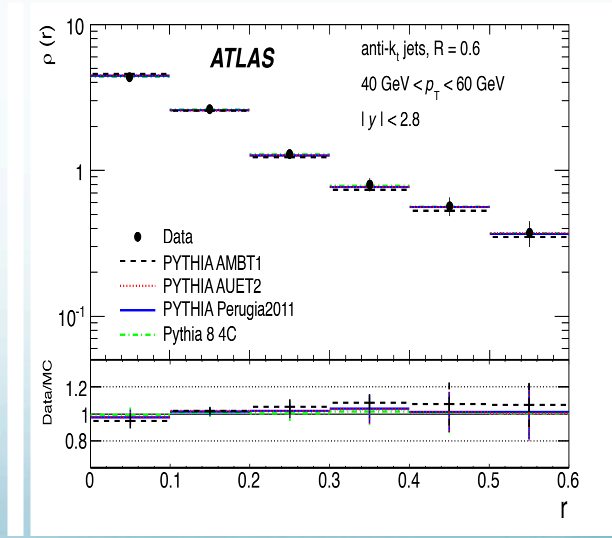


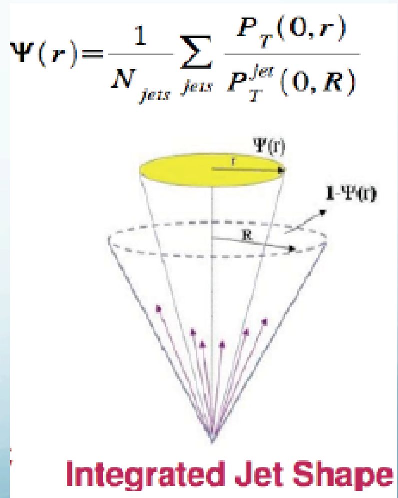
Pythia6, Herwig++ describe data very well,
Sherpa, Madgraph less good at small angles
Pythia8 needs tuning...

FSR off ISR partons

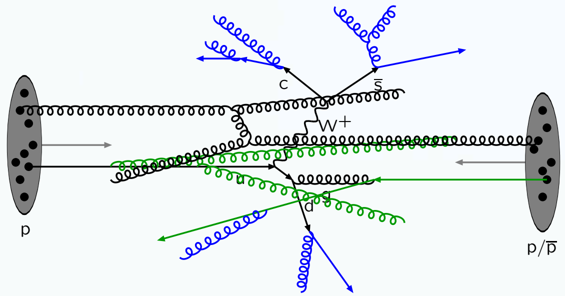
- ISR partons shower and produce jets
- Jet shapes are driven by FSR
- FSR off ISR could theoretically be different in pp collisions from LEP



