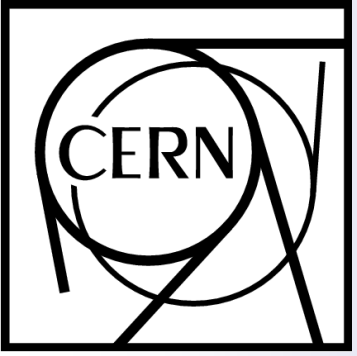


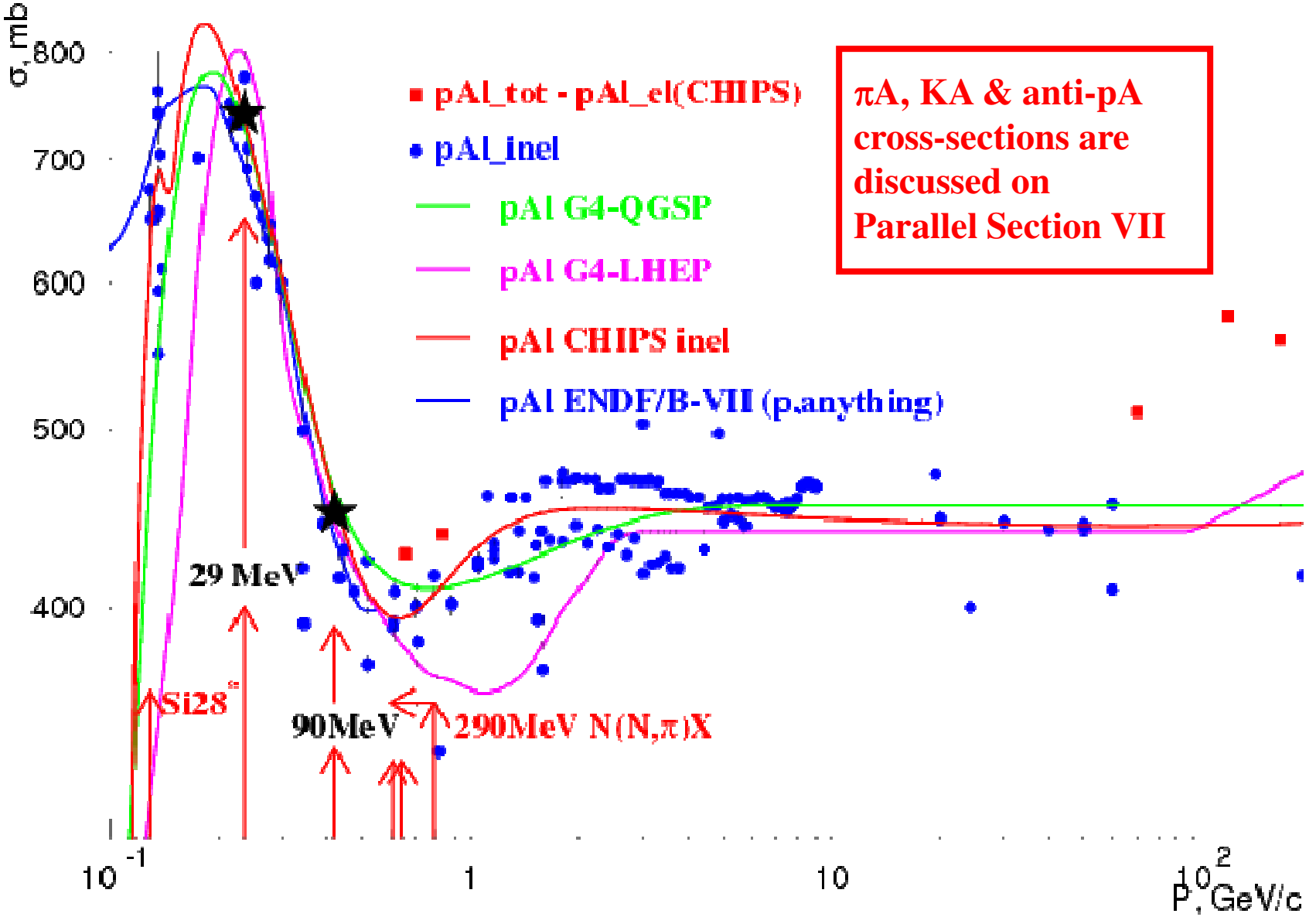
One model CHIPS physics lists (under development)

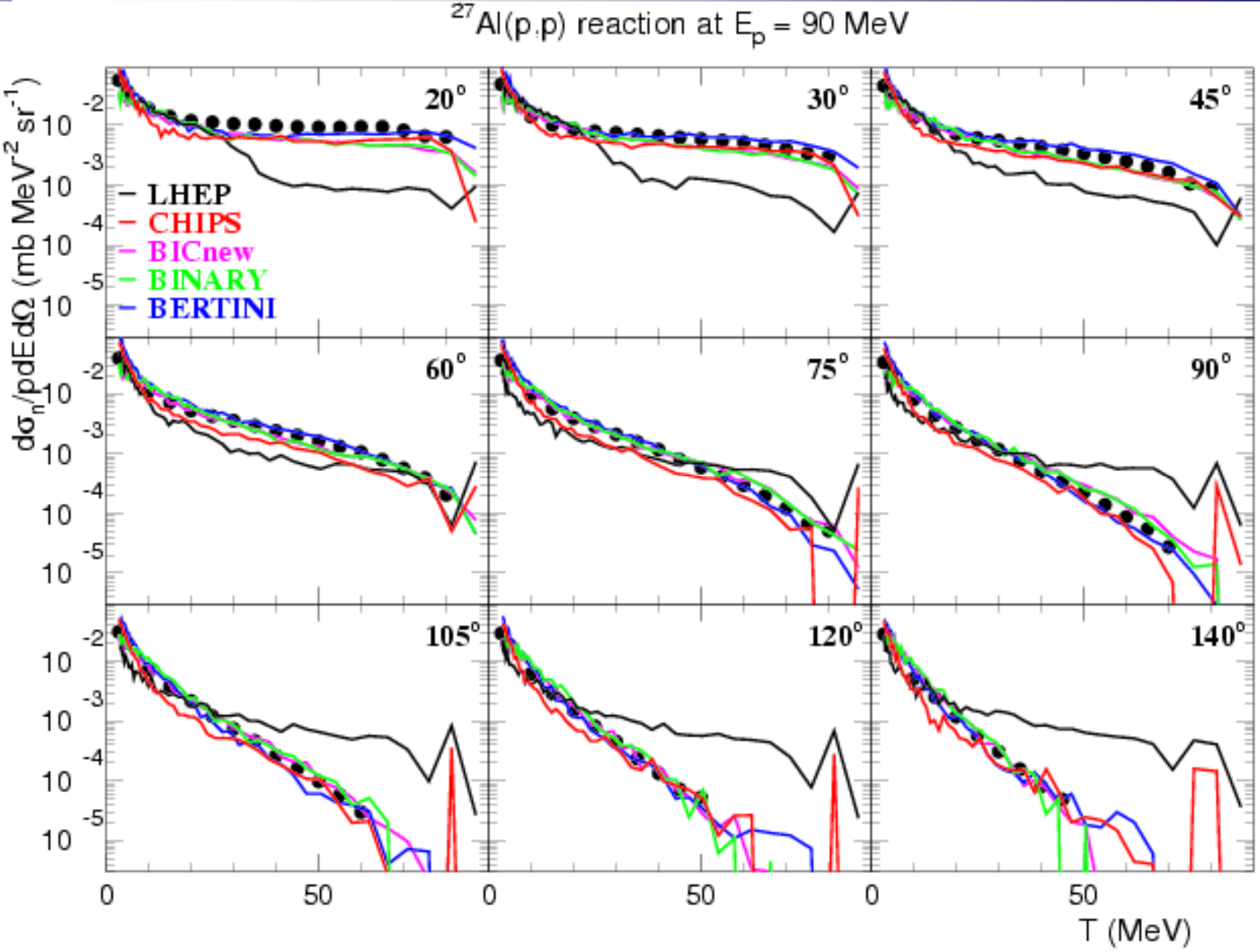
Mikhail Kosov, 14th Geant4 Users and Collaboration Workshop, 2009

