Hadronic Models and Validation

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- Overview
- Hadronic models
- Model validation
- Plans and Conclusions

Overview of Hadronic Validation (1)

- Hadronic model validation required by BaBar
  - Energy range of interest: ~50 MeV to ~3 GeV
  - Particles: p, n, π, K + anti-particles

- This energy range also useful for calorimetry in LC detectors
  - Difficult energy range:
    - Many resonances
    - Theoretically messy
    - Not typically covered by low energy models
    - Not covered by high energy models

Overview of Hadronic Validation (2)

- Until December 2002, only one model, LEP (aka GHEISHA), covered this range
- Now three more models (for some particles)
  - Binary cascade
  - Bertini cascade
  - JQMD
- All require extension, validation. Bug fixes required for some

LEP Model (1)

- Energy, angle, multiplicity distributions based on parameterizations of experimental data

- Aims to get average quantities right – conservation rules generally don't apply event-by-event

- Not designed for low energies (but used anyway)
- No modeling of nucleus

- Fast
- Applicable to all long-lived hadrons (T < 25 GeV)

LEP Model (2)

- Problems:
  - Bugs, many shortcomings
  - Reported to Geant4 by R. Cassell, G. Bower, D. Wright, some (but not all) fixes included in V5.0, 5.1
- Solutions:
  - Replace with new models where appropriate
  - If no new model for given particle, implement fixes

Binary Cascade Model

- Projectile is propagated through 3-D model of nucleus

- Only two-particle collisions are allowed
- Conservation laws observed

- Secondaries produced by decay of resonances and propagated to next collision

- 4 X slower than LEP
- Valid only for p, n (40 MeV < T < 10 GeV)

Bertini Cascade Model

- Nucleus treated as average nuclear medium

- Final state of each collision taken from cross section data
- Conservation laws observed

- Secondaries propagated to next collision

- 2-3 X slower than LEP
- Valid for p, n, π (100 MeV < T < 5 GeV)

Other Models

- JQMD (JAERI Quantum Molecular Dynamics)
- Geant4 interface to Fortran code by T. Koi
- Projectile propagated in field of nucleus, interacts with every nucleon in target

- Speed increases rapidly with A
  - 20 X LEP for C
  - 3300 X LEP for Pb

Validation Test Suite (1)

- Thin target (2-4 mm), pencil beam
- Allow only one interaction per event

- Look at final state particles at production vertex
- Only hadronic and transportation processes used

- Implement as simple Geant4 (5.0) example using JAIDA

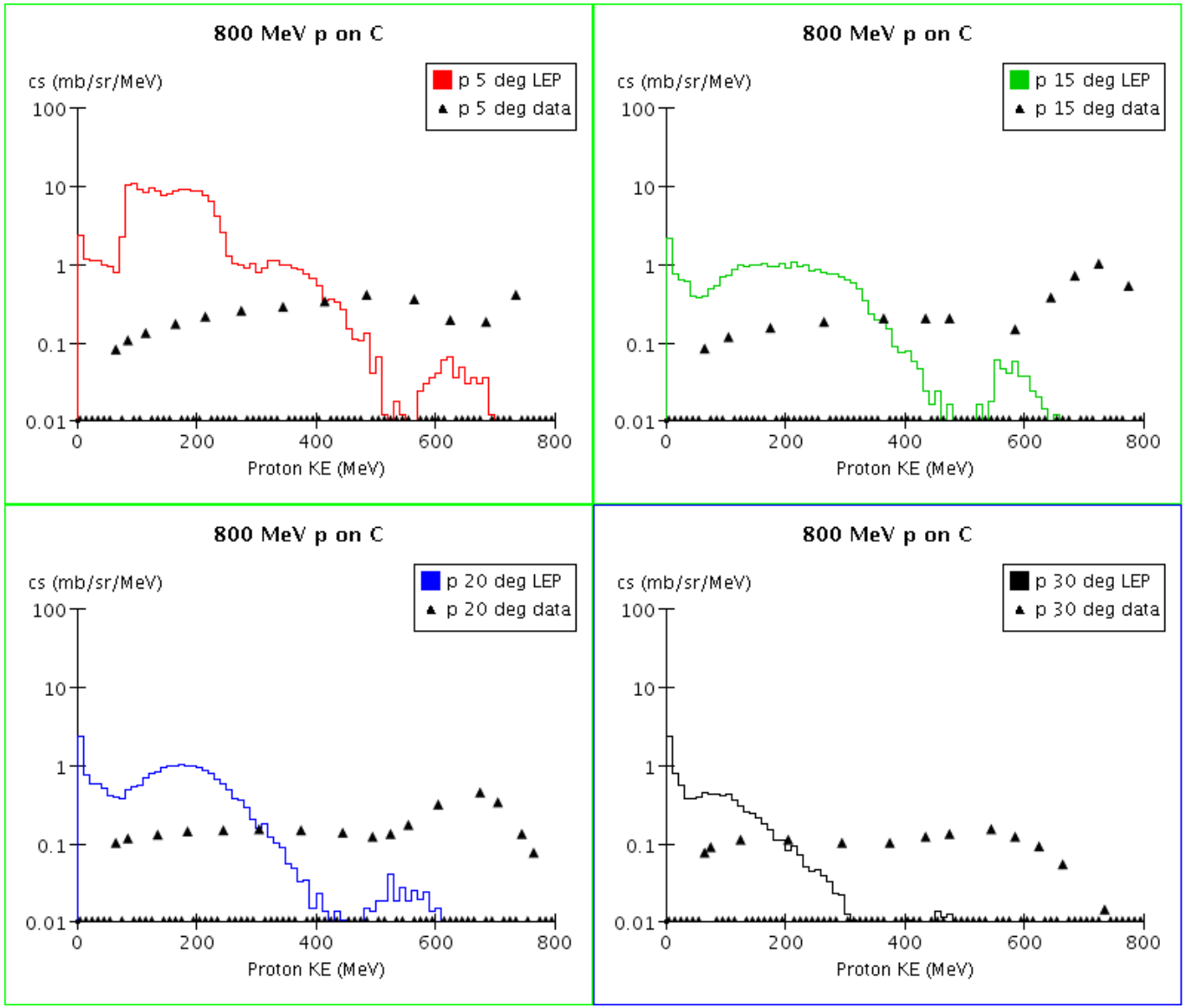
Validation Test Suite (2)

