LUND UNIVERSITY

Astronomy and Theoretical Physics Gathering
19 August 2008

Event-Generator Activitities

Outline

Physics overview
Monte Carlo principles
Lund interests

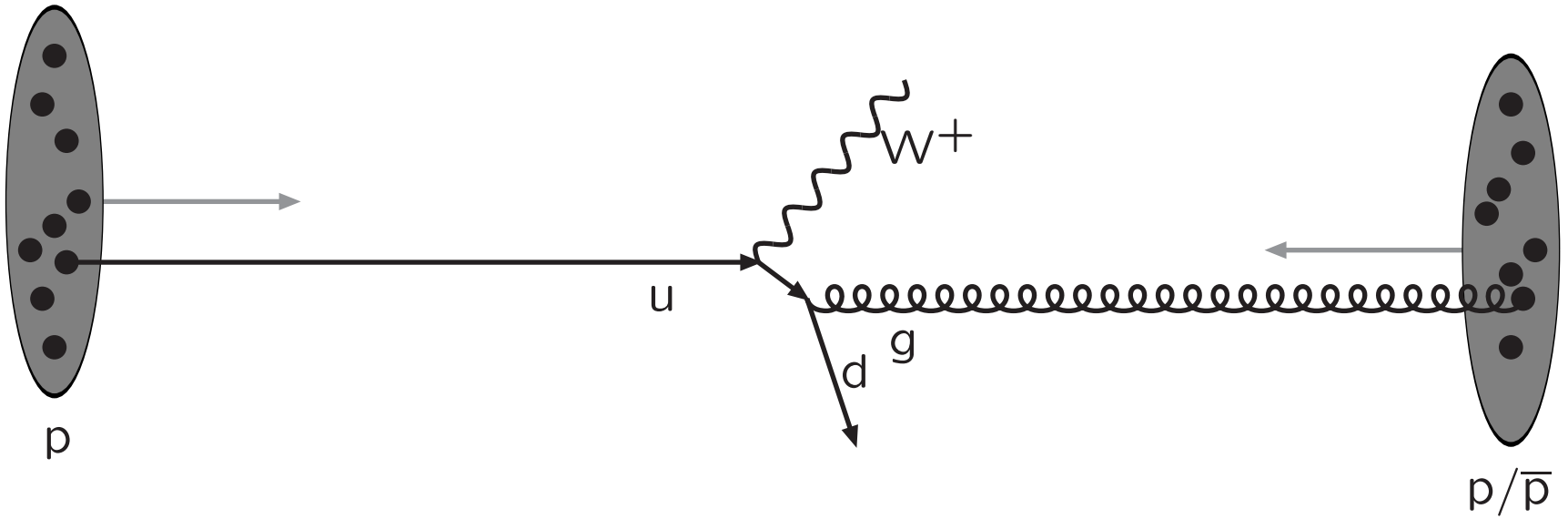
Involves

Torbjörn Sjöstrand	Prof
Leif Lönnblad	Prof
Hendrik Hoeth	postdoc
Richard Corke	graduate student
Christoffer Flensburg	graduate student
Nils Lavesson	graduate student

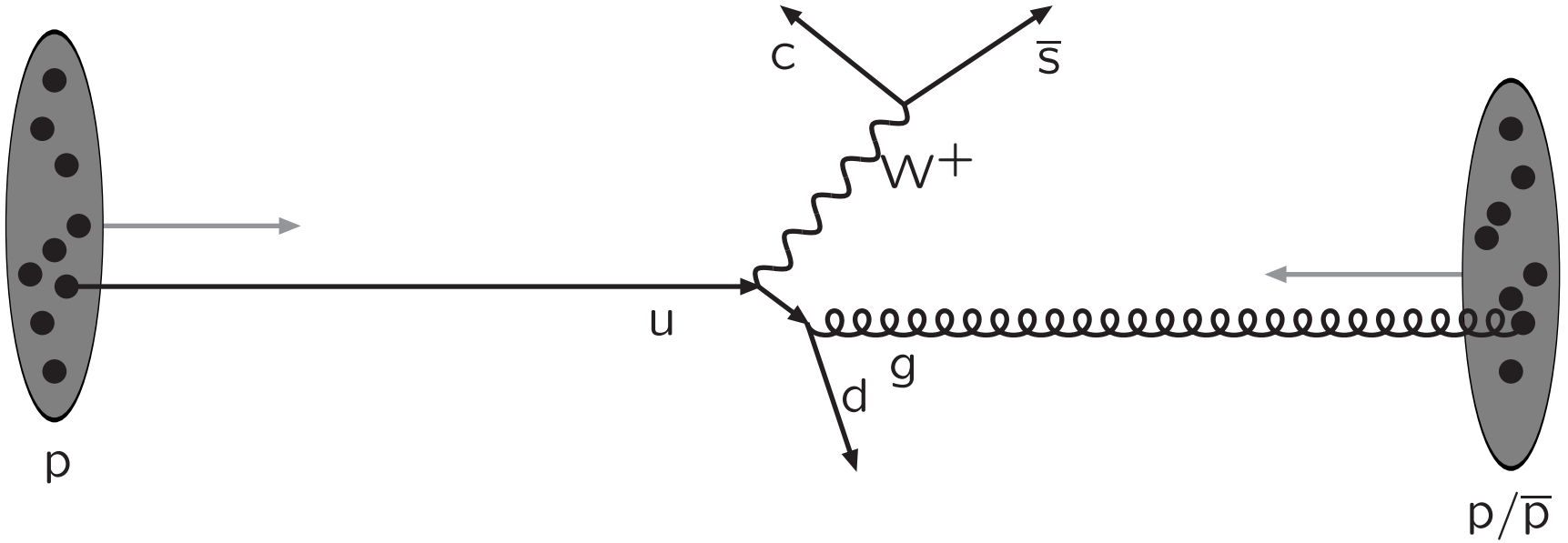
The structure of an event

Warning: schematic only, everything simplified, nothing to scale, . . .

