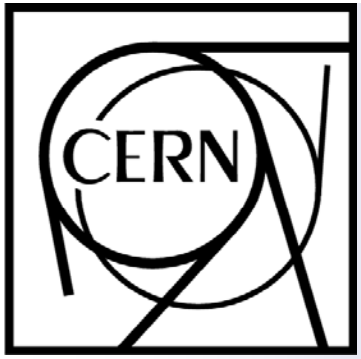


Geant4 models compared with the pre-compound energy pA data

Mikhail Kosov, Physics Validation, 01.04.09

Pre-compound energy range: E < 290 MeV N(p,N)Nπ threshold

1. **pA (Al, Au) E = 29 MeV (nuclear fragments)**
2. **pA (Al, Bi) E = 90 MeV (nuclear fragments)**
3. **pA (C, ^{56,64}Ni, Y, Pb) E=(180)200 MeV (pions)**

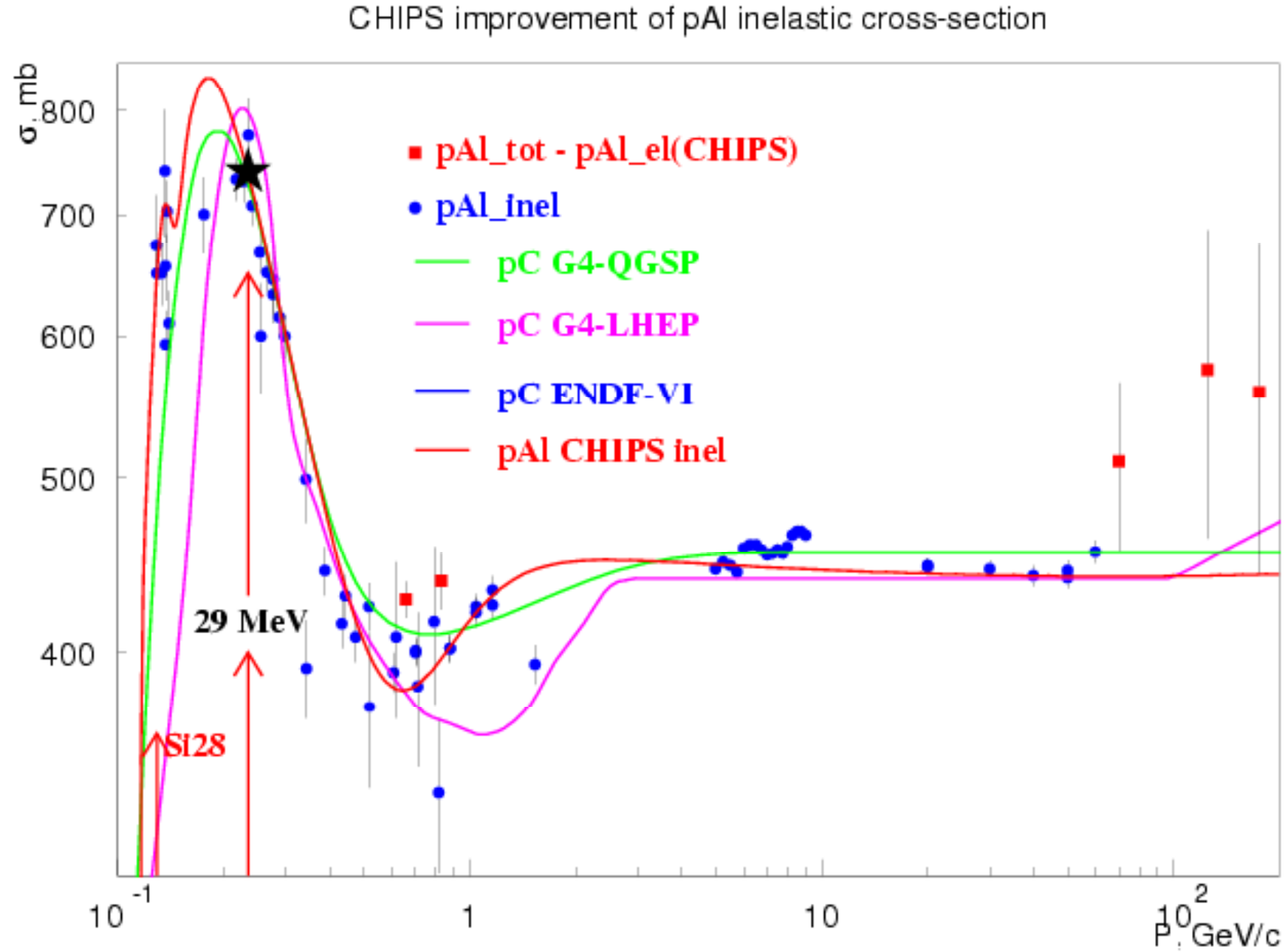
Introduction

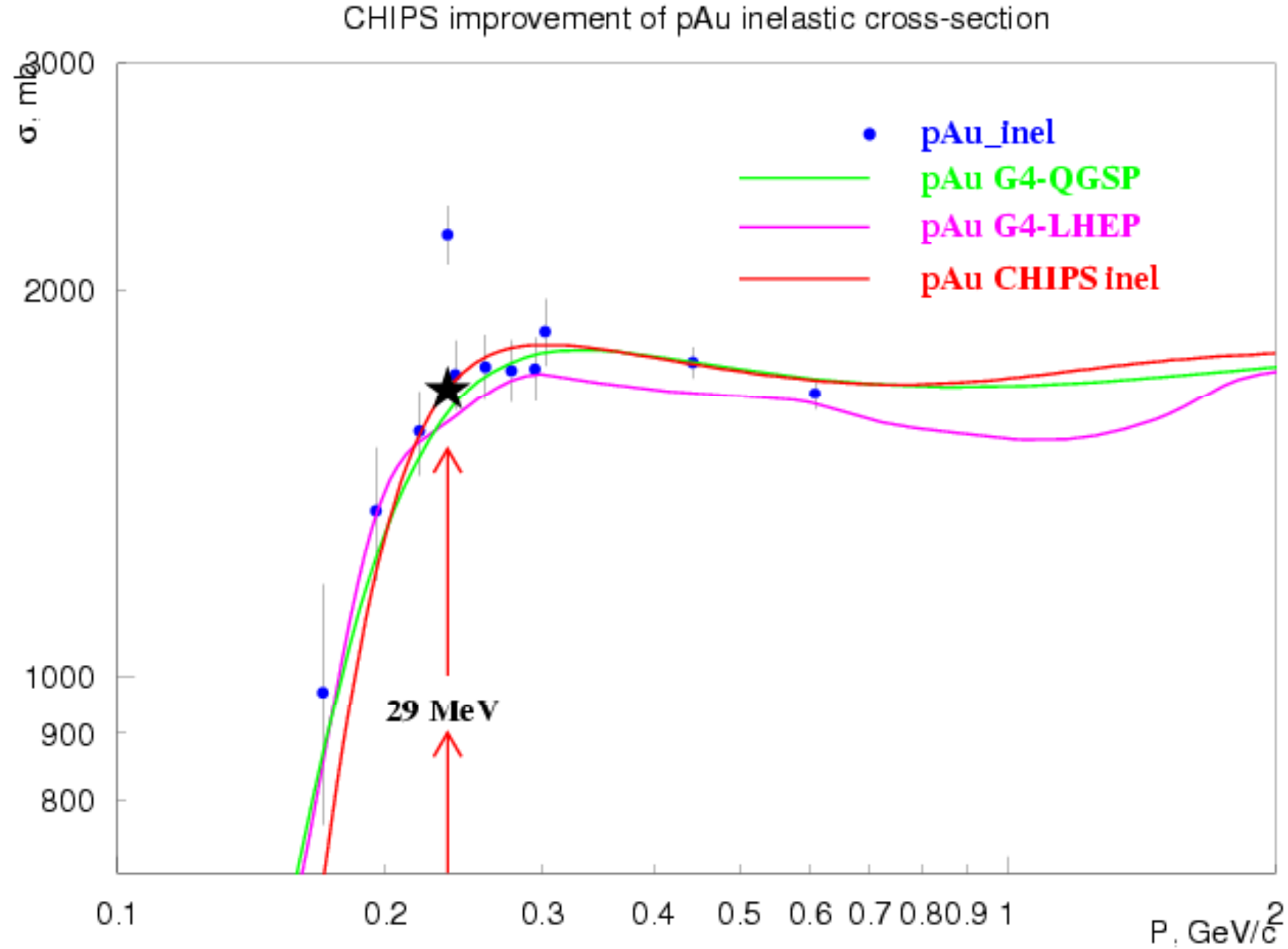
- All calculations have been done within the CHIPS **test19** multi-application framework
  - The basic **test19** directory can be used by the G4 Testing Group
  - Different use cases subdirectories (**gamma**, **preco**, **piprod** etc.)
  - It is made for the CHIPS tuning, but can be used for other models.
- CHIPS tuning strategy
  - Create the CHIPS proton-nuclear inelastic cross-sections (done)
  - Tune pA CHIPS in different energy regions:
    - Pre-compound energy region (**preco**, E < 290 MeV, this presentation)
    - Pion production region (**piprod**, E < 1 GeV, first step @ E=201)
    - Strangeness (kaons, L's) production region (**kprod**, E < 3 GeV)
    - Formation time region (**qgs**, E < 100 GeV)
    - Pomeron fusion region (**pomfus**, E > 100 GeV)

