Hadronic Physics 1-b

Cours Geant4 @ Paris 2007

4 au 8 juin 2007,

Ministère de la Recherche,

Paris, France

Gunter Folger

Overview

- Cascade models – Binary Cascade
- Parameterized models
- Elastic processes

Acknowledgement:
Most slides are taken from course prepared by Dennis Wright,
Geant4 course held at SLAC, May 2007

Binary Cascade

- Cascade type Model
  - Nucleus is explicitly modeled
    - Nucleons have momentum and are placed in space
    - momentum taken into account for scattering
  - hadron-nucleon collisions including re-scattering
    - resonances excitation and decay
    - Elastic scattering
    - Pauli blocking
  - particles follow curved trajectories in nuclear potential
  - At end of cascade, nucleus and exciton system is passed to pre-equilibrium model (precompound)

Binary Cascade (2)

- In Geant4 the Binary cascade model is currently used for incident p, n, (and π)
  - valid for incident p, n from 0 to <10 GeV
  - valid for incident π^+, π^- from 0 to 1.3 GeV
- A variant of the model, G4BinaryLightIonReaction, is valid for incident light ions, more in Hadronics 3

Using the Binary Cascade

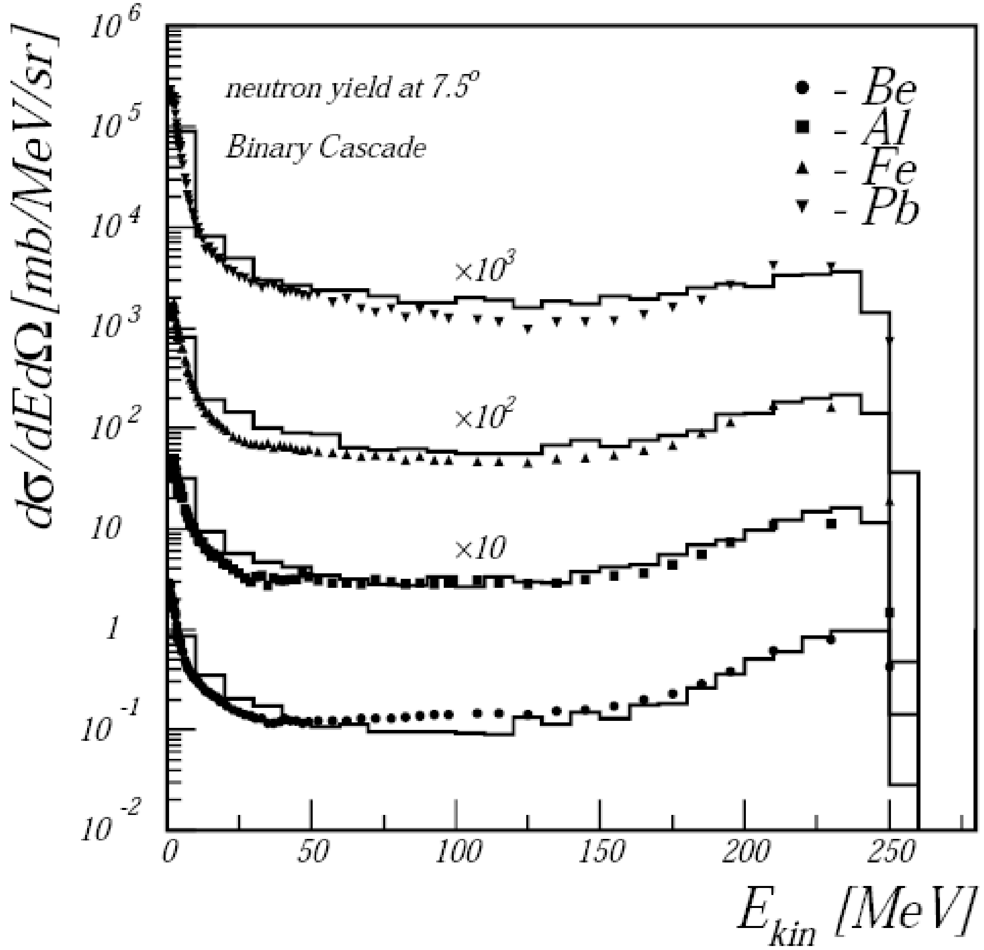
- Invocation sequence Binary cascade

```
G4BinaryCascade* binary = new G4BinaryCascade();
G4ProtonInelasticProcess* pproc = new G4ProtonInelasticProcess();
pproc -> RegisterMe(binary);
G4ProcessManager * p_manager=G4Proton::Proton()->GetProcessManager()
p_manager -> AddDiscreteProcess(pproc);
```