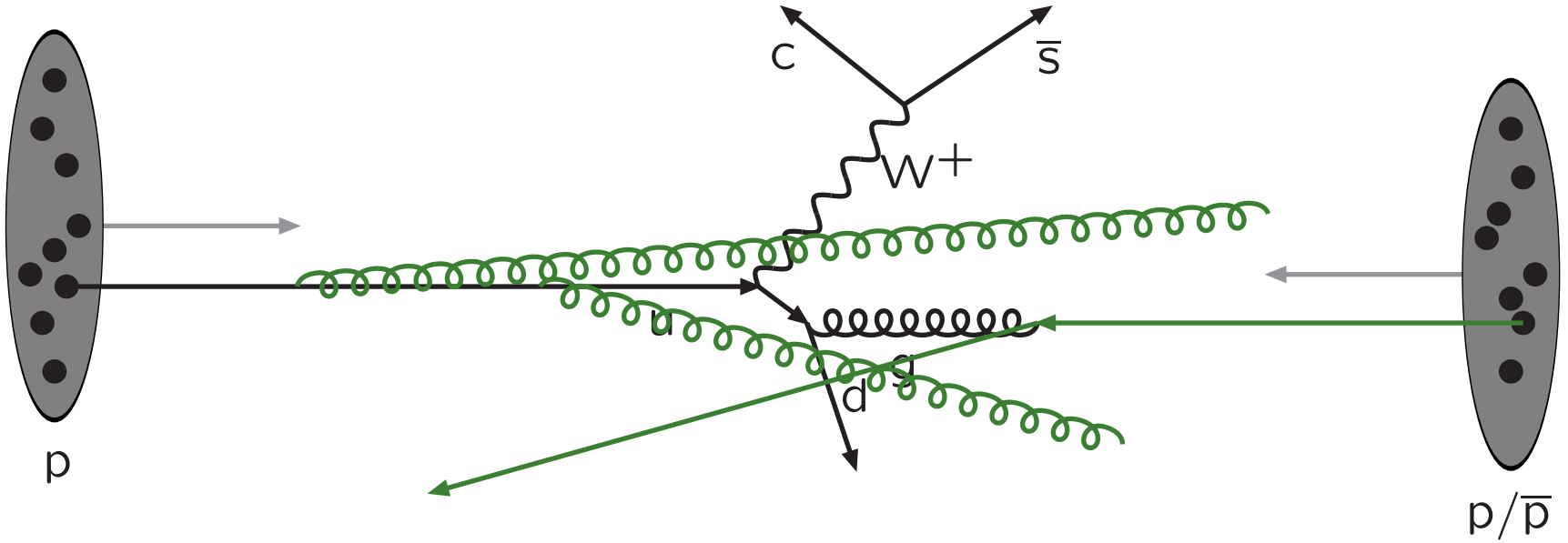
Incoming beams: parton densities



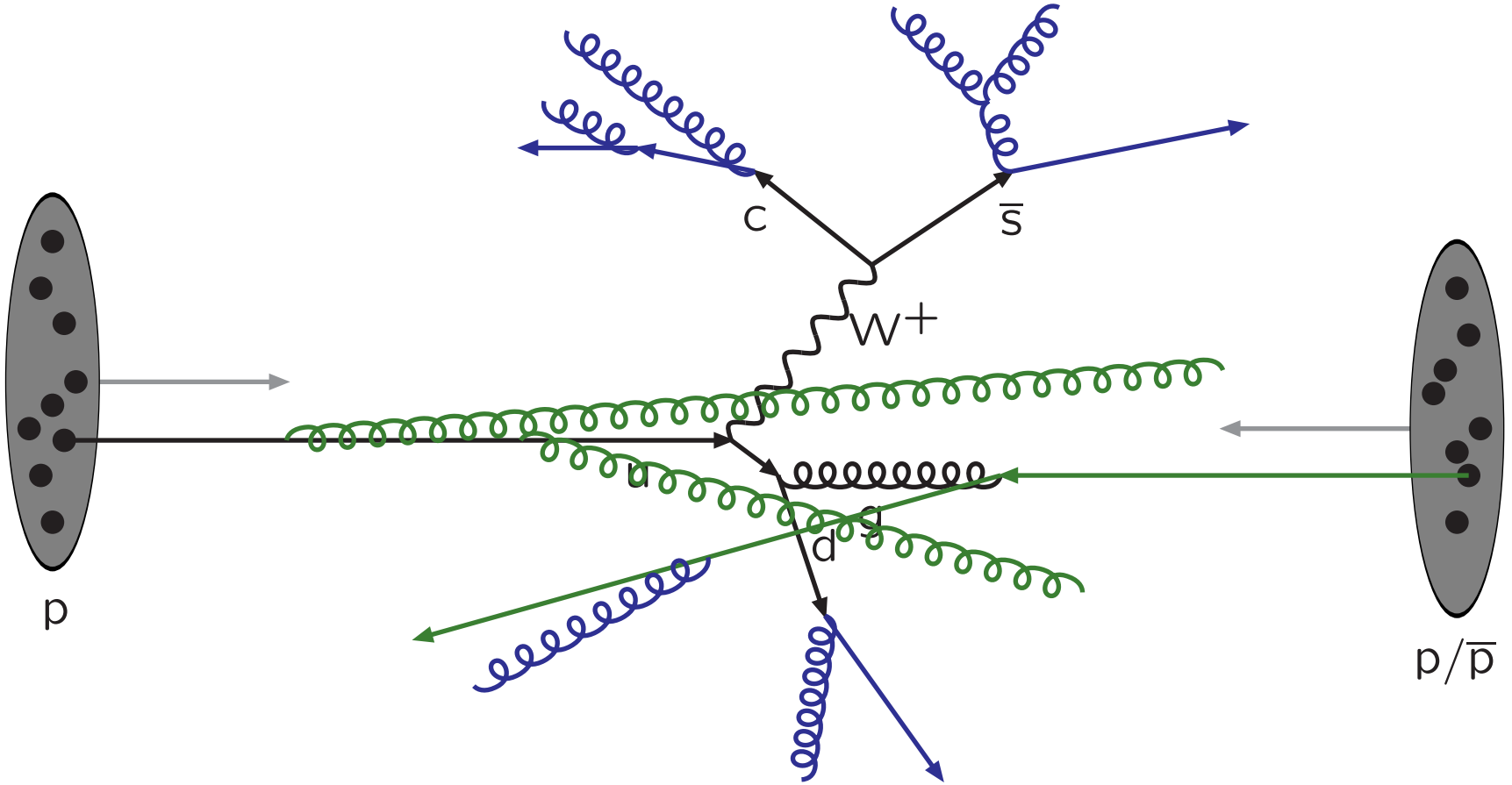
Hard subprocess: described by matrix elements



