Physics at the LHC

Pavel Starovoitov

Kirchhoff-Institut für Physik, Heidelberg

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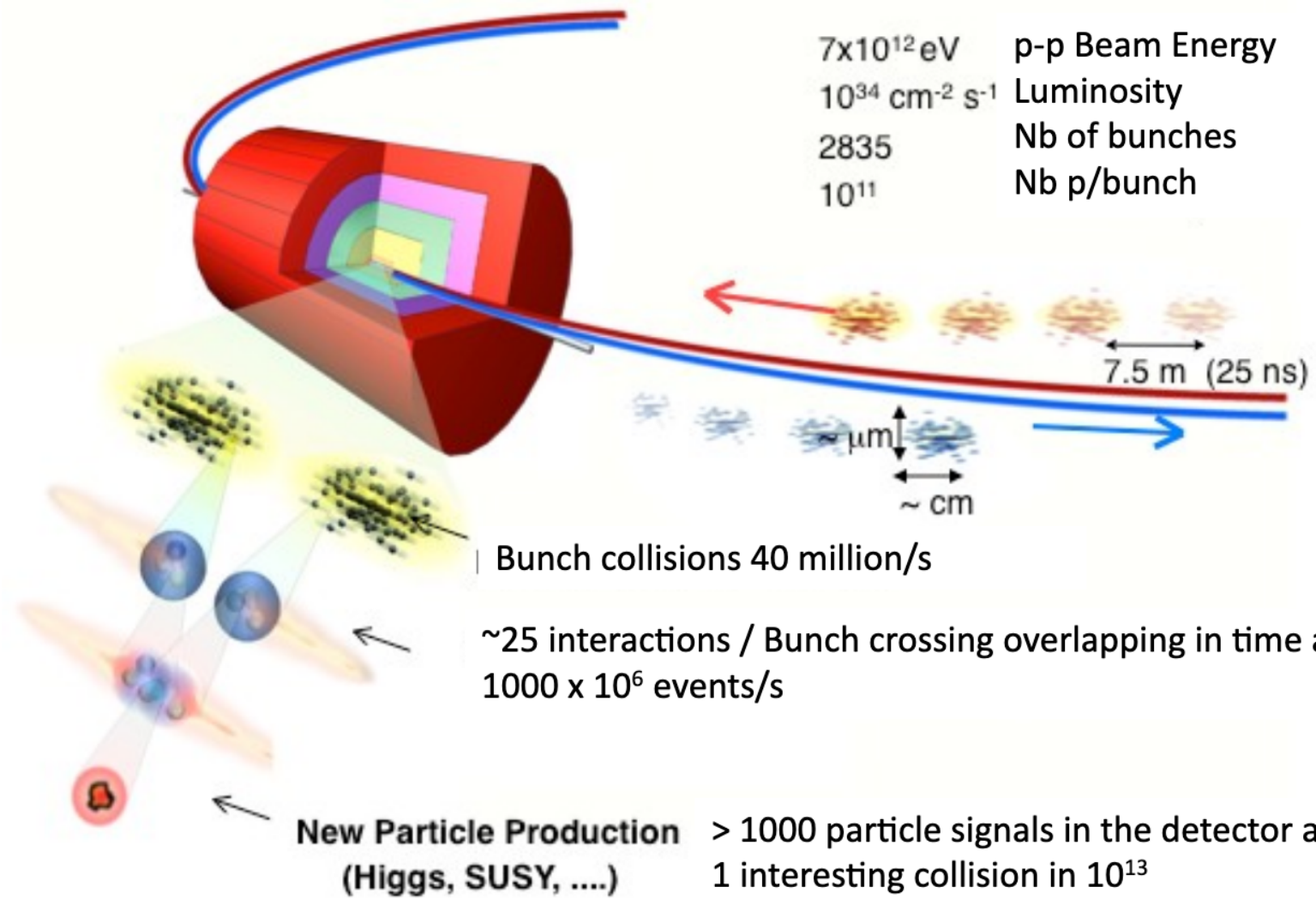
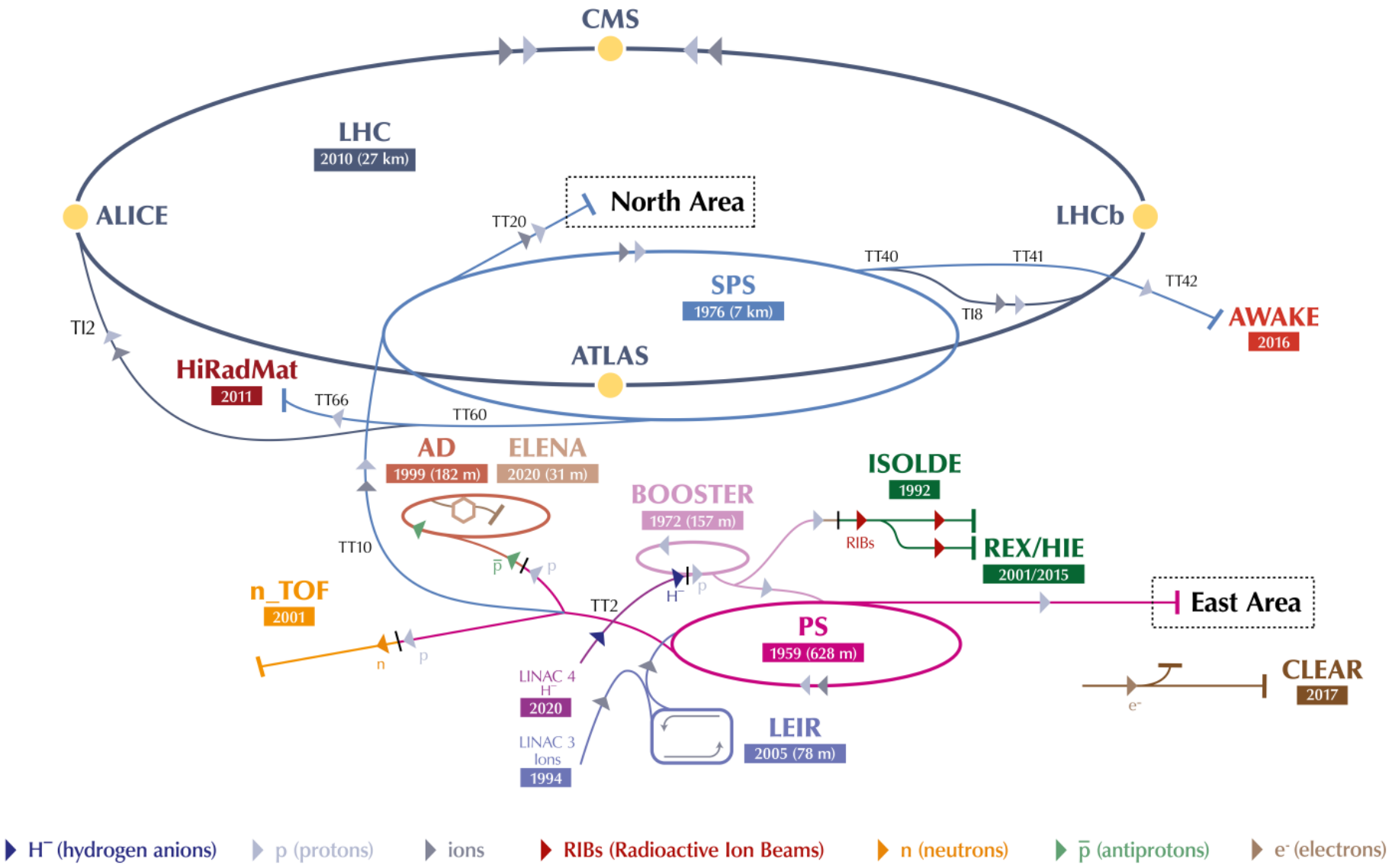
Outlook

- Large Hadron Collider
  - proton-proton collisions, pileup, event size, bandwidth and triggering.
- ATLAS detector
  - Calorimeters : electromagnetic and hadronic
- Jet definition, reconstruction and calibration
  - jet algorithms, infra-red stability, pileup mitigation, topo-clusters, jet energy calibration
- Jet cross-section measurements at 13 TeV
  - trigger strategy, event selection, detector effects, theory model, quantitative data to theory comparison
- Searches for a low-mass dijet resonance at 13 TeV
  - trigger strategy, data analysis, fit model, interpretation

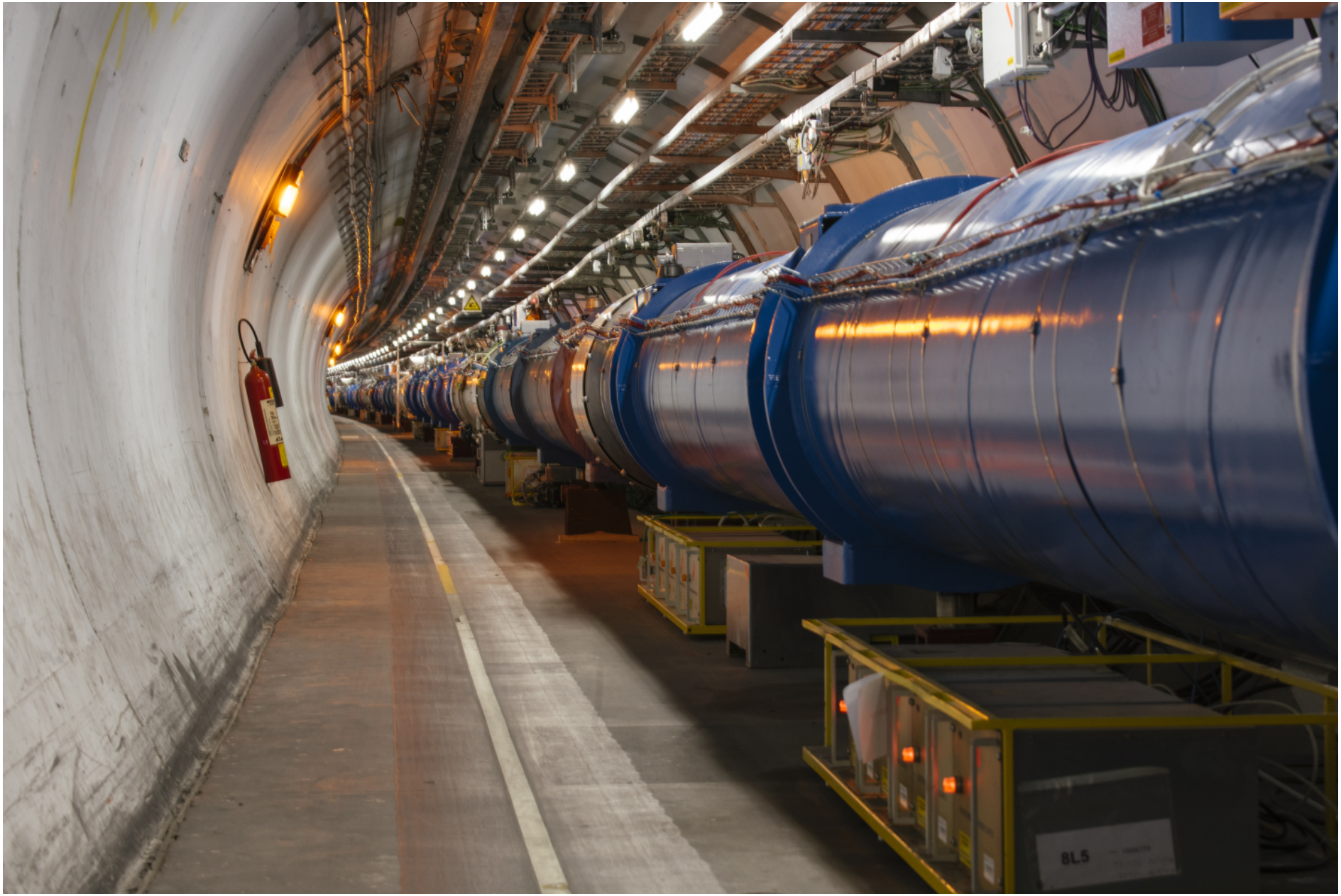
• LHC •

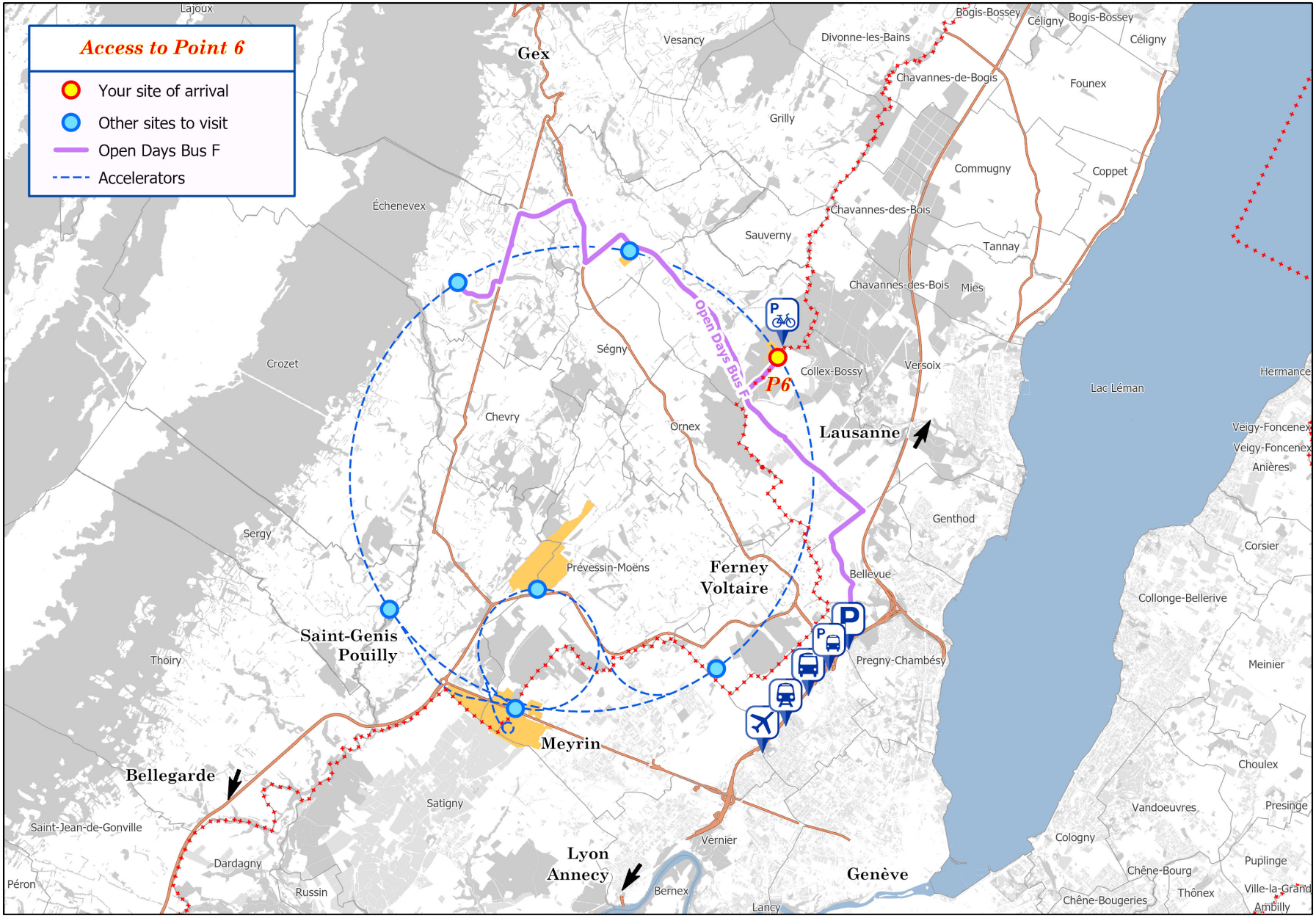

7x10¹² eV p-p Beam Energy
10³⁴ cm⁻² s⁻¹ Luminosity
2835 Nb of bunches
10¹¹ Nb p/bunch
7.5 m (25 ns)
~ μm
~ cm
Bunch collisions 40 million/s
~25 interactions / Bunch crossing overlapping in time and space
1000 x 10⁶ events/s
New Particle Production
(Higgs, SUSY, ...)
> 1000 particle signals in the detector at 40MHz rate
1 interesting collision in 10¹³