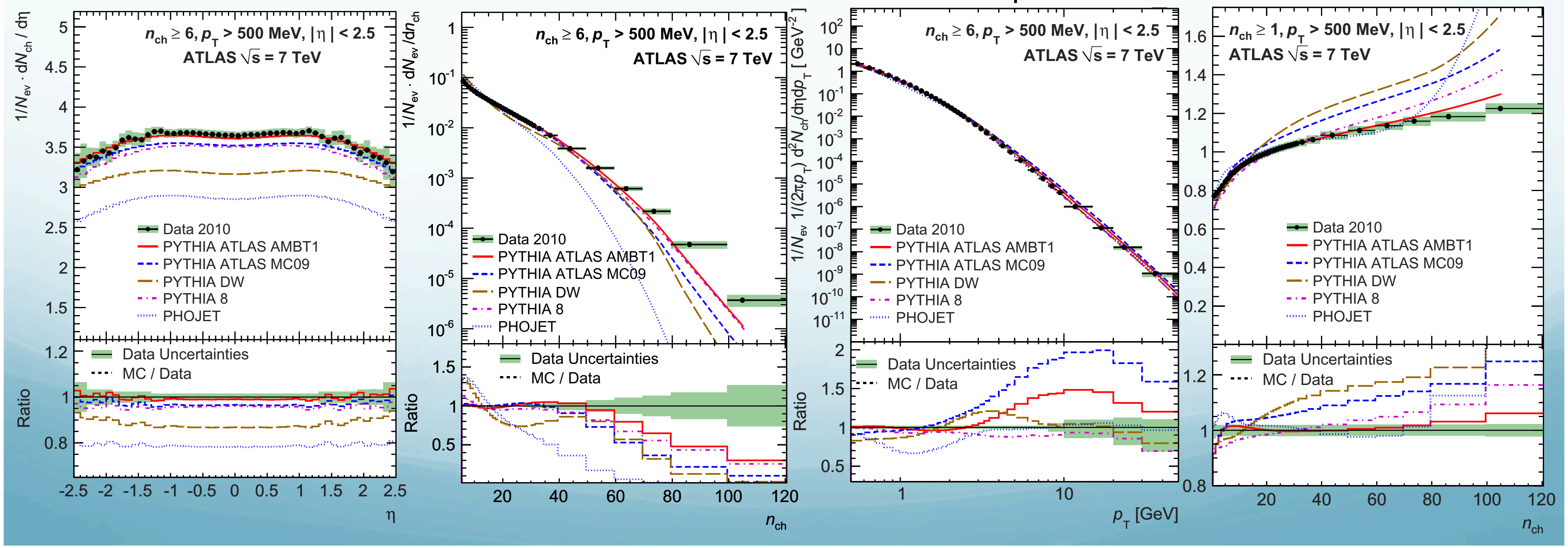




Multiparton interactions minimum bias

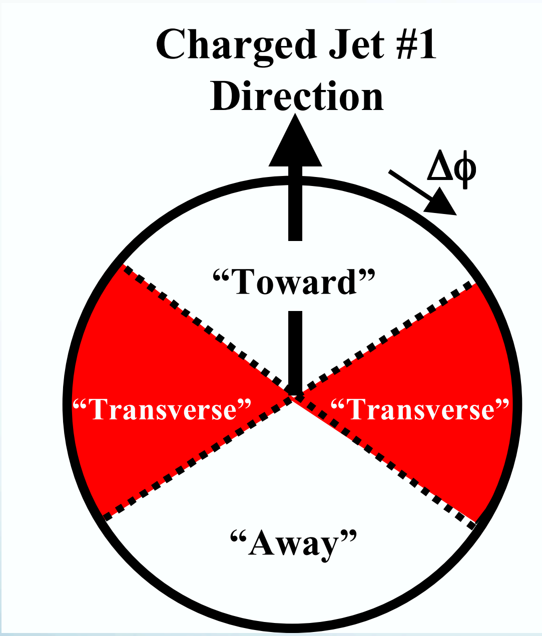


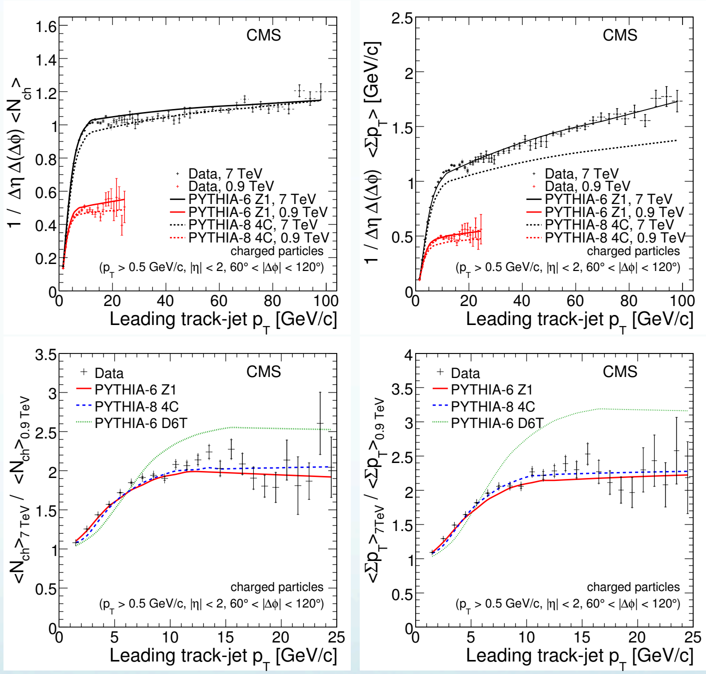
- First papers with data from LHC (ALICE, CMS, ATLAS)
- MPI is implemented as simultaneous parton-parton scattering via t-channel gluon exchange
- Rate of MPI modeled via impact parameters (geometrical overlap of colliding protons)
- Tuning with first LHC data of geometrical distribution and low pt cut-off