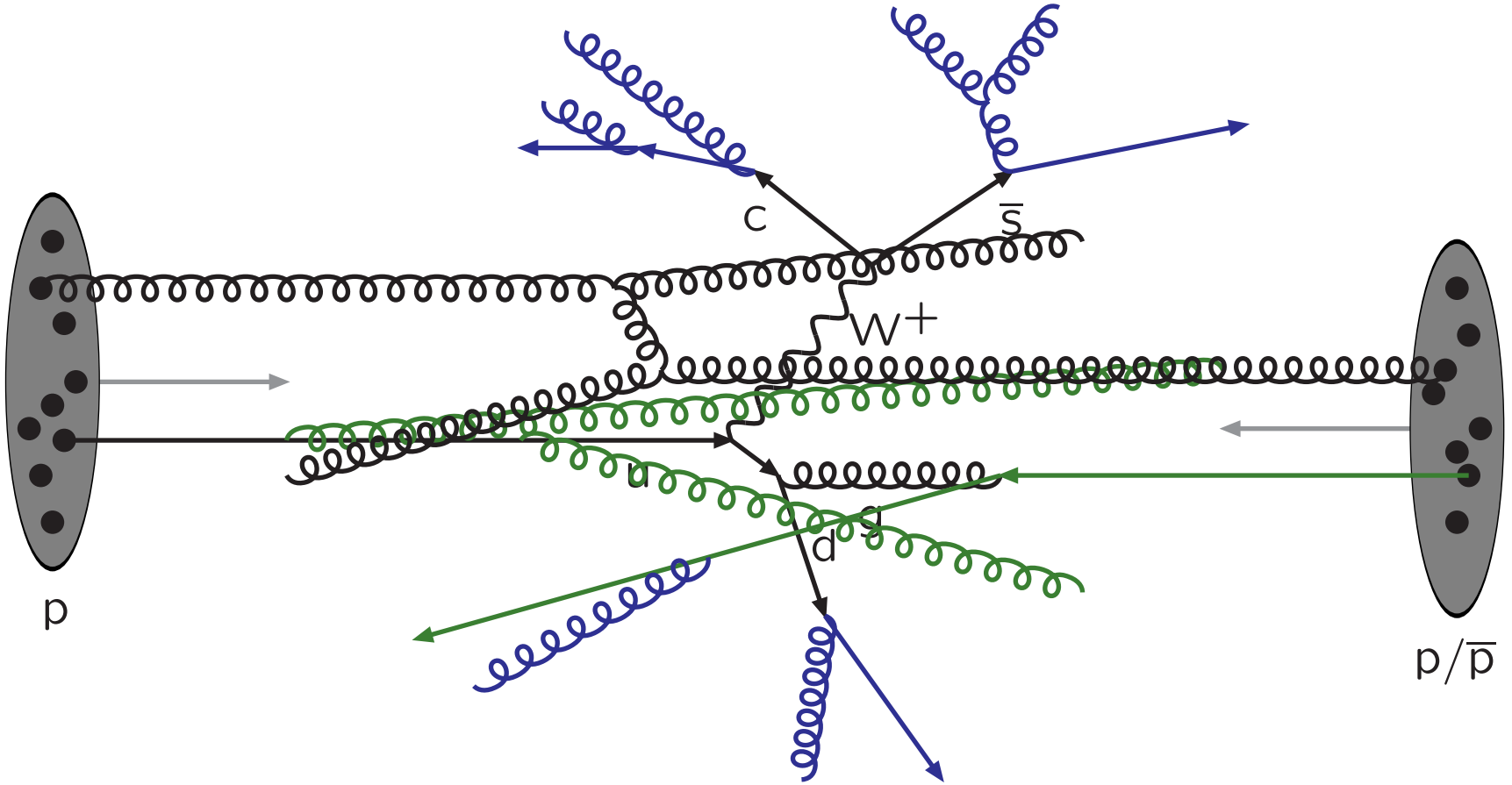
Resonance decays: correlated with hard subprocess