Production of nuclear fragments (n, p, d, t, ^{3}He, ^{4}He) in the A(p,f)X reaction @ 29 & 90 MeV

29 MeV dataset

- Data: F.E.Bertrand & R.W.Peelle, Oak Ridge Preprints (50's)
  - Targets: Al, Au (more nuclei for higher energies)
  - Spectra of p, d, t, and $\alpha = {}^4He$.
  - θ: 11^o, 30^o, 60^o, 90^o, 130^o .
- The data are compared with Preco, Bertini, Binary, LEProt (LHEP), CHIPS
  - Preco/Binari: isotropic p and good α on Al, too anisotropic p and a huge α yield on Bi (at 29 MeV Preco and Bertini are identical).
  - New Preco development increases d production & overestimates α.
  - Bertini is good for Al, but does not have fragments on Bi.
  - LHEP is angular independent, and fragments are too soft.
  - CHIPS is good for Al, should be tuned for Bi (no gamma deexcitation)
  - Timing $T_{LHEP} < T_{Bertini} < T_{CHIPS} < T_{Binary}$


CHIPS improvement of pAl inelastic cross-section
σ, mb
800
700
600
500
400
pAl_tot - pAl_el(CHIPS)
pAl_inel
pC G4-QGSP
pC G4-LHEP
pC ENDF-VI
pAl CHIPS inel
29 MeV
Si28
10^-1
1
10
10^2
P, GeV/c


CHIPS improvement of pAu inelastic cross-section
σ, mb
3000
2000
1000
900
800
pAu_inel
pAu G4-QGSP
pAu G4-LHEP
pAu CHIPS inel
29 MeV
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
P, GeV/c