The CERN accelerator complex
Complexe des accélérateurs du CERN

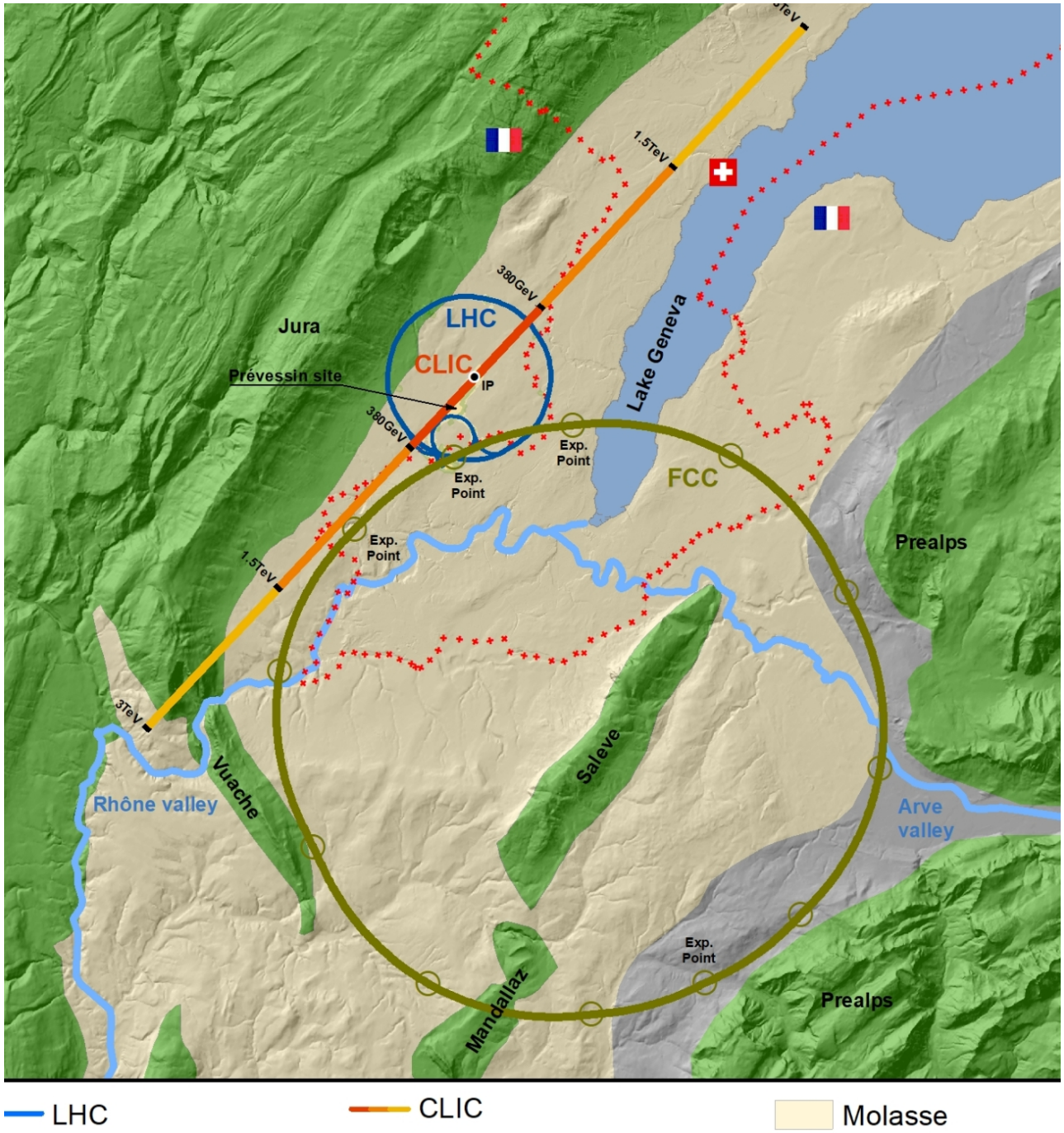


LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear

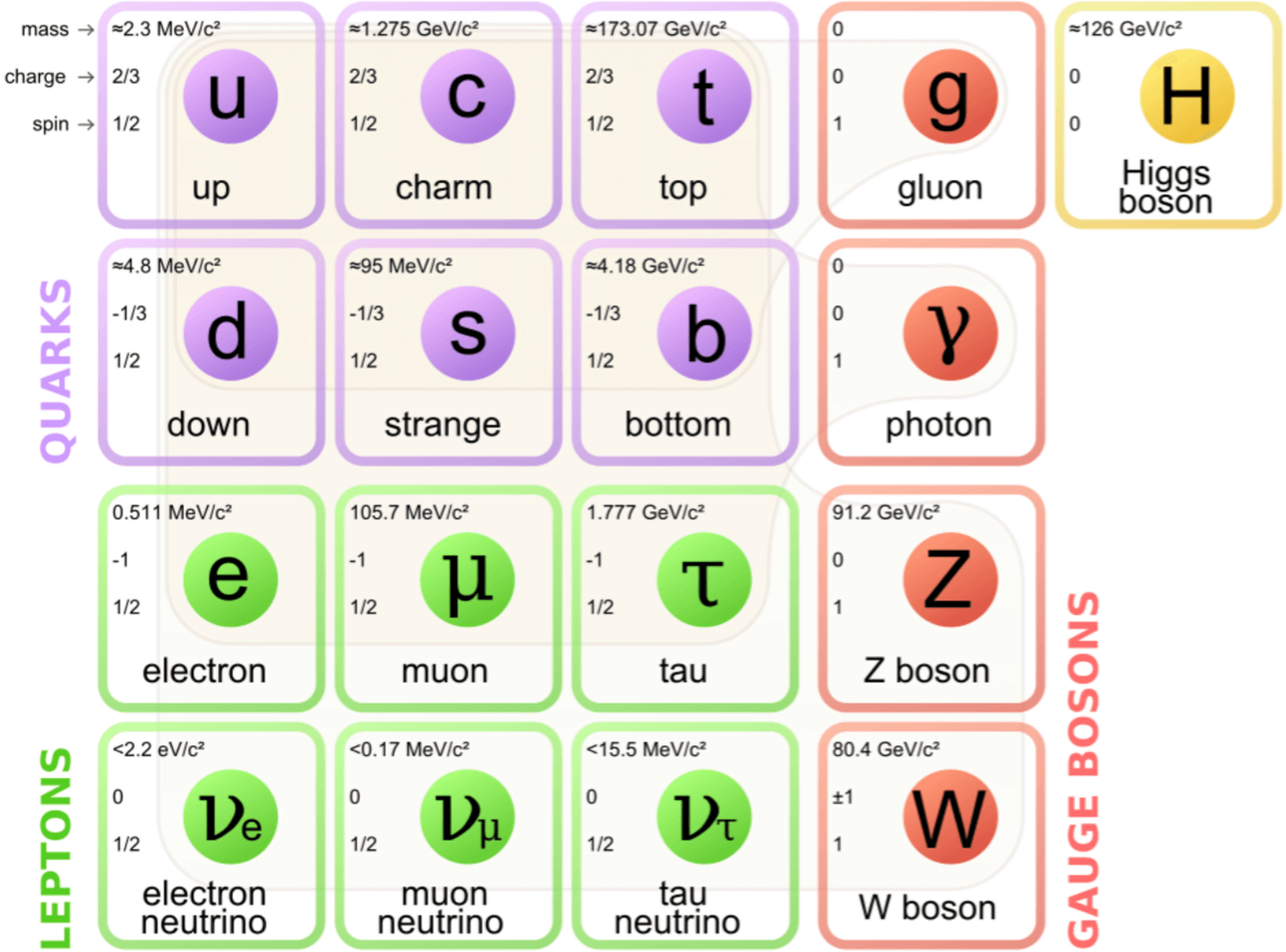

8L5


Access to Point 6
Your site of arrival
Other sites to visit
Open Days Bus F
Accelerators
Open Days Bus F
P6
Gex
Lausanne
Ferney Voltaire
Saint-Genis Pouilly
Meyrin
Bellegarde
Lyon Annecy
Genève
Lac Léman
Lajoux
Vesancy
Divonne-les-Bains
Bogis-Bossey
Céligny
Chavannes-de-Bogis
Founex
Grilly
Commugny
Coppet
Échenevex
Chavannes-des-Bois
Sauverny
Tannay
Mies
Crozet
Ségny
Collex-Bossy
Versoix
Hermance
Chevry
Ornex
Veigy-Foncenex
Anières
Genthod
Sergy
Prévessin-Moëns
Bellevue
Corsier
Collonge-Bellerive
Thoiry
Pregny-Chambésy
Meinier
Choulex
Satigny
Vandoeuvres
Presinge
Saint-Jean-de-Gonville
Vernier
Cologny
Dardagny
Puplinge
Péron
Russin
Bernex
Chêne-Bourg
Thônex
Ville-la-Grand
Chêne-Bougeries
Lancy
Ambilly

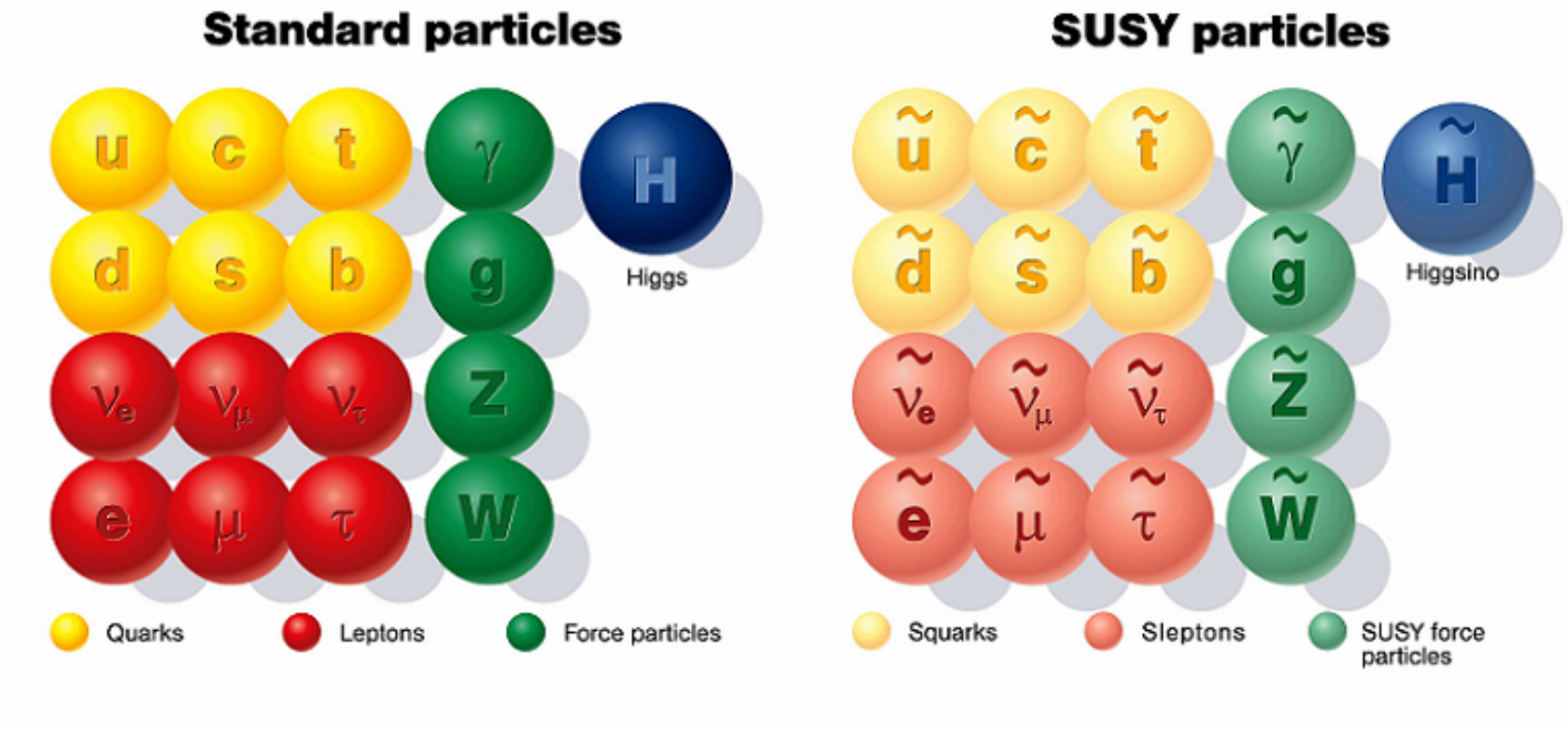
LHC vs FCC


Jura
LHC
CLIC
IP
Prévessin site
380GeV
1.5TeV
3TeV
Lake Geneva
Exp. Point
FCC
Prealps
Saleve
Vuache
Rhône valley
Arve valley
Mandallaz
LHC
CLIC
Molasse