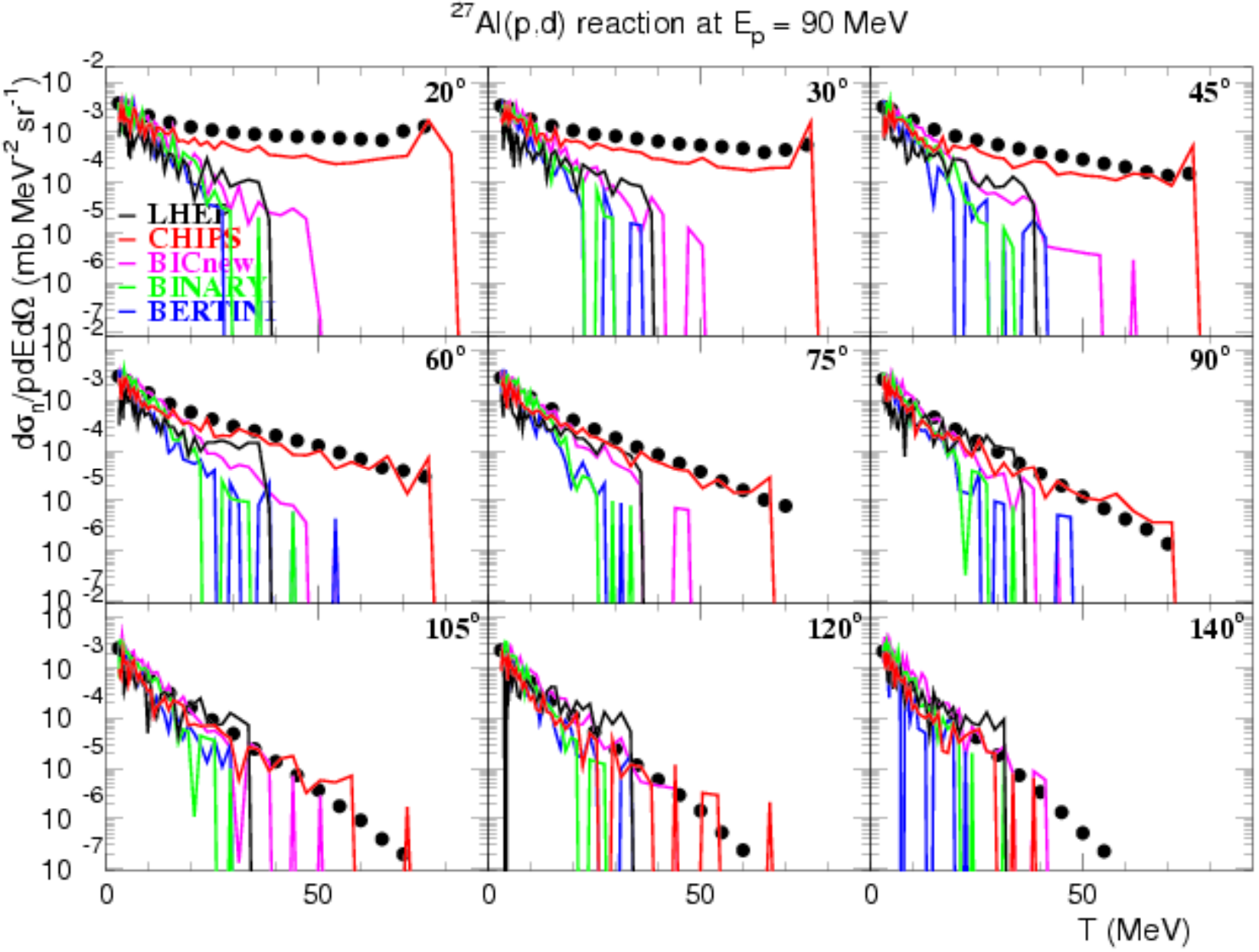
Introduction (history of QGSC_CHIPS)

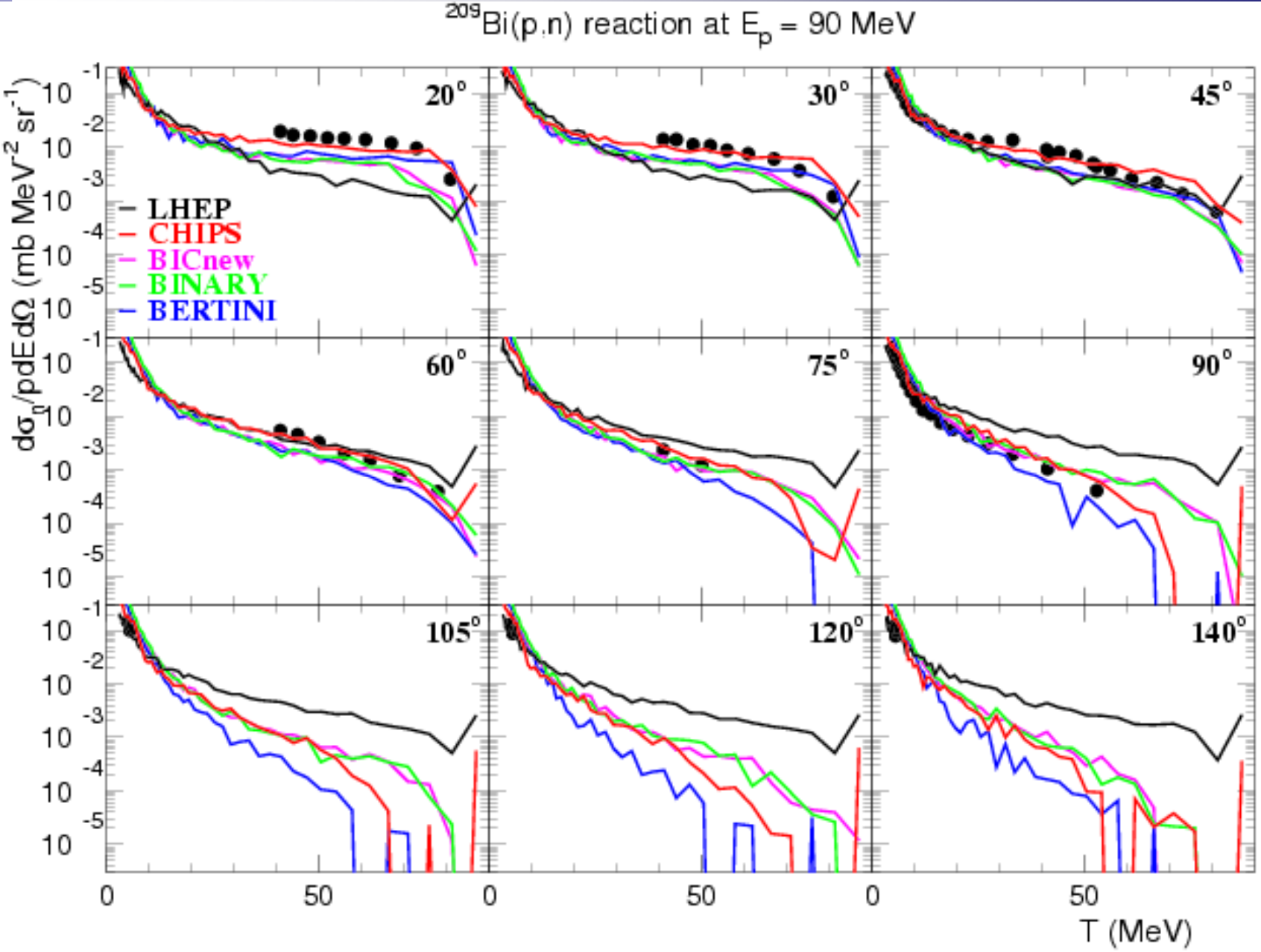
- Creation of the new QGSC_CHIPS physics list:
  - General intention to get rid of the temporary LHEP package
  - Planned implementation of the pure CHIPS physics list
  - From existing interaction cross-sections to new CHIPS XS
- Temporary usage of the QGSC extended to E=0.
  - Corrections, which let to use the QGSC model from E=0 for all particles using it as an interface to the CHIPS nuclear reactions
  - Creation of the G4QDiscProcessMixer process, which lets to combine QGSC (G4Had) and G4QCollision (CHIPS) processes
  - Significant progress in CHIPS simulation of low energy pA/nA reactions & improvement of the nA interaction cross-sections
- The main goal: create a physics list without model mixing

