http://www.geant4.org

Geant4 Validation

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U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Outlook

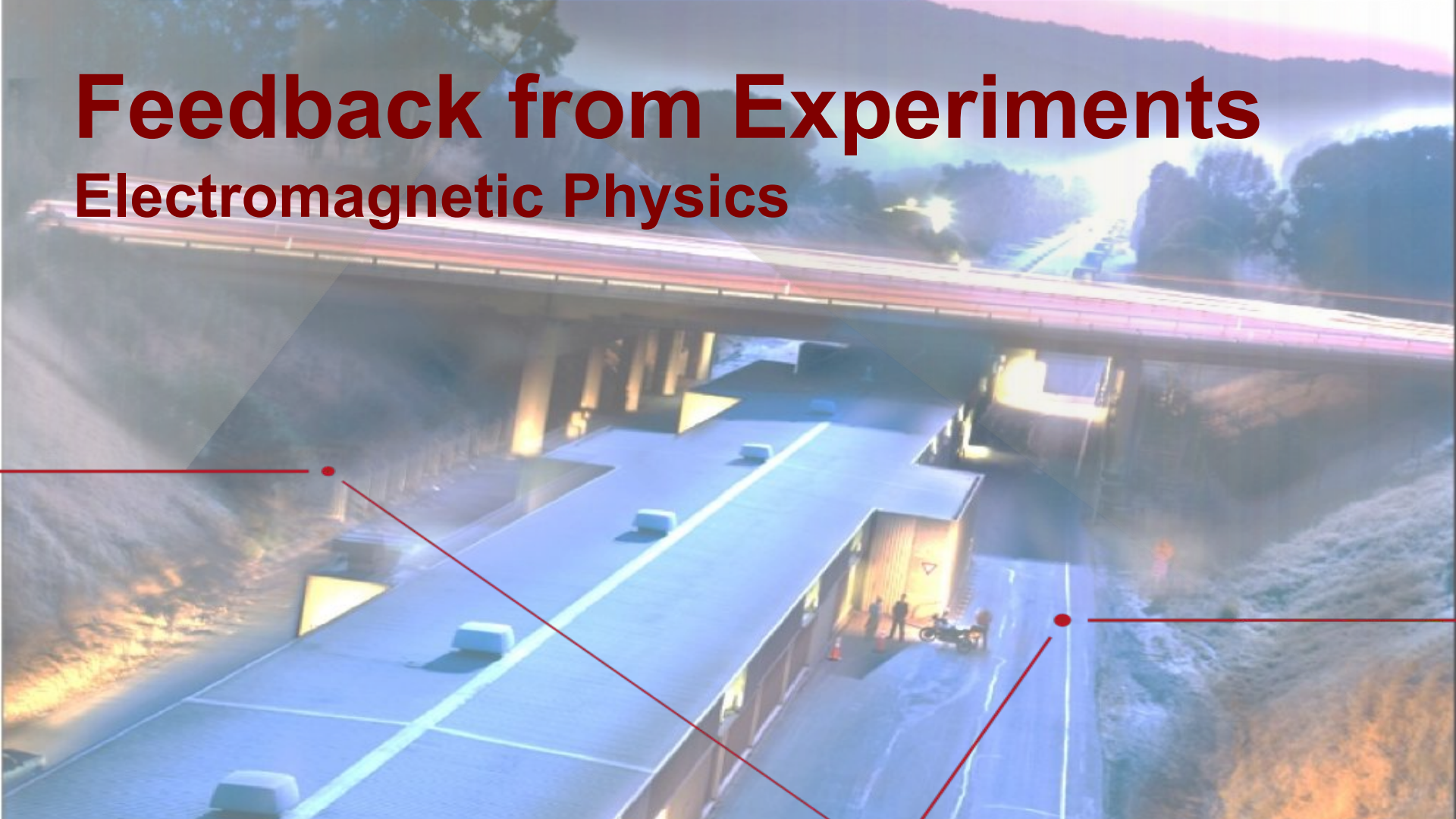
Electromagnetic Physics

Hadronic Physics

Prospects and conclusions

Feedback from Experiments

Electromagnetic Physics

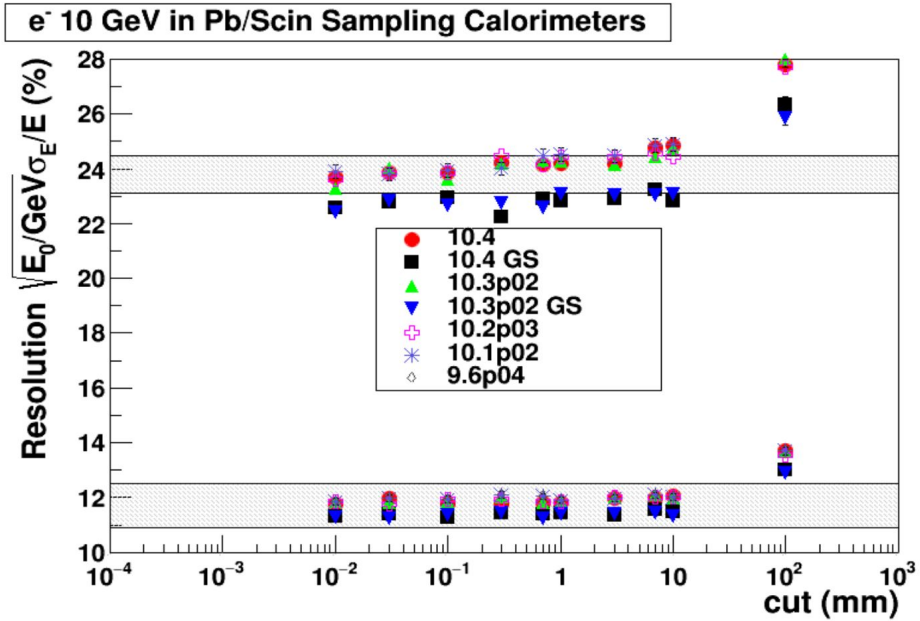


Summary of EM performances

Geant4 results stable w.r.t. releases results. E.g. ZEUS calorimeter

New developments focus on improving existing models or alternatives to specific models