- Look at energy, angle spectra of final state p, π from 730, 800 MeV incident p (typical BaBar hadron energies)
- Compare to (p,p') data of McGill (1984) and (p,p π) of Cochran (1972)
- Targets: C, Ca, Pb

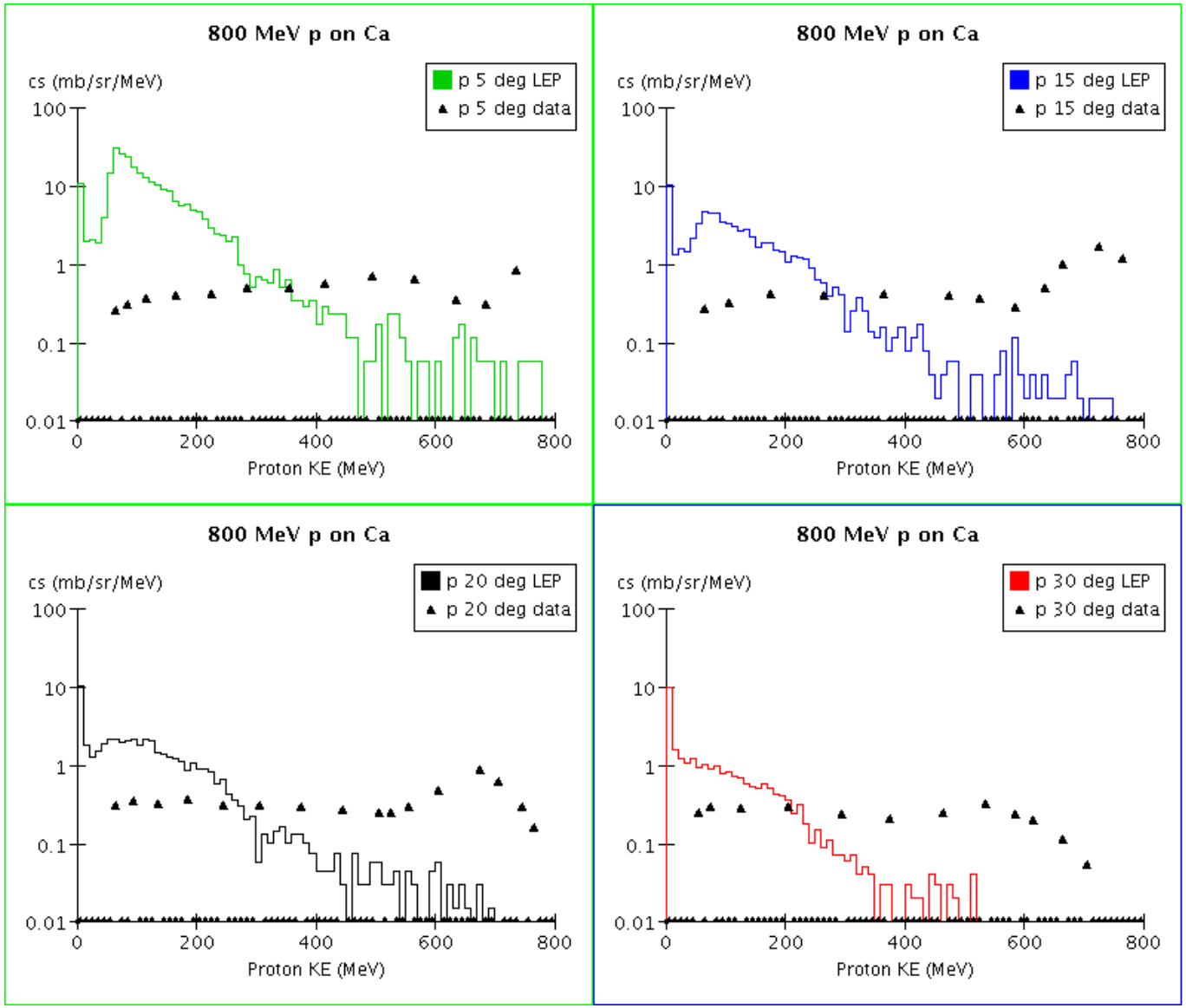
How To Invoke New Models

```
G4ProcessManager* pMan = G4Proton::Proton()->GetProcessManager();
G4ProtonInelasticProcess* theProtonInelProc = new G4PotonInelasticProcess();

G4BinaryCascade* theBinCascade = new G4BinaryCascade();
theBinCascade->SetMinEnergy(100.0*MeV);
theProtonInelProc->RgeisterMe(theBinCascade);

G4LEProtonInelastic* protonLEP = new G4LEProtonInelastic();
protonLEP->SetMaxEnergy(100.0*MeV);
theProtonInelProc->RegisterMe(protonLEP);

pMan->AddDiscreteProcess(theProtonInelProc);
```