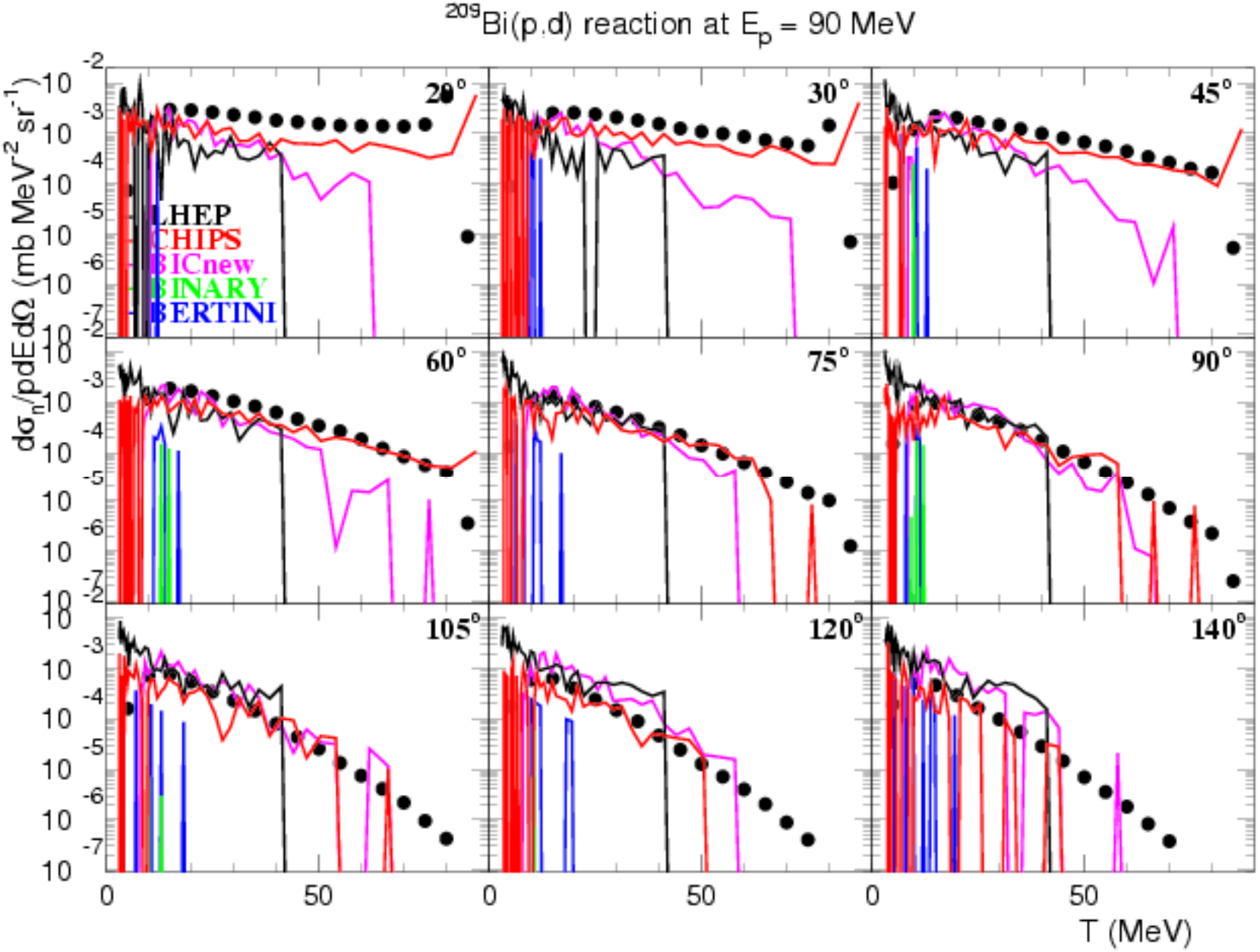
CHIPS improvement of pAl inelastic cross-section




^{27}Al(p,p) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI
T (MeV)


^{27}Al(p,d) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI
0
50
T (MeV)


209Bi(p,n) reaction at Ep = 90 MeV
dσn/pdEdΩ (mb MeV-2 sr-1)
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI
0
50
T (MeV)


209Bi(p,d) reaction at Ep = 90 MeV
dσn/pdEdΩ (mb MeV-2 sr-1)
T (MeV)
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI

Simulation is made using the test49 tool (Plenary Section VI) with specific CHIPS parameters

Time performance for 29 MeV and 90 MeV protons

protons 29 MeV (2009)

Model	Al	Au
PreCom	1.5	4.4
Binary	1.9	4.7
Bertini	0.40	0.42
CHIPS	2.7	2.8
LHEP	0.06	0.07
QLowE	0.10	0.10