CPU is one of the metrics being considered



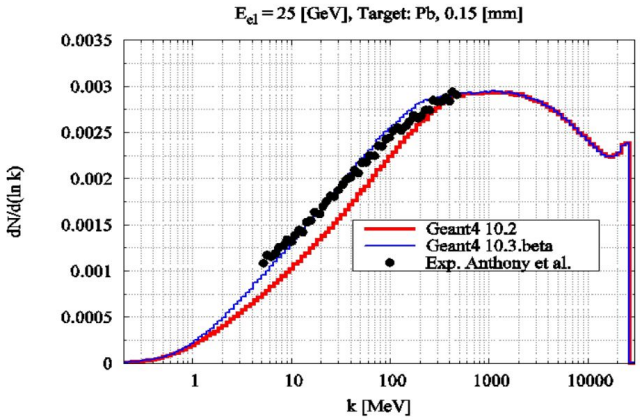
Recent EM improvements (10.3)

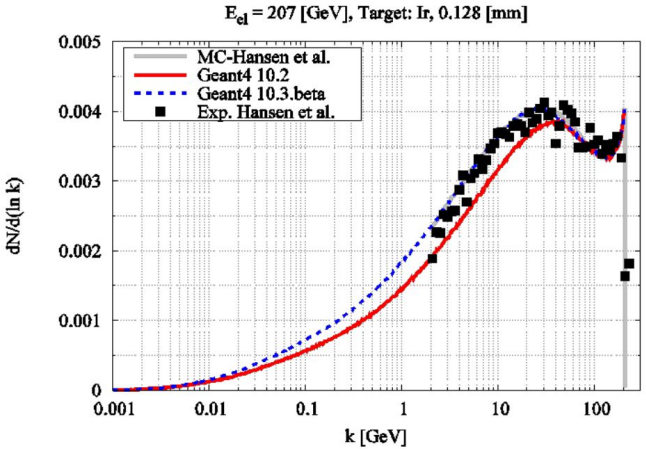
Upper energy limit extended to 100 TeV

LPM suppression in e^{+-} bremsstrahlung revised

Goudsmit-Saunderson MSC model

New model: e^+e^- pair production by e^{+-}



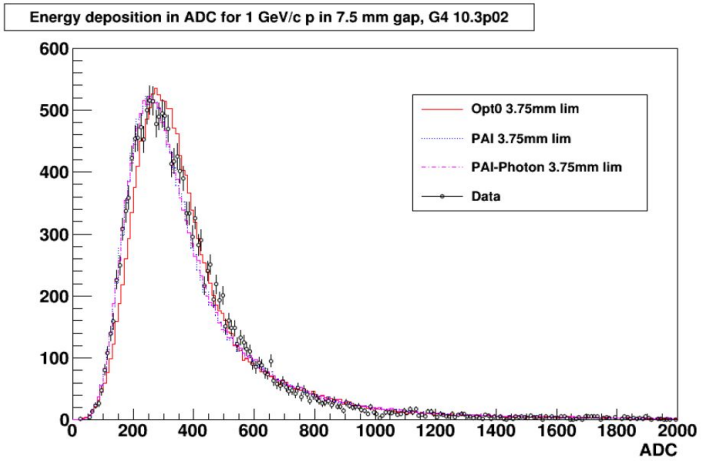


ALICE TPC benchmark

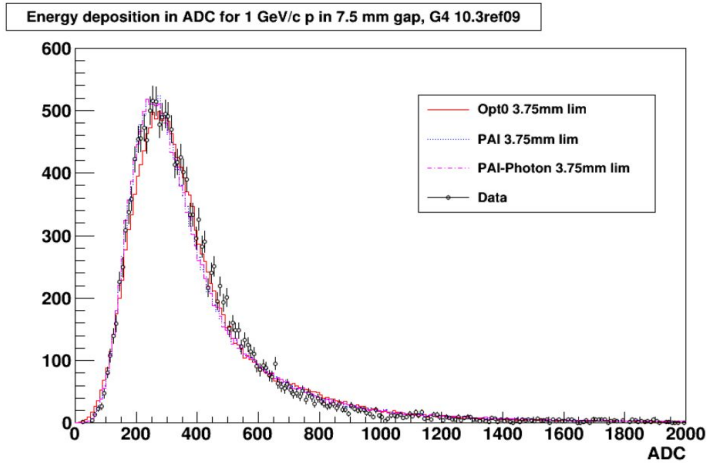
Two Geant4 models for fluctuation of energy loss

1. Urban model (default): parametrized based
   Best CPU performances, but more sensitive to step size
2. PAI model: photoelectric cross-sections. Stable versus cuts and step limits. Good results for gas/thin detectors