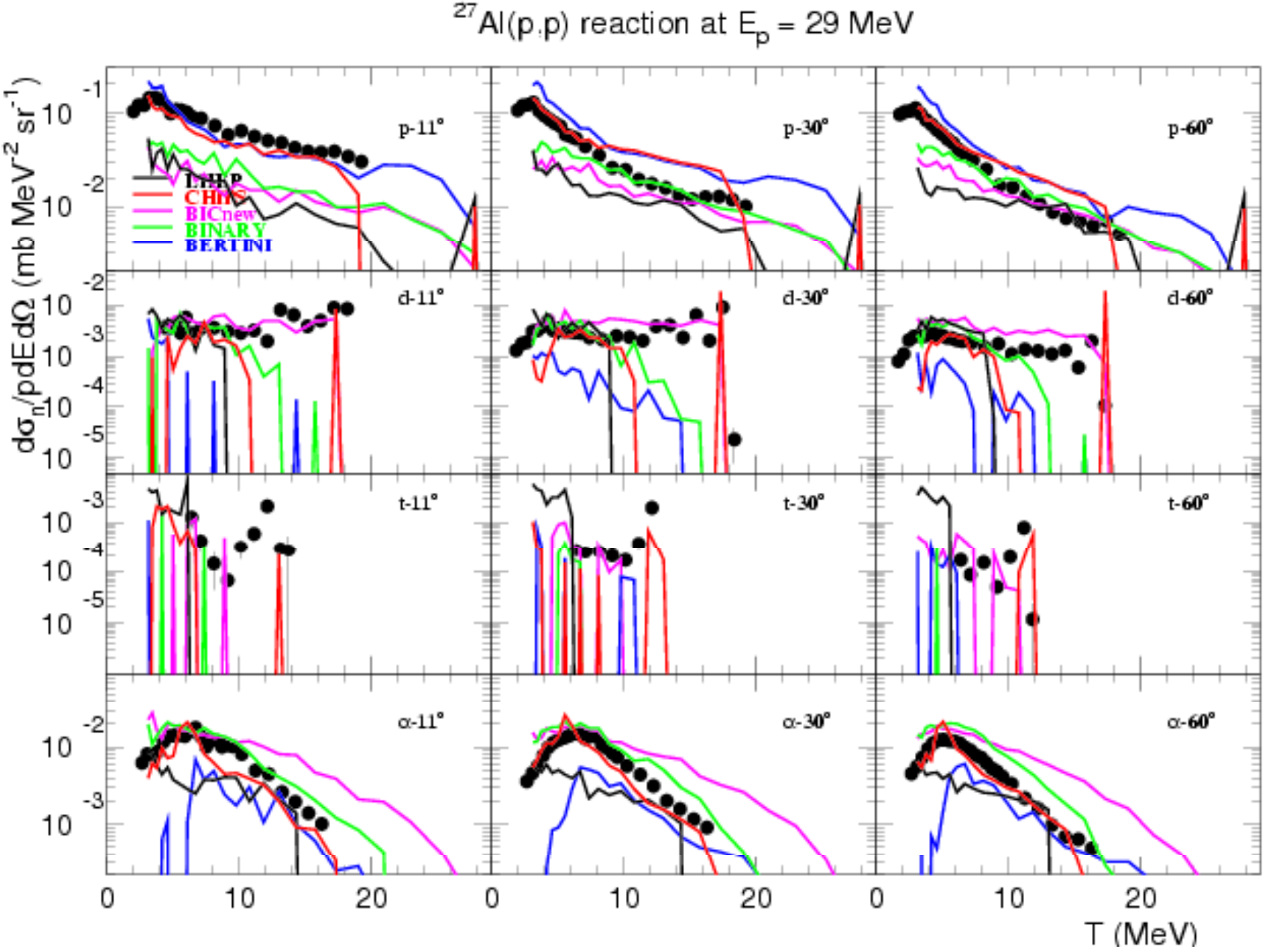
Time performance for 29 MeV and 90 MeV protons