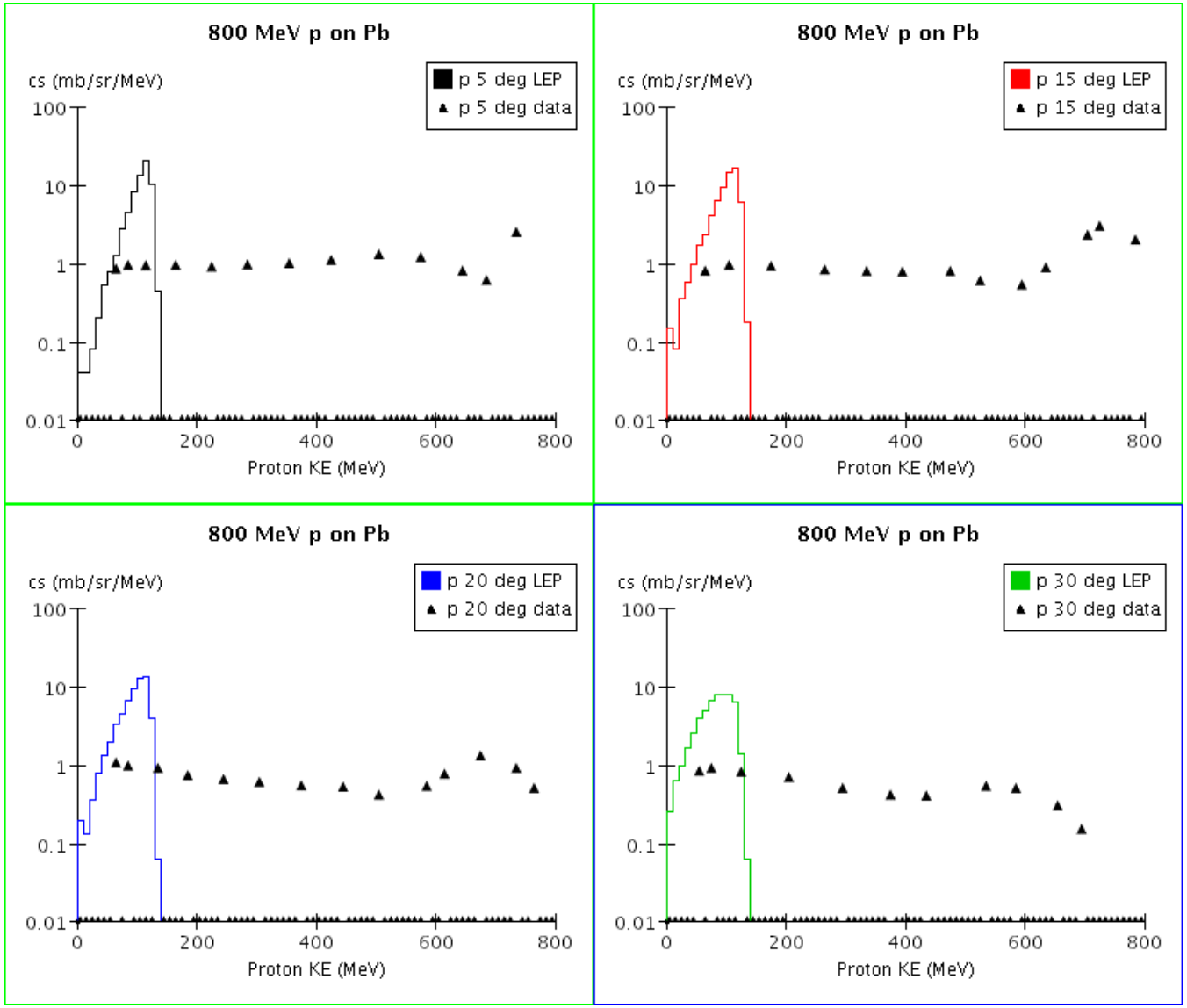
LEP Validation (1)



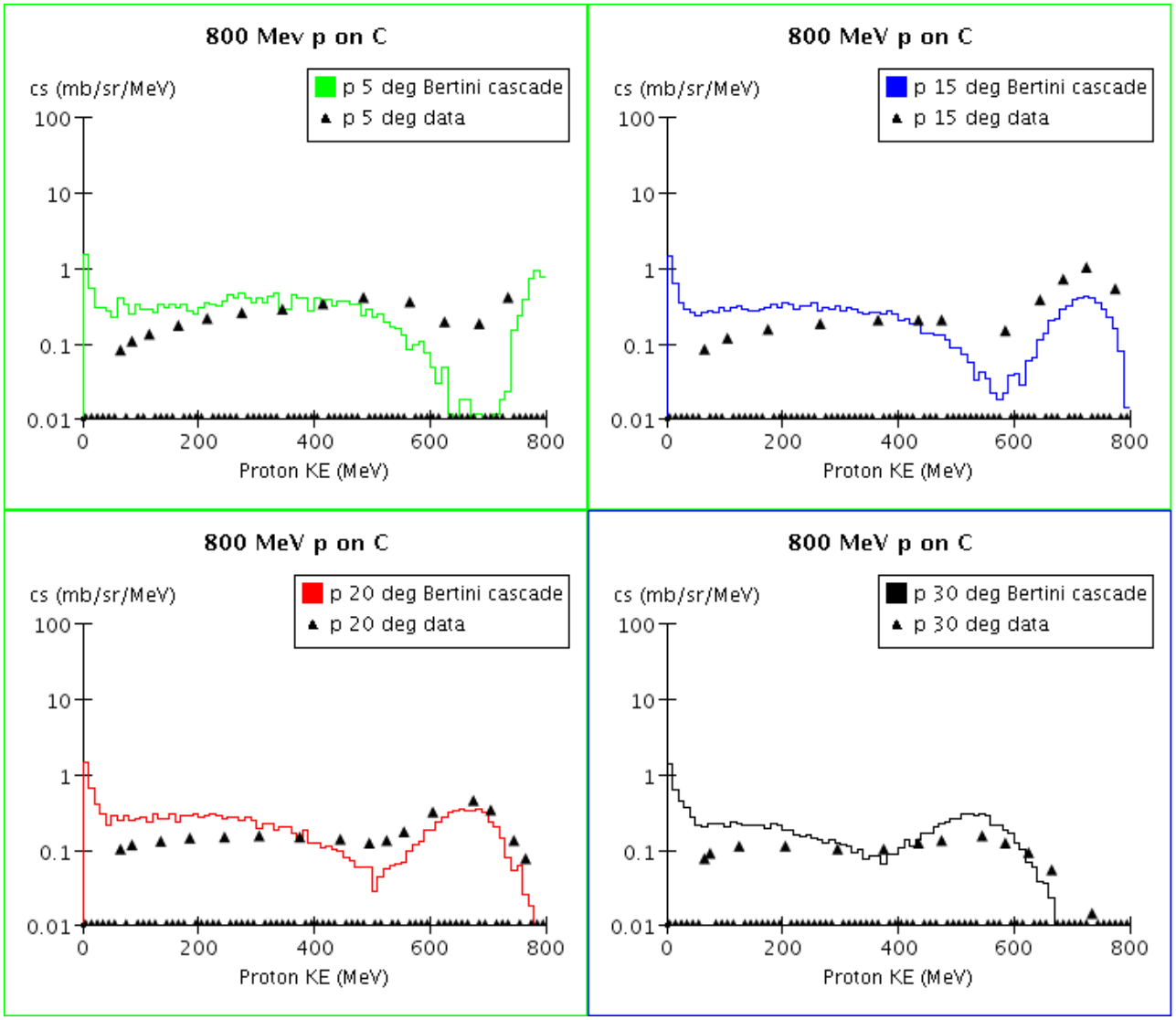
LEP Validation (2)