10.3p02



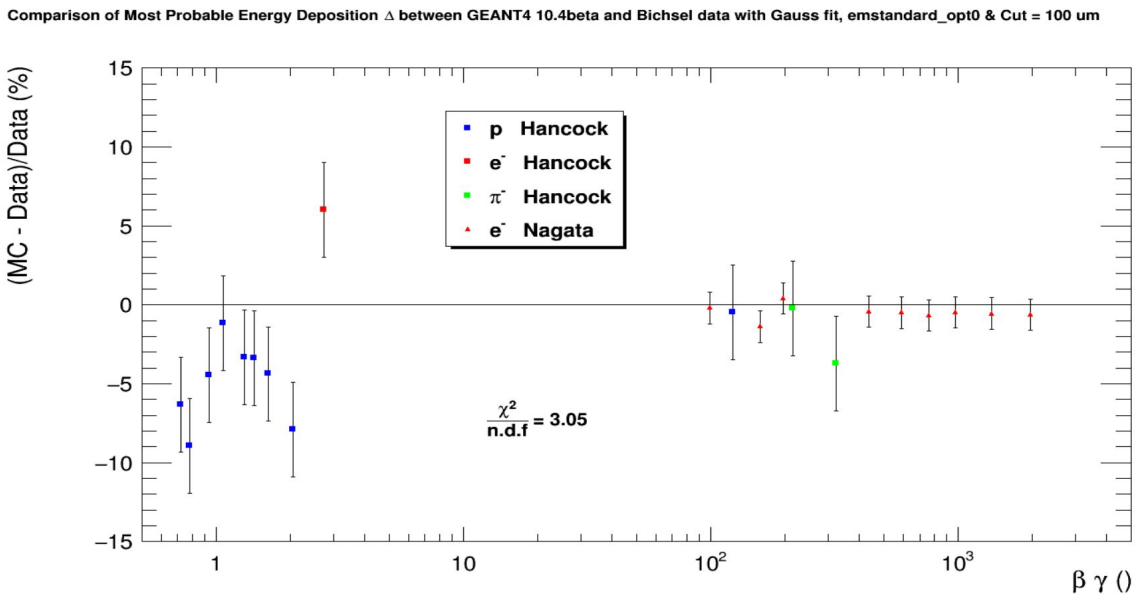
10.4



Energy deposits in Si Detectors

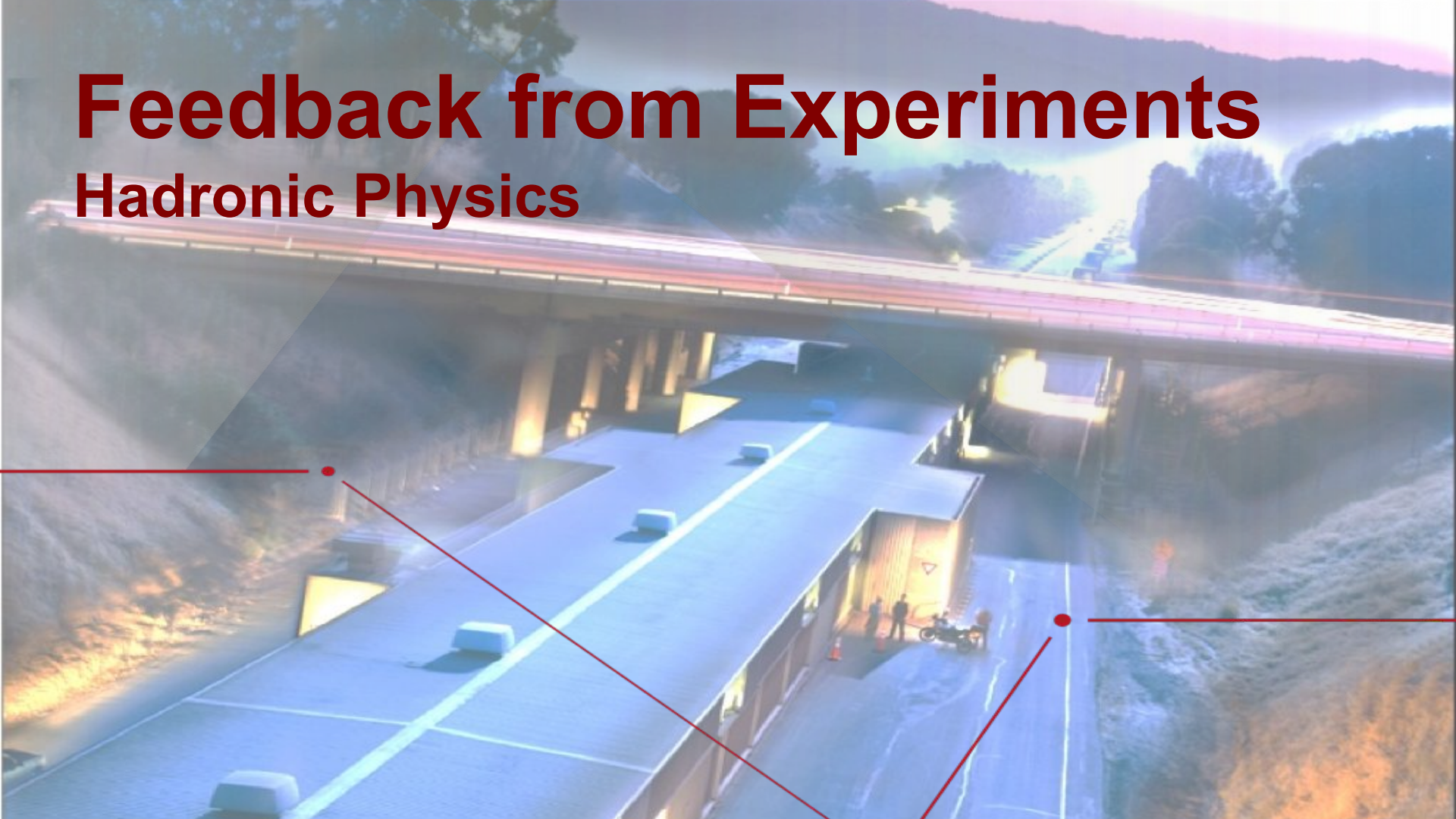
Both Urban and PAI models reproduce data well for relativistic beams