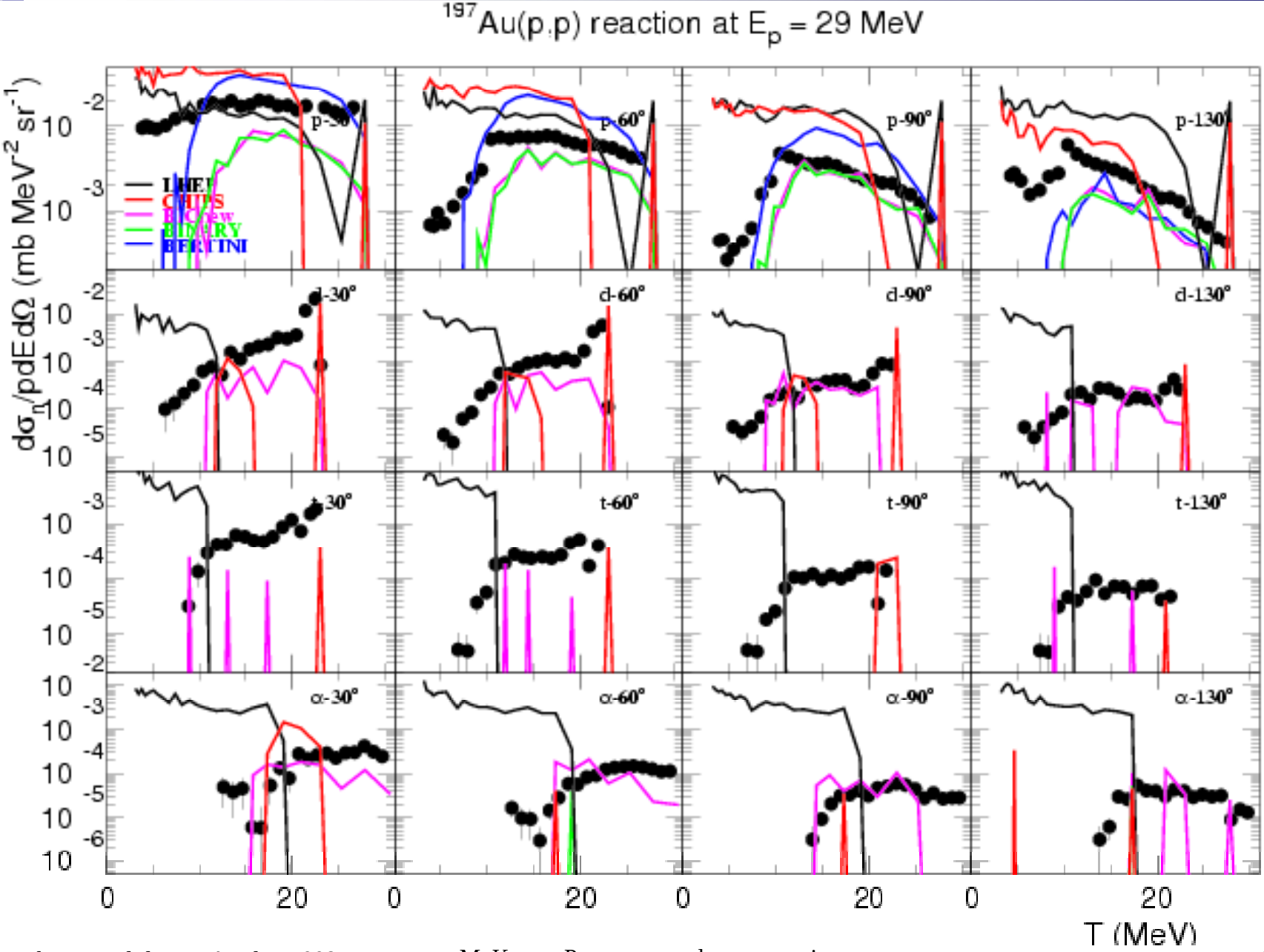
protons 29 MeV (2009)

Model	Al	Au
PreCom	1.5/1.3	4.4/4.2
Binary	1.9/1.7	4.7/4.5
Bertini	0.40	0.42
CHIPS	2.7	2.8
LHEP	0.06	0.07
QLowE	0.10	0.10

protons 90 MeV (2009)