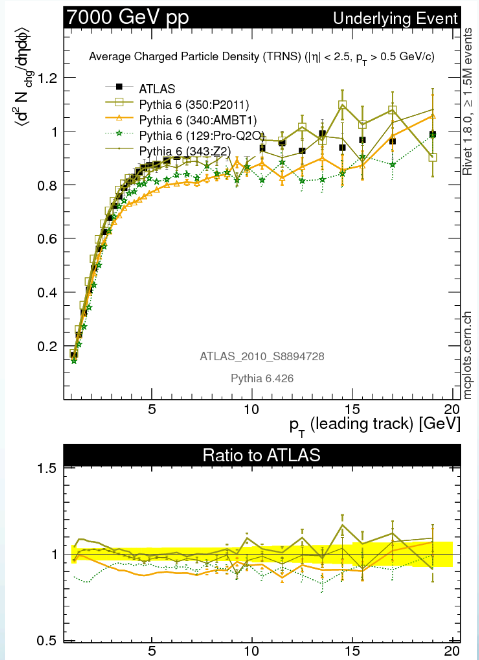


Multiparton interactions Underlying event

- MPI the same as in minimum bias events
- For measurement need to remove particle production of the hard scatter event -> geometrical cuts

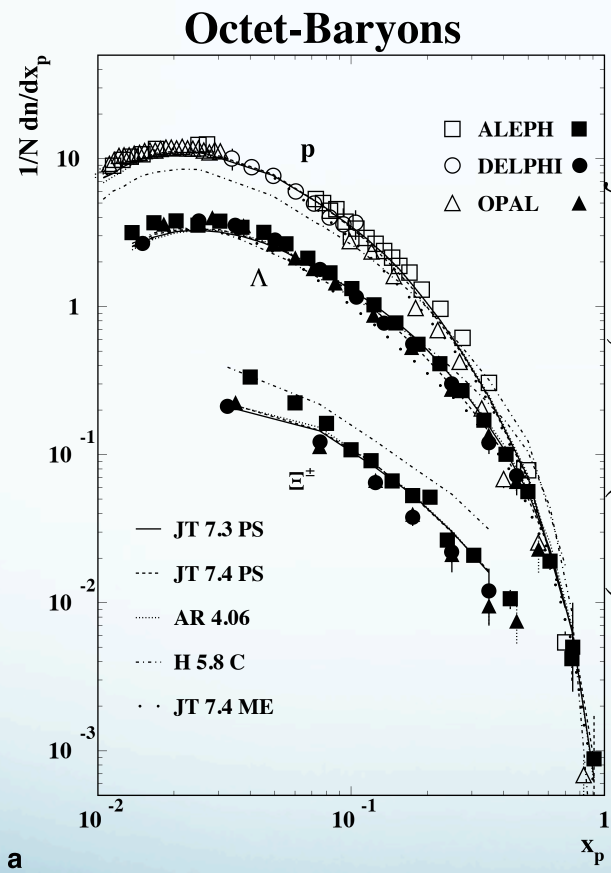






- Good description reached when tuned to UE data....
- ... but discrepancies to MPI modeling tuned to min bias data
- At Tevatron consistent picture possible