Less accurate for e- and proton for βγ~1: more data needed

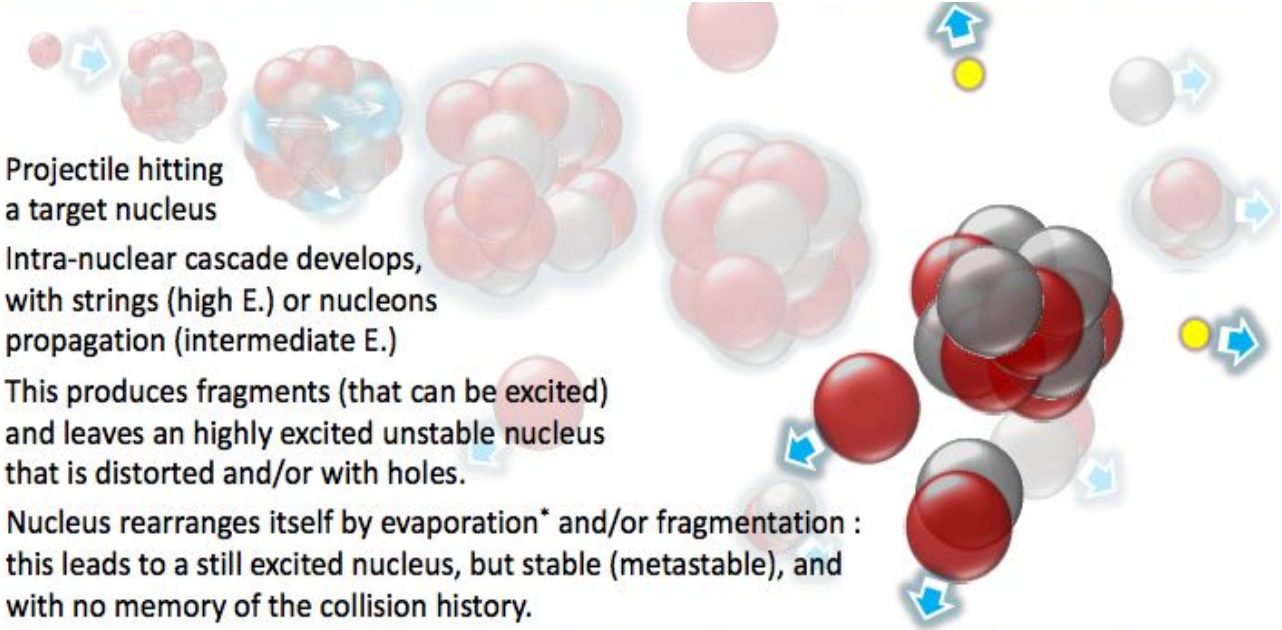


Feedback from Experiments

Hadronic Physics



Hadronic Physics in one slide



Projectile hitting a target nucleus

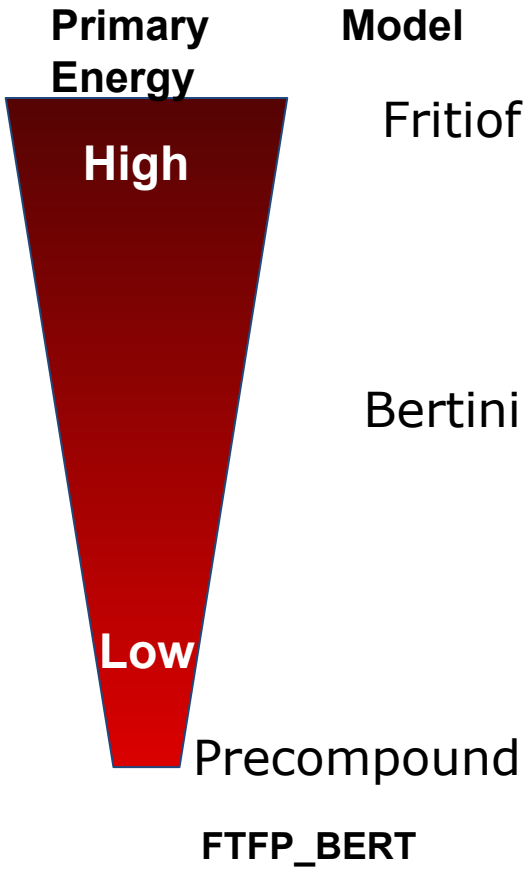
Intra-nuclear cascade develops, with strings (high E.) or nucleons propagation (intermediate E.)

This produces fragments (that can be excited) and leaves an highly excited unstable nucleus that is distorted and/or with holes.

Nucleus rearranges itself by evaporation* and/or fragmentation : this leads to a still excited nucleus, but stable (metastable), and with no memory of the collision history.