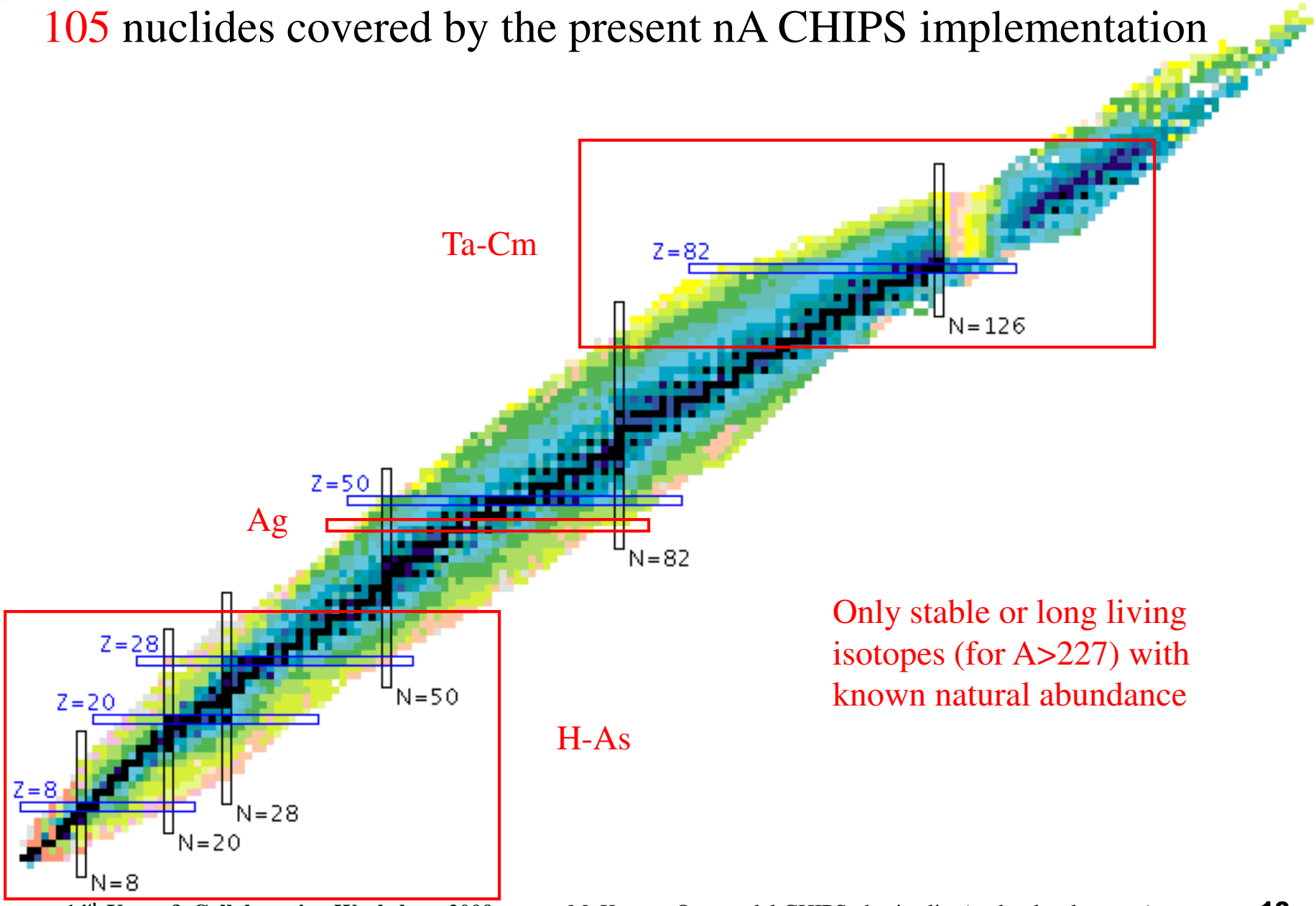
protons 90 MeV (2009)

Model	Al	Bi
PreCom	2.2	5.2
Binary	3.1	8.2
Bertini	0.48	0.62
CHIPS	2.5	3.1
LHEP	0.10	0.11
QLowE	0.12	0.14

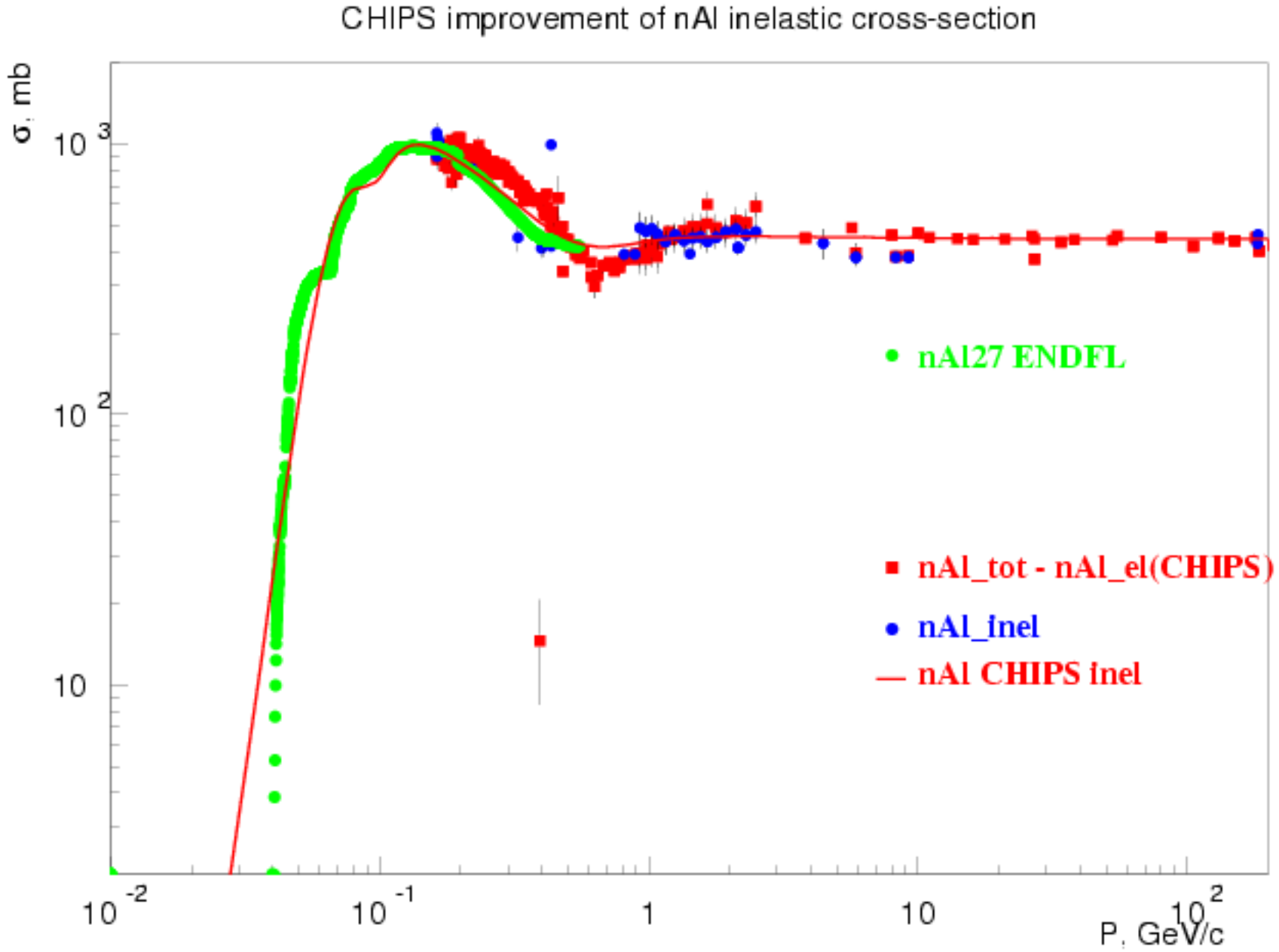
Parameterization of σ_{in} for nA interactions