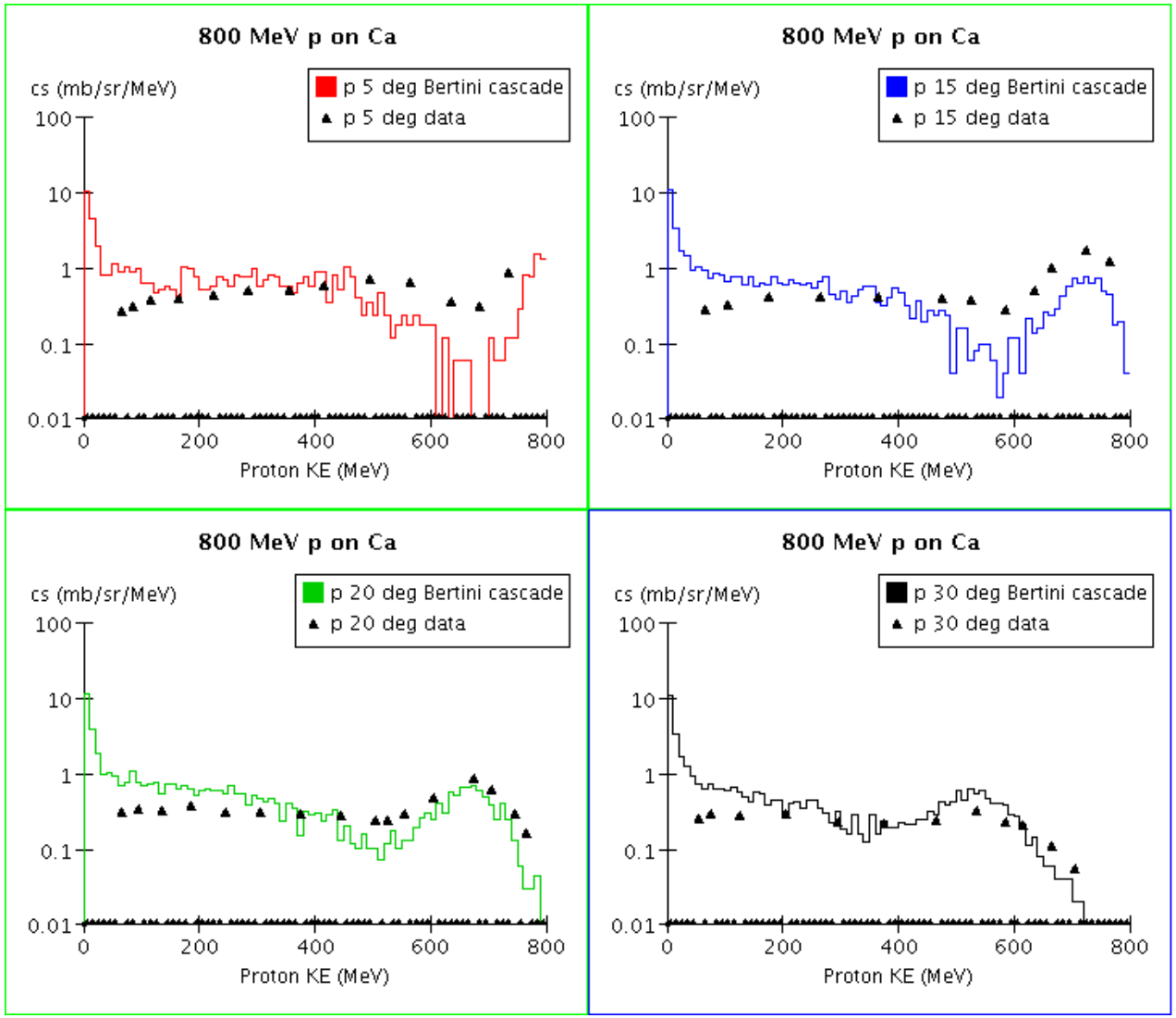
LEP Validation (3)



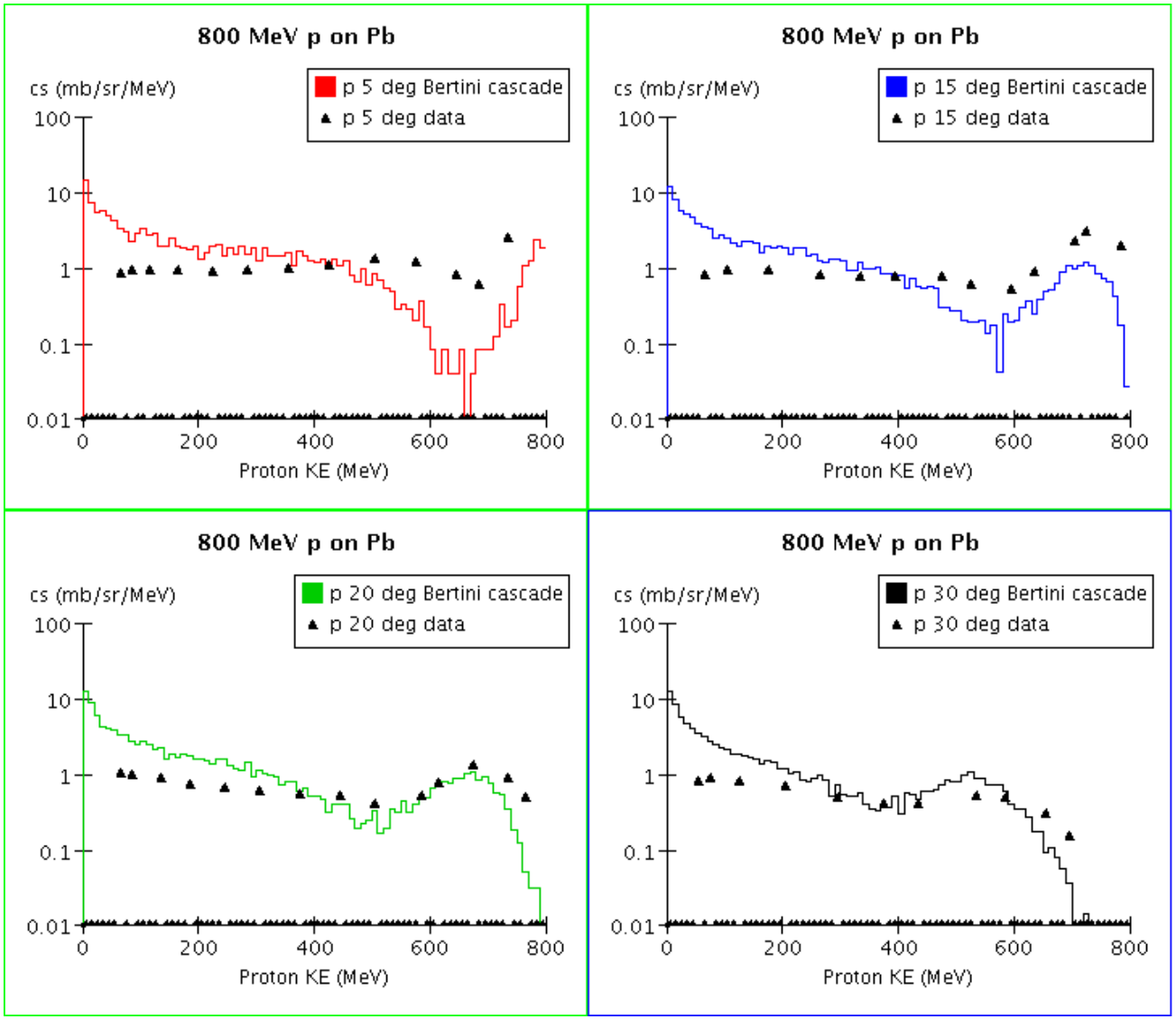
Bertini Cascade Validation (1)