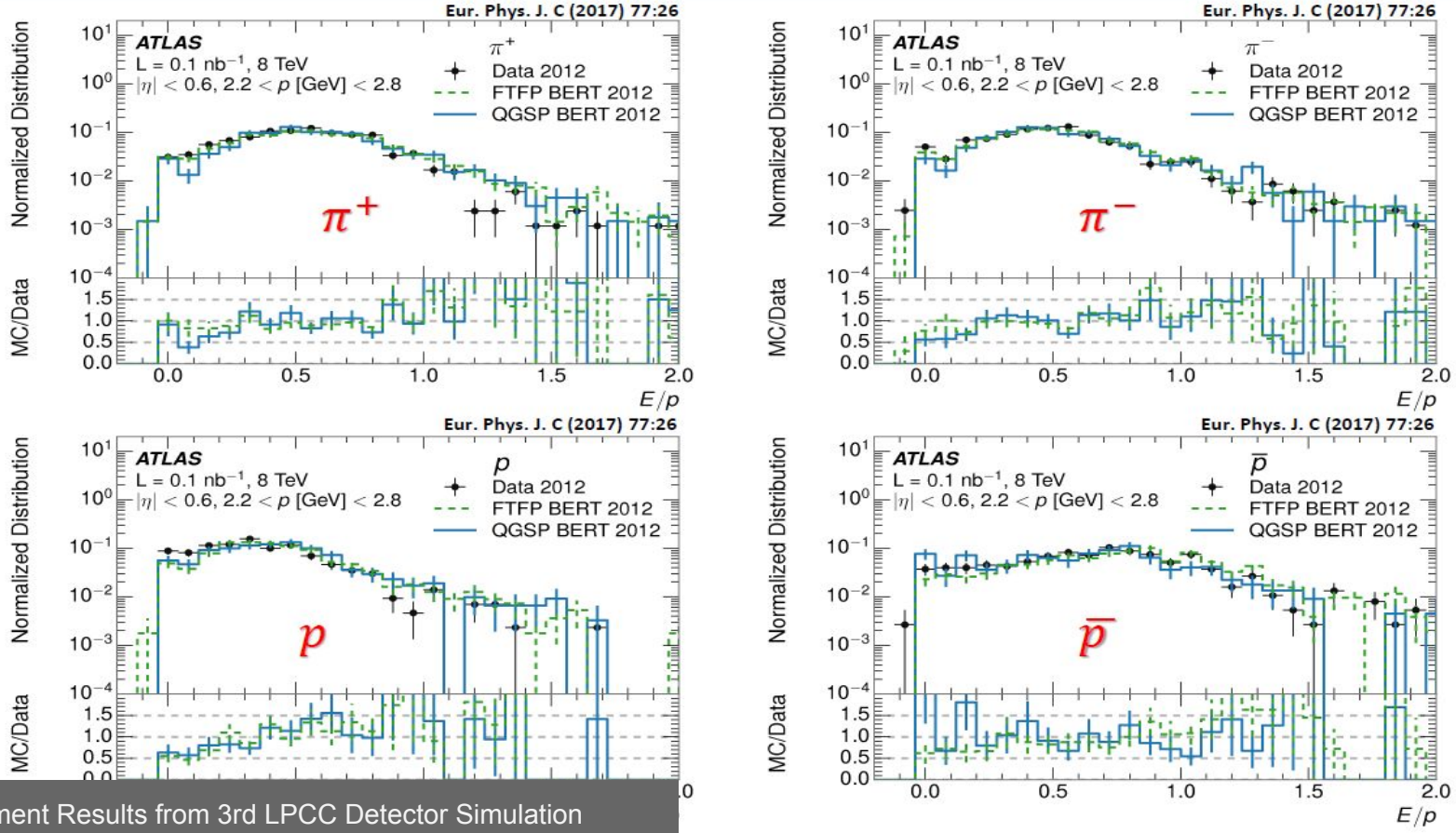
The nucleus undergoes final de-excitation by evaporation* or fission and ends-up in its ground state. In case of fission, further de-excitation of fragments may occur.

(*) **Evaporation** = de-excitation by emission of light nuclei ∈ {n, p, d, t, 3He, α} or photon



E/p for Identified Particles

Peter Loch
UAPhysics
THE UNIVERSITY OF ARIZONA
College of Science



Experiment Results from 3rd LPCC Detector Simulation Workshop: https://indico.cern.ch/event/614935/

Collision Data

- The level of disagreement between data and MC is between 2 to 5% depending on the region of the detector as well as the physics list used

Mean level of disagreement between MC and data

	$(E_{7x7}+H_{3x3})/p$ 10.0.p02	$(E_{7x7}+H_{3x3})/p$ 10.2.p02	$(E_{11x11}+H_{5x5})/p$ 10.0.p02	$(E_{11x11}+H_{5x5})/p$ 10.2.p02
Barrel 1	(1.1±0.4)%	(2.4±0.4)%	(2.5±0.4)%	(2.6±0.4)%
Barrel 2	(3.4±0.4)%	(3.6±0.4)%	(1.9±0.4)%	(2.2±0.4)%
Transition	(3.7±0.5)%	(4.9±0.5)%	(1.6±0.5)%	(2.2±0.5)%
Endcap	(1.1±0.3)%	(4.1±0.5)%	(4.7±0.4)%	(1.6±0.5)%