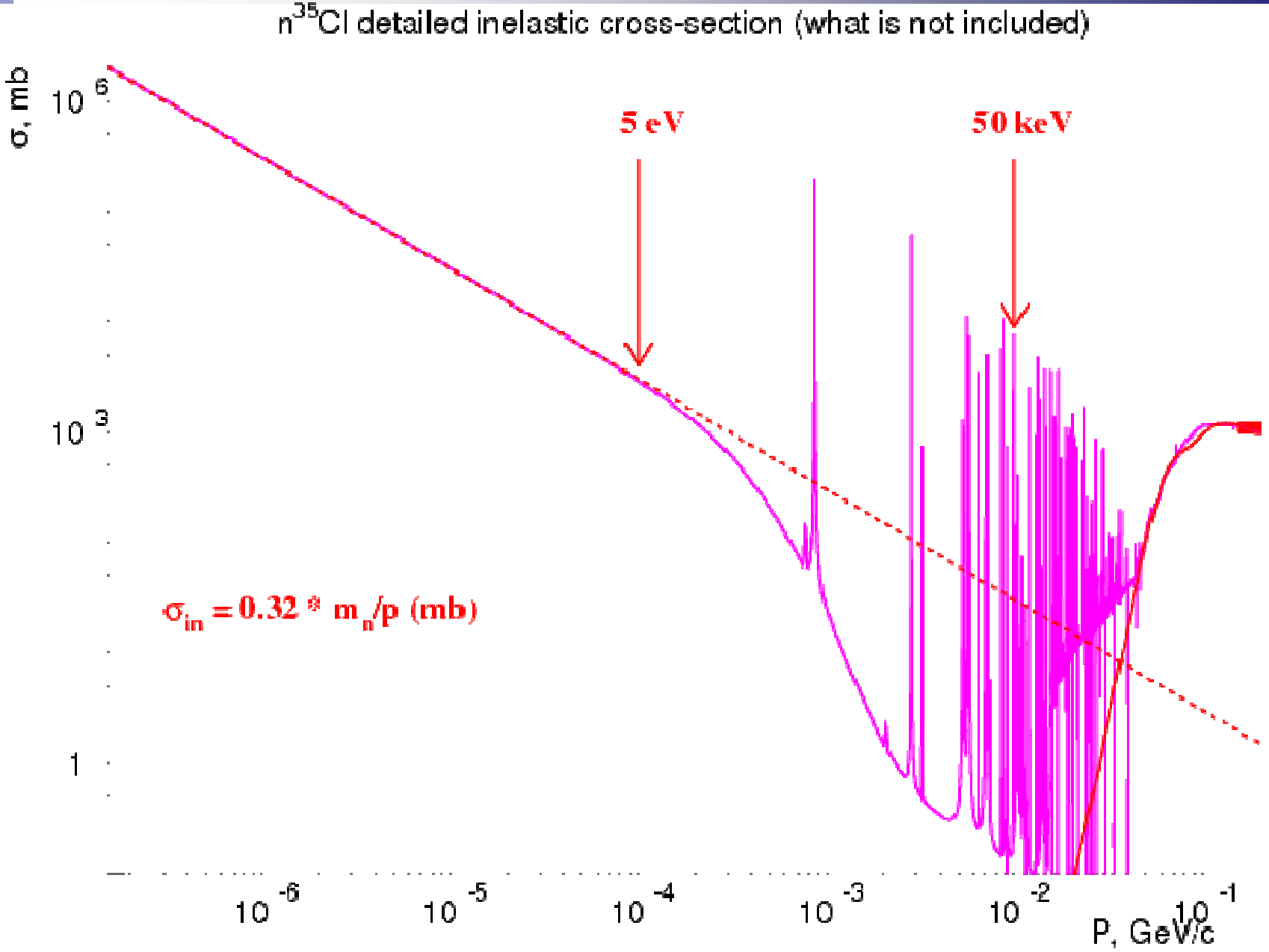
- Inelastic cross-sections must be accurately parameterized especially at low energies
  - There are big discrepancies between the low energy Barashenkov's parameterization & Low Energy DB parameterizations (like that used in HP)
  - The mean A approach for Elements (Z) does not work at low energies, because σ_{in}(nA) are very different for different isotopes
- The new CHIPS approximation
  - The high energy nA approximation is similar to the HE pA approximation
  - The main difference: only 13 isotopes have the absorption band for the pA interactions & the low energy nA absorption is big for almost all isotopes
  - The approximation is temporary and in future must be improved
  - The CHIPS nA elastic must be improved below 1.0 GeV for light nuclei
  - The approximation formula does not take into account the 1/v increase of the thermal interaction cross-sections. Cross-sections below 50 keV are ignored.

105 nuclides covered by the present nA CHIPS implementation



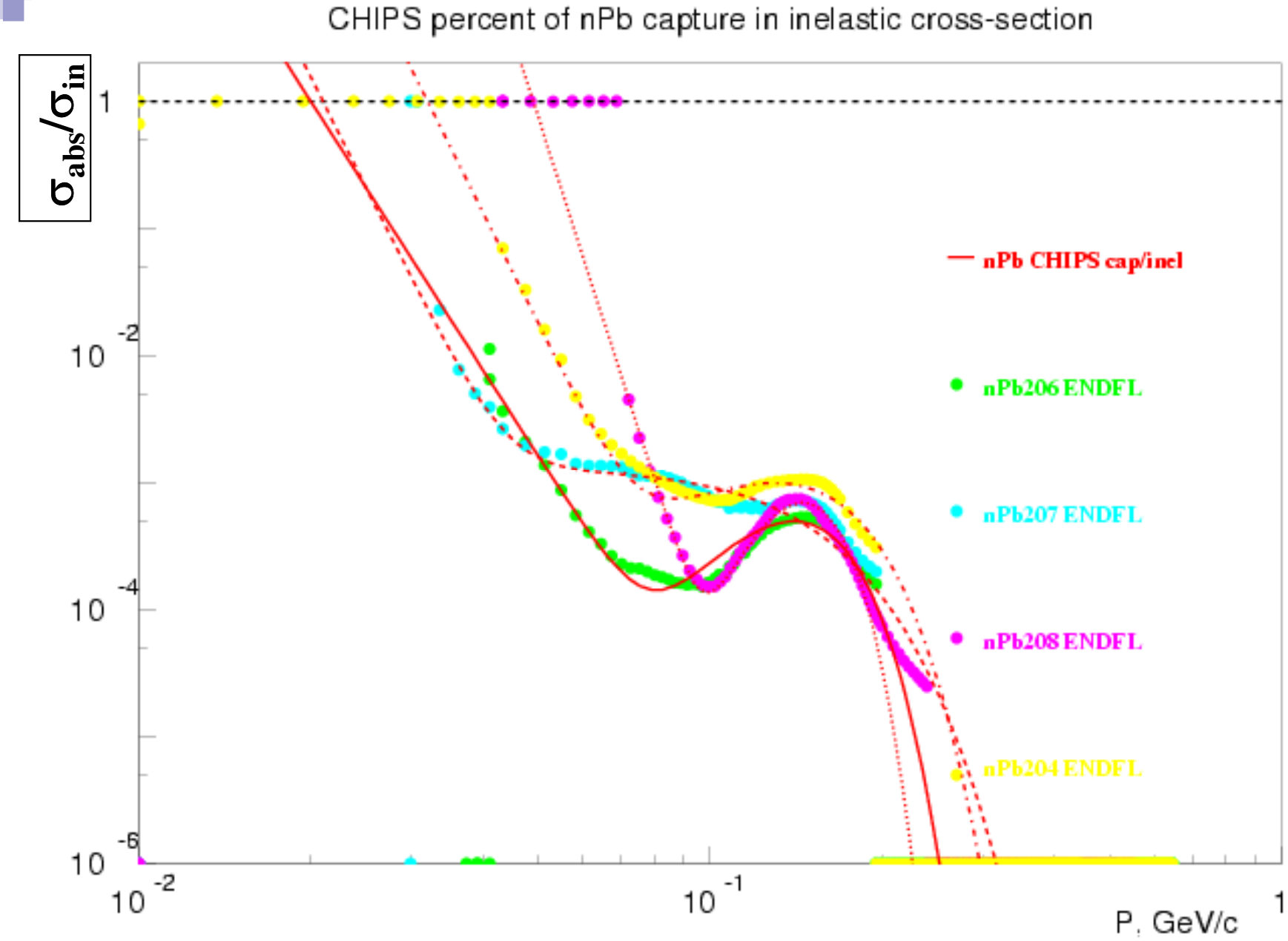
Only stable or long living isotopes (for A>227) with known natural abundance