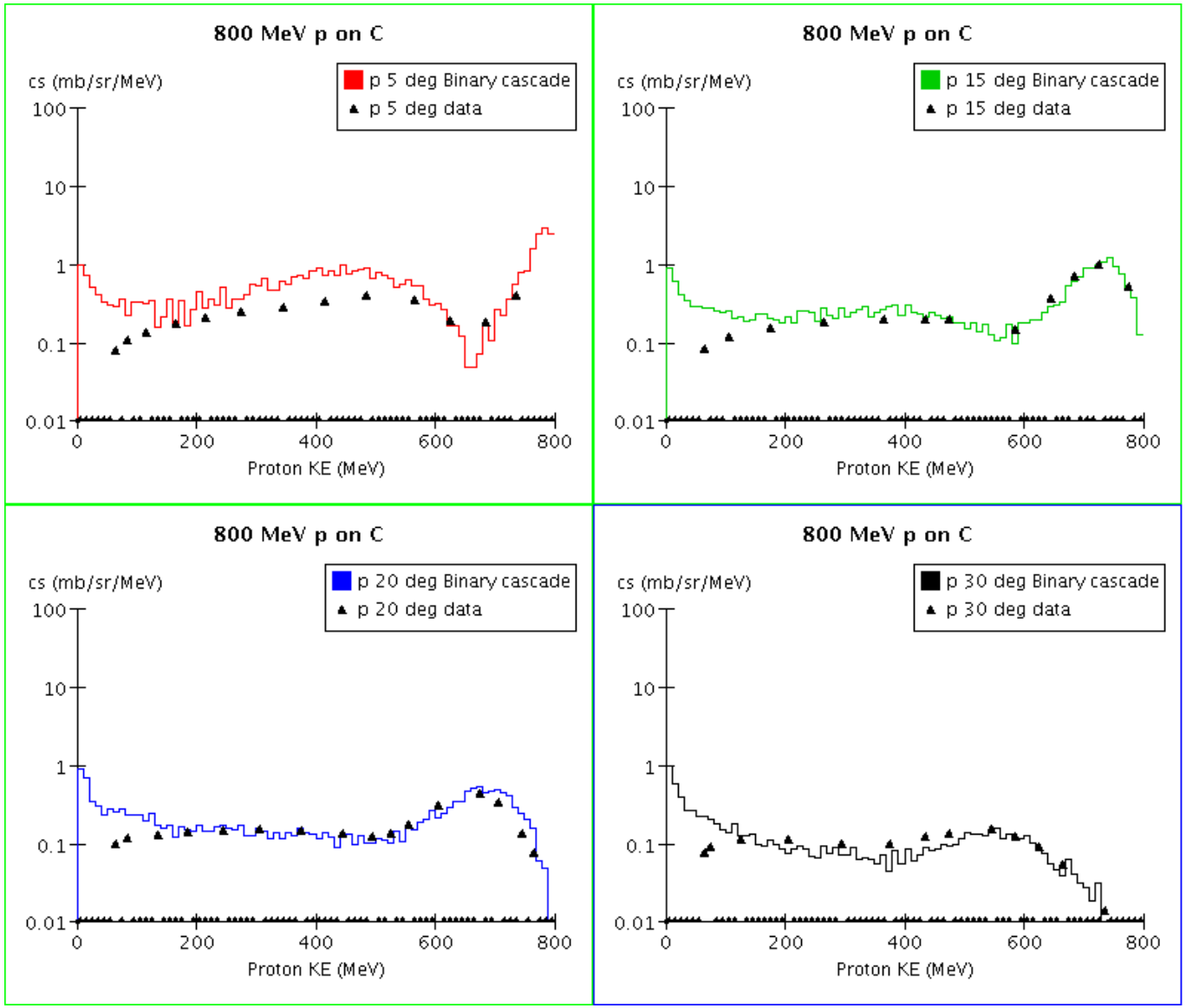
Bertini Cascade Validation (2)