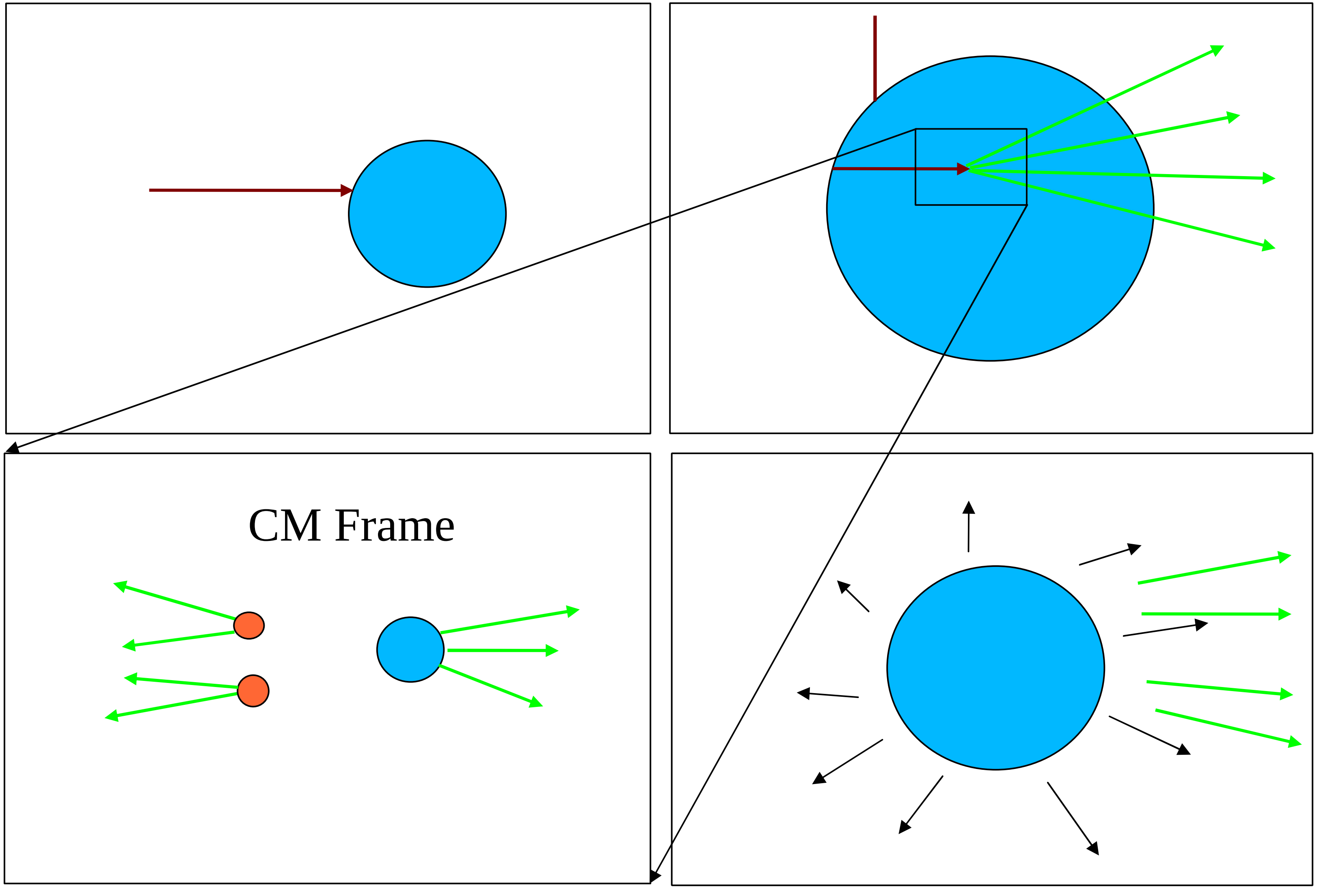
- Invocation sequence BinaryLightIonReaction

```
G4BinaryLightIonReaction* ionBinary = new G4BinaryLightIonReaction;
G4IonInelasticProcess* ionProc = new G4IonInelasticProcess;
ionProc->RegisterMe(ionBinary);
genericIonManager->AddDiscreteProcess(ionProc);
```