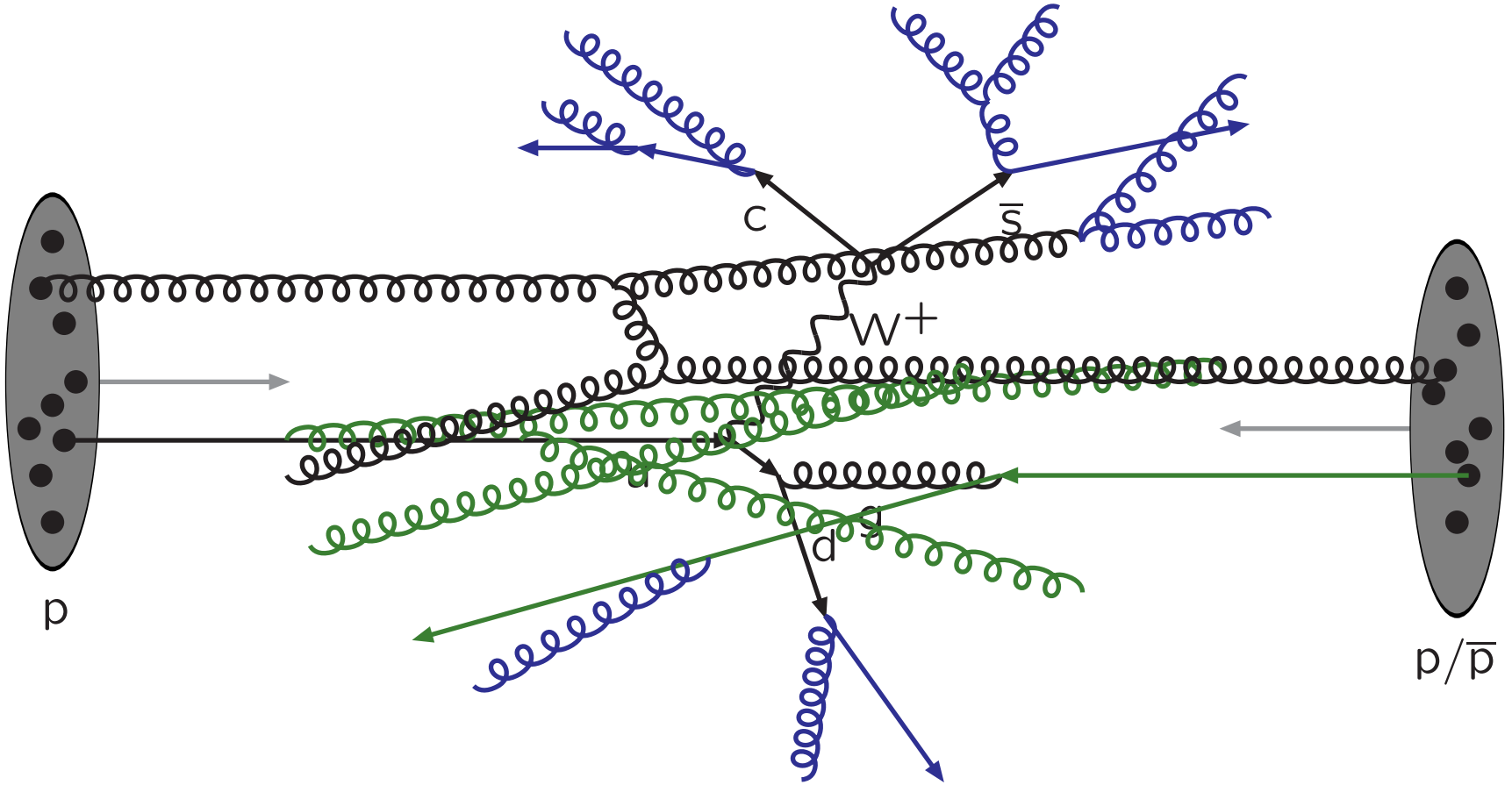
Initial-state radiation: spacelike parton showers



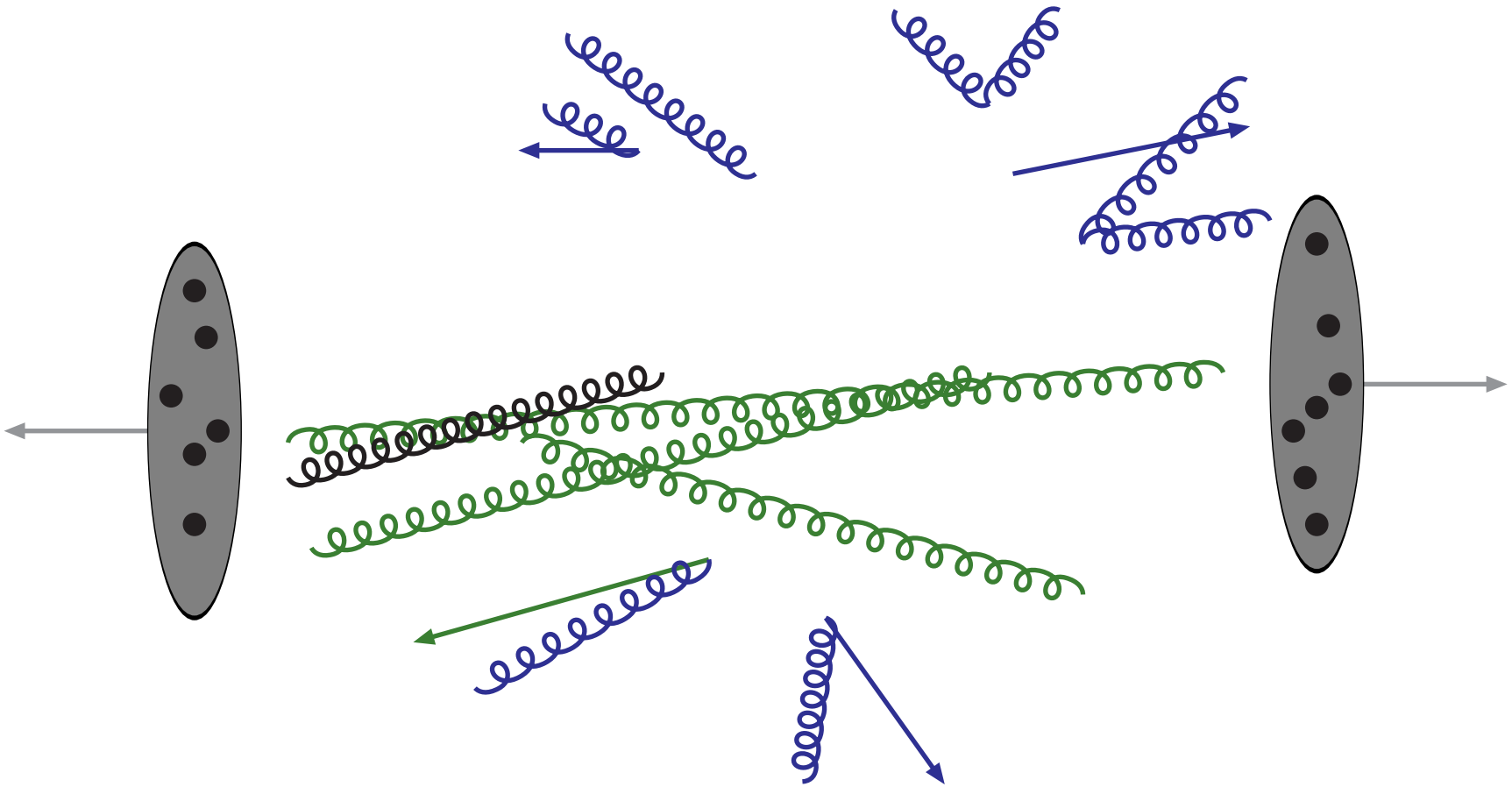
Final-state radiation: timelike parton showers