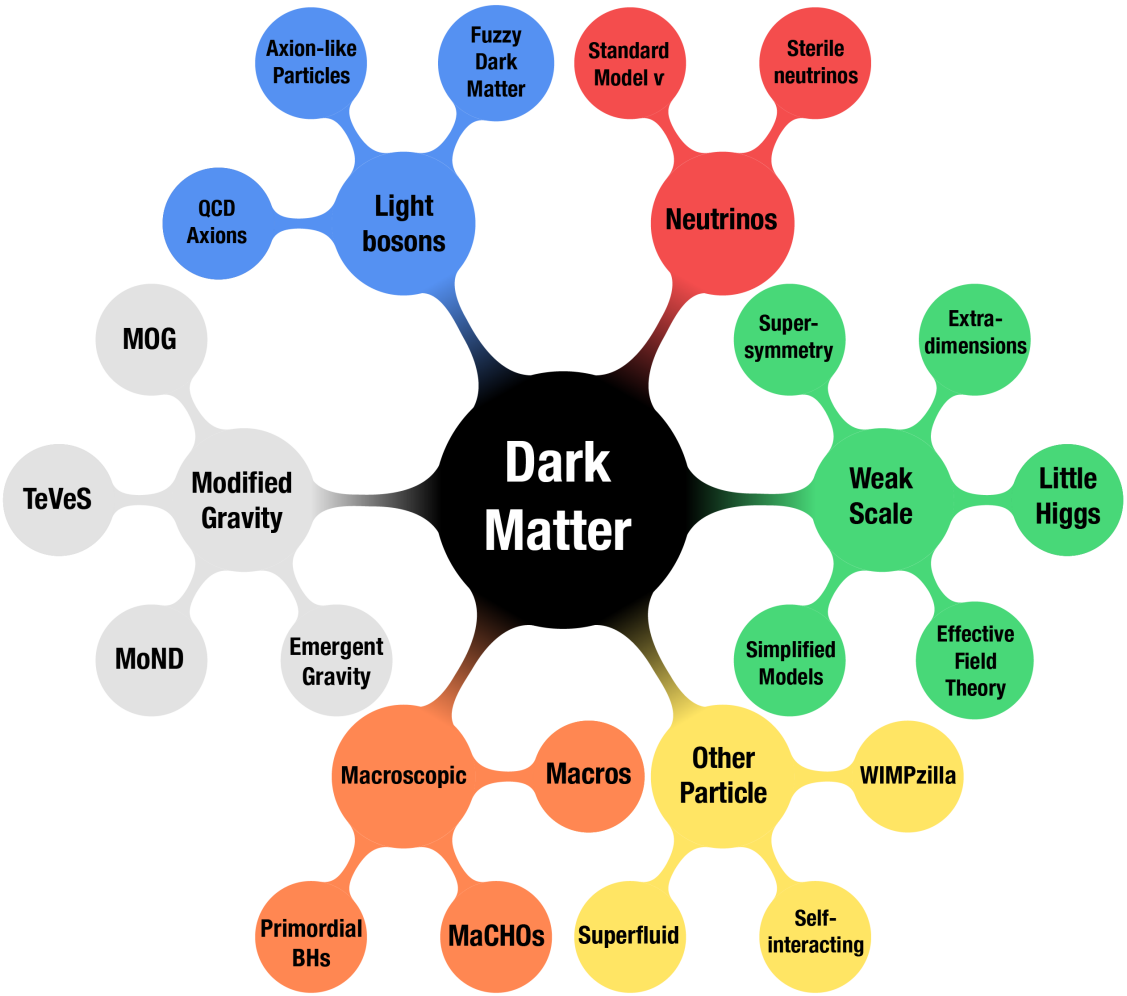
Standard Model

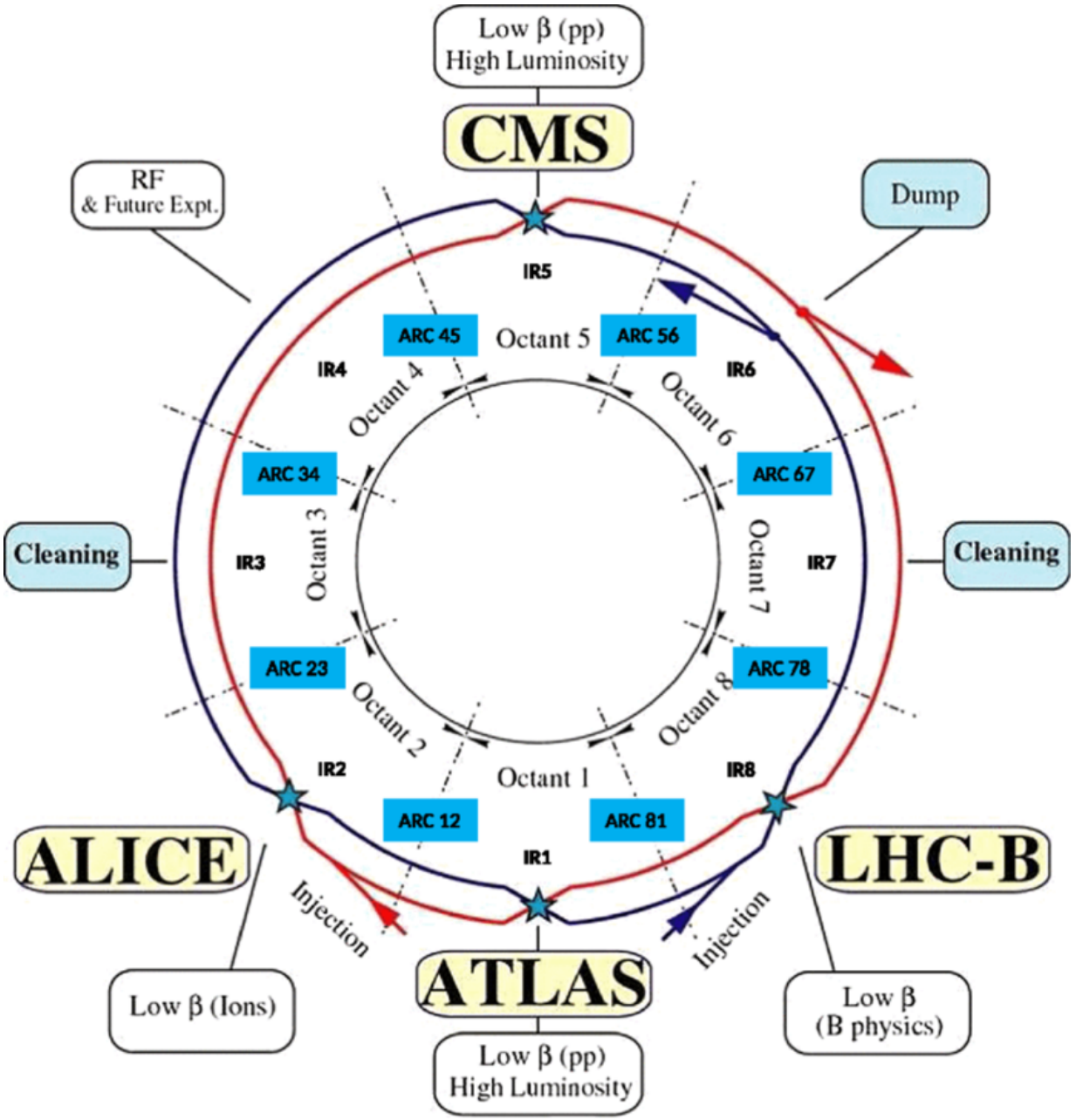


Beyond Standard Model

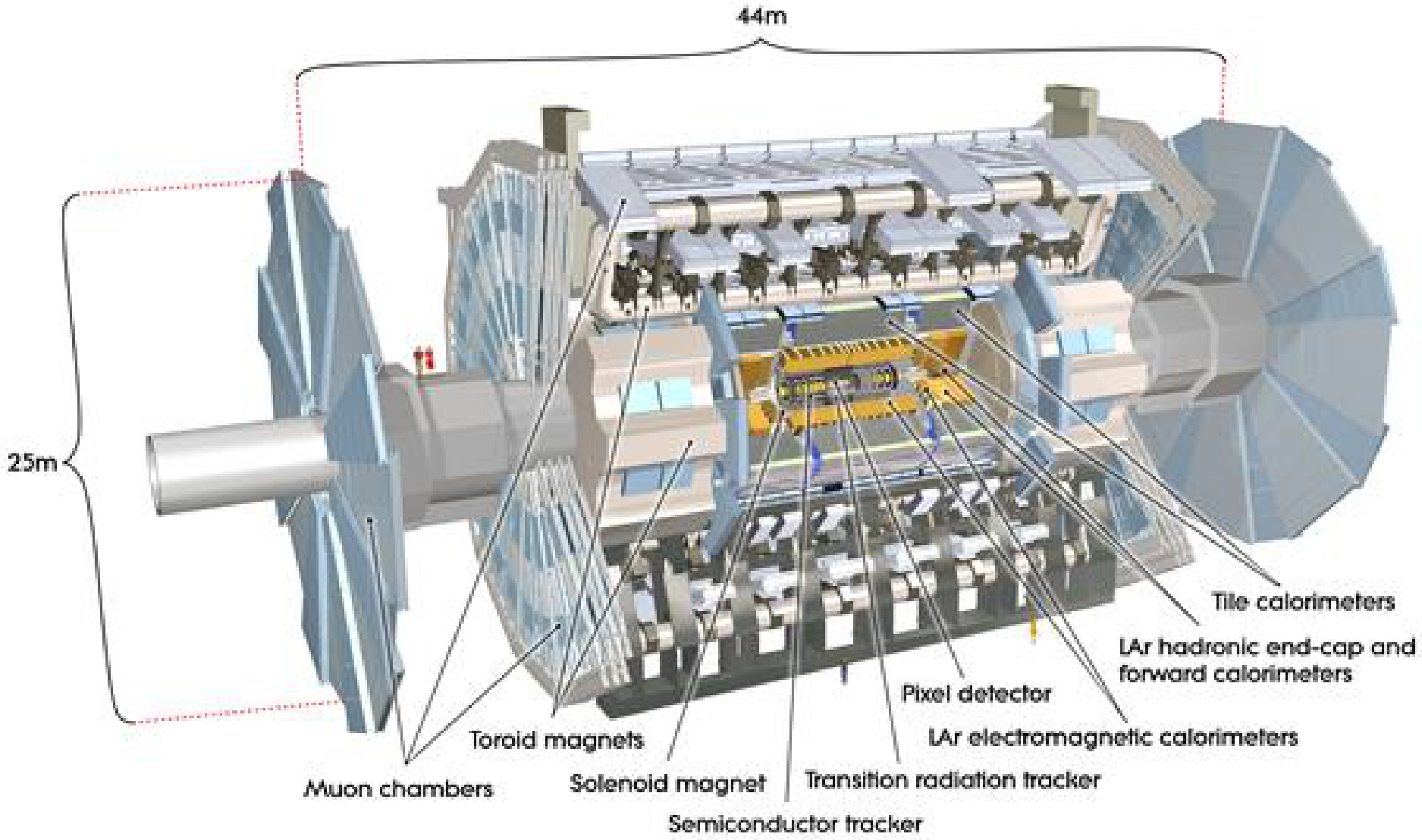


Beyond Standard Model

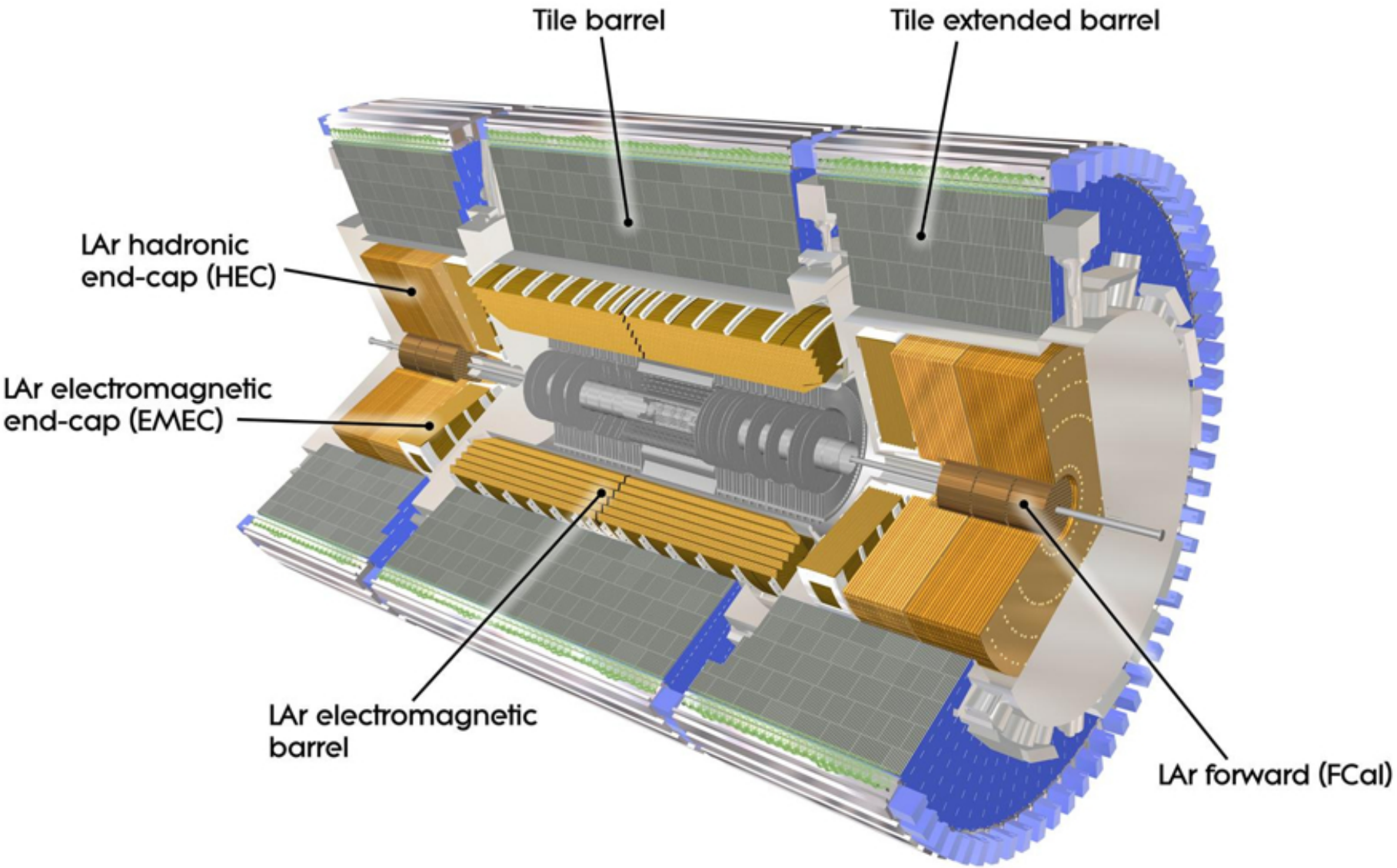



Low β (pp)
High Luminosity
CMS
RF
& Future Expt.
Dump
IR5
ARC 45
Octant 5
ARC 56
IR4
IR6
Octant 4
Octant 6
ARC 34
ARC 67
Cleaning
IR3
Octant 3
Octant 7
IR7
Cleaning
ARC 23
ARC 78
Octant 2
Octant 8
IR2
Octant 1
IR8
ARC 12
ARC 81
ALICE
IR1
LHC-B
Injection
Injection
Low β (Ions)
ATLAS
Low β
(B physics)
Low β (pp)
High Luminosity