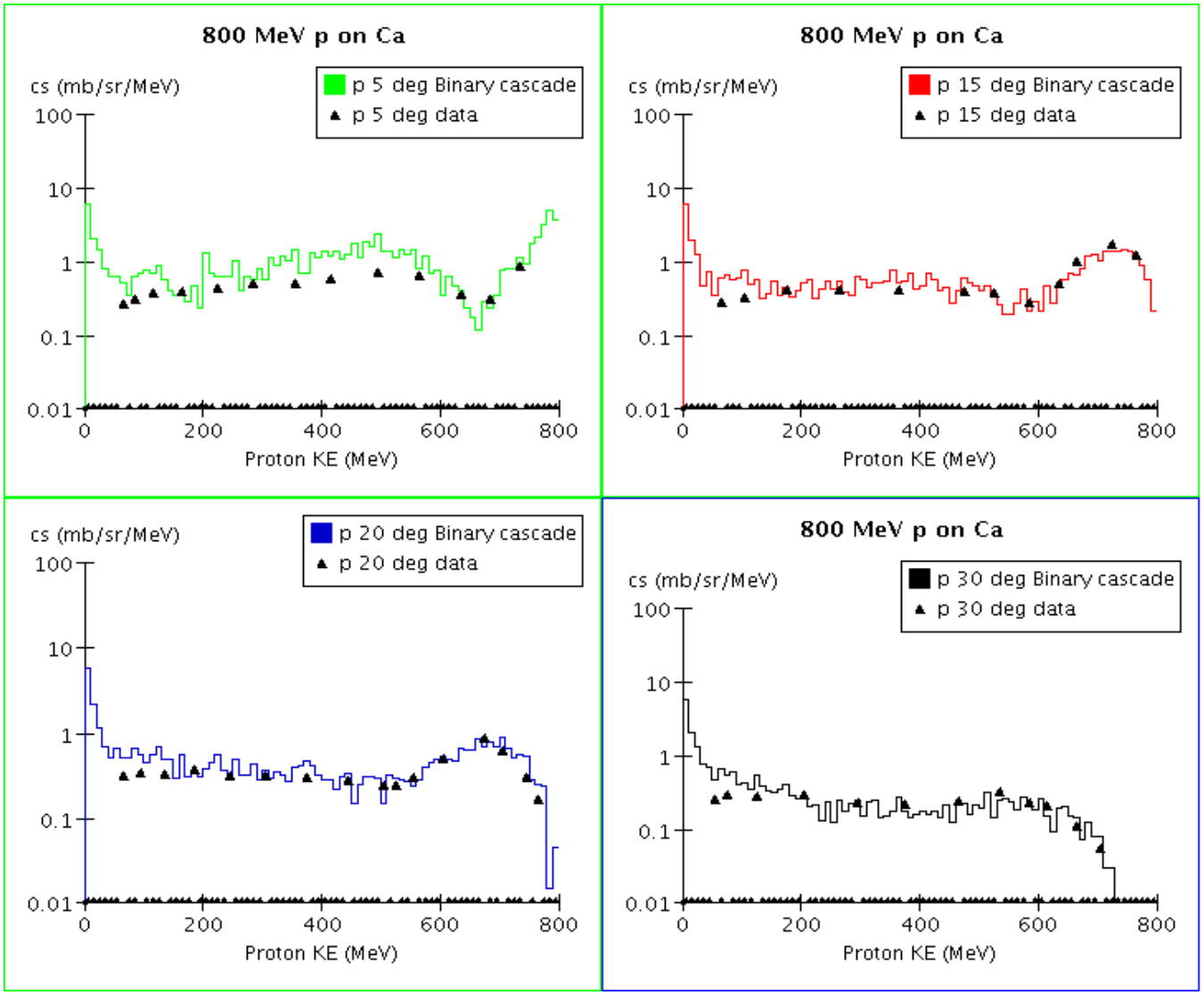
Bertini Cascade Validation (3)



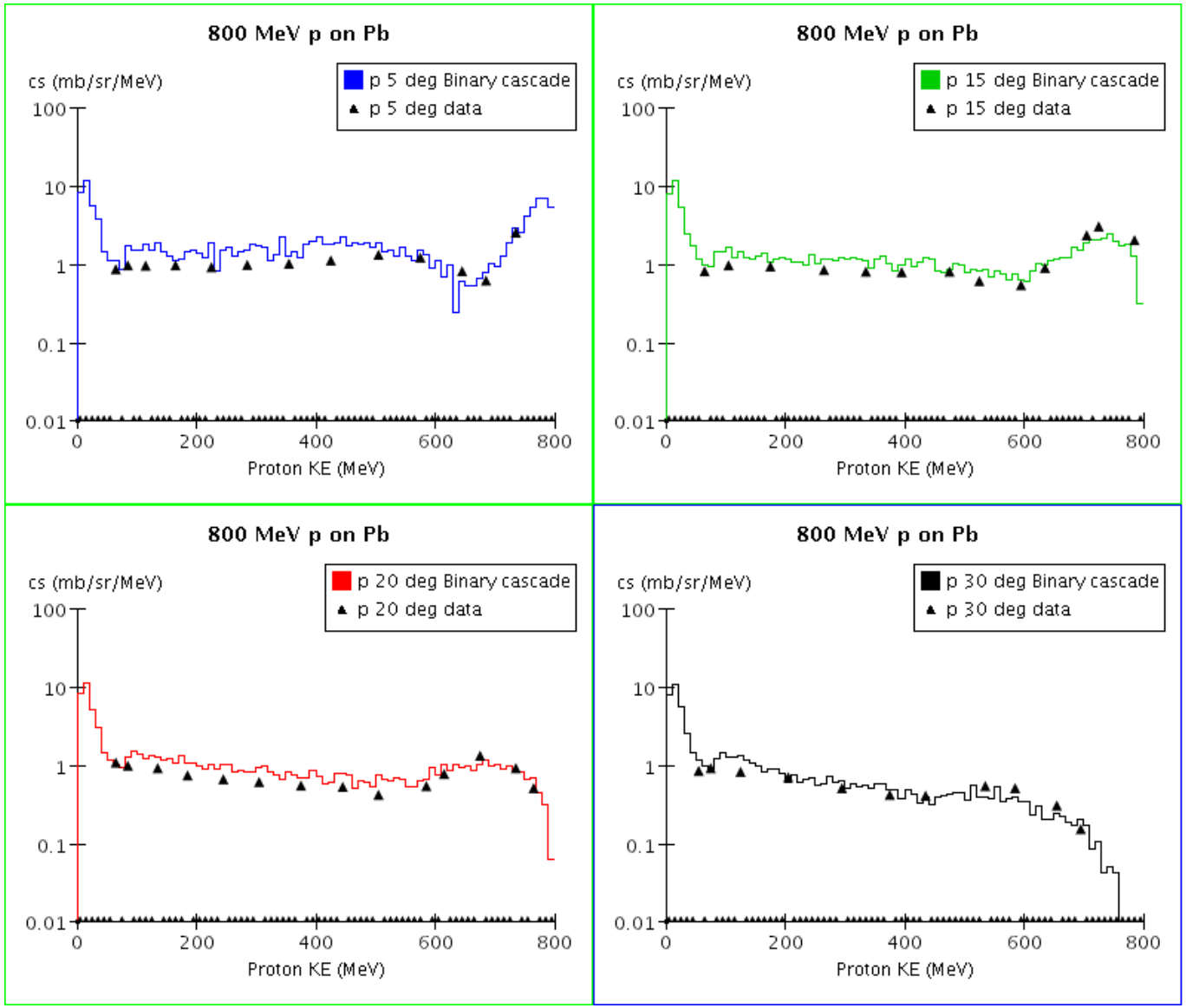
Binary Cascade Validation (1)