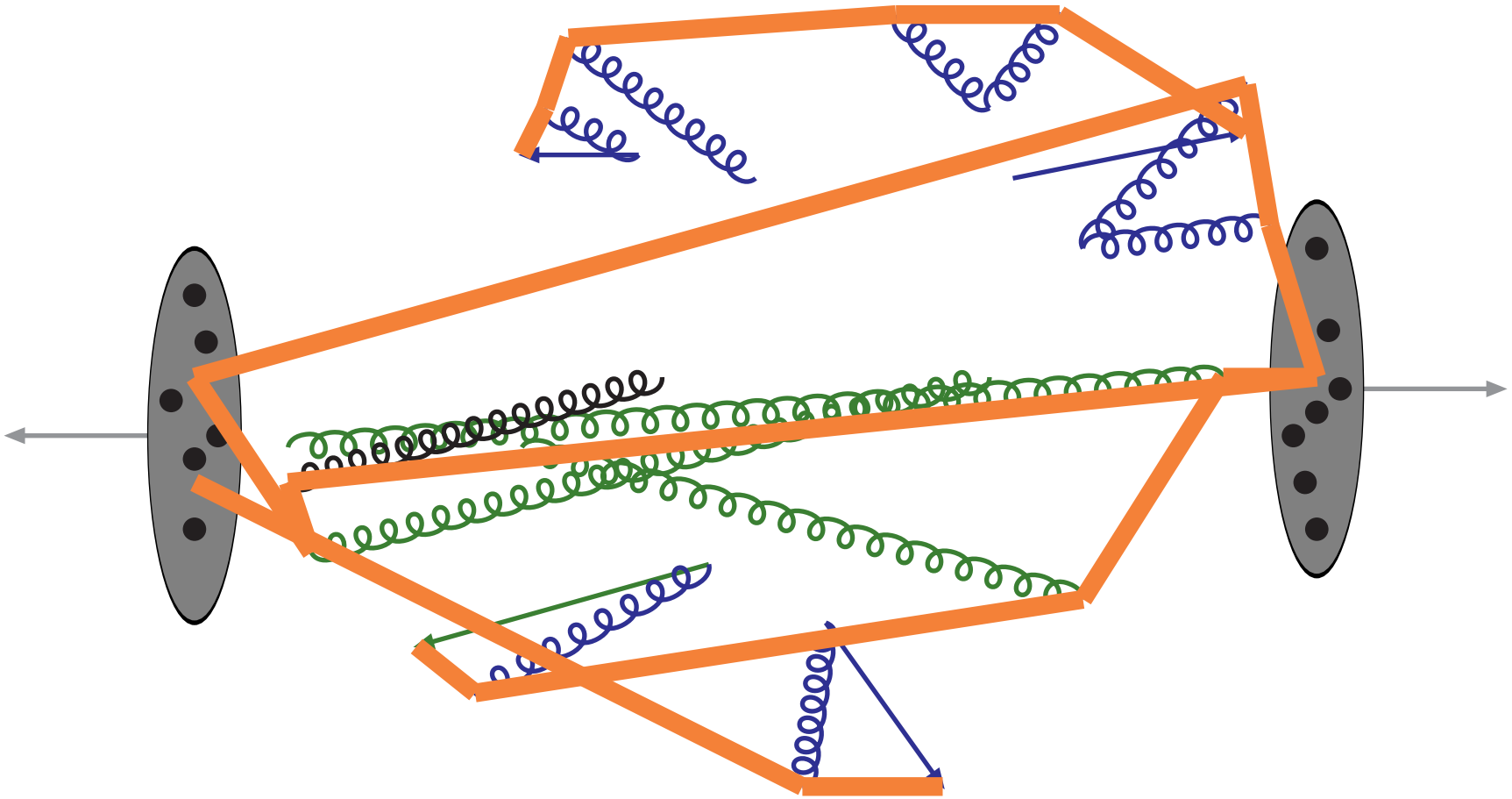
Multiple parton–parton interactions . . .



