Diffraction at the LHC

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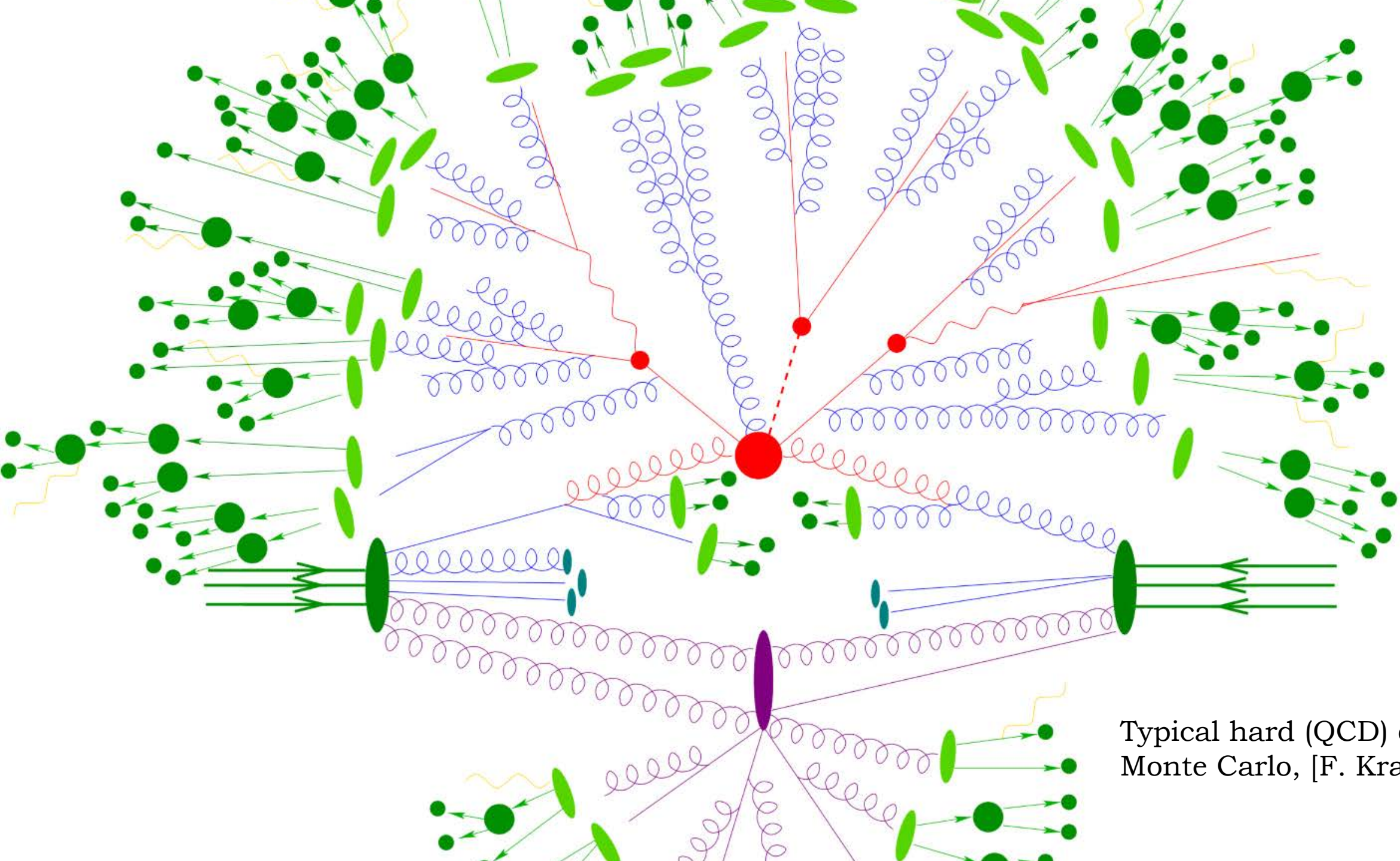
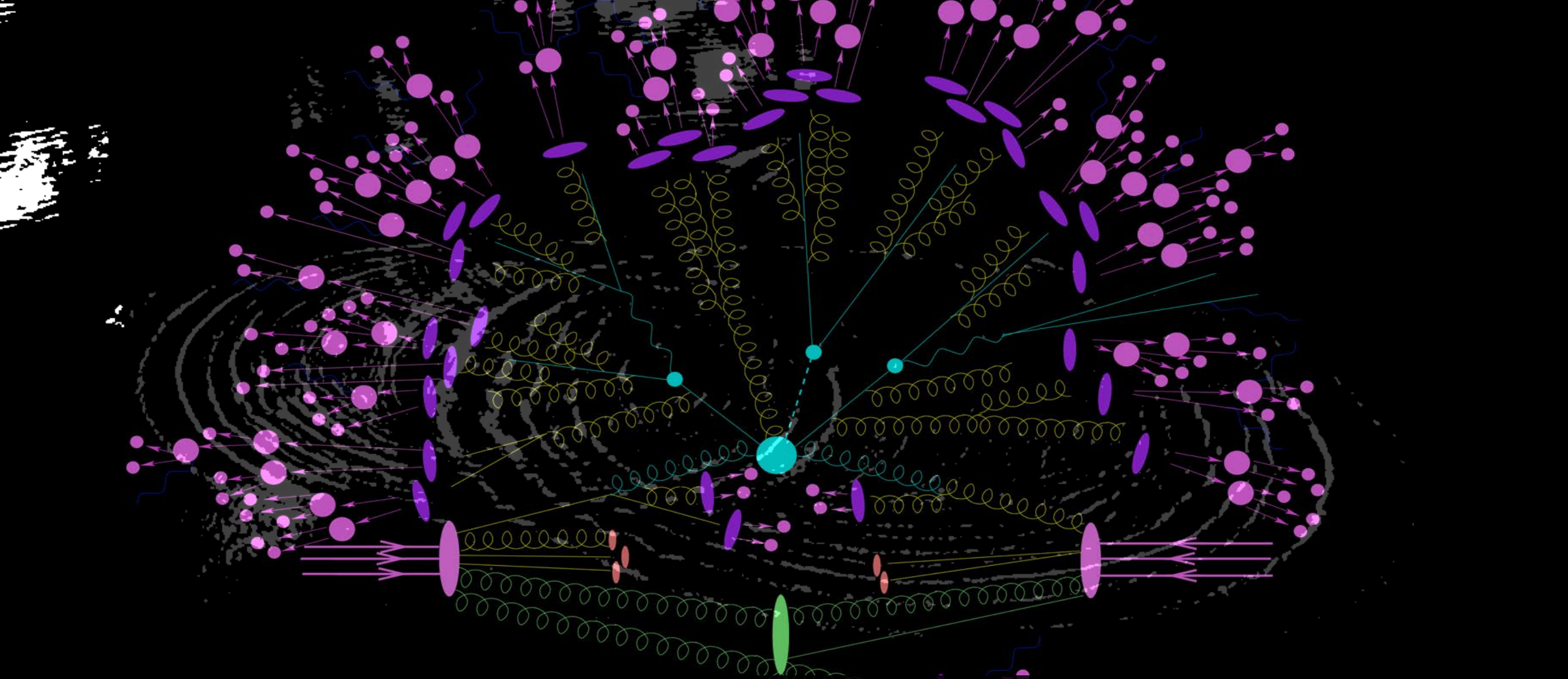