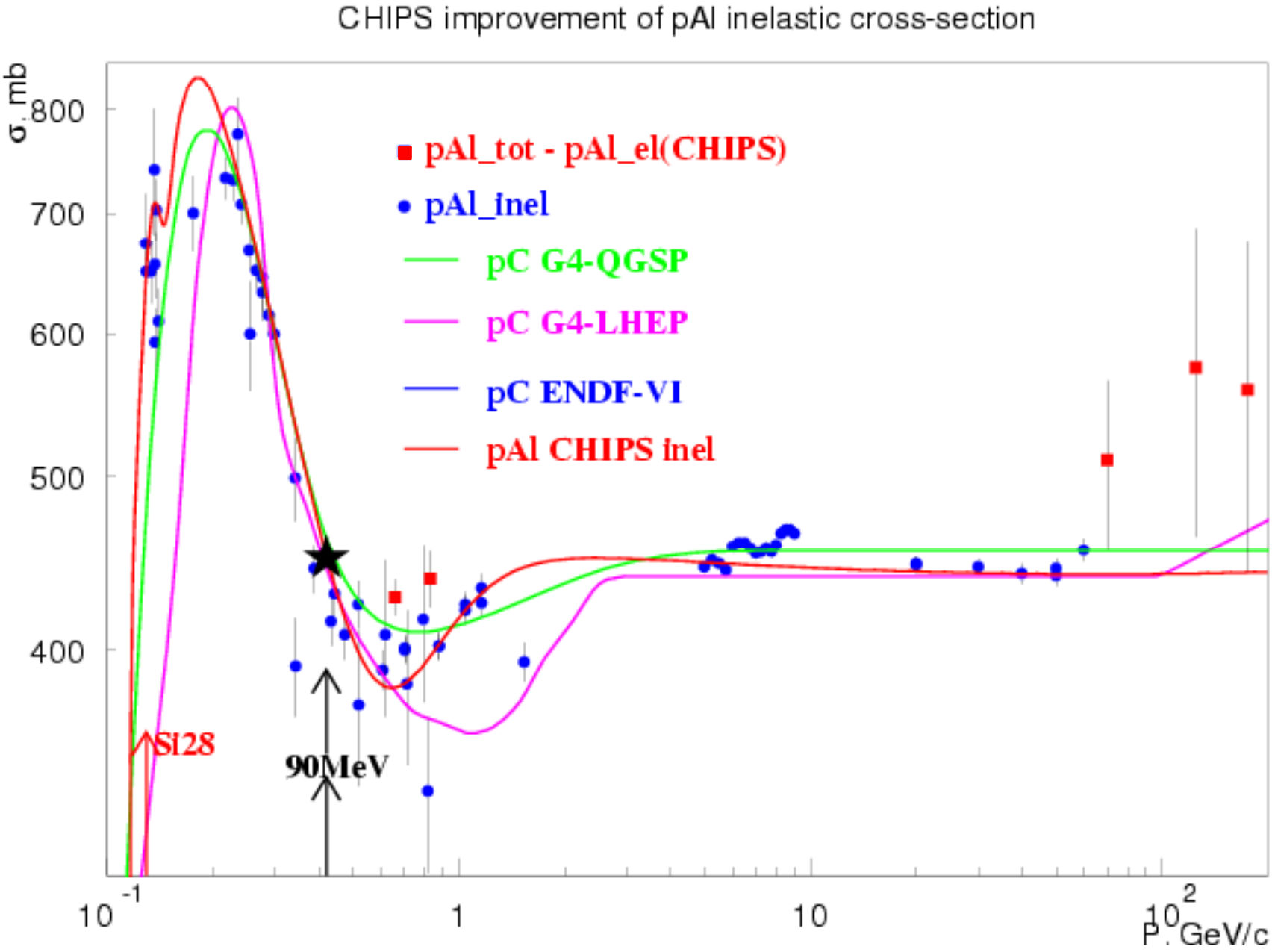
Model	Al	Bi
PreCom	2.2	5.2
Binary	3.1	8.2
Bertini	0.48	0.62
CHIPS	2.5	3.1
LHEP	0.10	0.11
QLowE	0.12	0.14


^{27}Al(p,p) reaction at E_p = 29 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
LAHEP
CHIPS
BICnew
BINARY
BERTINI
p-11°
p-30°
p-60°
d-11°
d-30°
d-60°
t-11°
t-30°
t-60°
α-11°
α-30°
α-60°
T (MeV)