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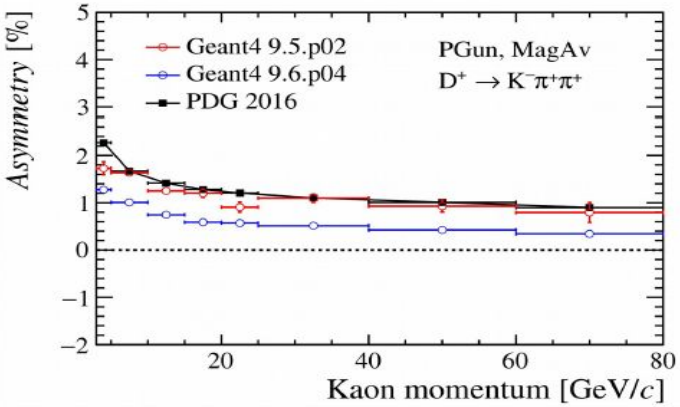
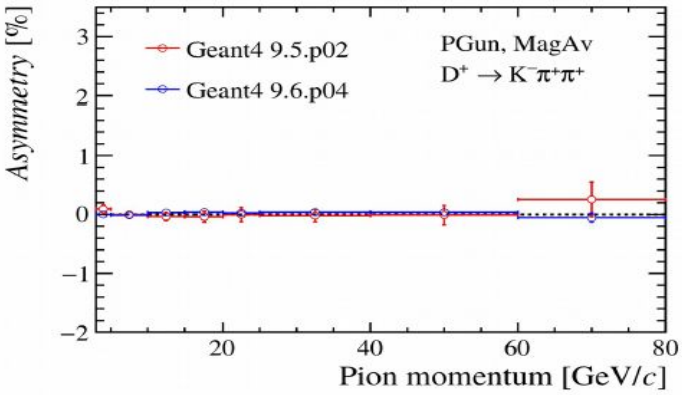
Kaon Asymmetries at LHCb

Simulated asymmetries update





- FTFP_BERT used for hadronic cross-sections, Geant4 v96r4p0g1 includes LHCb additions, slight changes in material description
  - Pion asymmetry agrees with expectations
  - Kaon asymmetry seems too low now
- Work ongoing to directly compare with measurement

  $\longrightarrow$ Needed for understanding of other asymmetries

Sascha Stahl

Experiment Results from 3rd LPCC Detector Simulation Workshop: https://indico.cern.ch/event/614935/

"Quality Matrix"

Electromagnetic showers: generally well described
Exceptions:

- detailed shower mode (option EMY) needed for gaseous calorimeters
- number of hits and hit sizes at shower start for scintillator/tungsten

Hadronic showers

	W	Fe
Scintillator	✔ energy (✔) longitudinal profile ✘ shower start: # of hits, hit size	✔ energy ✔ longitudinal profile ✔ tracks
Silicon	✔ energy ✘ longitudinal profile ✔ tracks, angles	n.A.
Gas	?	✘ number of hits (✔) tracks

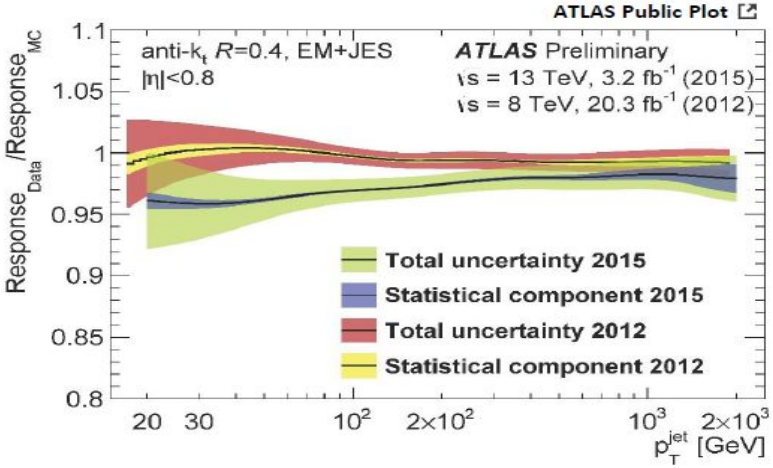
CAVEAT: sometimes significant changes between Geant4 versions

Experiment Results from 3rd LPCC Detector Simulation Workshop: https://indico.cern.ch/event/614935/

Brief Insert: Jet Response Run 1/2

Loss of hadronic response in jets Run 1 – Run 2

QGSP_BERT (G4.9.4, 2012 Run 1) vs FTFP_BERT (G4.9.6p3, 2015, Run 2)



Introduced FTFP_BERT_ATL for Run 2

Reversion to jet response similar to 2012 QGSP_BERT in detector simulation

Experiment Results from 3rd LPCC Detector Simulation Workshop: https://indico.cern.ch/event/614935/

Recent issues for hadronic physics

Differently from what happened in the past, in the most recent years:

- development/tuning of FTF **does improve** “single-interactions”, but **does not improve** showers in calorimeters (and in some cases worsen comparison with data)
- these tunes are **not** included in production versions of G4

Possible causes:

- FTF overproducing π^0? thin-target data seems to indicate no, calorimeter data yes
- Are the thin-target improvements robust? maybe we look to too small - or not so important - corners of the phase space
- Are the available thin-target data, dominated by light materials (H & C), driving us away from the heavier ones (Fe, Cu, W, Pb) relevant for calorimetry ?
- ….