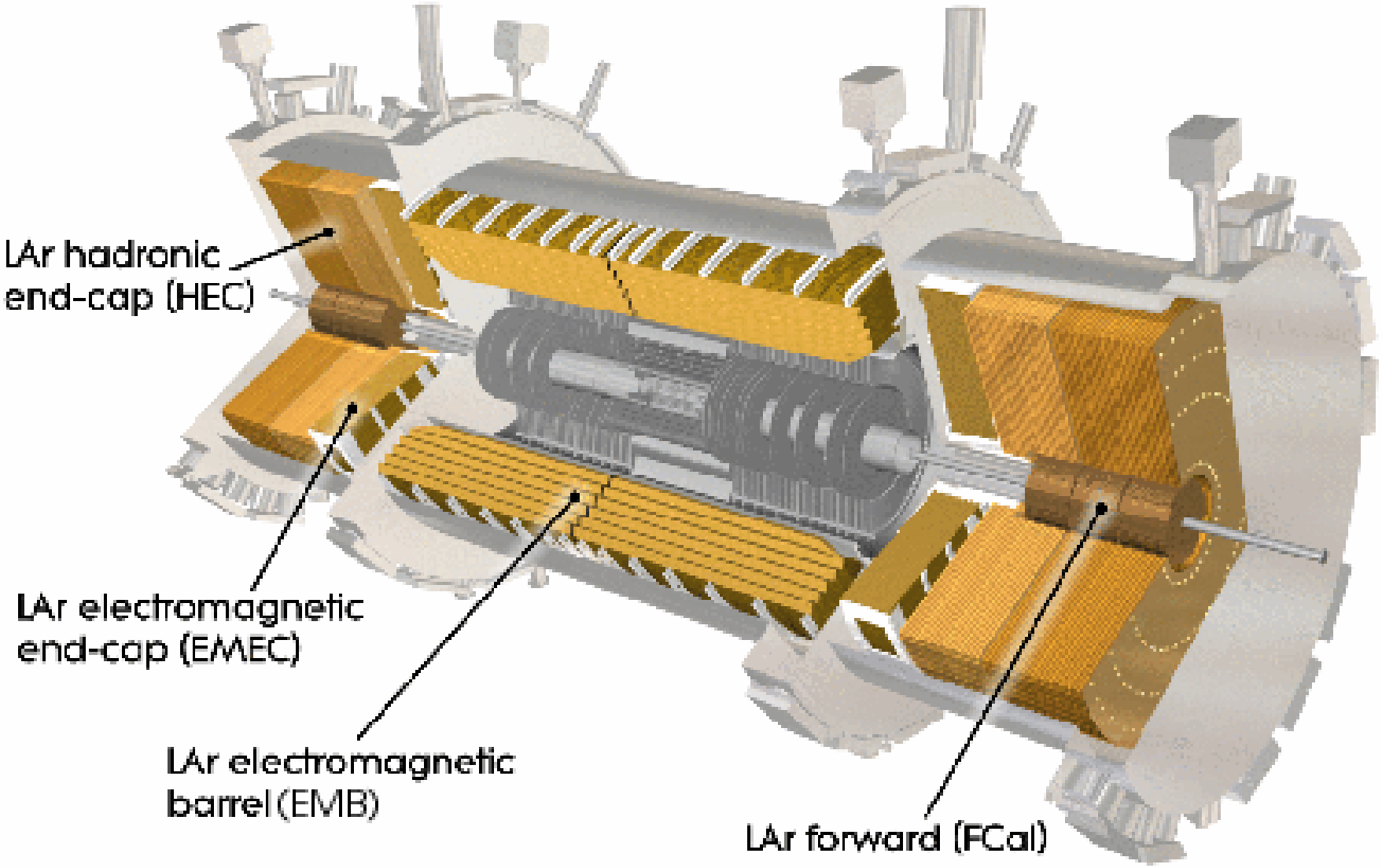
ATLAS detector



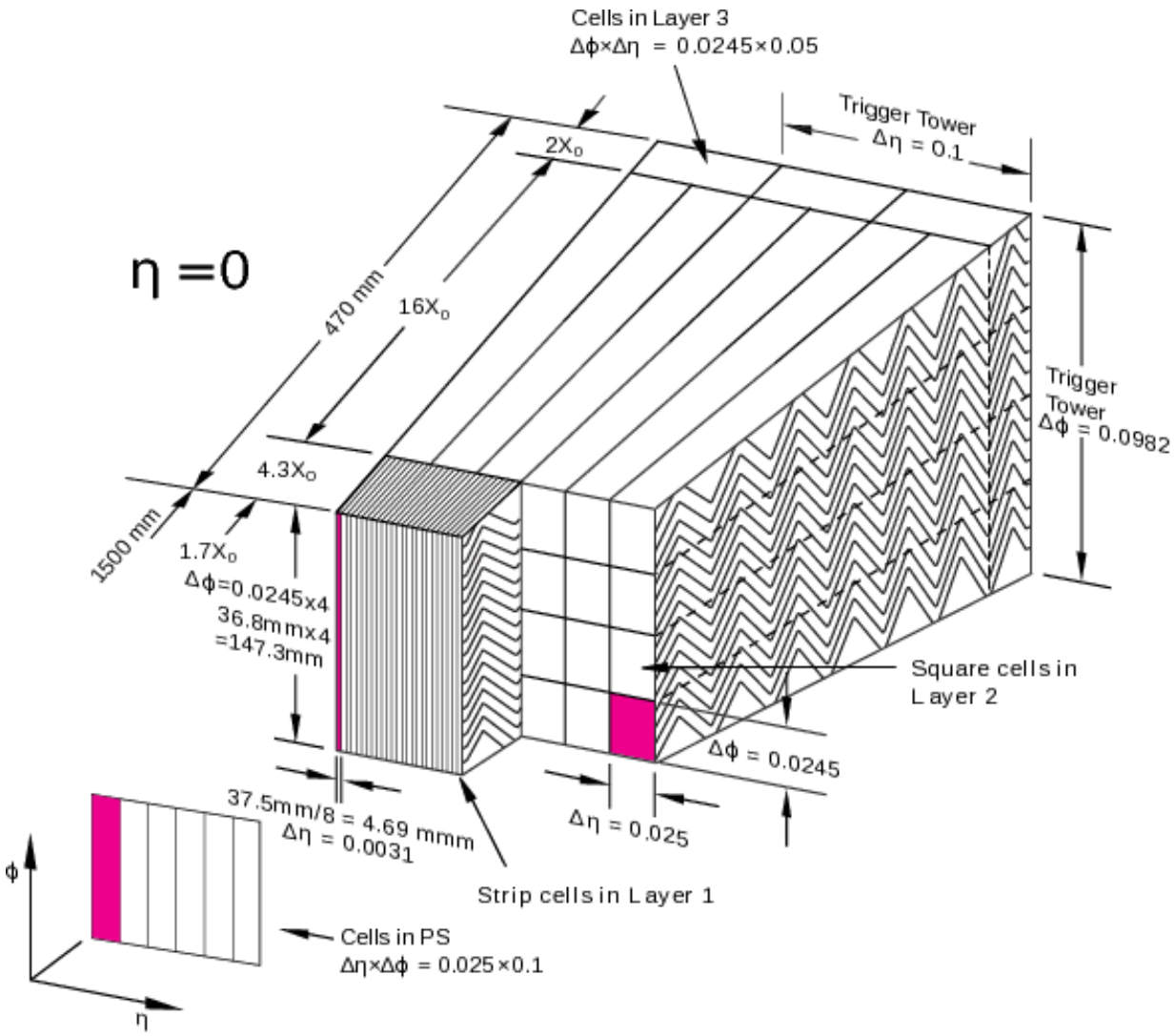
ATLAS Calorimeters

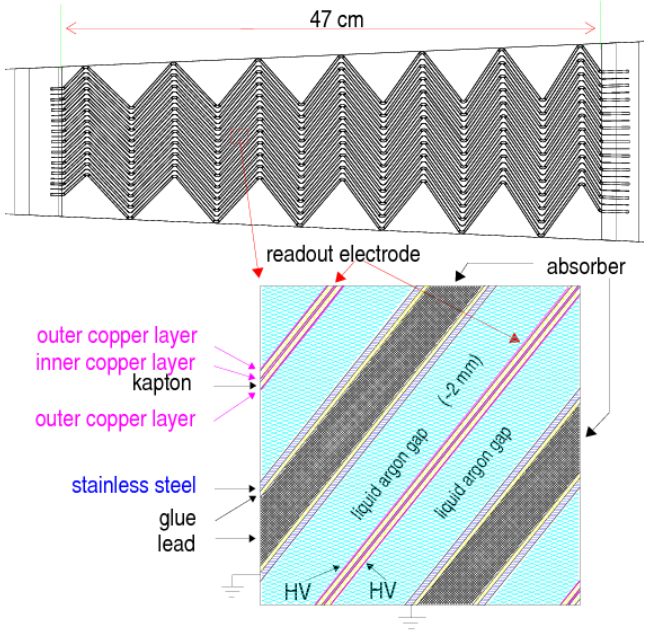


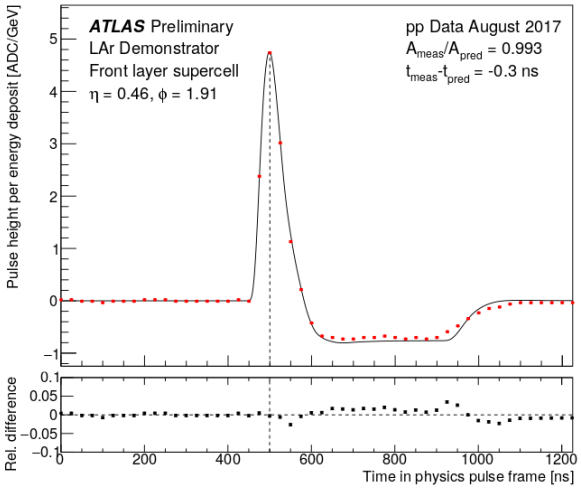
LAr Calorimeter



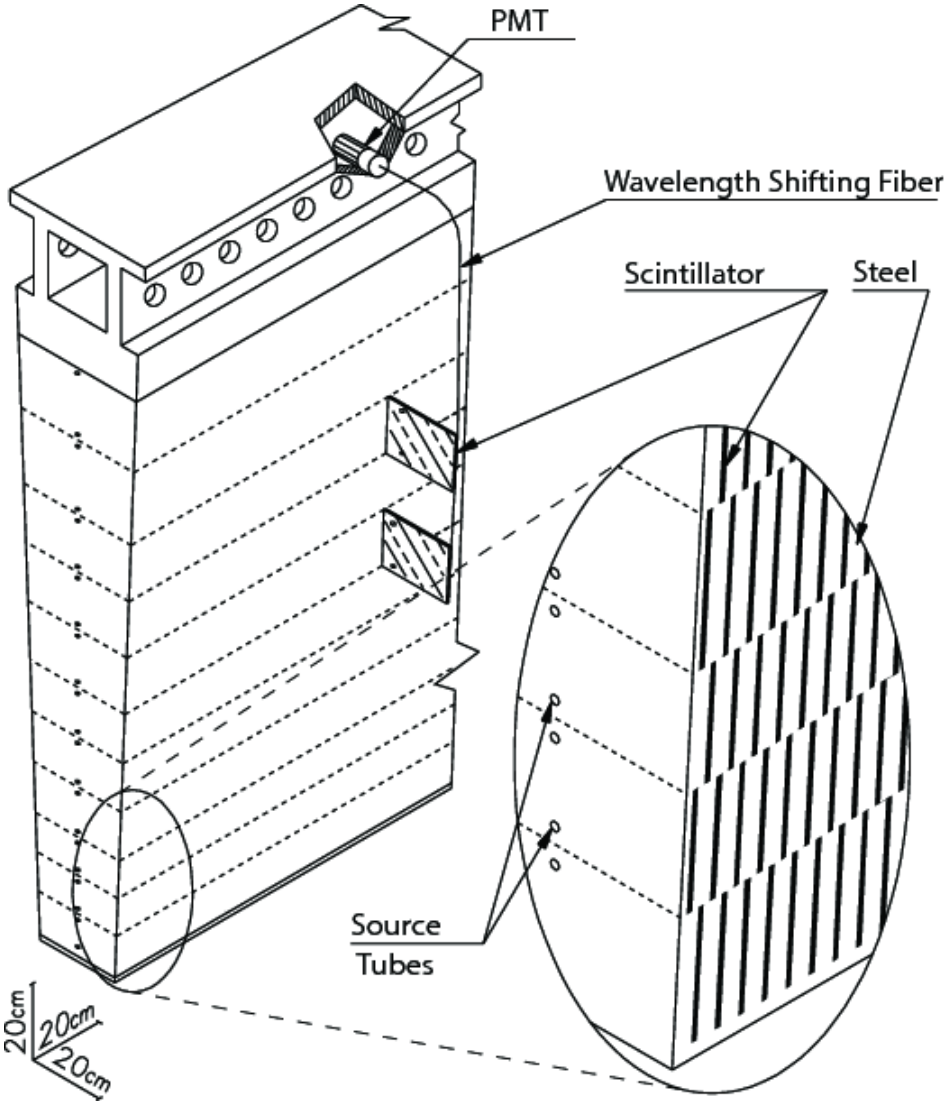
LAr Calorimeter

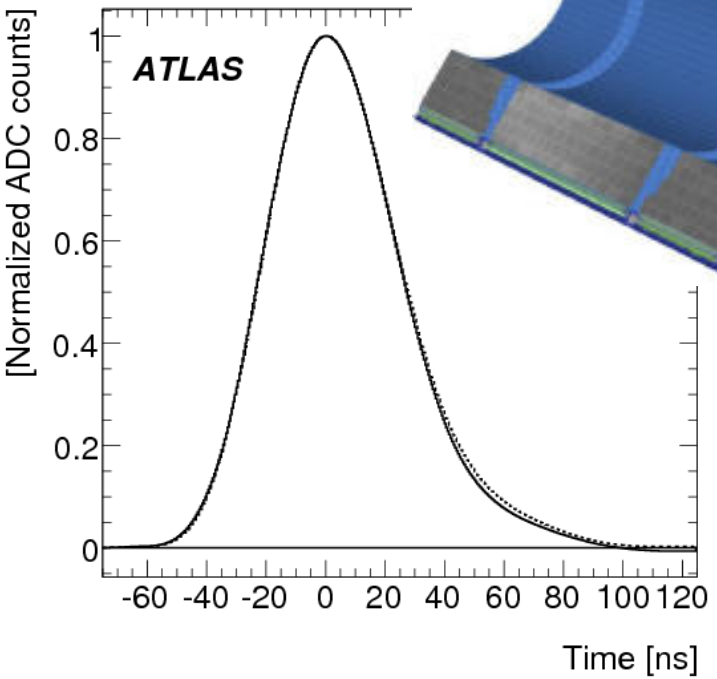


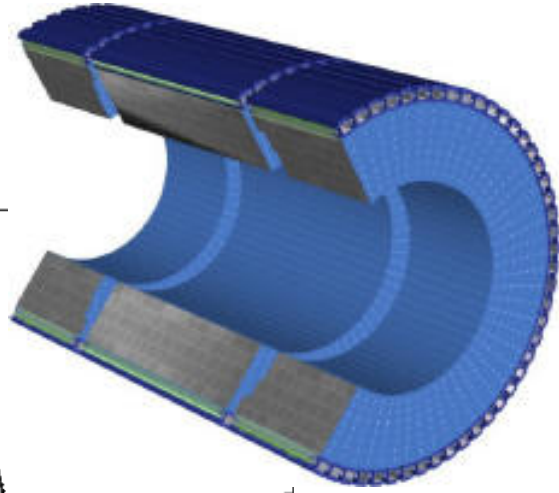


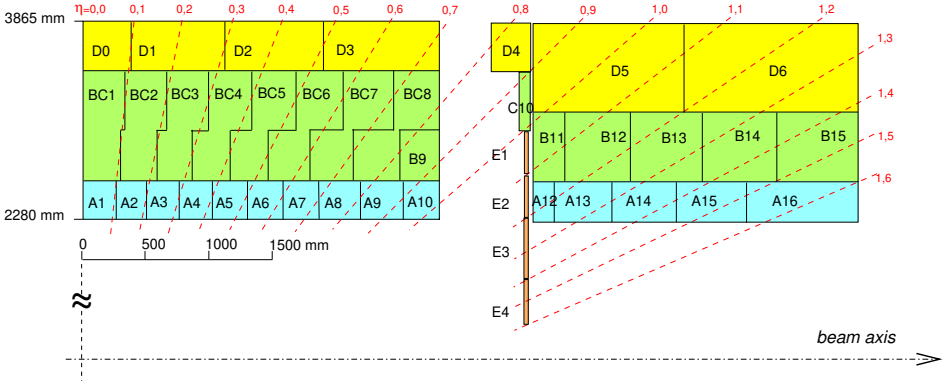


Tile Calorimeter





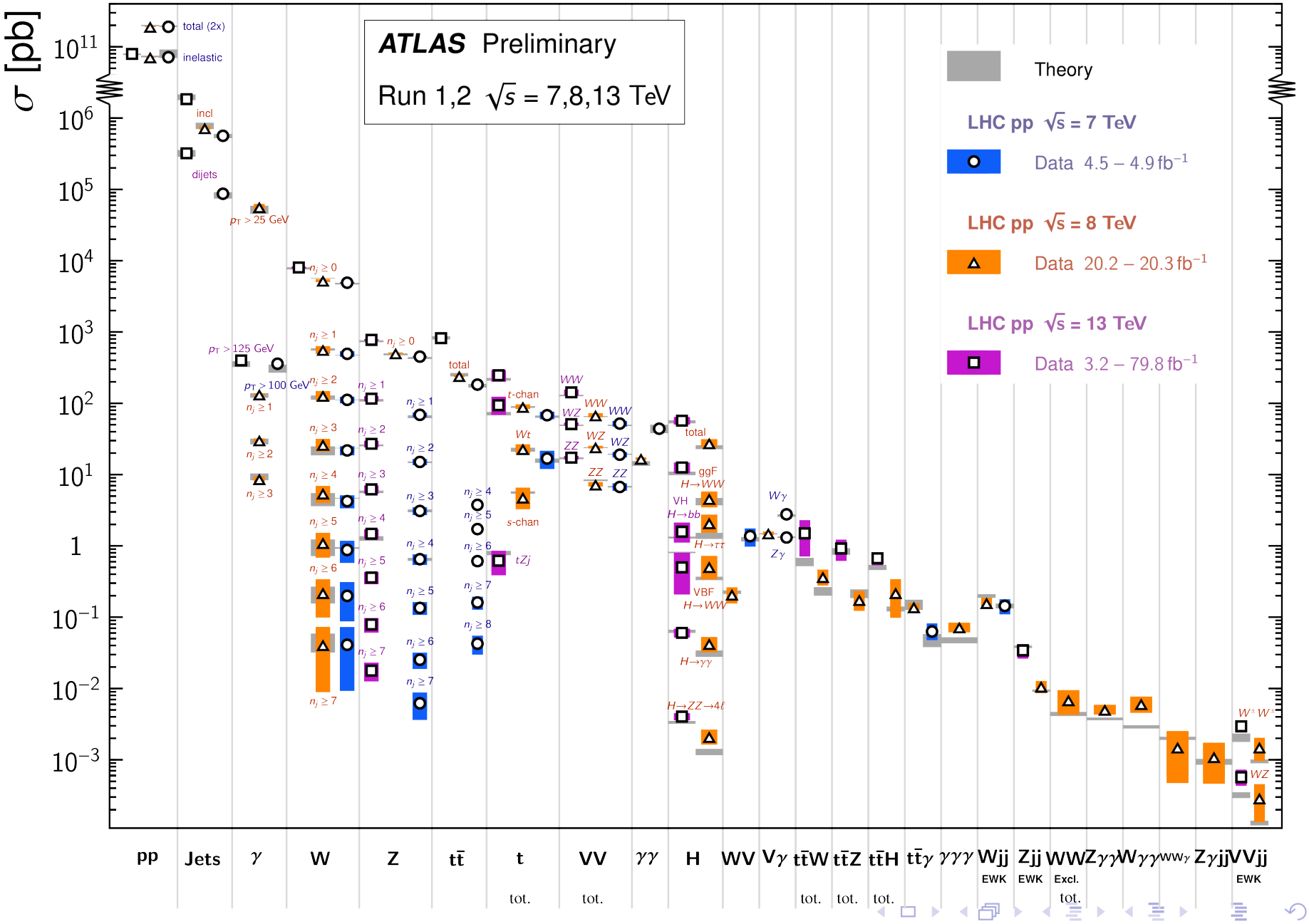




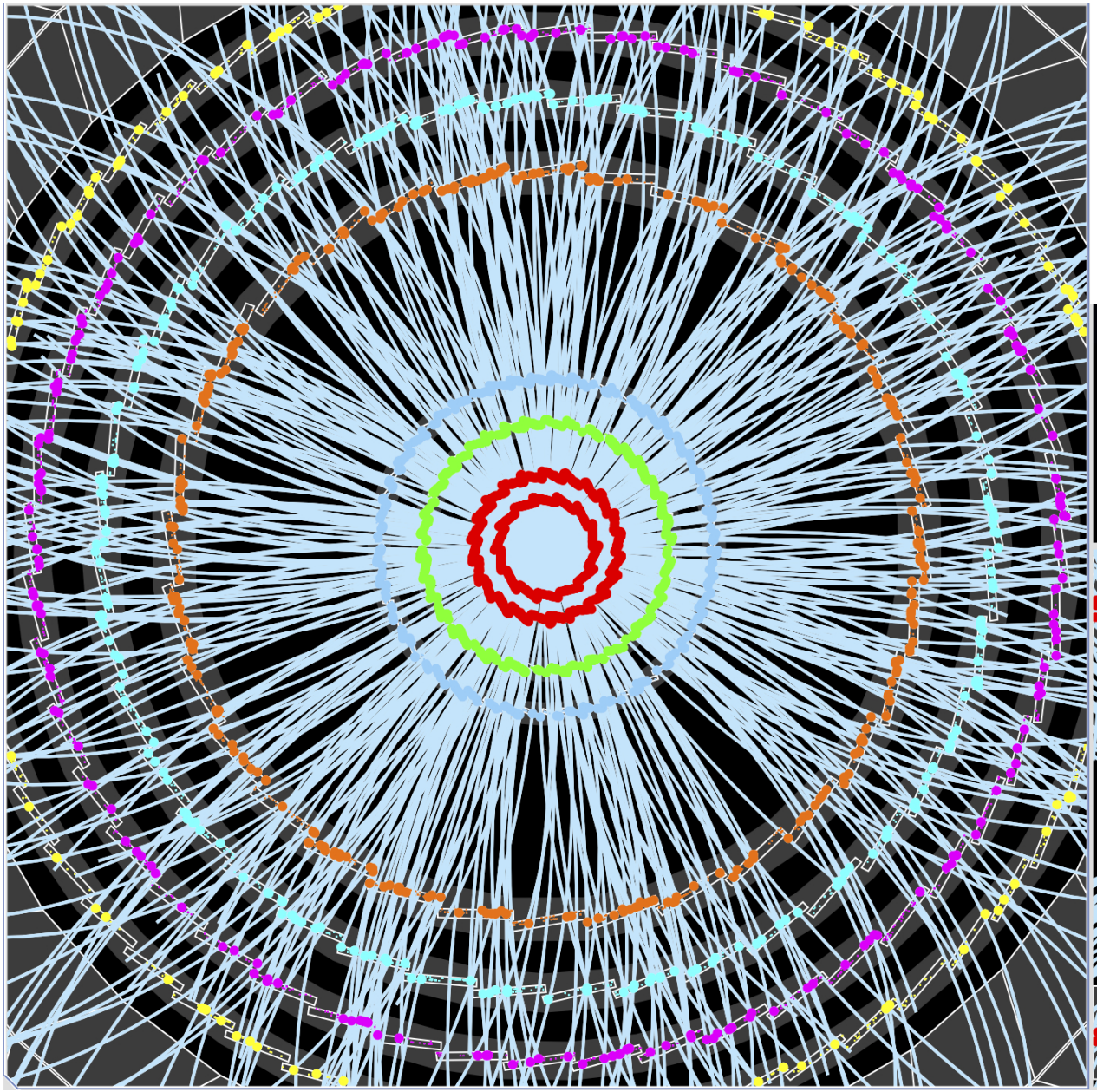
Tile Calorimeter

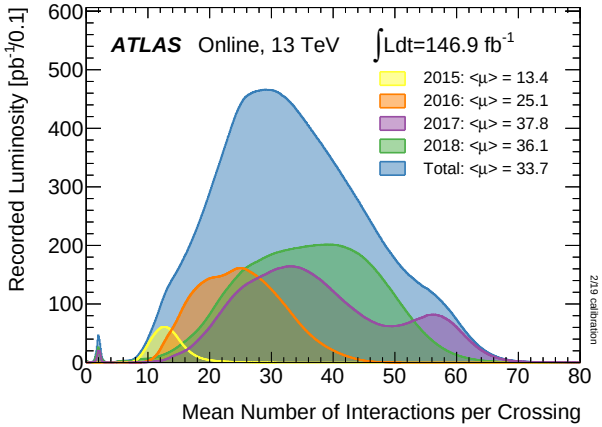
Standard Model Production Cross Section Measurements