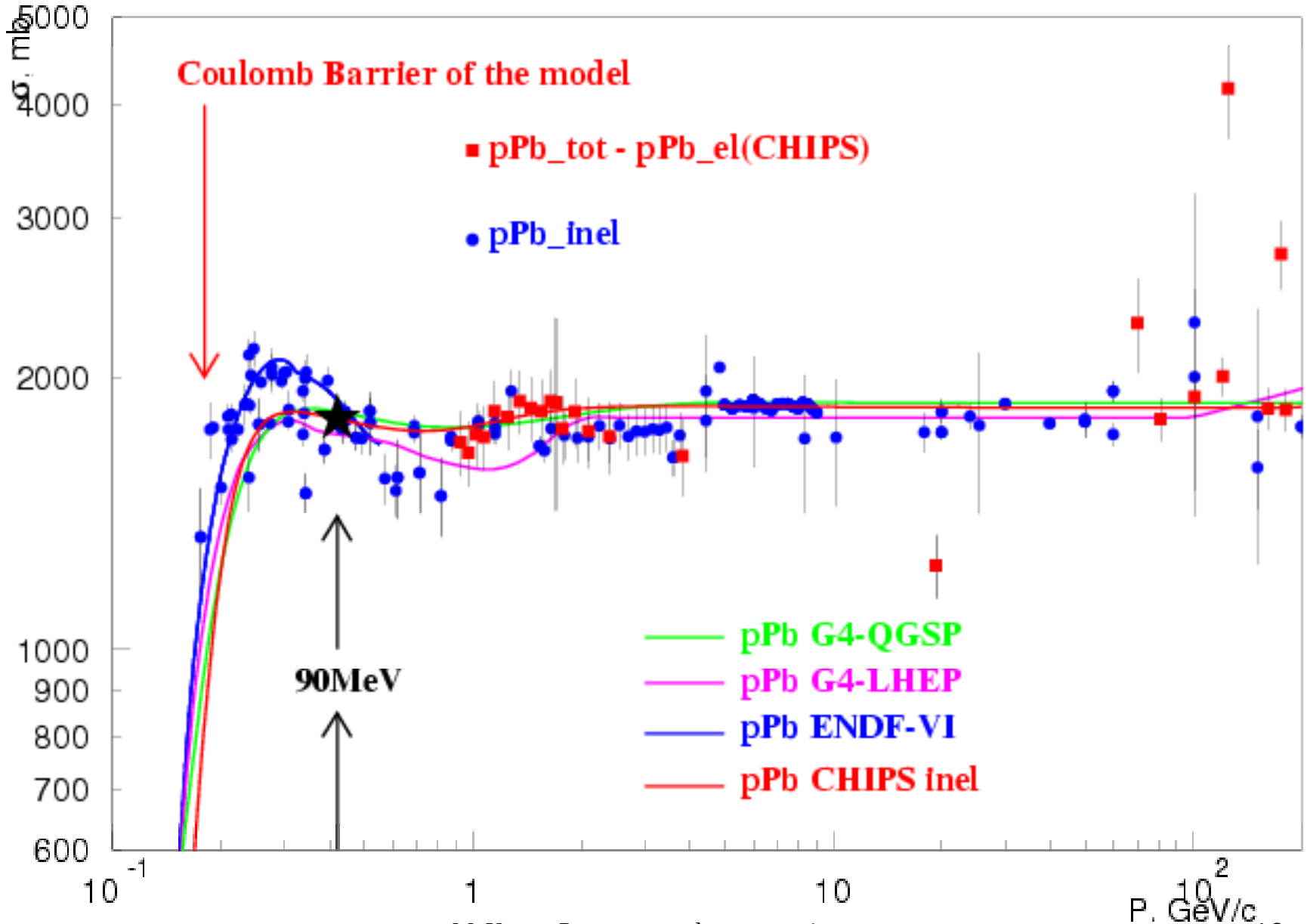

^{197}Au(p,p) reaction at E_p = 29 MeV
LAHET
CEM03
INCrew
BINARY
BERTINI
p-30°
p-60°
p-90°
p-130°
d-30°
d-60°
d-90°
d-130°
t-30°
t-60°
t-90°
t-130°
α-30°
α-60°
α-90°
α-130°
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
T (MeV)