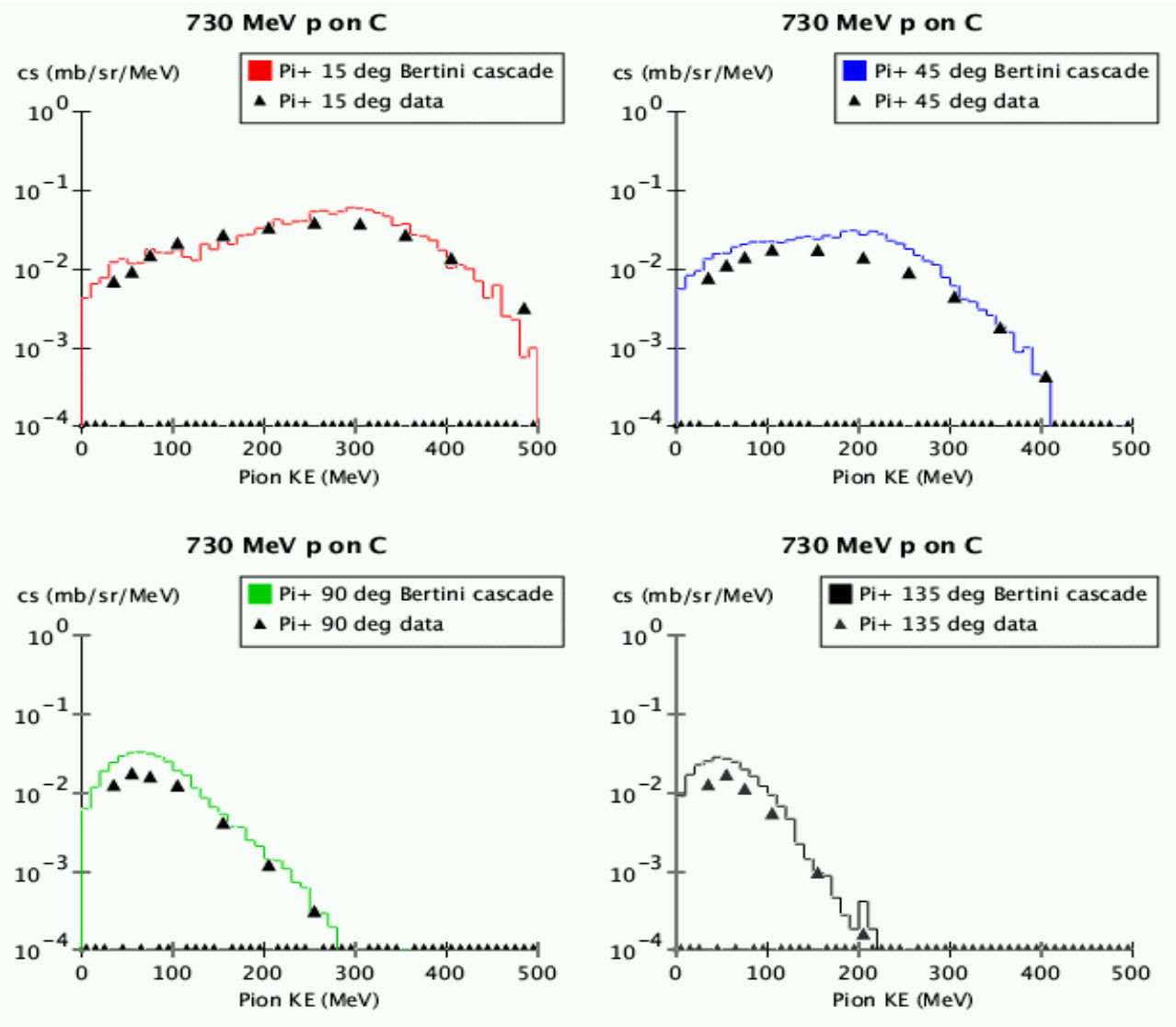
Binary Cascade Validation (2)



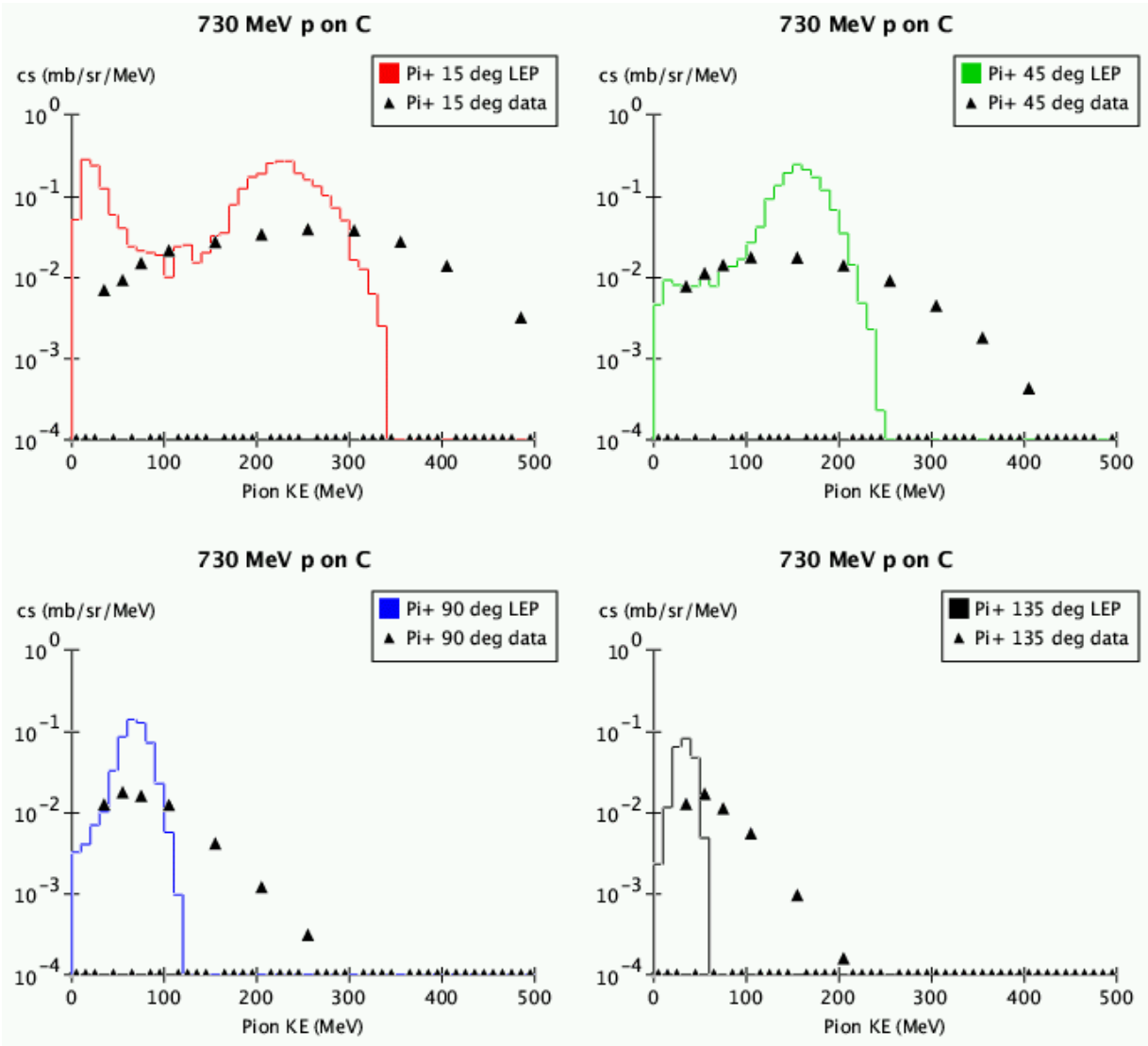
Binary Cascade Validation (3)