Future activities

What ProcessLevel is

A general purpose testing application that can simulate any G4Process **single interactions** specifying

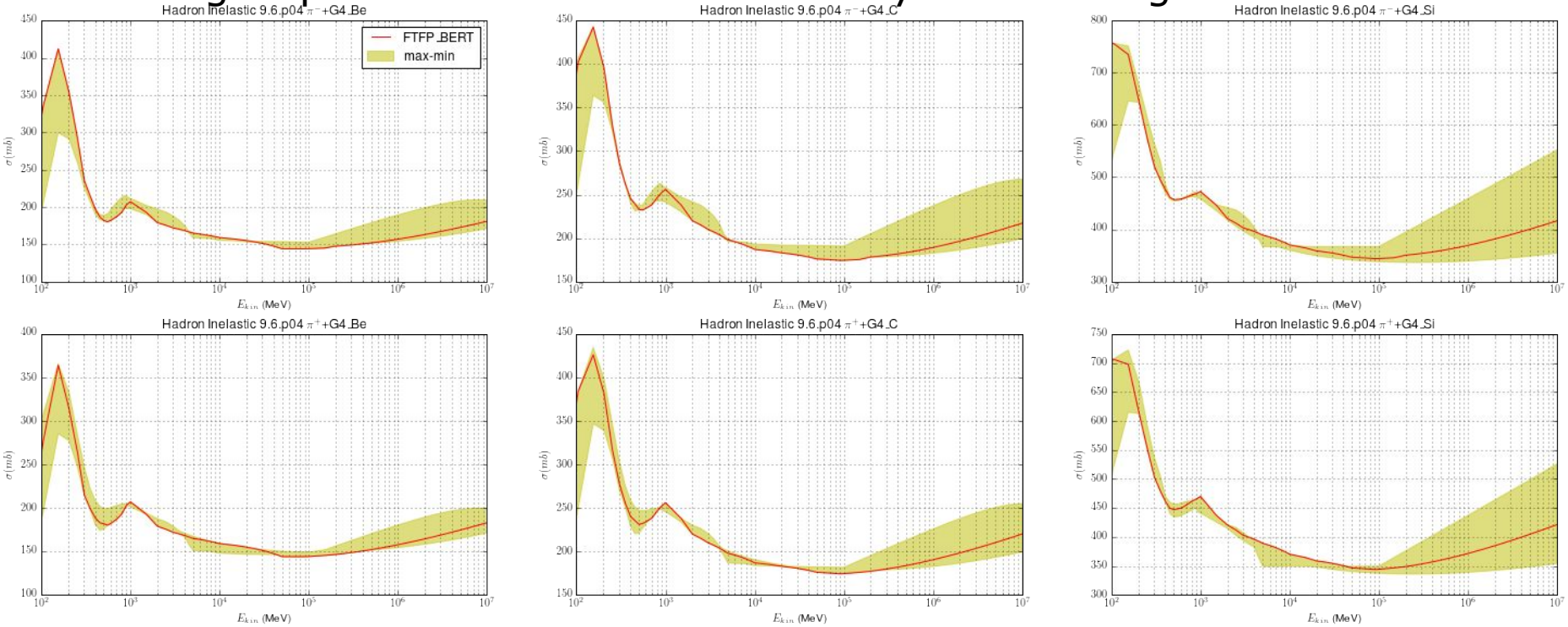
- primary type and energy
- target material or isotope
- process type and sub-type

Everything is configured via macro-commands

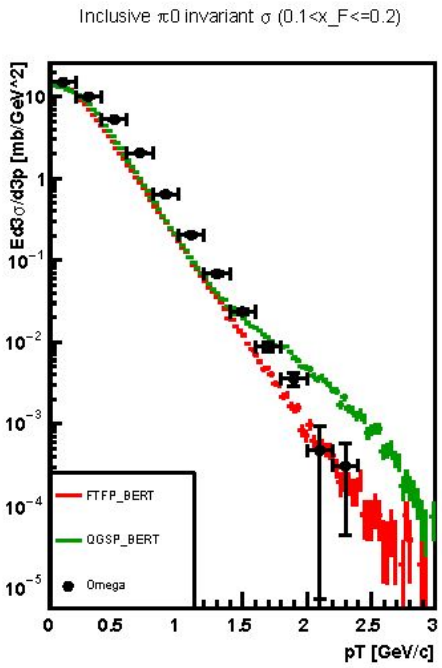
- goal: reduce at minimum coding
- includes **run-time definition of output** (histograms, ntuples)
- more complex analysis algos can be added via a simple plugin mechanism

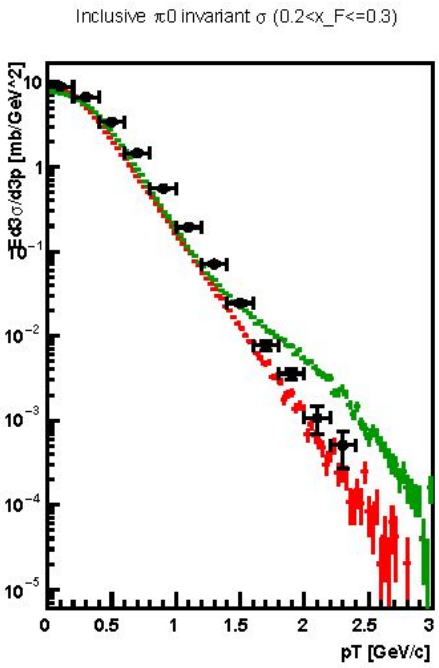
Total had inelastic cross-sections studies