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

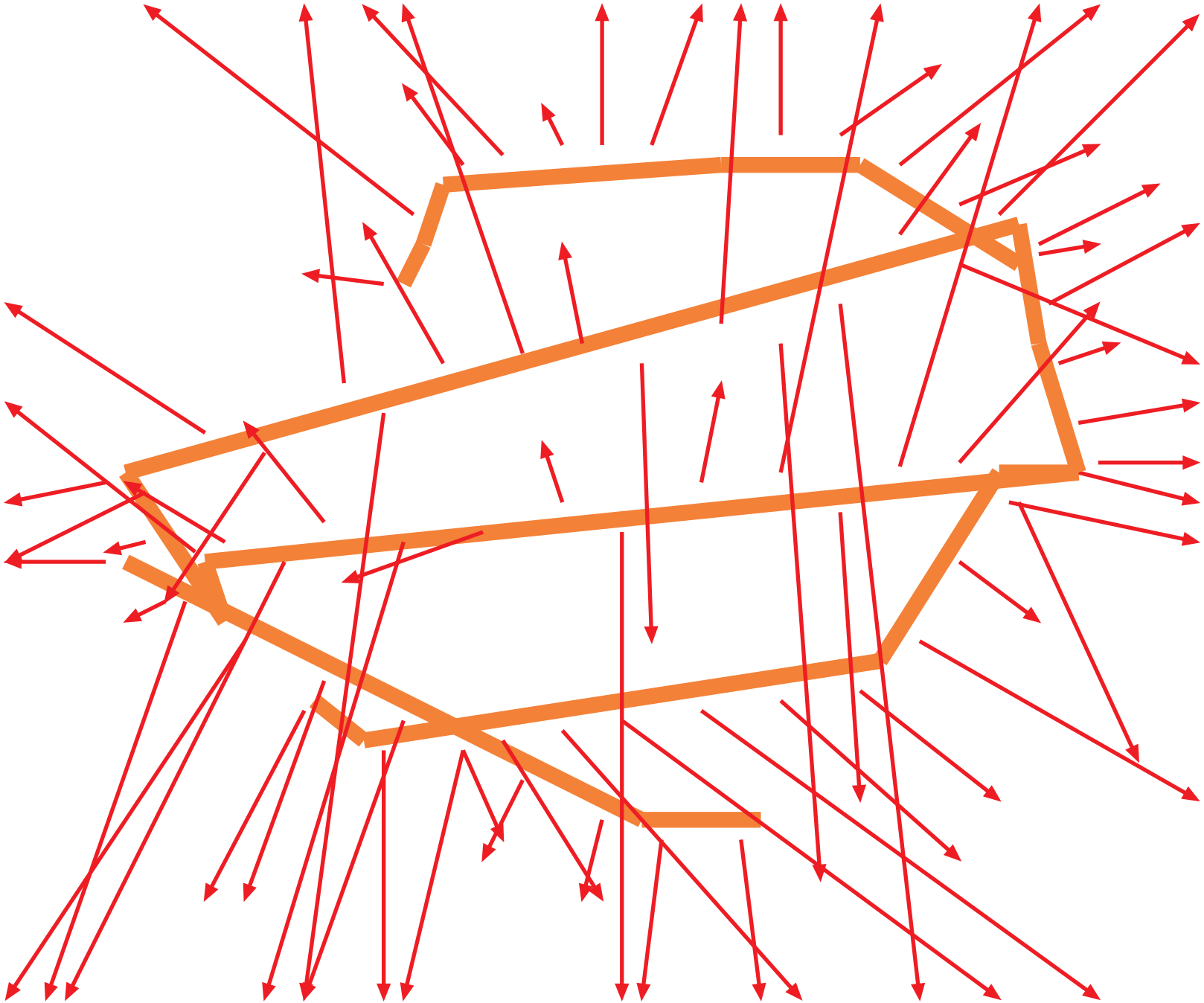


Beam remnants and other outgoing partons

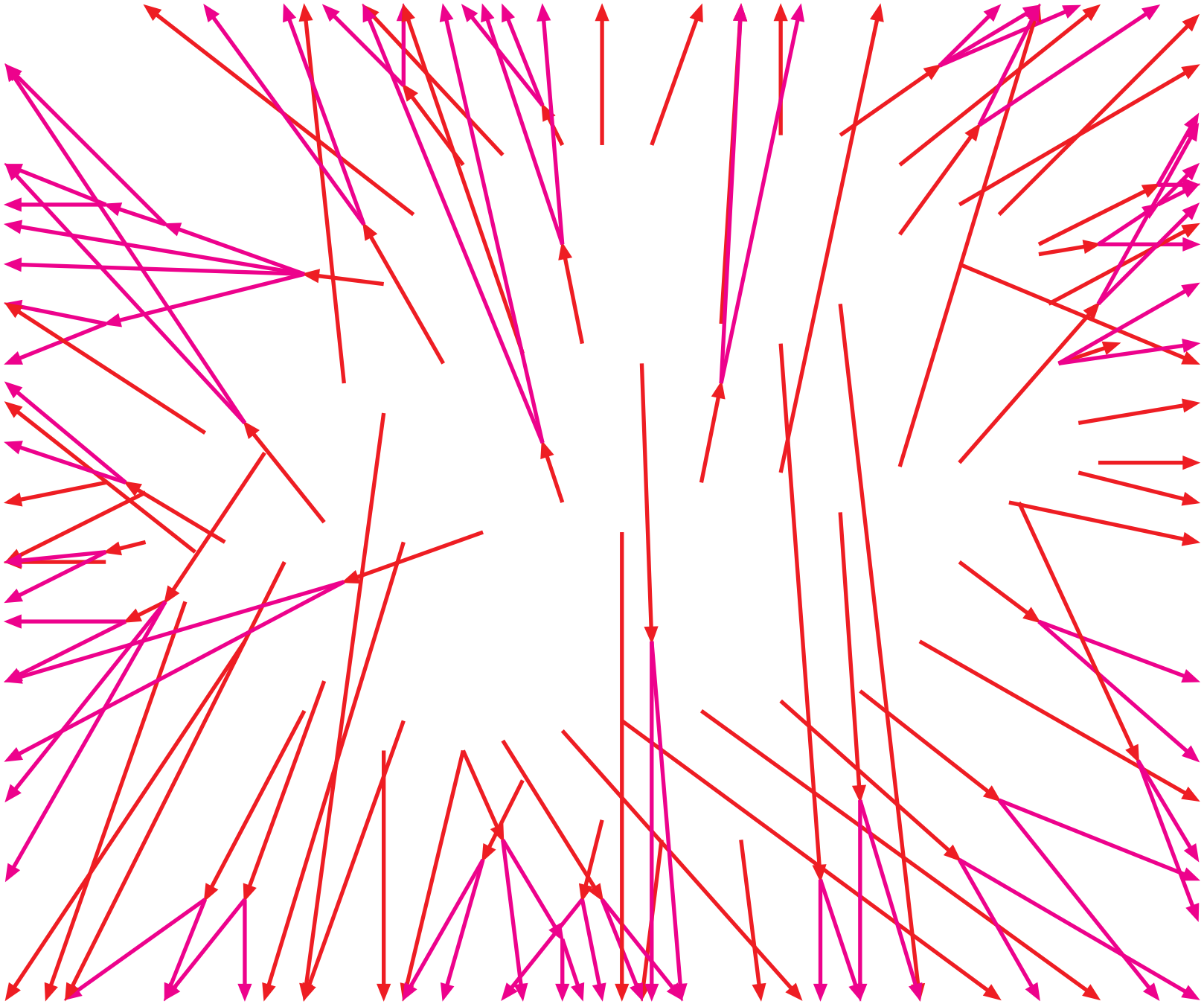