CHIPS improvement of nAl inelastic cross-section
σ, mb
10 3
10 2
10
10 -2
10 -1
1
10
10 2
P, GeV/c
nAl27 ENDFL
nAl_tot - nAl_el(CHIPS)
nAl_inel
nAl CHIPS inel

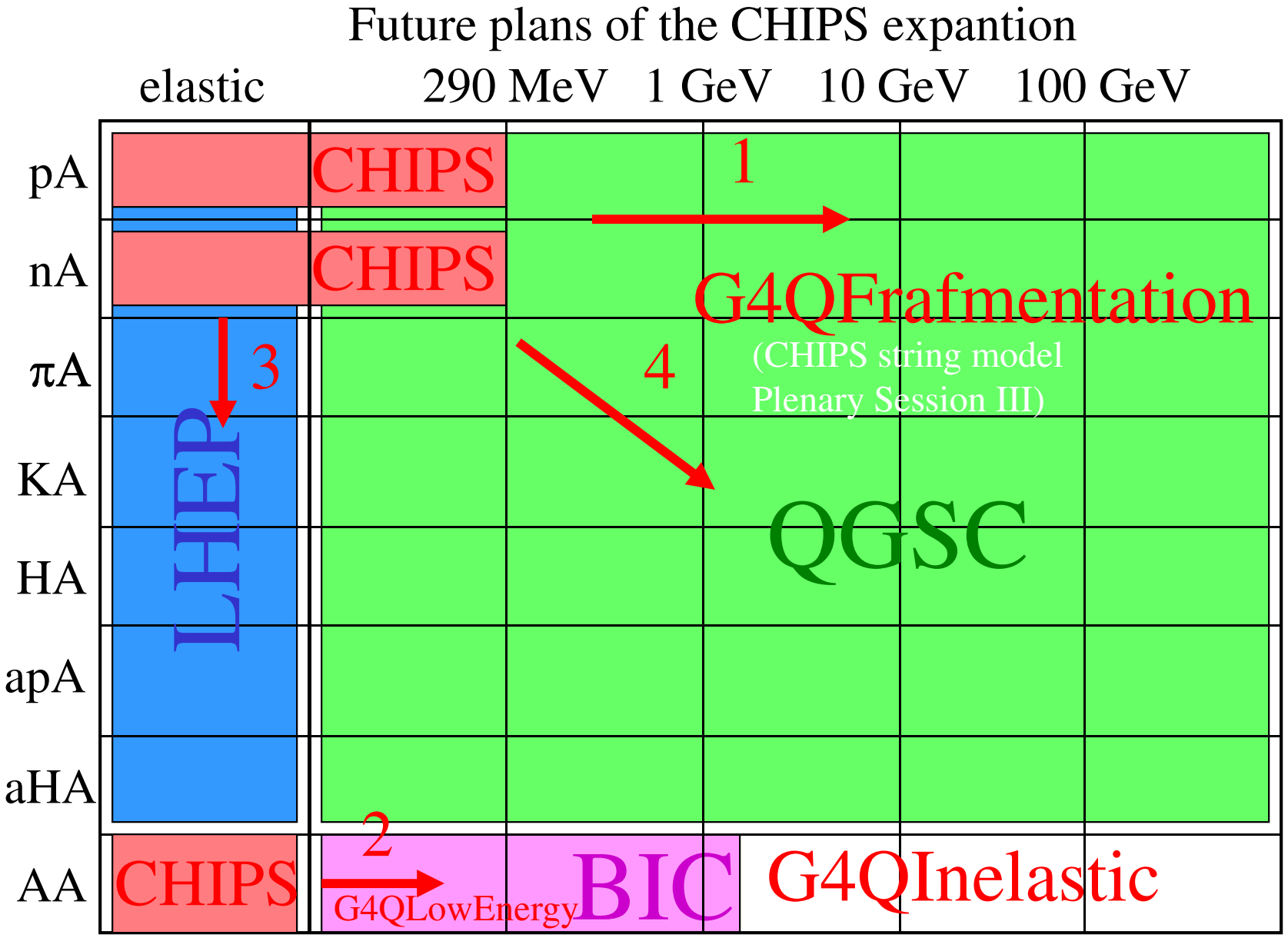

n35Cl detailed inelastic cross-section (what is not included)
σ, mb
10 6
10 3
1
5 eV
50 keV
σin = 0.32 * mn/p (mb)
10 -6
10 -5
10 -4
10 -3
10 -2
10 -1
P, GeV/c

Fit for the absorption contribution σ_{abs}/σ_{in}

- Only ENDF/B VII evaluation data are used
  - $R(p)=\sigma_{abs}/(\sigma_{tot}-\sigma_{el})=\sigma_{abs}/\sigma_{in}$
  - Approximation: $R(p)=(p/B)^{-D}+EXP[C-(p-M)^2/W]$ (if R>1: R=1)
  - The parameter "B" is a threshold of the non-absorption reaction
- Simulation
  - The binary isotropic (n,γ) reaction can be simulated rather fast
  - Simulation of A(n,fission) reactions for A>225 is possible (?)
  - The rest of inelastic reactions are simulated by CHIPS and the simulation is much slower than (n,γ), but…
  - at low energies a big part of the CHIPS simulation is quasi-elastic scattering on quasi-free nucleons and nuclear clusters, so the low energy simulation is expected to be fast enough.


CHIPS percent of nPb capture in inelastic cross-section
σabs/σin
1
10-2
10-4
10-6
10-2
10-1
1
P, GeV/c
nPb CHIPS cap/incl
nPb206 ENDFL
nPb207 ENDFL
nPb208 ENDFL
nPb204 ENDFL