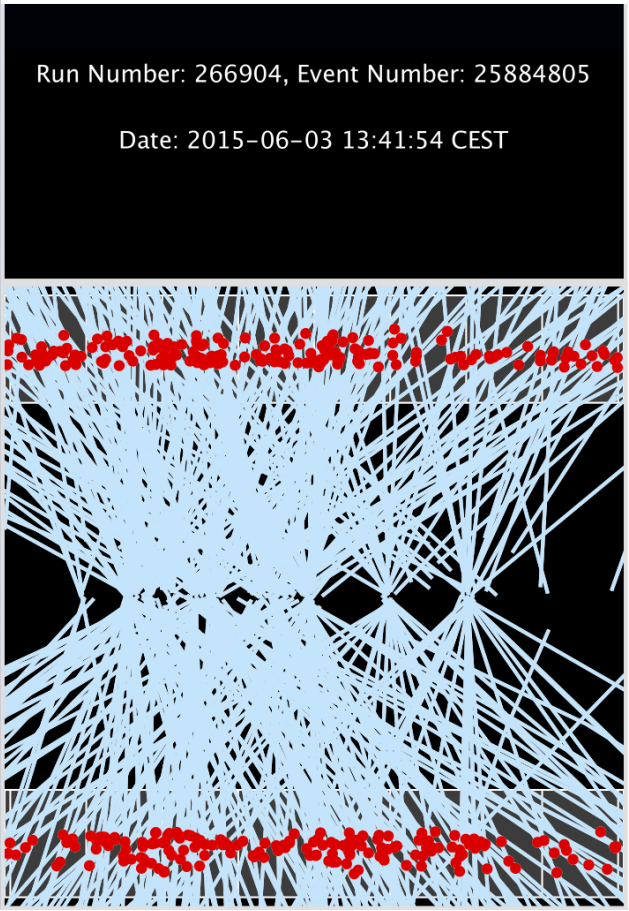
Status: July 2018



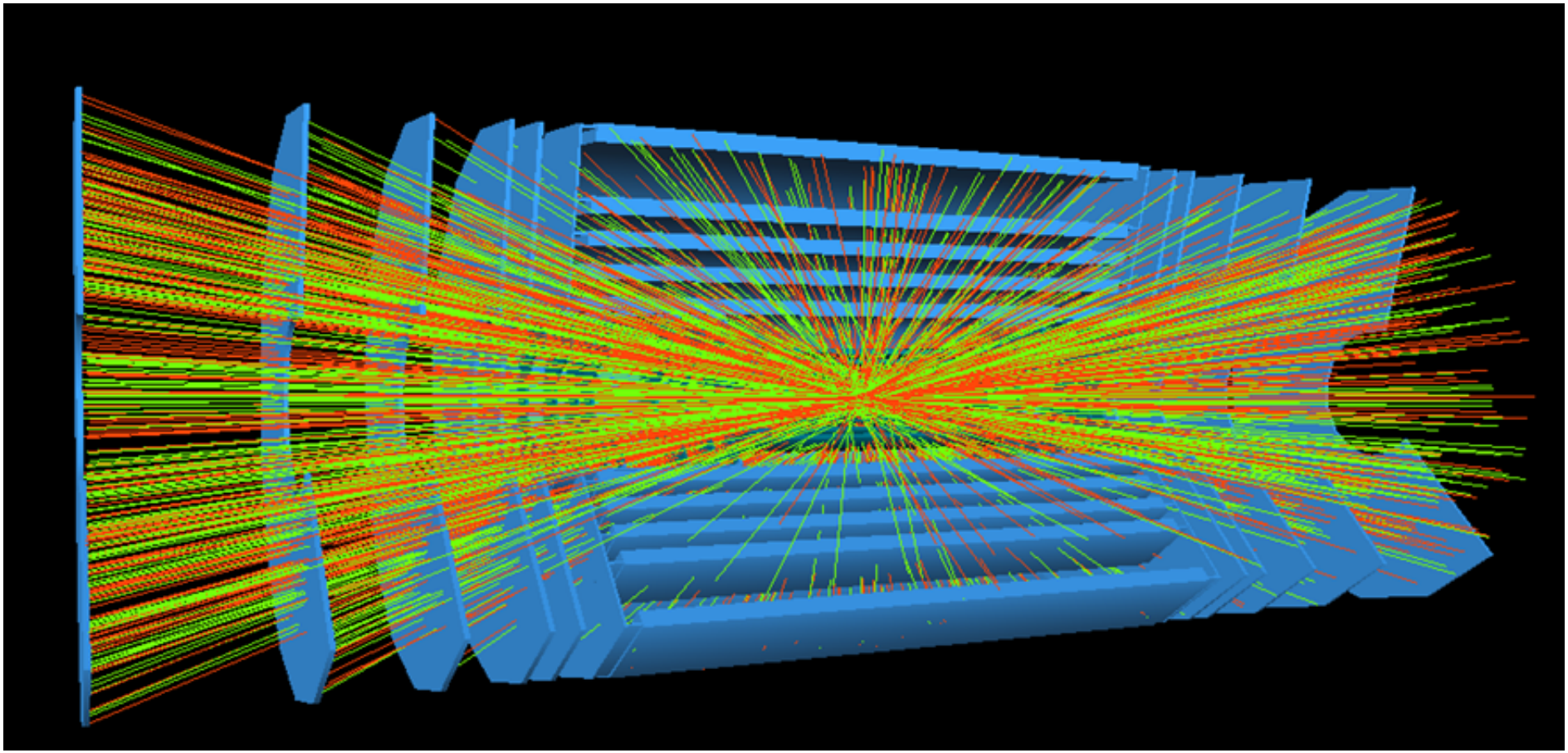
Pileup $N_{\mathrm{PV}} = 17$

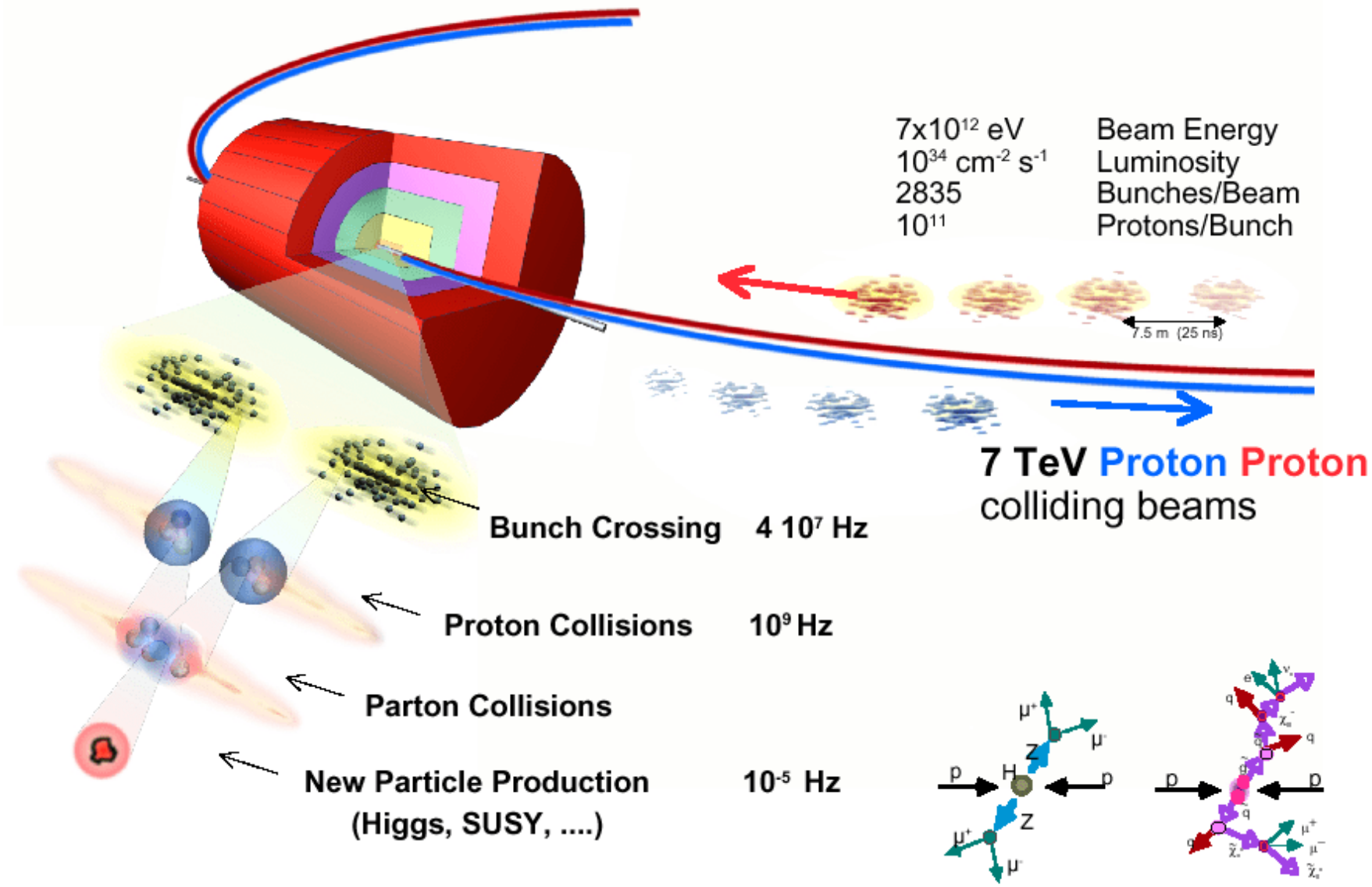






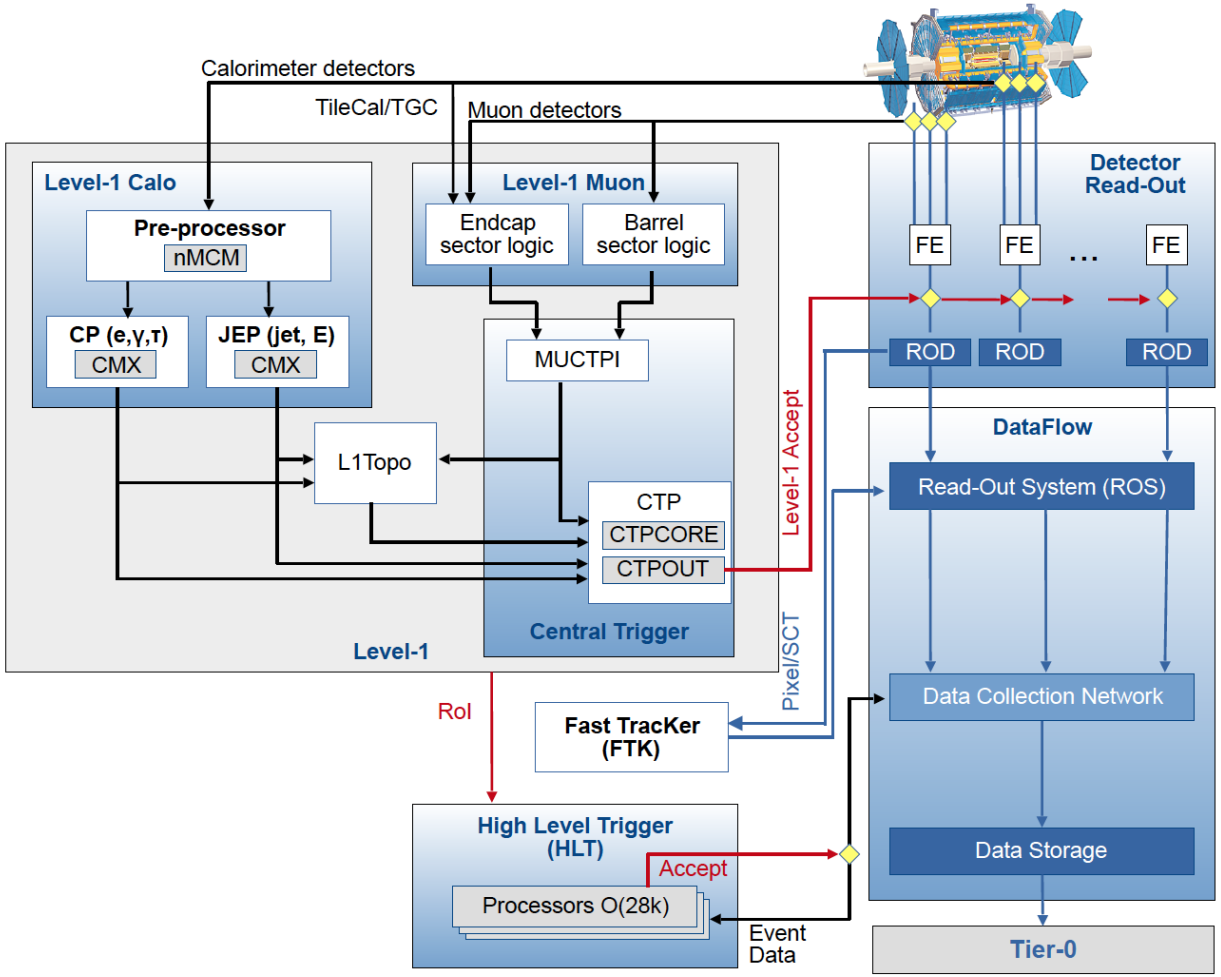
Pileup $N_{\mathrm{PV}} = 230$



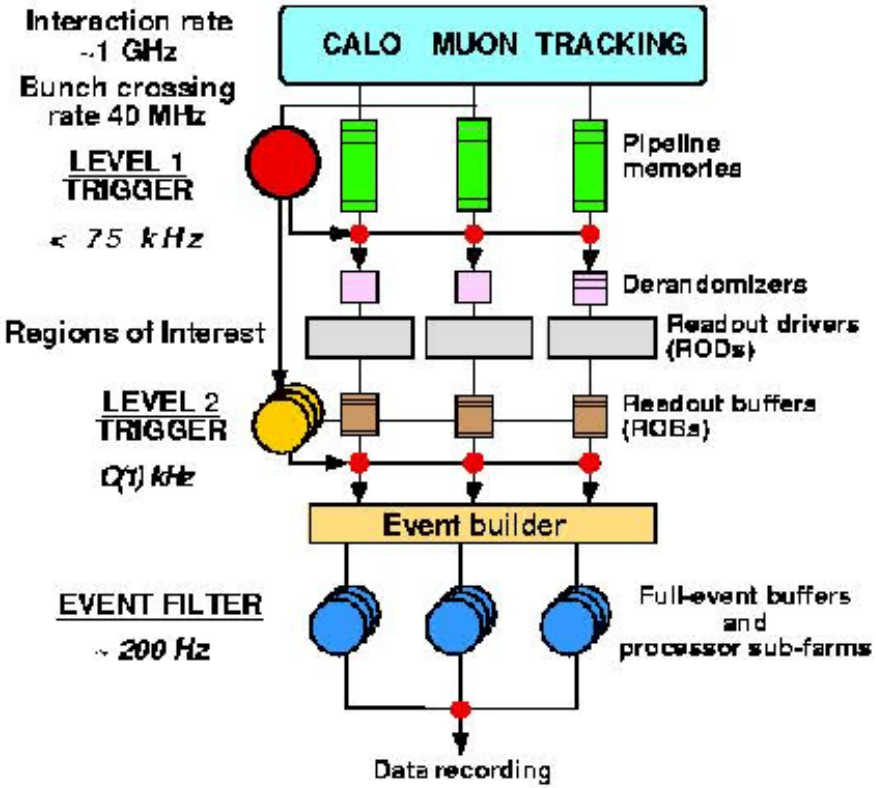

7x10^12 eV Beam Energy
10^34 cm^-2 s^-1 Luminosity
2835 Bunches/Beam
10^11 Protons/Bunch
7.5 m (25 ns)
7 TeV Proton Proton
colliding beams
Bunch Crossing 4 10^7 Hz
Proton Collisions 10^9 Hz
Parton Collisions
New Particle Production
(Higgs, SUSY, ...)
10^-5 Hz
Selection of 1 event in 10,000,000,000,000

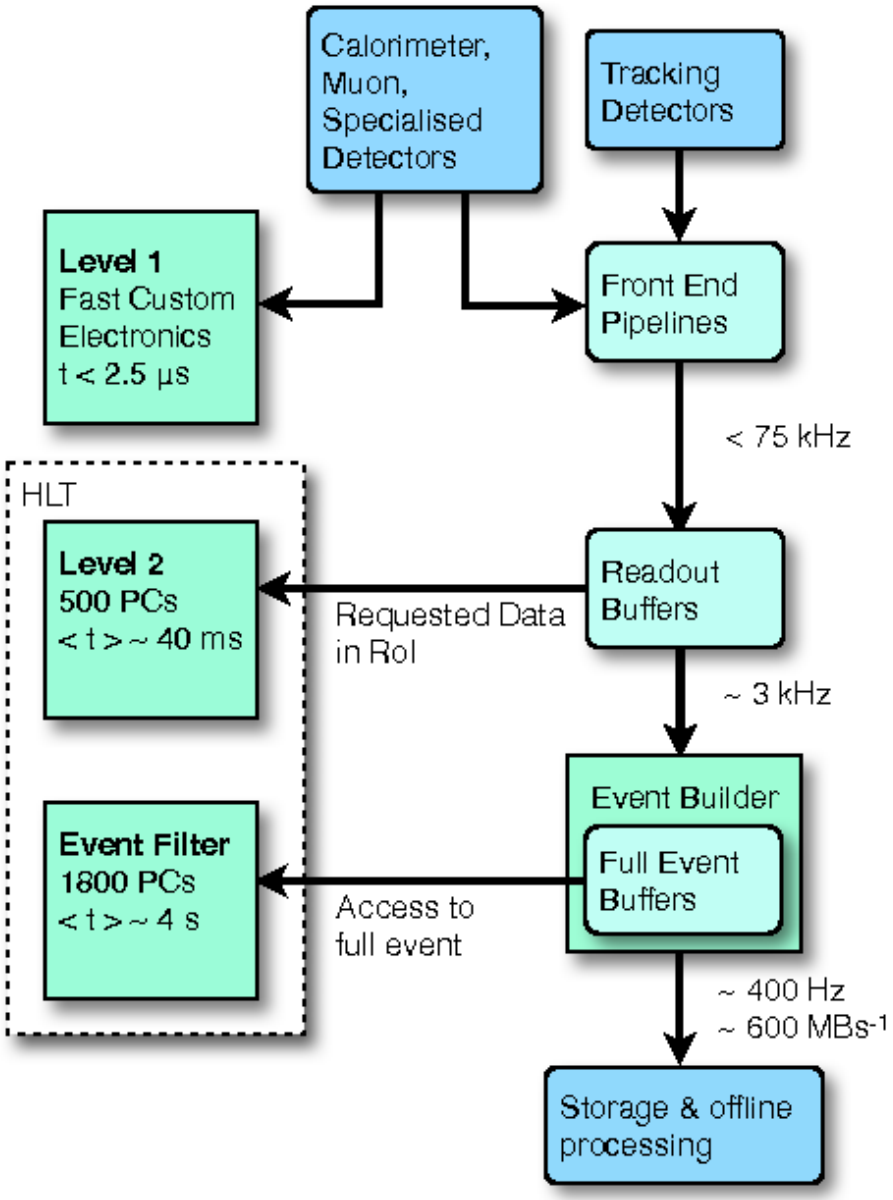
Data acquisition system

- L1Calo : any EM/HAD objects
- L1Muon : thresholds and multiplicities
- L1Topo : Combines information from L1Calo/L1Muon
- CTP : final decision



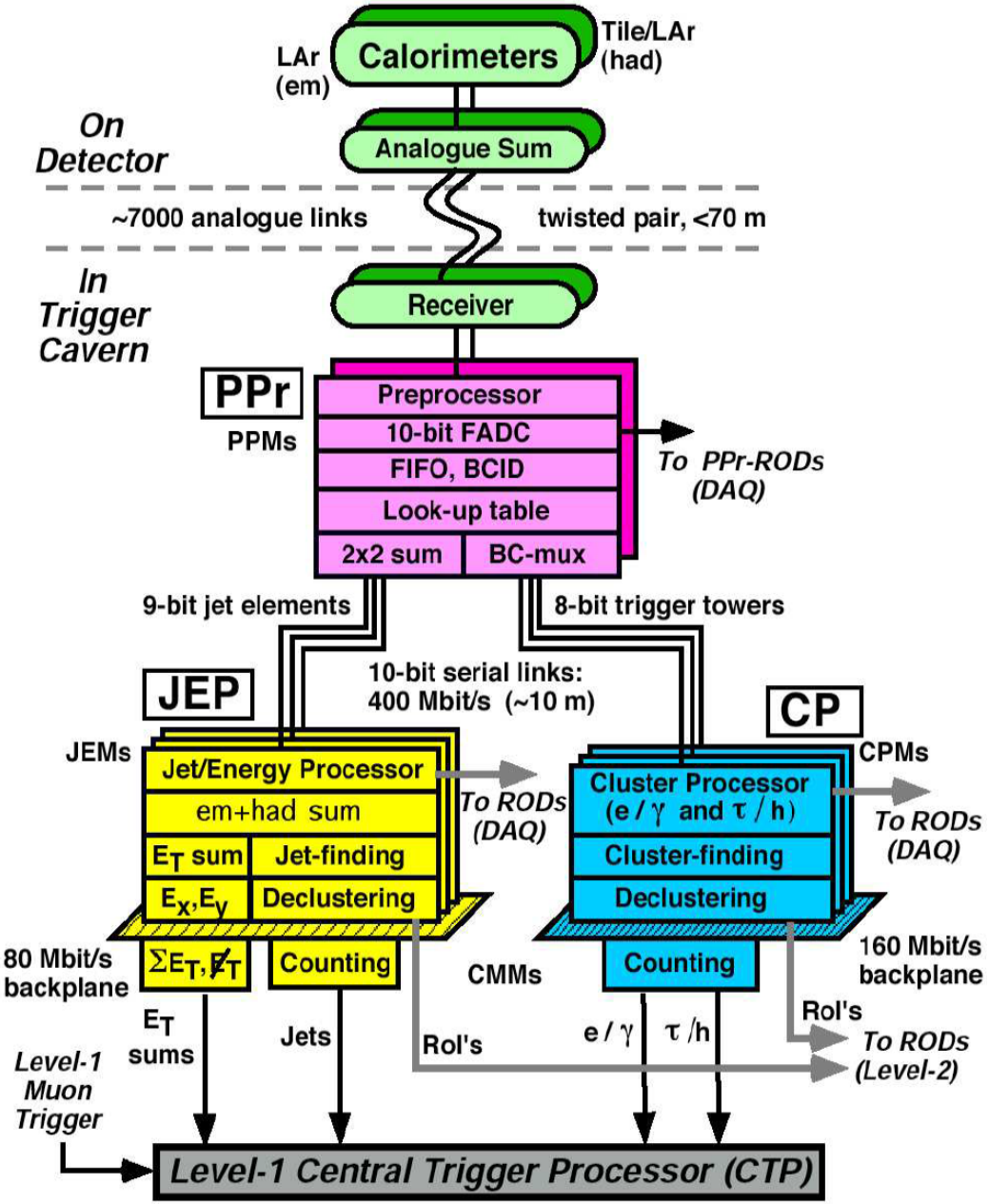
Trigger system





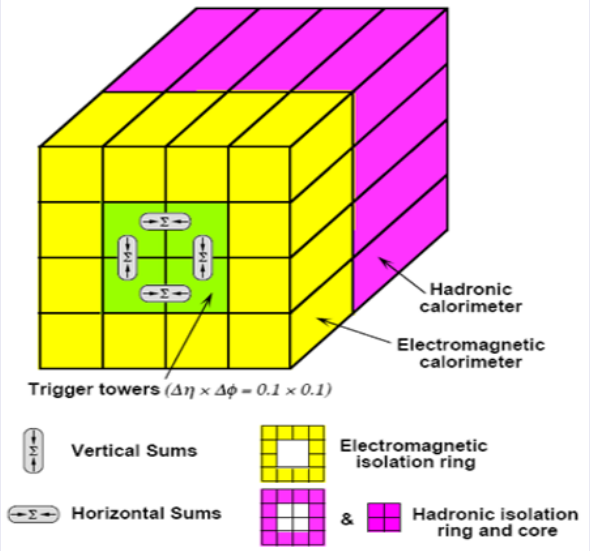
L1Calo trigger system

- L1Calo : Fixed latency 2μs, HW based on custom electronics
- $\sim$300 VME modules of 10 different types housed in 17 crates
- Off detector
  - PPr : digitisation and BCID
  - CP : electrons/photons/single hadrons
  - JEP: Jet findings and energy sums