Everything is connected by colour confinement strings

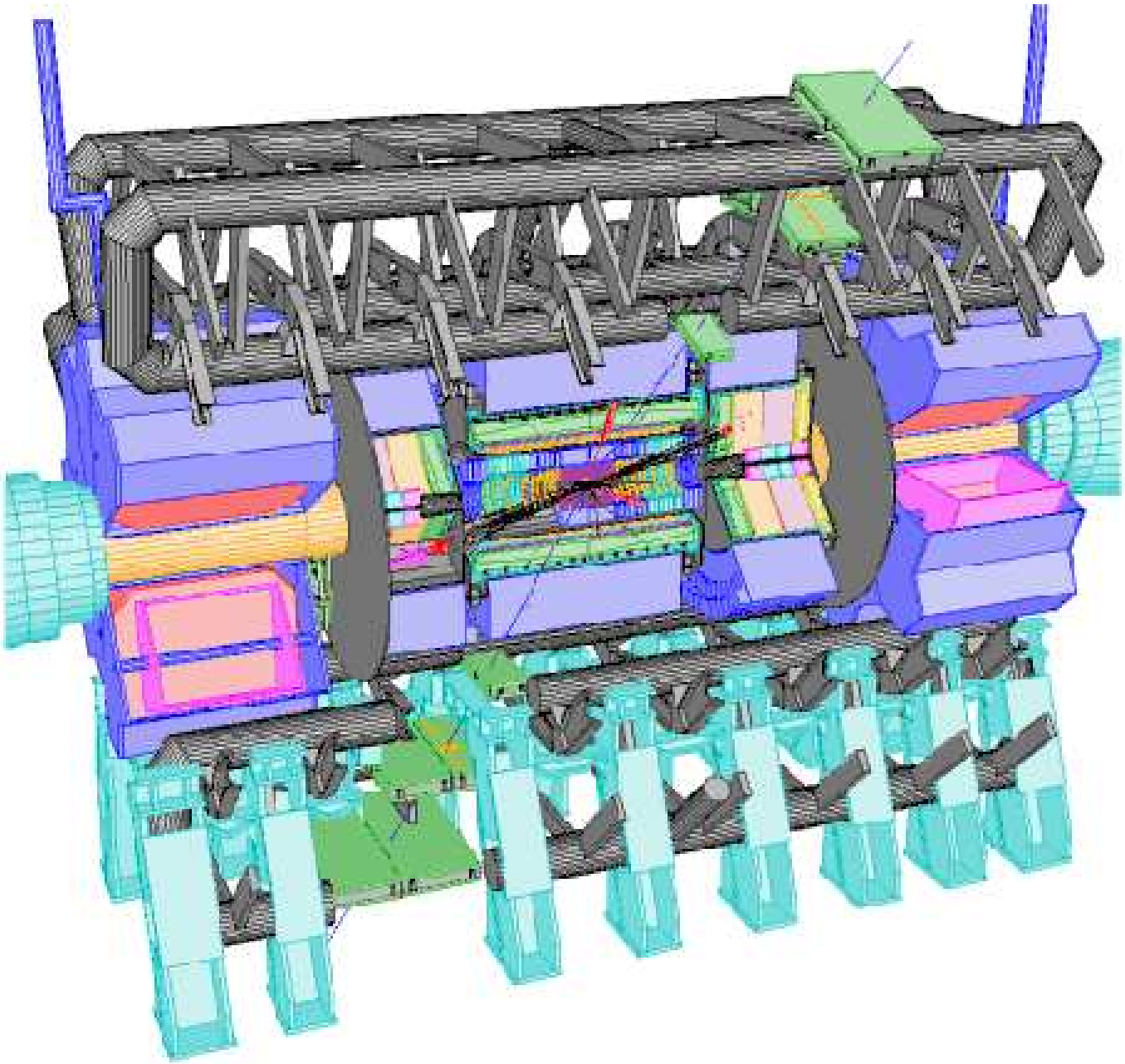
Recall! Not to scale: strings are of hadronic widths