Future plans of the CHIPS expantion



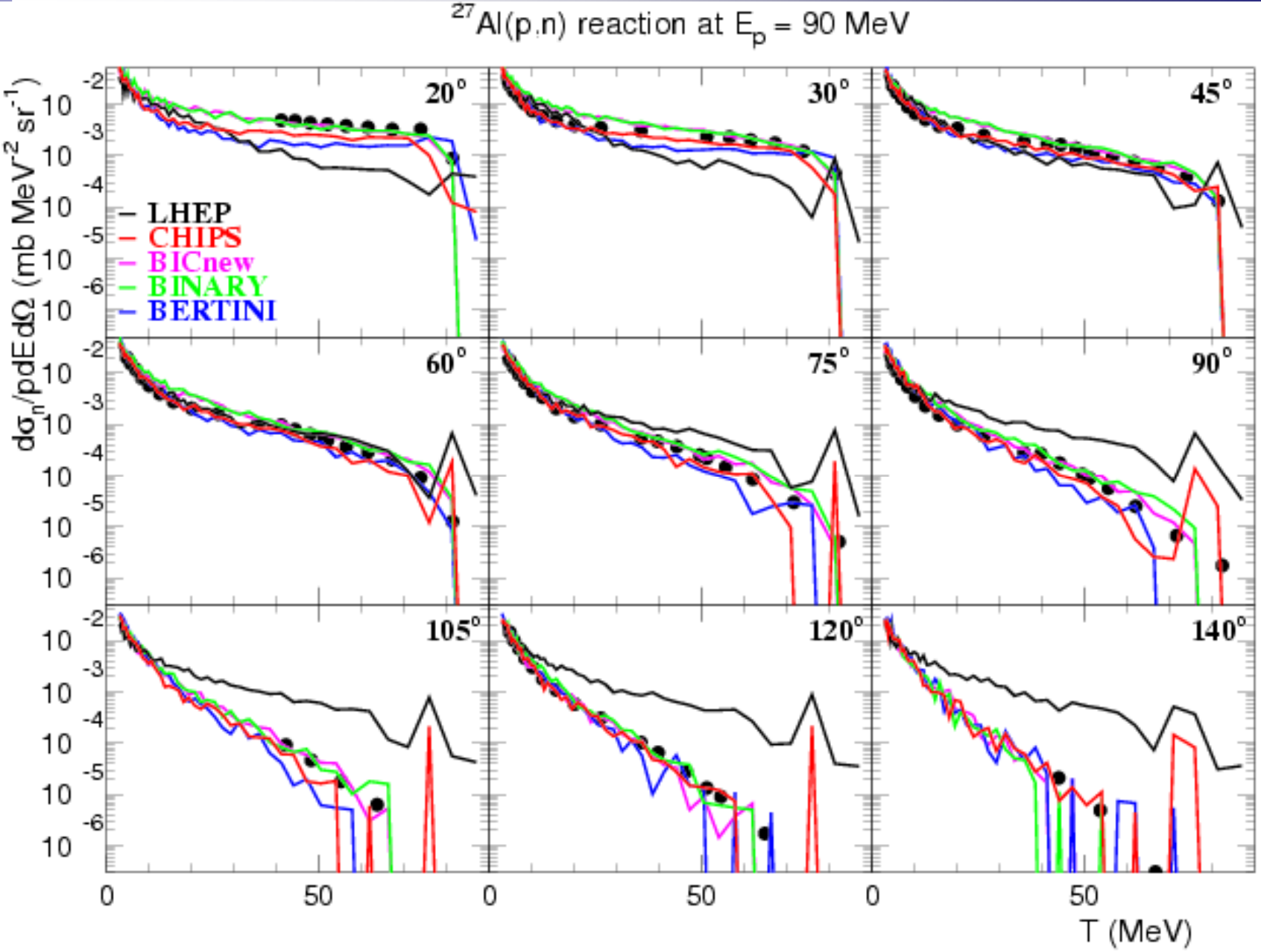
Conclusion

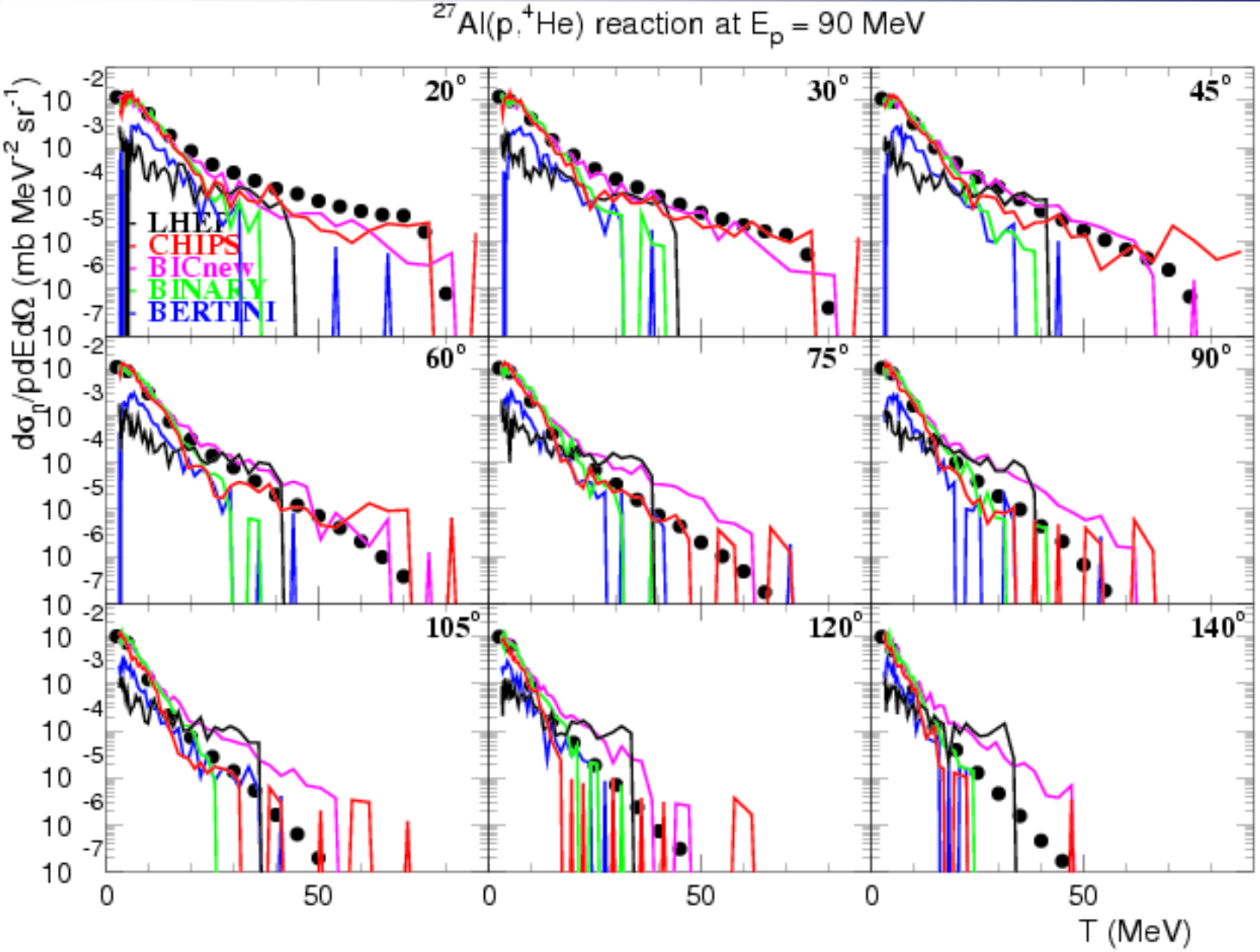
- At 90 MeV CHIPS fits spectra of p, n, and light fragments in pA reactions
- The accurate fit of (n,γ) reactions starting from 10 MeV/c (50 keV), with Neutron Killer for low energy neutrons (for acceleration).
- In the new QGSC_CHIPS physics list the low energy neutron simulation by the G4QCollision (CHIPS) process is mixed with the QGSC process by the G4QDiscProcessMixer class.
- In November 2009 the first one-model CHIPS physics list can be implemented for testing