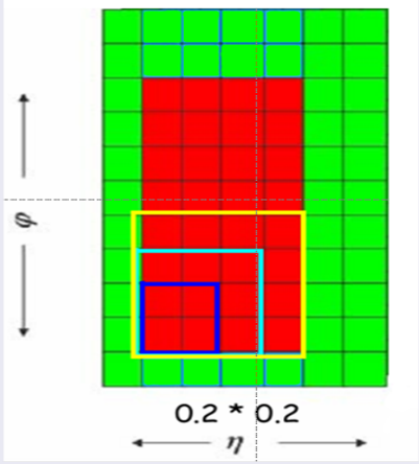
CP vs JEP

Cluster Processor



- e/γ or τ/single hadron
- Granularity 0.1 x 0.1

Jet/Energy-sum Processor



- Jets, Missing & total E_{T}
- Granularity 0.2 x 0.2
- Summation of EM + Had

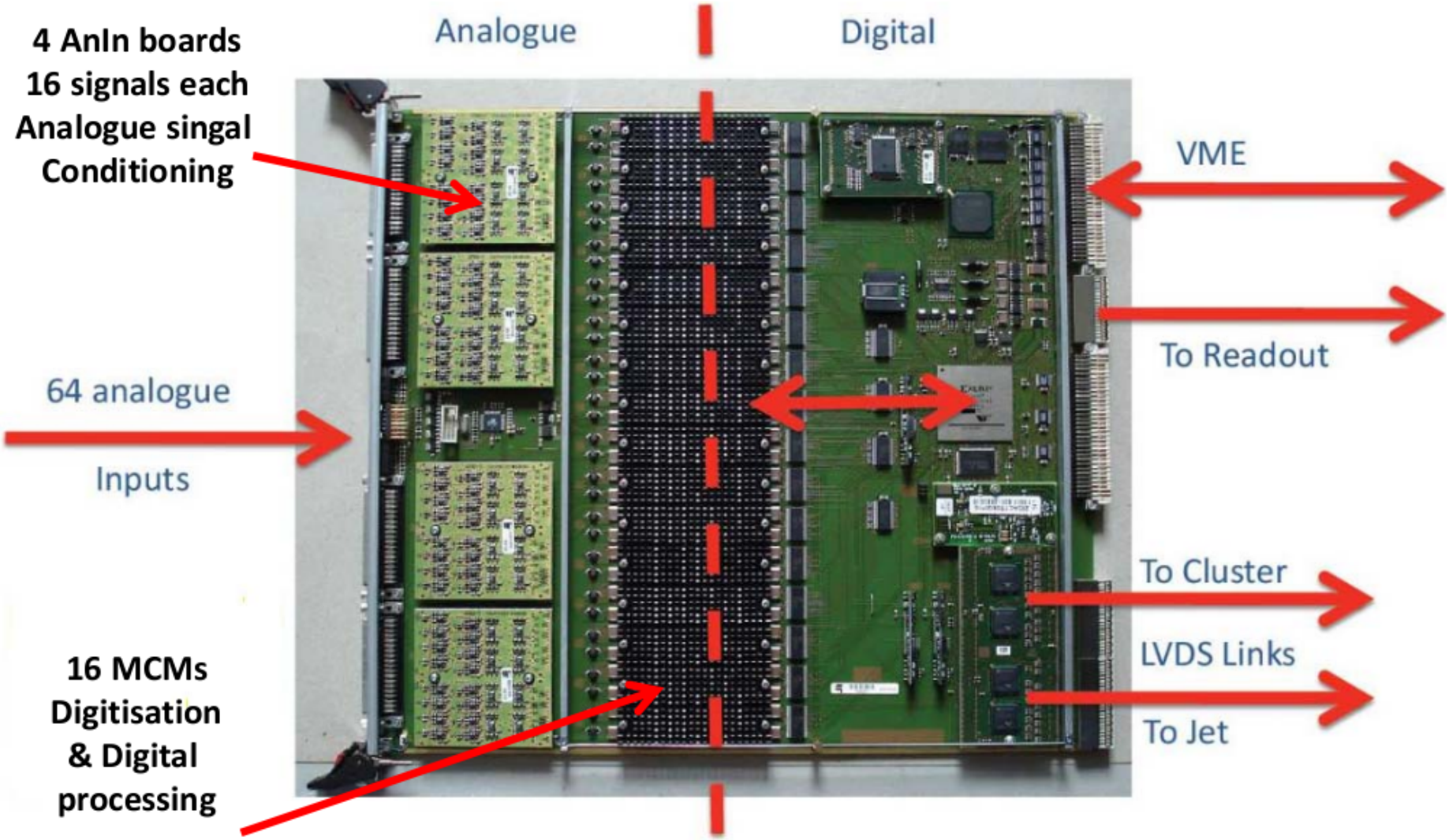
L1Calo

Receivers& PPr

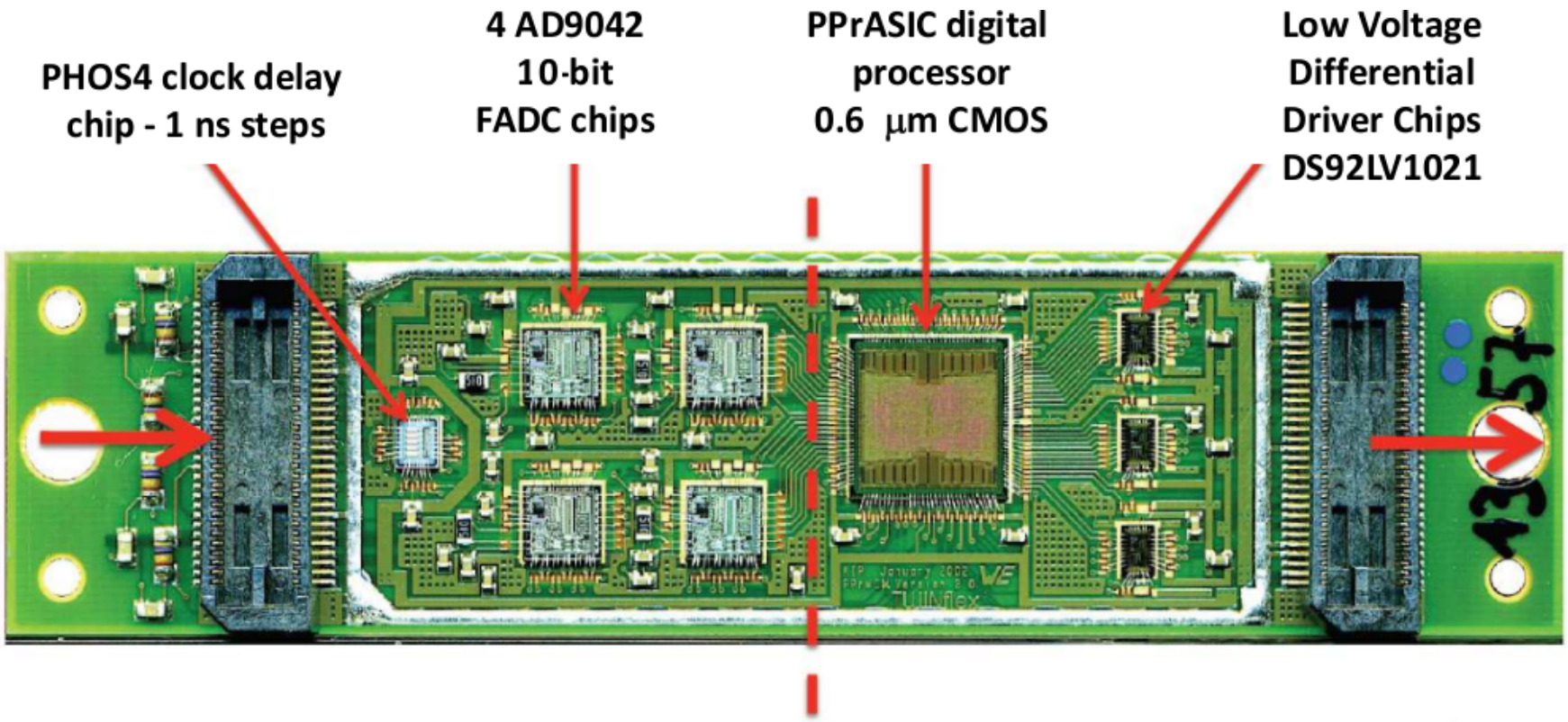
Processors

Readout drives

Preprocessor



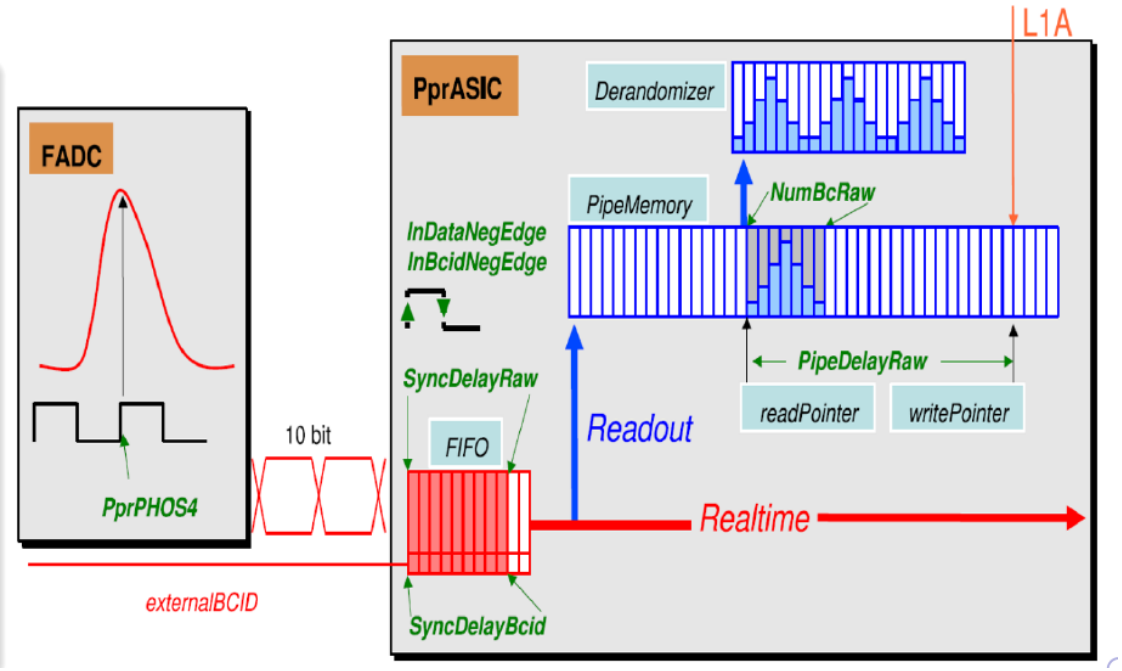
MCM



- Each FADC chip represents a L1Calo trigger tower

Timing calibration

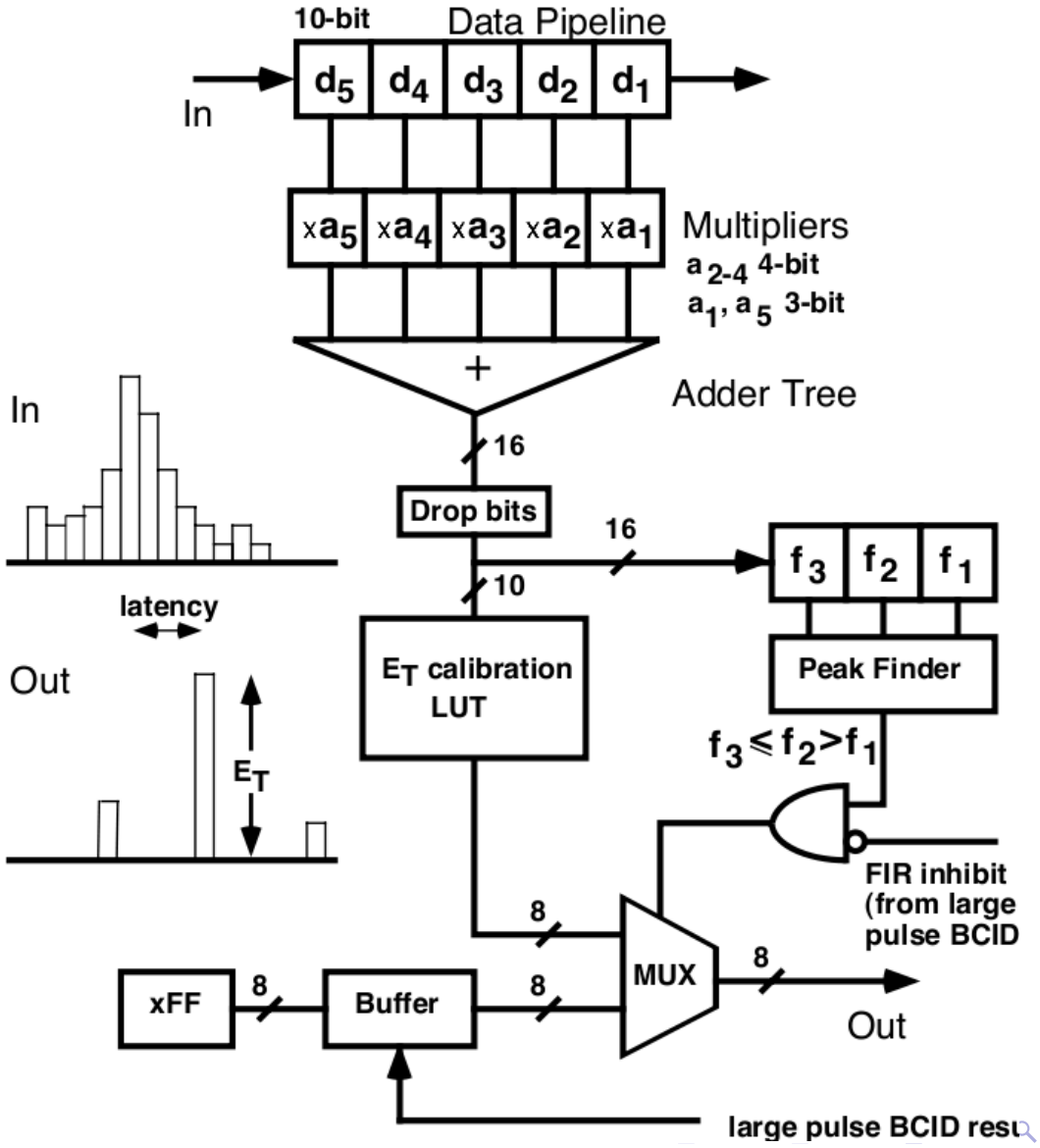
- The pp collisions take place at the interaction point
- Time of flight to calorimeters is η-dependent
- Large variation in cable lengths from calorimeters to L1Calo



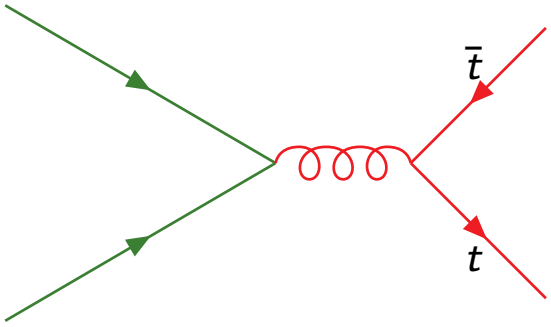
- Need to buffer early signals and process everything in time
- If we get the timing wrong we record the wrong event
- Timing calibration
  - For high physics acceptance everything must be in time
  - Coarse timing set in FIFO : Steps of 25 ns
  - Fine timing set by Phos4 : Steps of 1 ns

Finite Impulse response (FIR) filters

- Calorimeter signal pulses span many bunch-crossings
- The FIR filter cofficients improve:
  - BCID
  - Noise rejection
  - Energy measurement

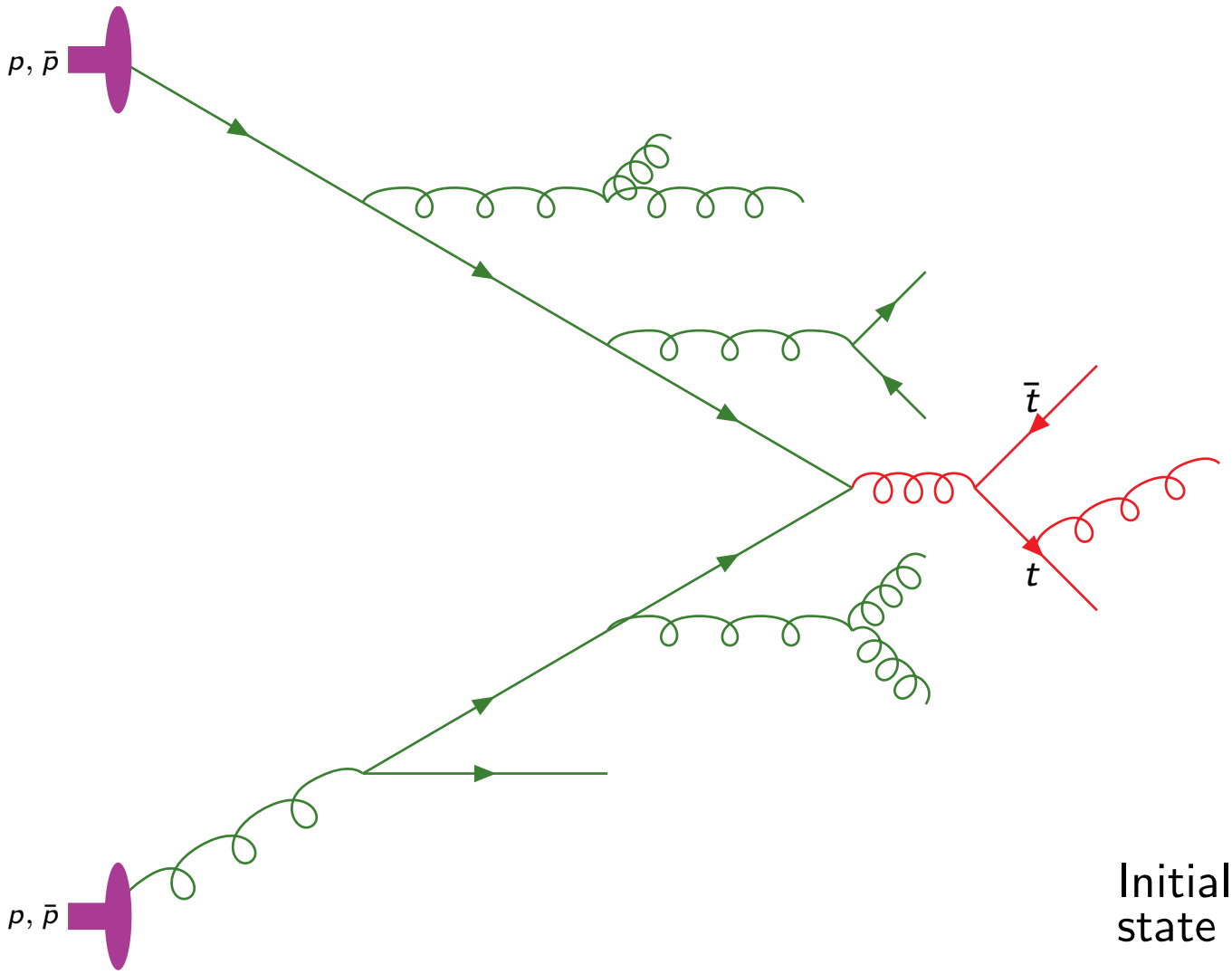


Proton-proton collision : Monte Carlo event



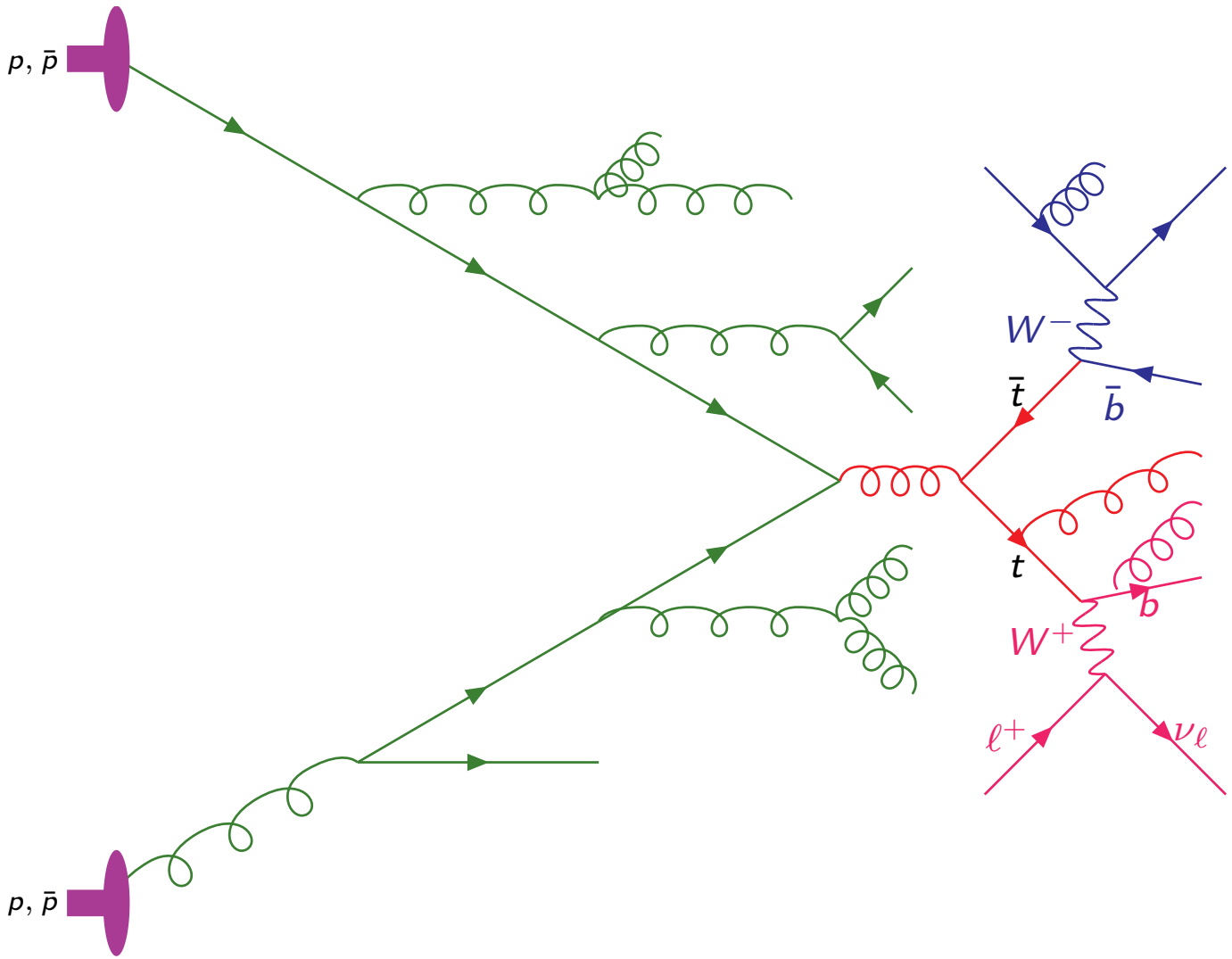
Hard Process, usually calculated at leading order