Typical hard (QCD) event in Monte Carlo, [F. Krauss]



QCD Diffraction - phenomena played by coherent ***soft/long-wavelength*** gluons in "Regge domain" ($s \to \infty$, $|t| \lesssim$ a few GeV^2)

(coherence effects elsewhere too, e.g., jet radiation "antenna" patterns!)

A short keyword list..

Approx chronological order (excluding the ”pre-historical” observations):

Young’s double slit (1803), Fourier-Bessel (Hankel) transform, Fresnel (~near-field approx.) and Fraunhofer (~far-field approx.) diffraction, Kirchhoff diffraction theory (1883), X-ray crystallography (Laue ’14, Brag ’15), de Broglie hypothesis (’24) of particle-wave duality → QM-electron diffraction Davisson-Germer (’27), S-matrix program (Heisenberg init.) → analyticity + unitarity → ?, Regge theory (complex J, $A \sim s'^{\alpha(t)}$) (’59), mesons on Regge trajectories, Pomeron trajectory postulated (’61), Good-Walker ”diffractive eigenstates” (’62), Froissart bound, Regge poles and/versus cuts, Eikonal ”optical” models (Glauber etc.), Gribov’s Reggeon Calculus or ”Field Theory” (’68), (wee) partons (Feynman, Bjorken), Veneziano duality, triple-Pomerons & generalized optical theorem (A. Mueller), large rapidity gaps emerge to folklore, QCD (’73), Abramovski-Gribov-Kancheli (AGK) cutting rules (’73), CERN-ISR experiments, shrinkage of diffraction cone (t-distribution), Pomeron in hard QCD (color singlets) (Low-Nussinov gg, BFKL y=log(1/x) ”ladders”) (’75), Glueballs anticipated, Monte Carlo generators emerge (Lund hadronization strings etc.), hard diffraction (jets) observed at CERN-SPS UA8 (’88), Mueller’s dipole BFKL (’94), Diffraction in Deep(ly) Inelastic Scattering (DIS) @ HERA (90’s), photoproduction (γ^*-Pomeron) of vector mesons (Ryskin LLA ’92, VMD already in 60’s), HERA ep, CERN-UA8 & Tevatron-CDF ppbar results and ”factorization breakdown”, low-x gluon distributions (high Q^2 & low-x from HERA ’93 onwards) and saturation (non-linear evolution, CGCs), Pomeron-Graviton AdS/CFT duality (Brower, Polchinski, Strassler, Tan) (’06), CERN-LHC era (10’s)

What makes this interesting

The very complicated hadronic (proton) structure and its coherent evolution during high energy collisions – from deeply non-perturbative to semi-perturbative domain. There are very basic (=fundamental) questions like what happens to the total cross sections, when $s \to \infty$ ...

Observables of Diffraction

♠ A mathematical construction of ***soft*** diffraction observables, including for example some novel applications of **combinatorial** incidence algebras (Möbius inversion) etc.

♣ The main idea is to decompose this problem in a multivariate (vector) space of observables, motivated by complicated experimental issues and theoretical (Regge) concepts, such as AGK cutting rules. Also formulated carefully in terms of statistical/probabilistic inference ⇒ extraction of Regge phenomenology parameters.

Work in progress, for a short proceedings see:

[MM,Orava, http://arxiv.org/abs/1612.00980]

ALICE project

Measurements in progress

♦ Inclusive Proton-Proton Diffractive Cross Sections at $\sqrt{s}$ =13 TeV

♦ Central Exclusive Production (CEP) at $\sqrt{s}$ = 7 and 13 TeV, ”the glueball production channel”, (Pomeron-Pomeron, γ*-Pomeron), full partial wave analysis for spin-parity deduction etc.

For more info, see my talk for the ALICE collaboration:

[MM, Diffractive proton-proton scattering in ALICE at the LHC, PPNC16, 6-8th of July, CERN]

LHC ring "hacking" idea by prof. Orava

- **New Scientist, 25.4.2016,** www.newscientist.com/article/2085759-hacking-the-lhc-to-sift-trash-could-help-find-a-mystery-particle/

- Central Production p+p → p+X+p leaves two forward protons propagating through the LHC beam optics lattice, to exit at points $z_{1,2}$ (m) dictated by longitudinal momentum losses of protons $\xi_{1,2}=1-p_{1,2,z}'/p_z$. Central system mass is then with a good accuracy* given by $M^2 \simeq \xi_1 \xi_2 s$.

~4000 Beam Loss Monitors (around the LHC) ⇒ use monitors within a few hundred meters from the experiments ⇒ with LHC optics lattice simulation (MAD-X, SixTrack Merlin…) construct an inverse map $z \mapsto \xi$.

[Kalliokoski, Lämsä, MM, Orava, http://arxiv.org/abs/1604.05778]

*Due to exclusive dynamics of the process, forward proton kinematics with $|p_t| \ll |p_z|$, as in elastic scattering.


Thanks!