Validation of the Binary Cascade 256 MeV protons



LEP, HEP (Comic Book Version)



LEP, HEP models (text version)

- Modeling sequence:
  - initial interaction of hadron with nucleon in nucleus
  - highly excited hadron is fragmented into more hadrons
  - particles from initial interaction divided into forward and backward clusters in CM
  - another cluster of backward going nucleons added to account for intra-nuclear cascade
  - clusters are decayed into pions and nucleons
  - remnant nucleus is de-excited by emission of p, n, d, t, alpha

Using the LEP and HEP models

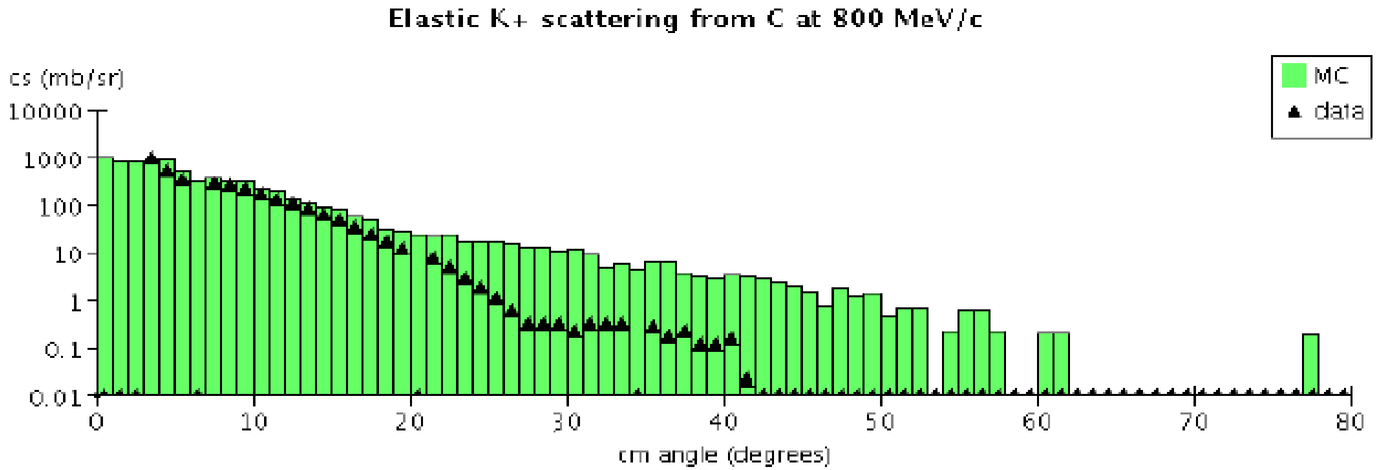
- The LEP and HEP models are valid for p, n, π, Κ, Λ, Σ, Ξ, Ω, α, t, d
  - LEP valid for incident energies of 0 – ~30 GeV
  - HEP valid for incident energies of ~10 GeV – 15 TeV
- Invocation sequence