Following request from ATLAS: uncertainty on XS using difference PLs



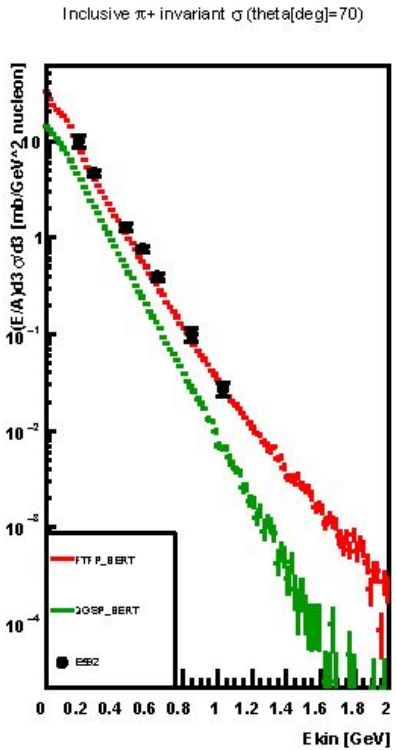
Forward pi0 production: Omega experiment

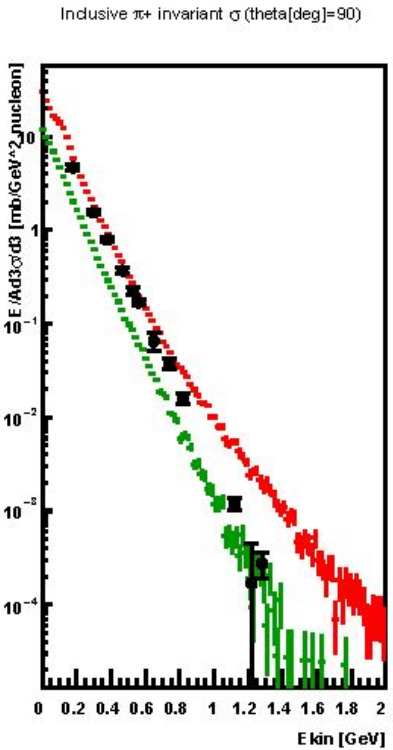




Lorentz-Invariant differential XS in bins of X_f

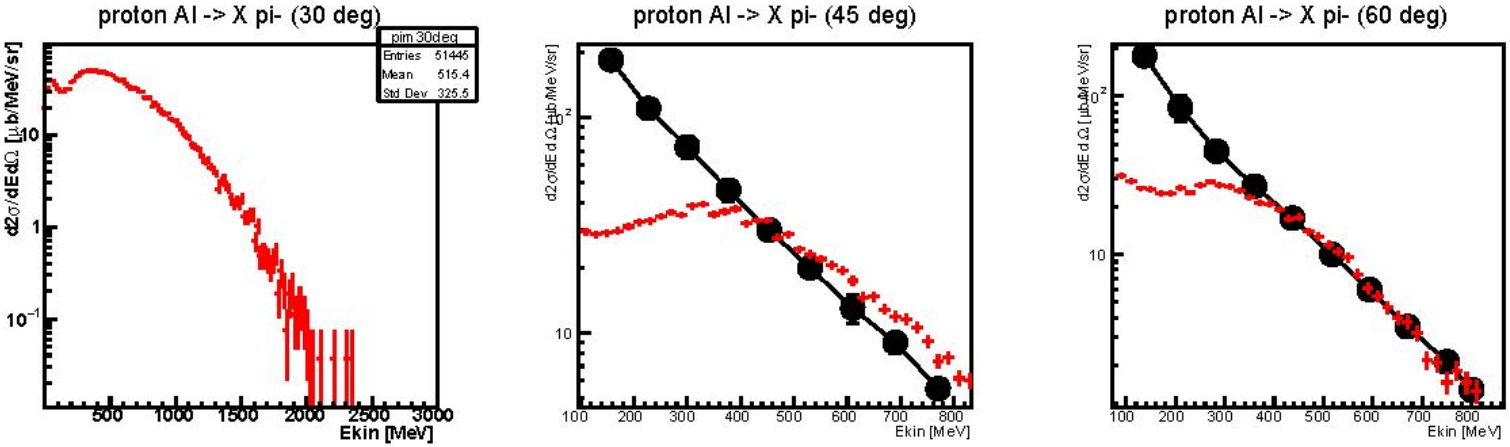
Inclusive charged pion production: E592 experiment





Lorentz-Invariant differential XS in bins of theta

Bertini validation test-suite



Double-differential cross-sections

Note that some plots are always created even when no data are available: to compare models

Conclusions

Workplan

Use the existing test-suites (ProcessLevel, SimplifiedCalorimeter, HepExpMT) to define a physics list for EIC:

- What are the detector materials/types (thin layers, gas, ?)
- What is the typical final-state to be simulated in G4, energy? species?
- Which is the best combination of hadronic models? Transition energies?

Can be achieved by a motivated PhD student or post-doc within one year

New physics – new opportunities: Geant4 workplan non EIC related

Physics of FCC: EPOS model to complement high-energy string

Neutrino interactions: interface to GENIE

Dark Matter searches

- scintillation in noble liquids (NEST)
- electron/hole drift in semiconductor and phonon physics

Channeling effects and physics with **crystal structure** in general

Muonic atom

Single atom irradiation

Target material polarization

Chemical reactions of radicals at DNA-scale

Geant4 kernel is mature, complete and stable. These enables risk-free extensions to new physics.

New computing trends

HPC and cloud

- Combining MPI and MT
- Smart data collection from millions of threads

Code reengineering

- Some R&D ongoing. One of them being Geant Vector Prototype
- VecGeom solid library, EM physics

GPU as a co-processor

- Off-loading some calculations to GPU, e.g. EM physics, thermal neutron physics, DNA physics and chemical processes, etc.

Many activities already started, in some cases very good progress made

- When mature, will be integrated into Geant4