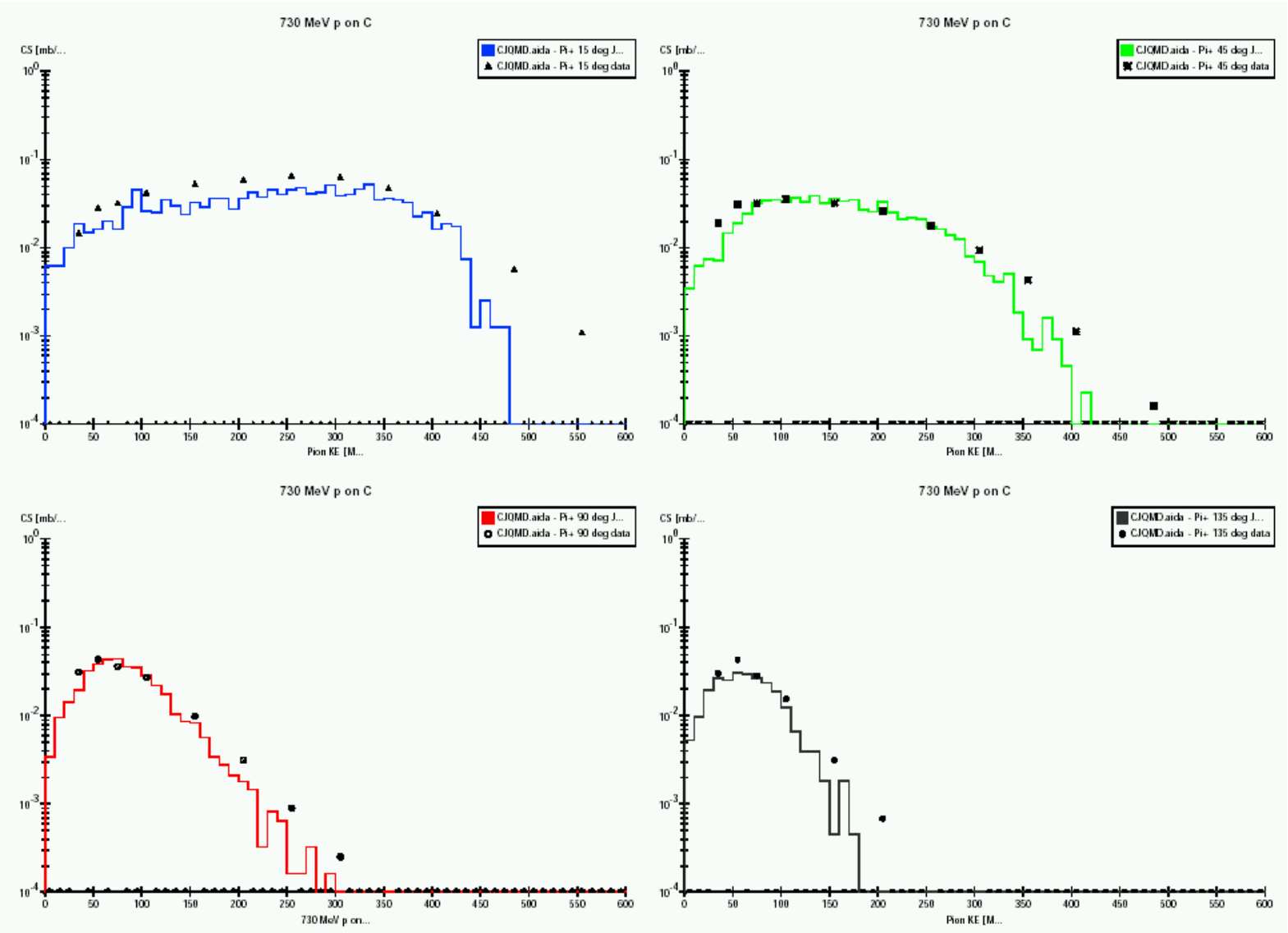
Pion ProductionValidation (1)



Pion ProductionValidation (2)



Pion Production Validation (3)



Plans

- Much more thin target validation to be done in this energy range
  - Lower and higher energies
  - n, π, K projectiles
- Use BaBar data for validation
  - So far, not easy to see model differences
  - Still looking for clean tests
  - Test beam data at these energies would be great

Conclusions

New hadronic models now available in Geant4

- Bertini cascade, binary cascade, JQMD
- For energy range 50 MeV – 5 GeV
- Not yet available for all hadrons

- Validation tests are in progress (turning the crank)

- Early result: LEP model should be replaced wherever possible, but repairs should continue

- Plan to include new hadronic processes in next version of BaBar simulation production