Proton-proton collision : Monte Carlo event



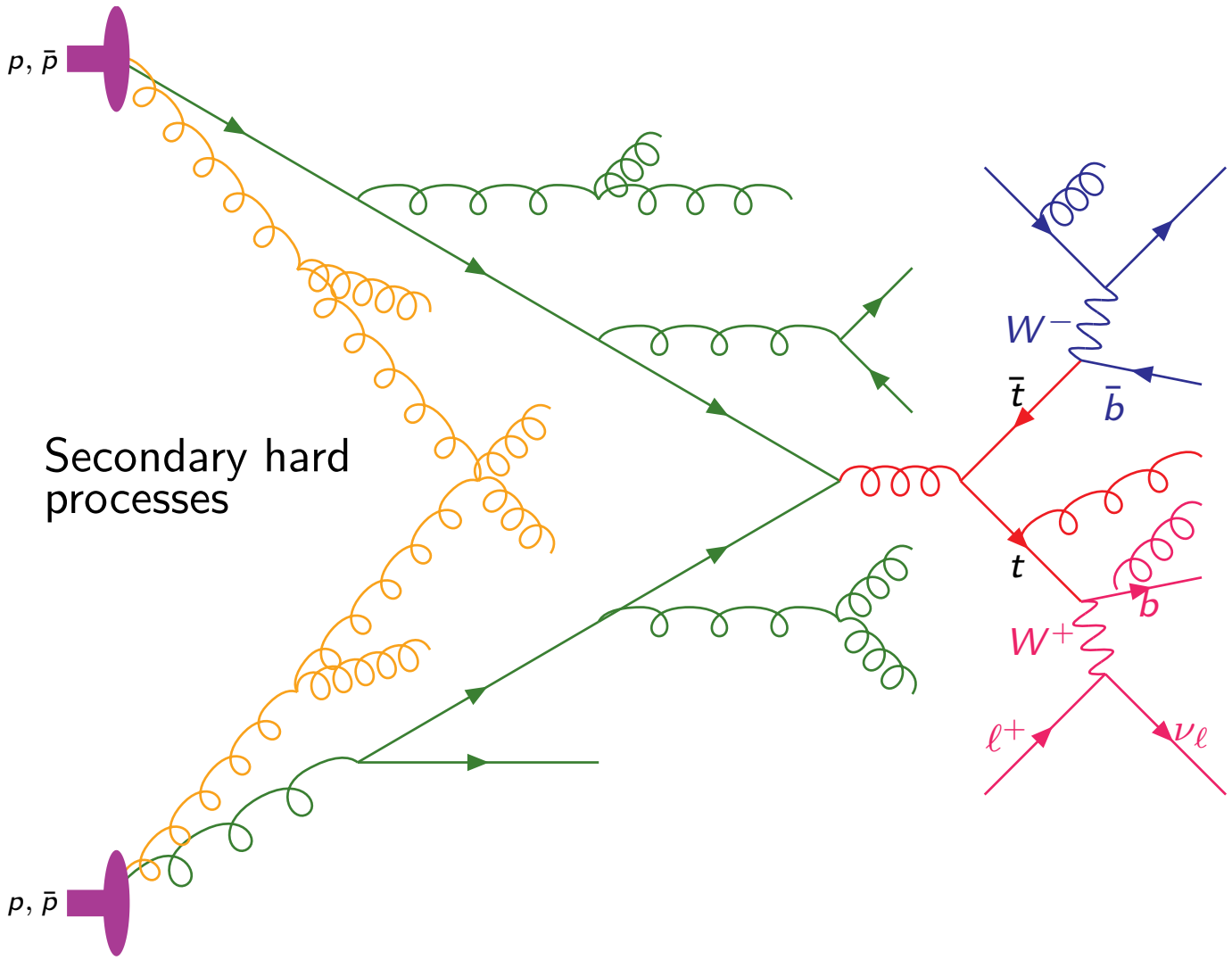
Initial- and final-state parton shower

Proton-proton collision : Monte Carlo event

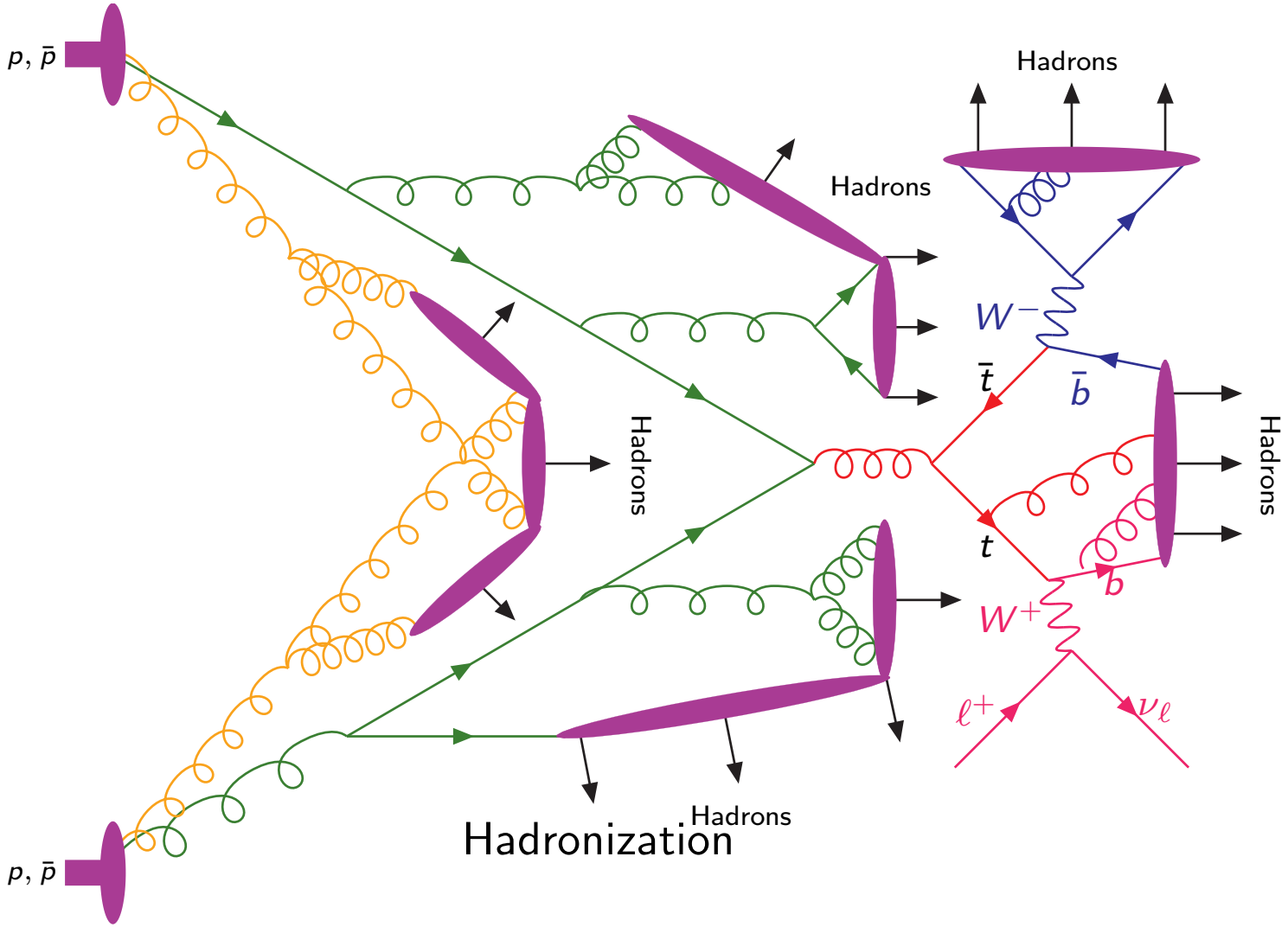


Perturbative decays of heavy particles

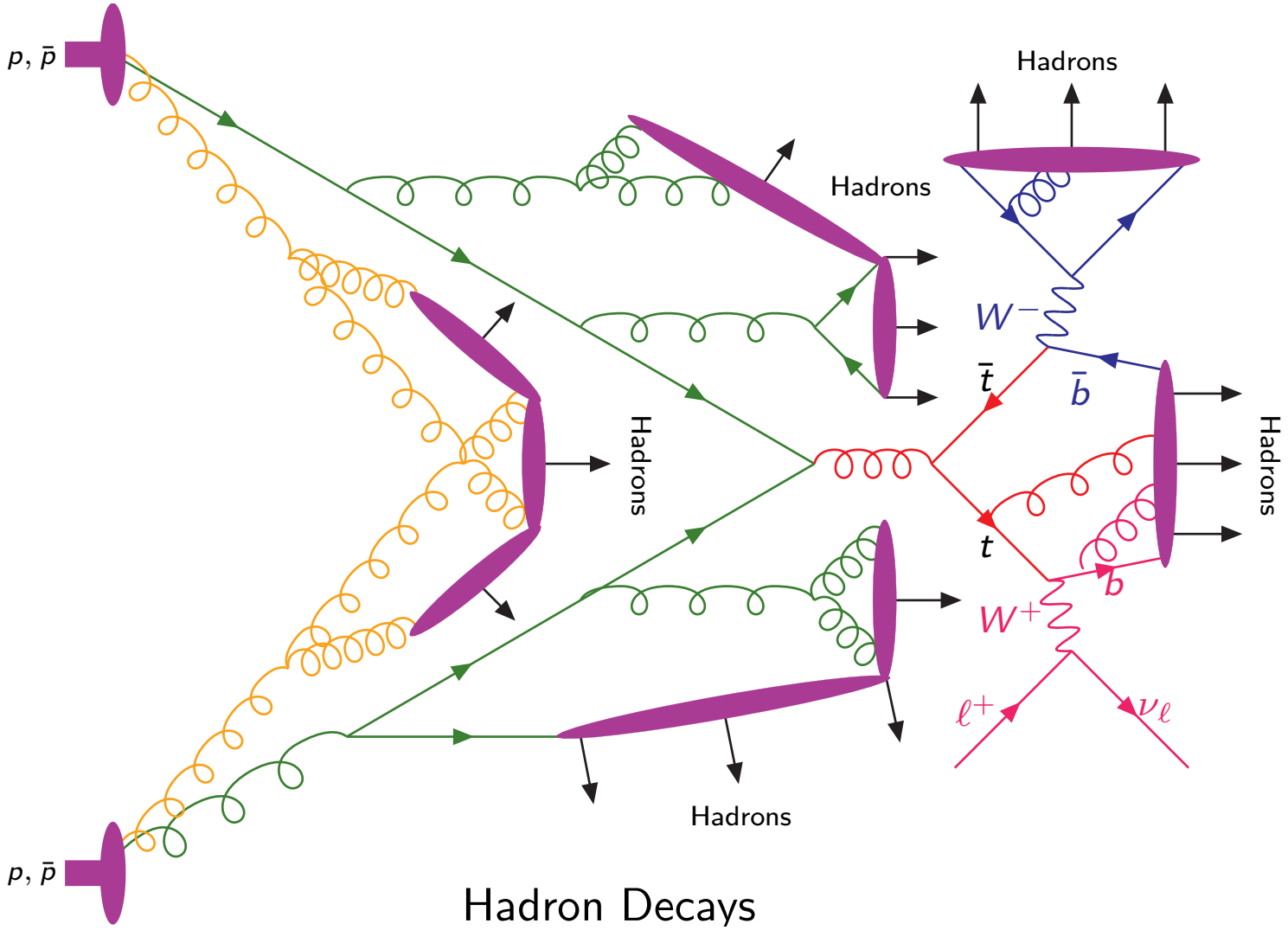
Proton-proton collision : Monte Carlo event

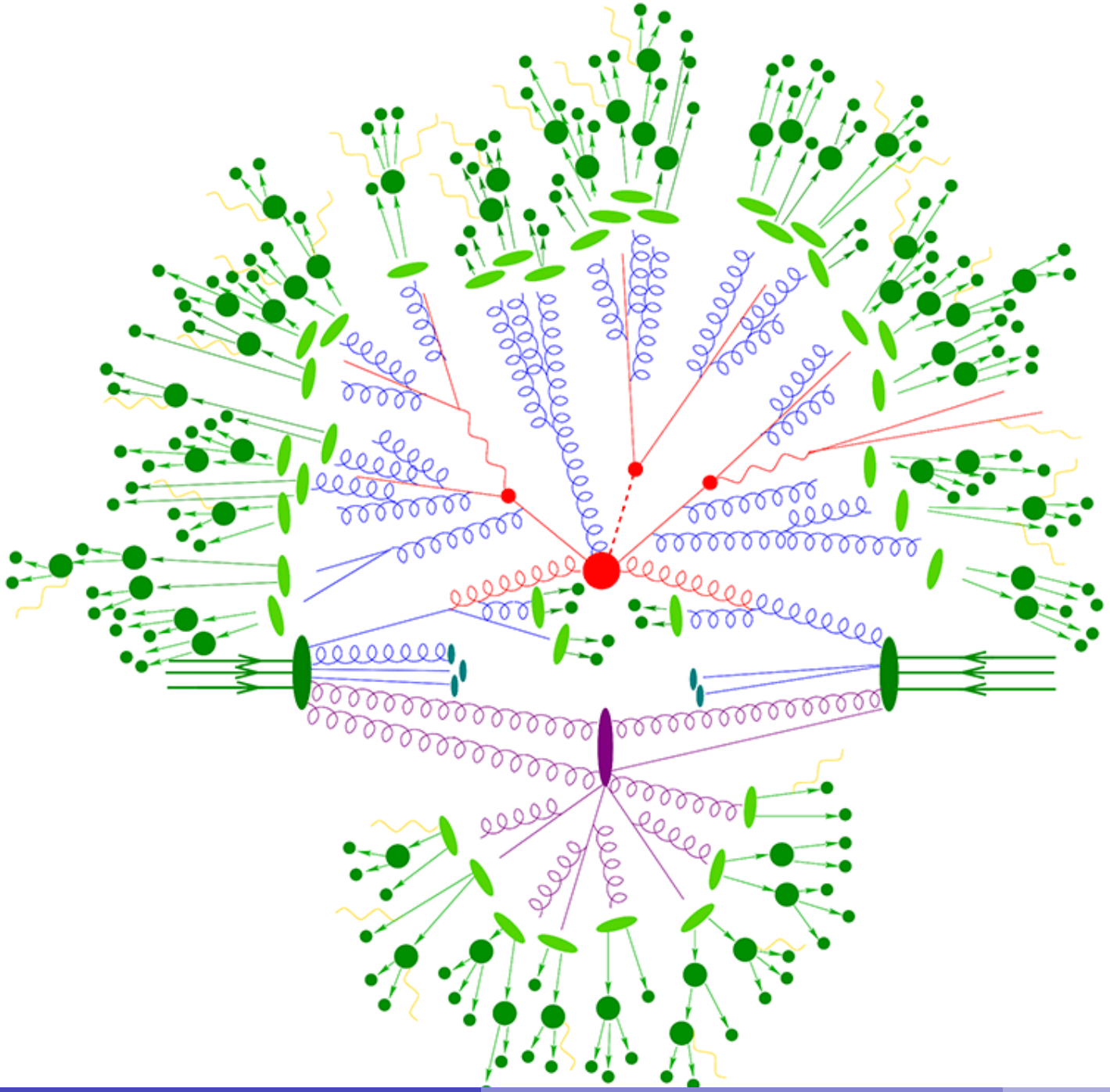


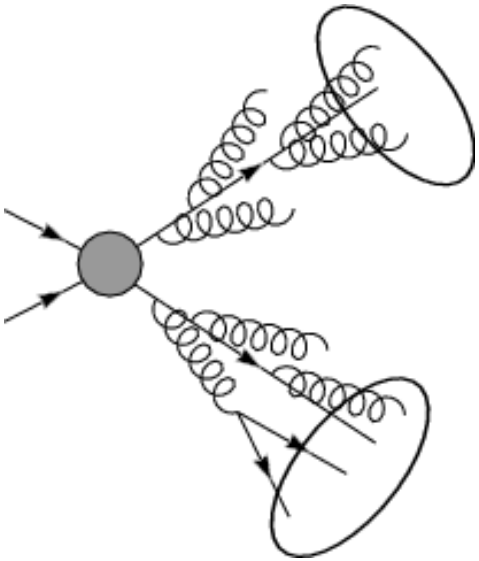
Proton-proton collision : Monte Carlo event