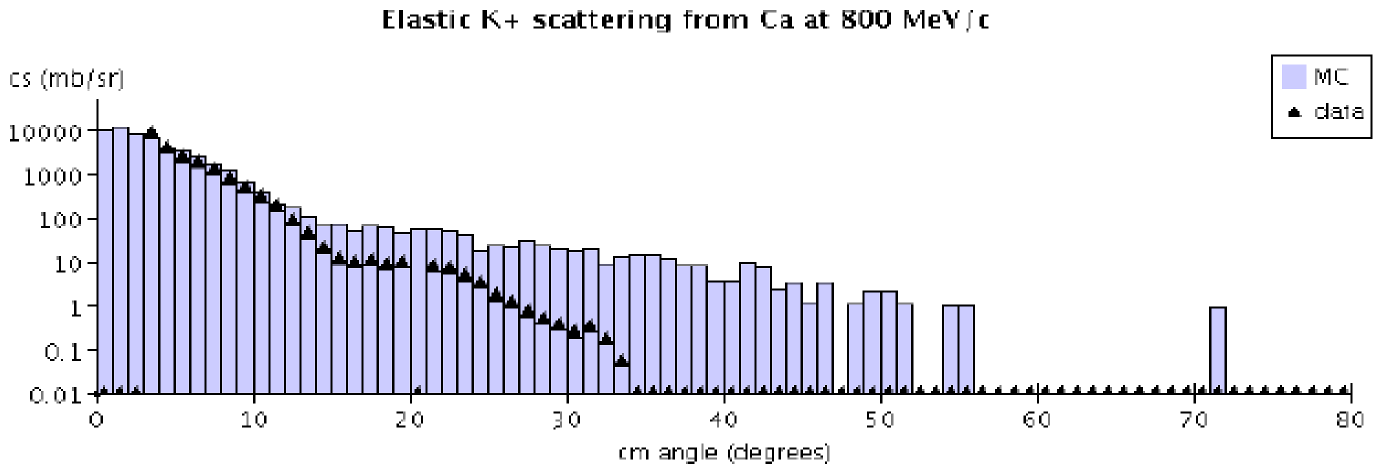
```
G4ProtonInelasticProcess* pproc = new
G4ProtonInelasticProcess();
G4LEProtonInelastic* LEproton = new G4LEProtonInelastic();
pproc -> RegisterMe(LEproton);
G4HEProtonInelastic* HEproton = new G4HEProtonInelastic();
HEproton -> SetMinEnergy(20*GeV);
pproc -> RegisterMe(HEproton);
proton_manager -> AddDiscreteProcess(pproc);
```