Hadronisation



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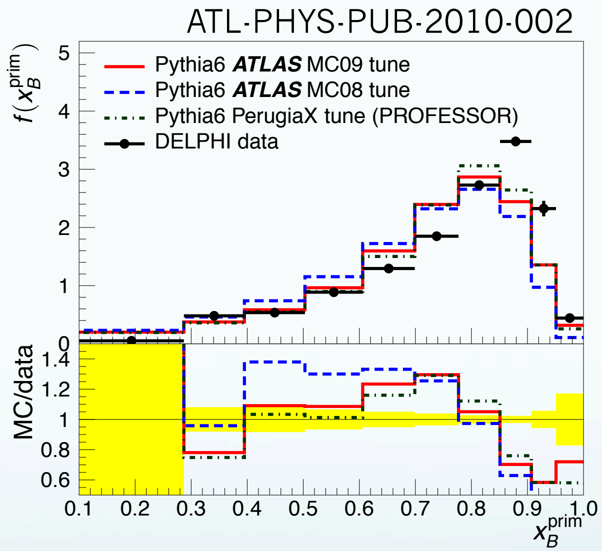
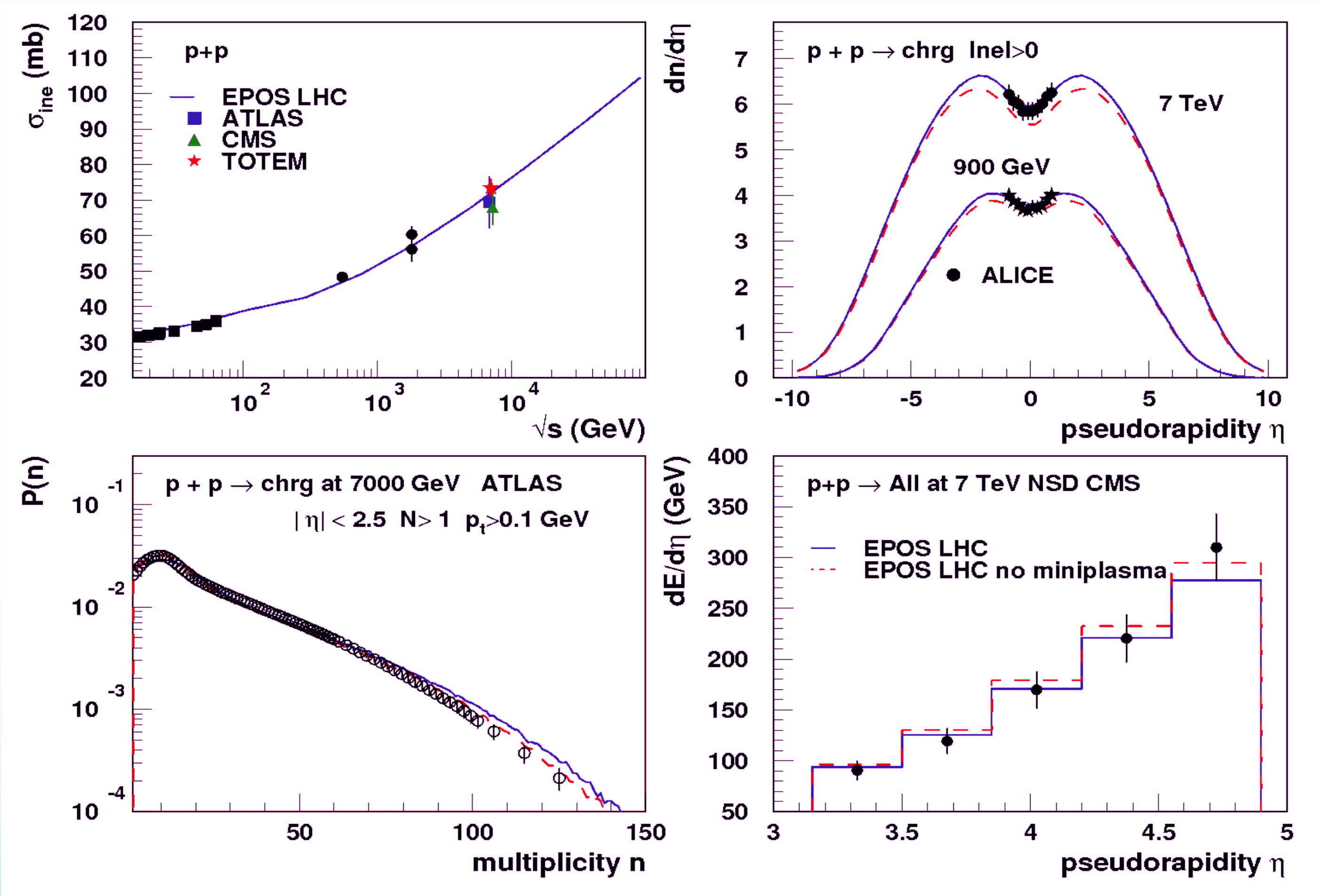
Tuned to LEP data



(a) b-fragmentation ($x_{\mathrm{B}}^{\mathrm{prim}}$)

Pile-Up: Minimum bias modeling



EPOS :Gribov-Regge based model (with modeling alternatives for All components) describes min.bias data very well (best?)

Used for pile-up simulations and soft QCD modeling

References

- MC lecture by T.Sjoestrand:

  http://indico.cern.ch/conferenceDisplay.py?confId=a042790

- Many data-mc comparisons with different MC programs and tunes

  http://mcplots.cern.ch/

Summary

- Many MC generators exist with various quality of

describing

Models to be tuned for LHC

- Multi-parton interaction (MPI)
- Color reconnection
- Initial state radiation (ISR)
- Intrinic kt
- Final state radiation off ISR partons

Soft QCD: min.bias+
Underlying event

Jet multiplicities and
angular correlations,Wpt,Zpt
Wpt,Zpt

Jet shapes