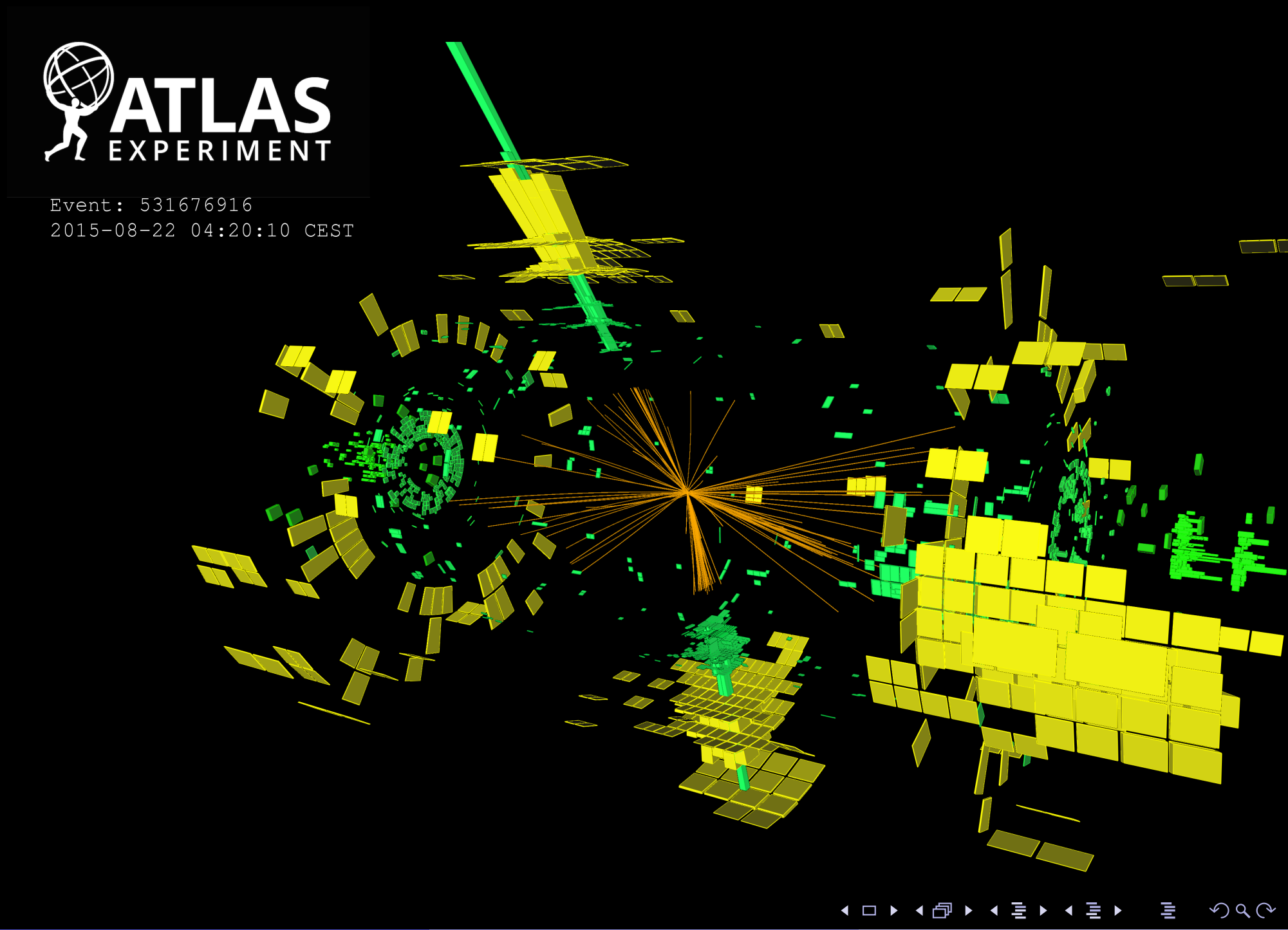


Proton-proton collision : Monte Carlo event

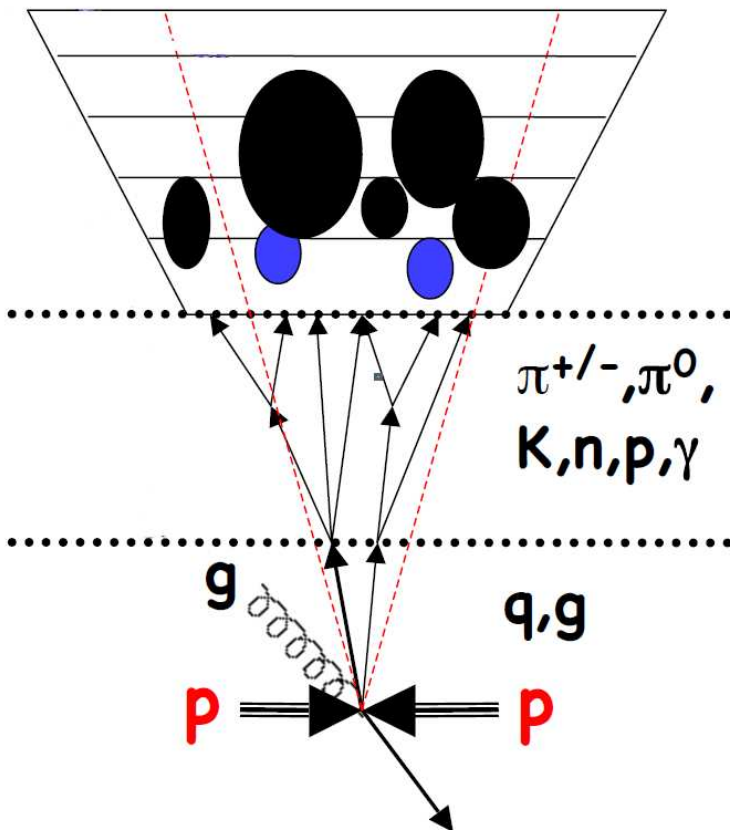






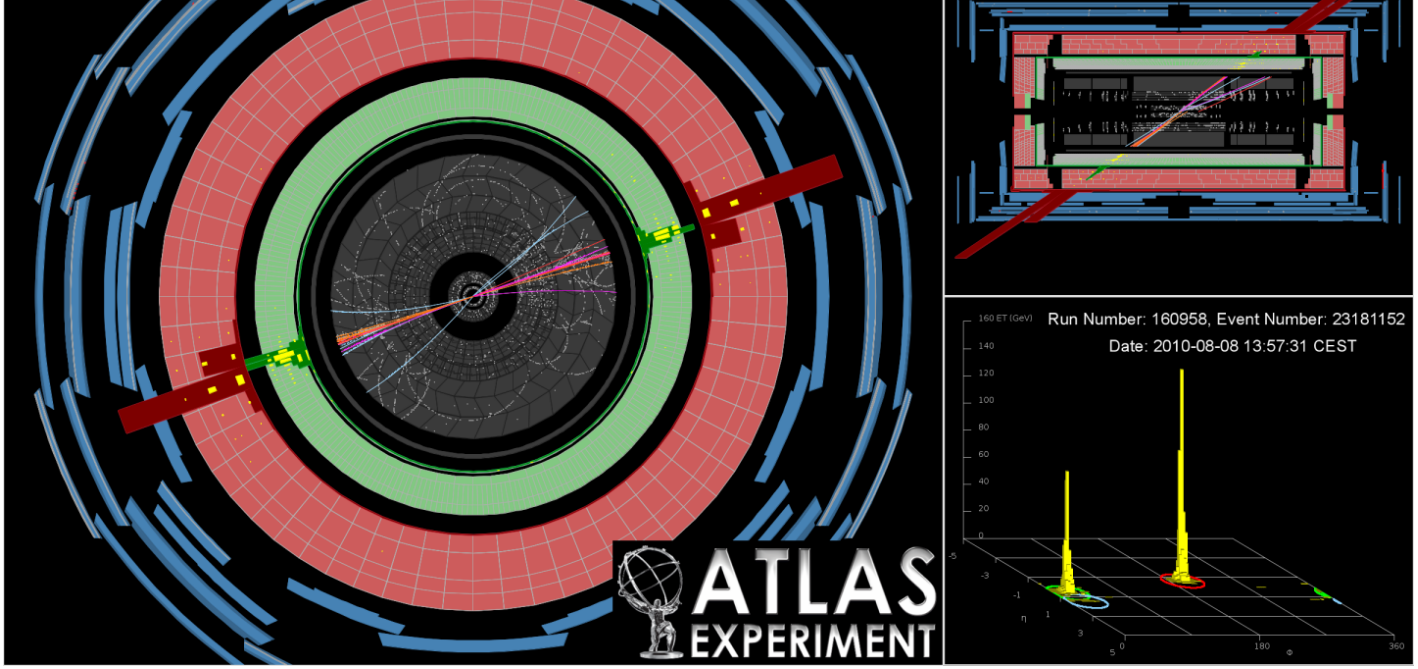

ATLAS
EXPERIMENT
Event: 531676916
2015-08-22 04:20:10 CEST

Hadron jet



- JET is a collimated spray of energetic hadrons
- HEP phenomena involving strong force $\rightarrow$ quarks/gluons
- partons fragment and hadronise into particles
- parton $\leftrightarrow$ jet (both ambiguous)
- Jet algorithm : set of rules to group constituents together

A good algorithm can be applied to experimental objects (cells, clusters, towers) AND fixed order calculations (LO, NLO, NNLO,. . .) AND parton shower MCs providing a common ground for the description of different types of events.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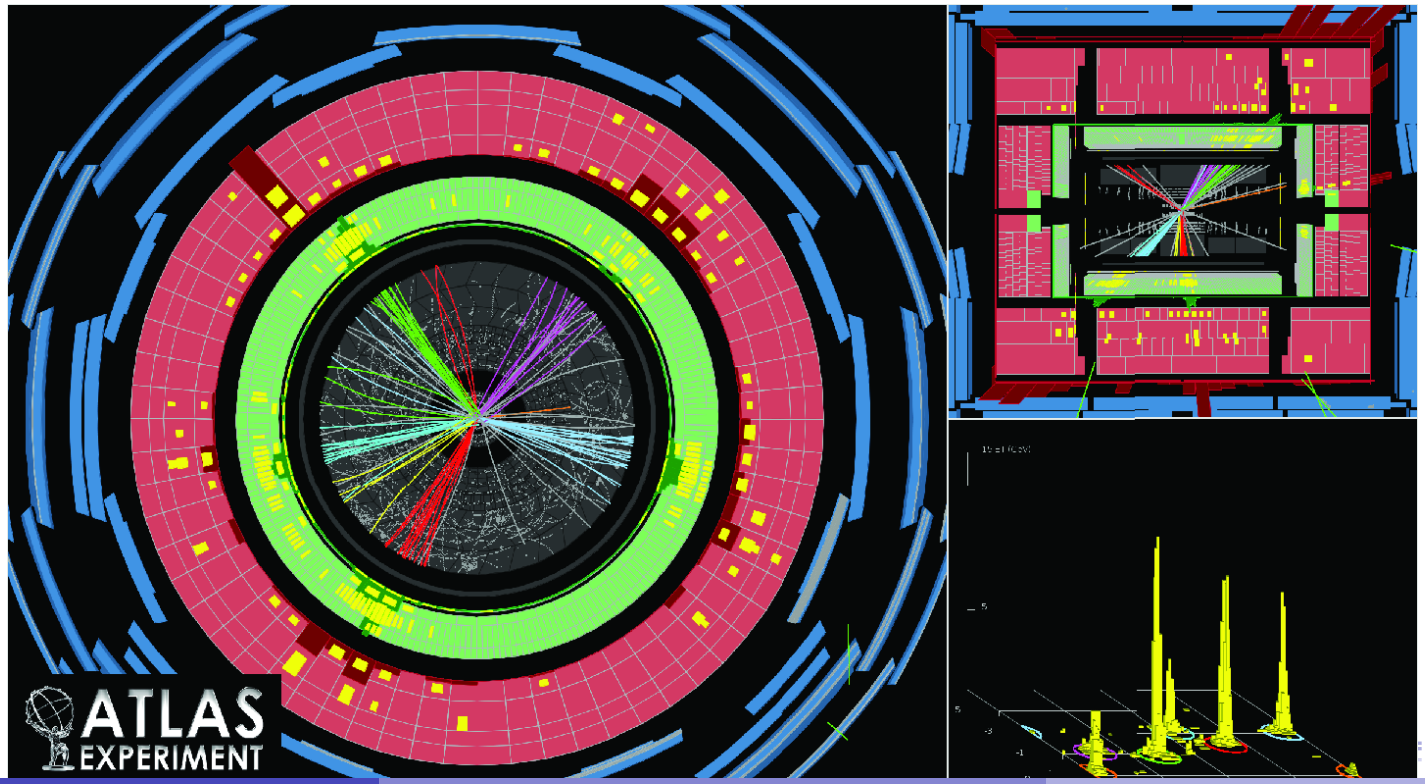
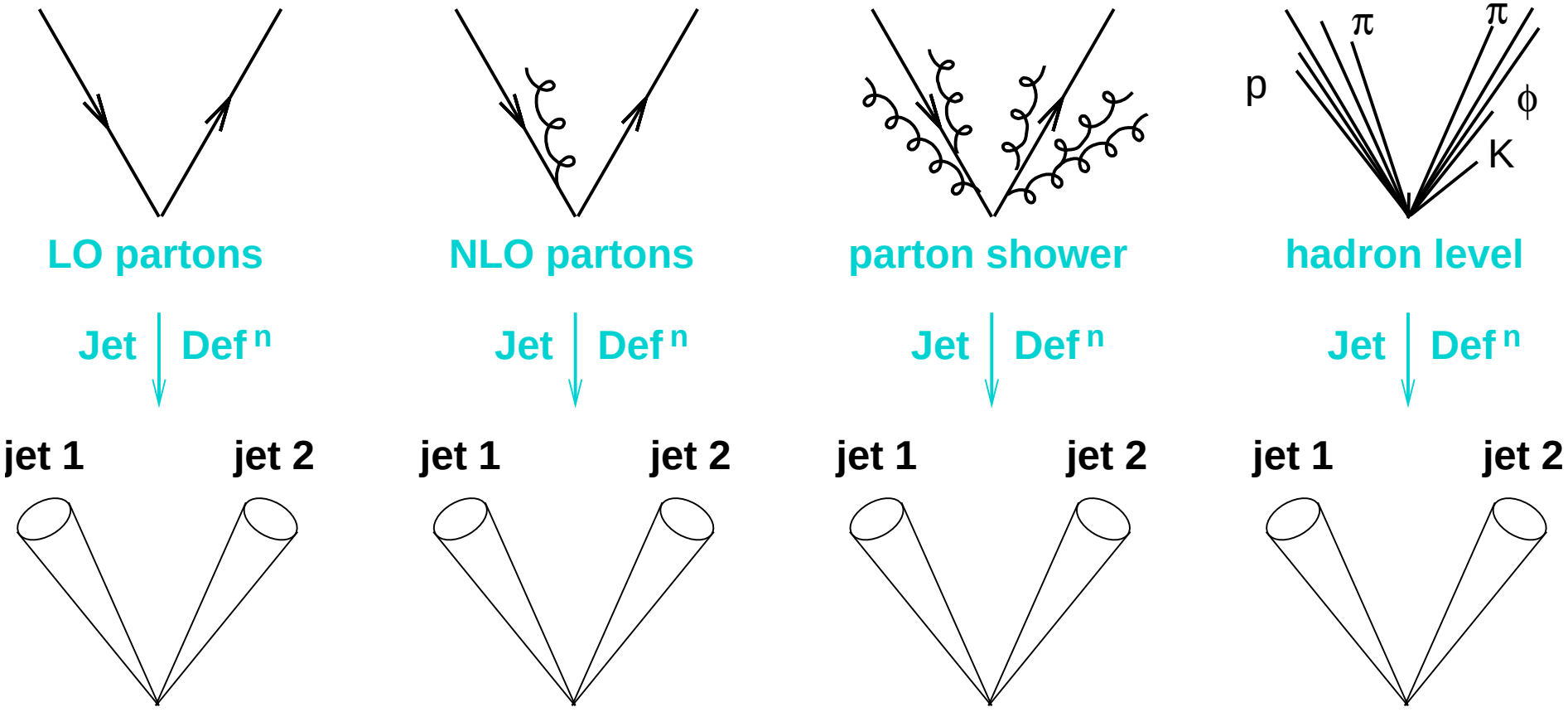
Date: 2010-08-08 13:57:31 CEST


ATLAS
EXPERIMENT

Jets as proxies to initiating partons



Jets should be stable against theory (radiation, underlying event, hadronisation) and experiment (noise, pile-up) effects

Jet algorithm : IRC safety

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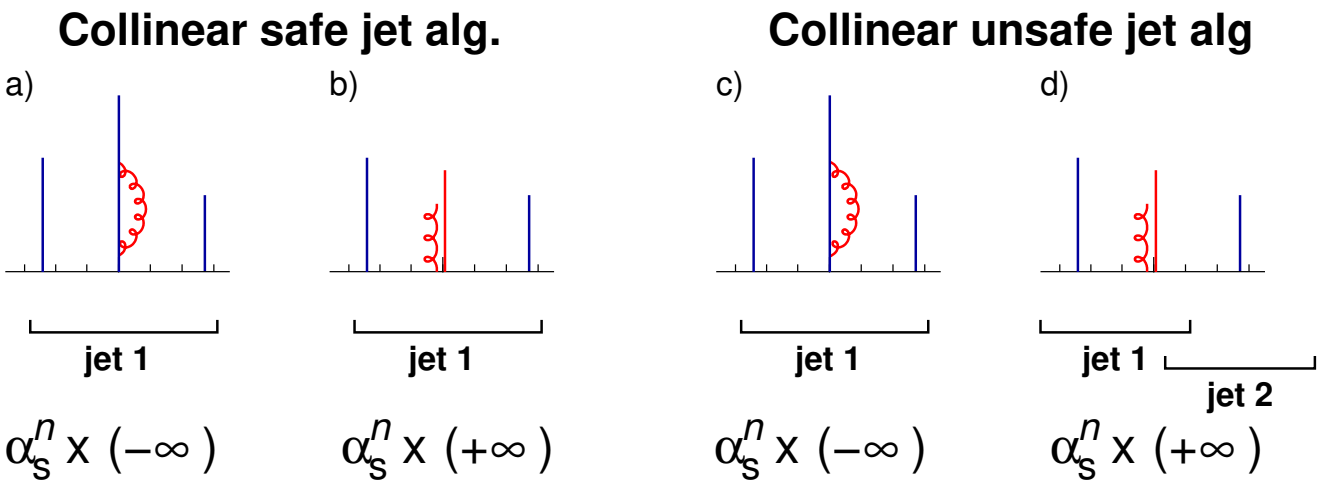
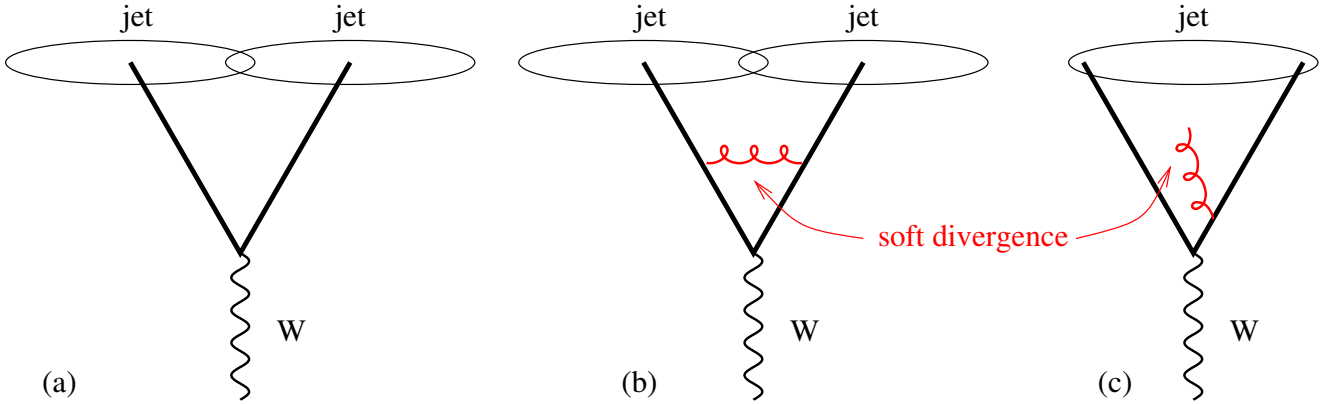


iterative cone-progressive removal alg



iterative cone-split/merge alg

Different jet algorithms

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