The strings fragment to produce primary hadrons

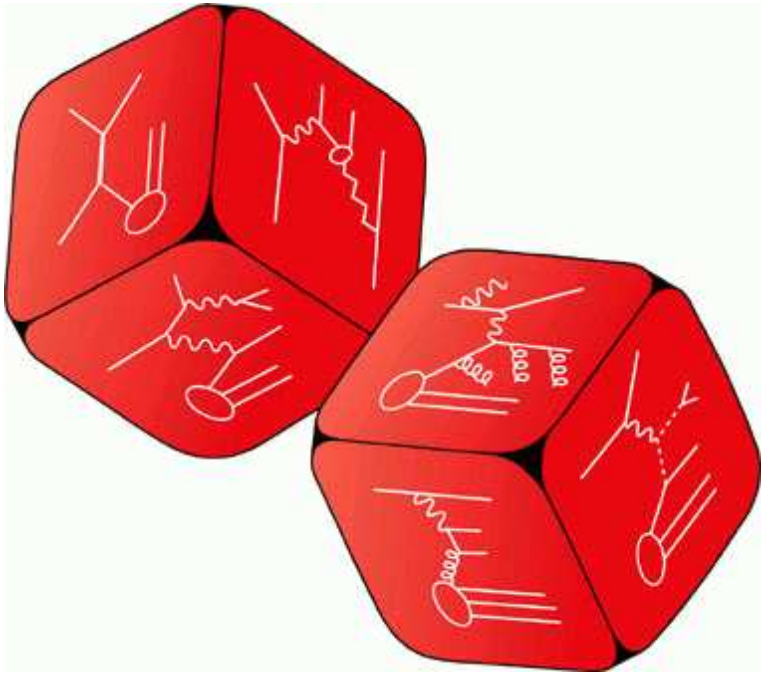


Many hadrons are unstable and decay further



These are the particles that hit the detector

A tour to Monte Carlo



. . . because Einstein was wrong: God does throw dice!

Quantum mechanics: amplitudes $\Longrightarrow$ probabilities

Anything that possibly can happen, will! (but more or less often)

The Monte Carlo method

Want to generate events in as much detail as Mother Nature

$\Longrightarrow$ get average *and* fluctutations right

$\Longrightarrow$ make random choices, $\sim$ as in nature

$$\sigma_{\text{final state}} = \sigma_{\text{hard process}} \mathcal{P}_{\text{tot,hard process}\to\text{final state}}$$

(appropriately summed & integrated over non-distinguished final states)

where $\mathcal{P}_{\text{tot}} = \mathcal{P}_{\text{res}} \mathcal{P}_{\text{ISR}} \mathcal{P}_{\text{FSR}} \mathcal{P}_{\text{MI}} \mathcal{P}_{\text{remnants}} \mathcal{P}_{\text{hadronization}} \mathcal{P}_{\text{decays}}$

with $\mathcal{P}_i = \prod_j \mathcal{P}_{ij} = \prod_j \prod_k \mathcal{P}_{ijk} = \ldots$ in its turn

$\Longrightarrow$ **divide and conquer**

an event with n particles involves $\mathcal{O}(10n)$ random choices,

(flavour, mass, momentum, spin, production vertex, lifetime, . . .)

LHC: ~ 100 charged and ~ 200 neutral ($+$ intermediate stages)

$\Longrightarrow$ several thousand choices

(of $\mathcal{O}(100)$ different kinds)

Lund involvement

topic	physics contributions	active
hard processes	(colour flow; heavy user)	–
parton distributions	(only γ; heavy user)	–
parton showers	conventional	1984 – 2000
	dipole	1986 –
	small-x	1995 –
	matching h.p.$\rightarrow$p.s.	1986 –
beam remnants	**multiple interactions**	1985 –
hadronization	**string fragmentation**	1977 –
	colour reconnection	1994 –
decays	(charm, bottom)	–

Come together in generators:

JETSET: string fragmentation + e^+e^- , now in PYTHIA

PYTHIA: complete generator, $\sim$ 50,000 lines of code,

heavily used by experimental community ($\sim$ 8,000 citations)

recently (+ ongoing) “converted” to C++

ARIANE/LDCMC: models for showers, “plug-in” to PYTHIA

ThePEG: generic framework for C++ generators

Why?

Interesting

- QCD – theory of strong interactions – “correct” but not “solved”
- Generators allow a “divide and conquer” strategy, so that we . . .
- can model and study many intricate aspects of QCD
- $\Leftrightarrow$ theoretical & experimental studies of *complex* multiparticle physics
- Large flexibility in physical quantities that can be addressed
- Vehicle of ideology to disseminate ideas to experimentalists

Useful

- study detector requirements $\Rightarrow$ optimize detector/trigger design
- predict event rates and topologies $\Rightarrow$ estimate feasibility
- simulate possible backgrounds $\Rightarrow$ devise analysis strategies
- study detector imperfections $\Rightarrow$ evaluate acceptance corrections
- Needed also in searches for or studies of other physics within and beyond the Standard Model

Heavily involved in LHC preparations – now waiting for the show to start!