Hadron Elastic Scattering

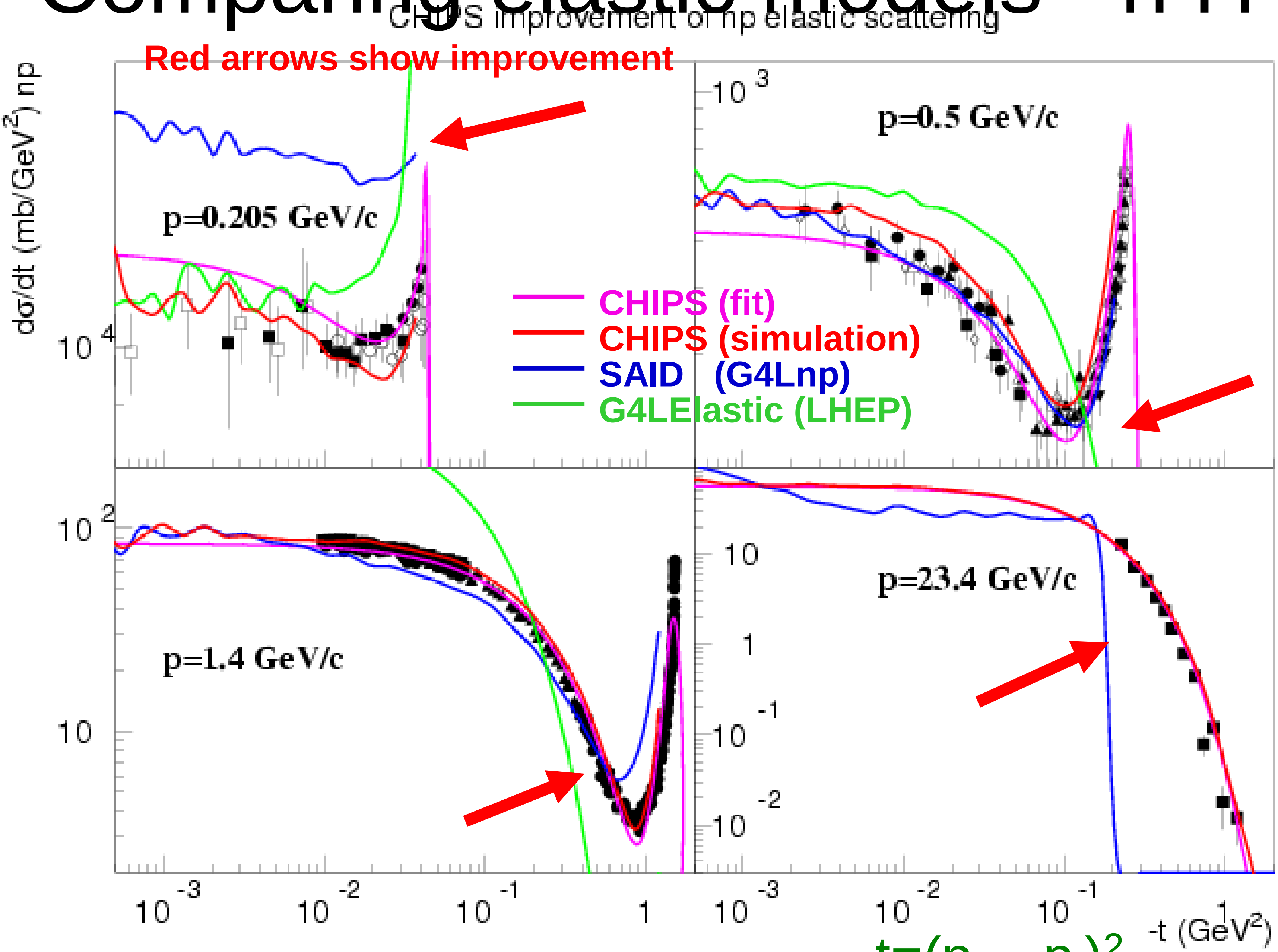
- GHEISHA-style (G4LElastic)
  - classical scattering (not all relativistic)
  - simple parameterization of cross section, angular distribution
  - can be used for all long-lived hadron projectiles, all energies
- Coherent elastic
  - G4LEpp for (p,p), (n,n) : taken from detailed phase-shift analysis, good up to 1.2 GeV
  - G4LEnp for (n,p) : same as above
  - G4HadronElastic for (h,A) : nuclear model details included as well as interference effects, good for 1 GeV and above, all long-lived hadrons
  - G4QElastic for (p,A), (n,A) : parameterization of experimental data (M.Kossov), part of CHIPS modeling

Elastic Scattering Validation (G4LElastic)