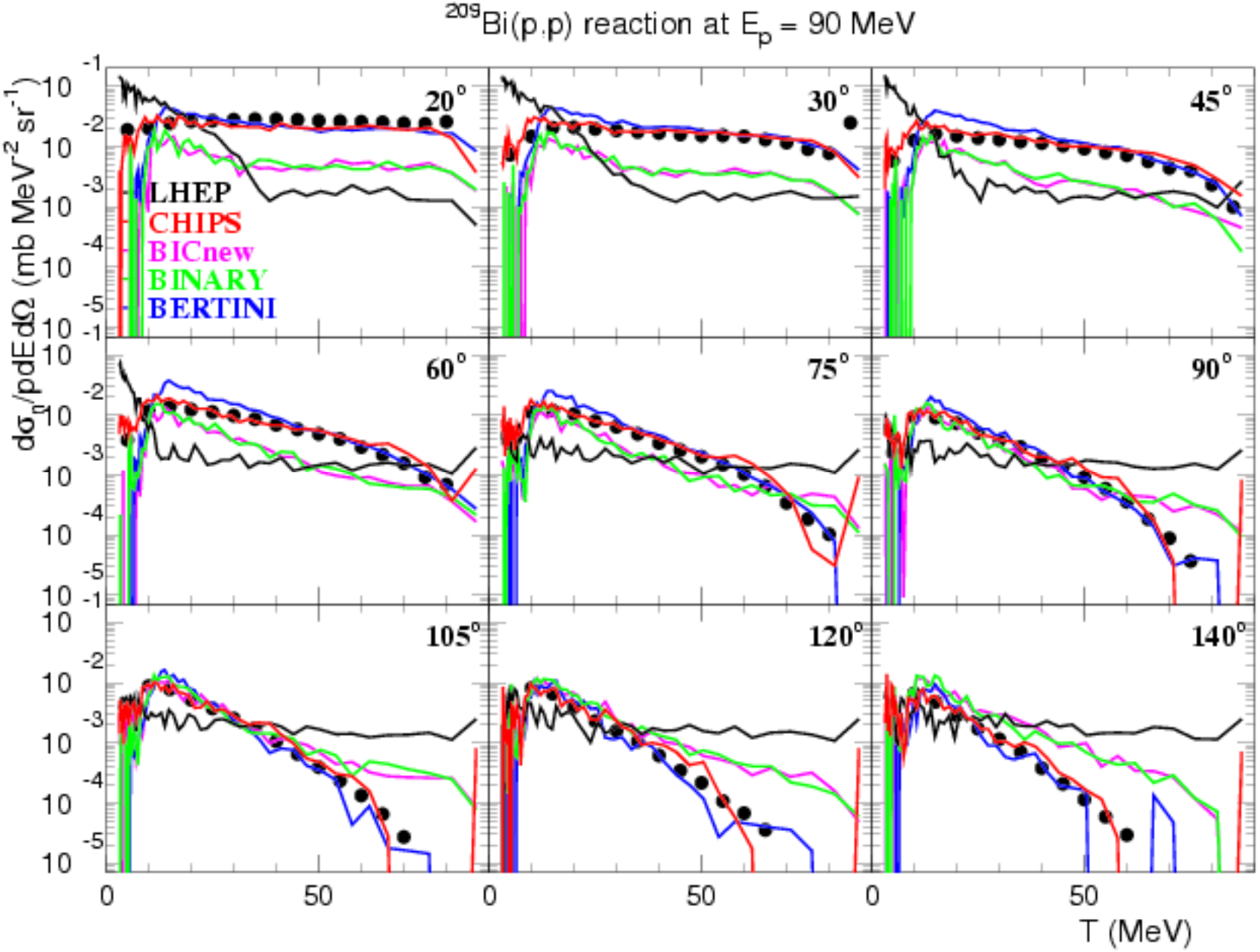
Backup slides following

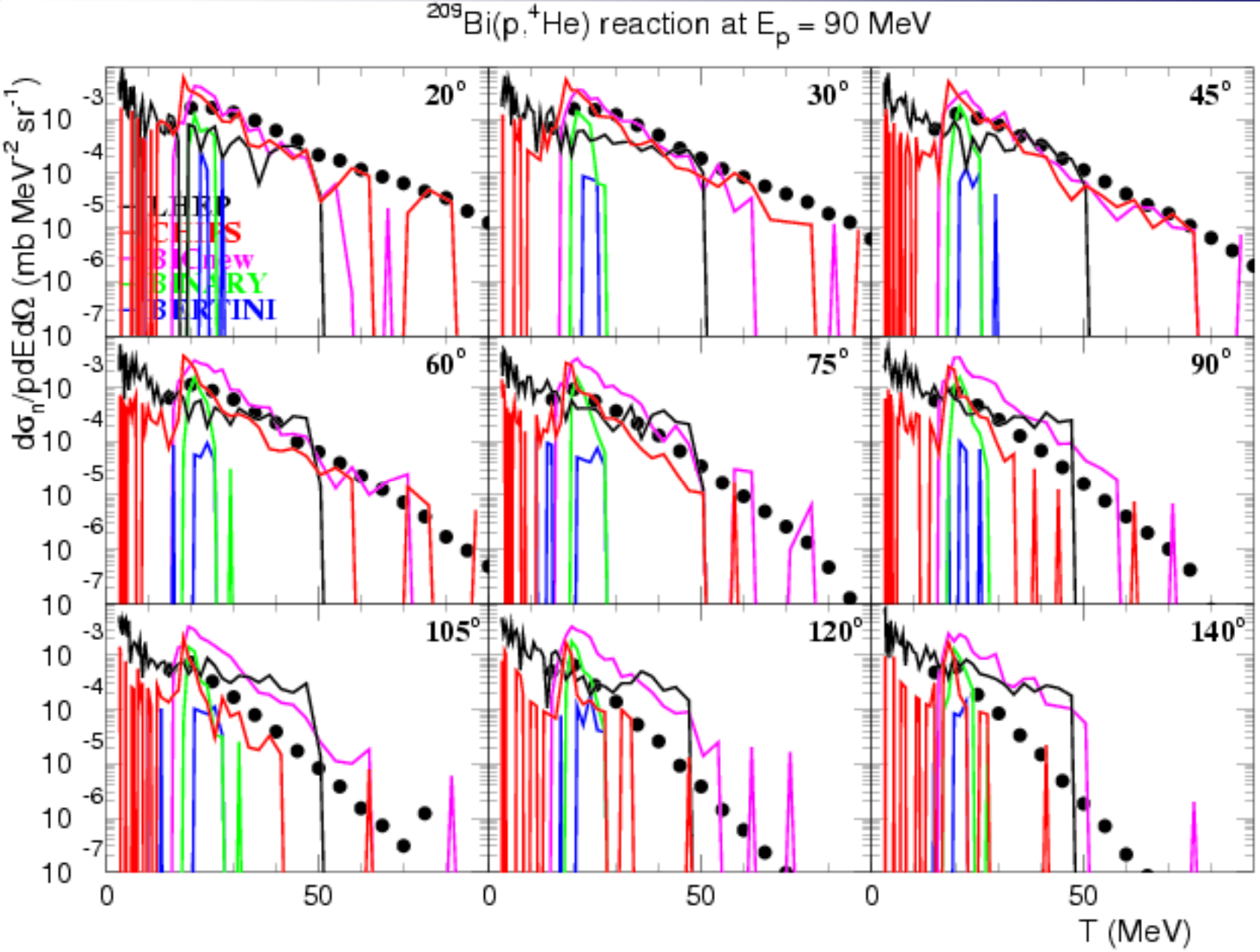
Data for tuning and validation

- COMPAS and Barashenkov data sets for total and inelastic cross-sections (no isotopes)
  - The direct inelastic XS measurements correspond to blue markers
  - The total XS measurements – CHIPS Elastic XS = red markers
- The ENDF/B VII data evaluation for σ_{in}
  - In the ENDF/B VII there are different data sets for "inelastic", "nonelastic", and "(n,anything)", but the $\sigma_{in}=\sigma_{tot}-\sigma_{el}$ was used
  - Data table format for isotopes: T_n(eV), σ_{tot}, σ_{el}, σ_{abs}, $\sigma_{fission}$(b)
  - 105 of 283 isotopes are covered: ^{2}H-^{75}As (except for ^{13}C, Ne, ^{50}V), ^{107,109}Ag, ^{181}Ta-^{247}Cm (excluding Os & Pt for which no data)
  - CHIPS does not cover p<10 MeV/c (T<50 keV), so the Temperature of the Material is not important (Neutron Killer)


^{27}Al(p,n) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
LHEP
CHIPS
BICnew
BINARY
BERTINI
20°
30°
45°
60°
75°
90°
105°
120°
140°
T (MeV)


^{27}Al(p,^{4}He) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI
T (MeV)


^{209}Bi(p,p) reaction at E_p = 90 MeV
$d\sigma_0/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
T (MeV)
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI


209Bi(p,4He) reaction at Ep = 90 MeV
dσn/pdEdΩ (mb MeV-2 sr-1)
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BIC new
BINARY
BERTINI
T (MeV)