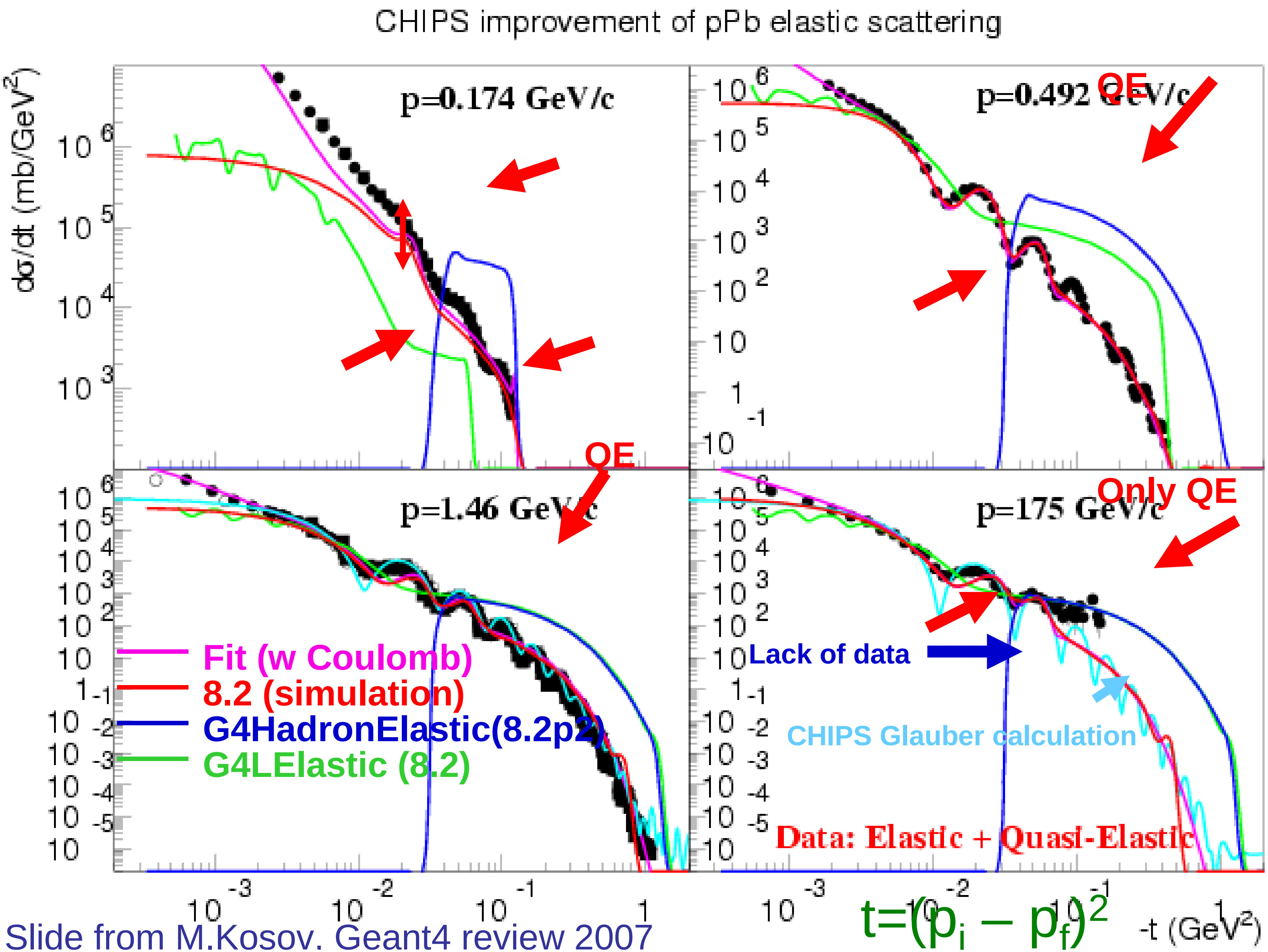
Comparing elastic models - n H



$t=(p_i - p_f)^2$

Slide from M.Kosov. Geant4 review 2007

Comparing elastic models - p Pb



$t=(p_i - p_f)^2$

Slide from M.Kosov. Geant4 review 2007

Summary (1)

- Geant4 hadronic physics allows user to choose how a physics process should be implemented:
  - cross sections
  - models
- Many processes, models and cross sections to choose from
  - hadronic framework makes it easier for users to add more

Summary (2)

- Parameterized models (LEP, HEP) handle the most particle types over the largest energy range
  - based on fits to data and some theory
  - not very detailed
  - fast
- Two main types of elastic scattering are available:
  - GHEISHA-style
  - Coherent (under development)
- Cascade models (Bertini, Binary) are valid for fewer particles over a smaller energy range
  - more theory-based
  - more detailed
  - Slower
- Precompound models are available for low energy nucleon projectiles and nuclear de-excitation