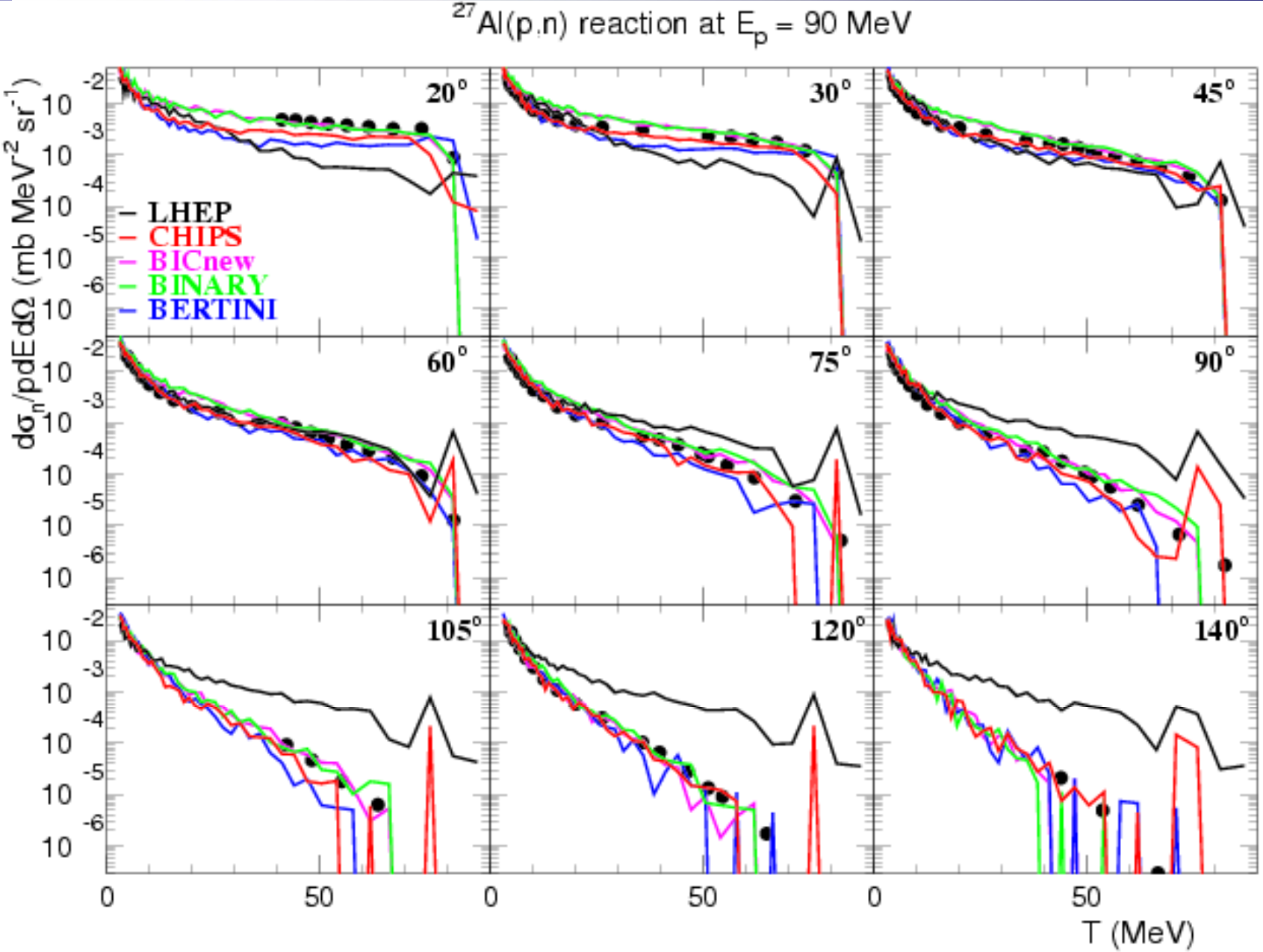
90 MeV dataset and Geant4 models

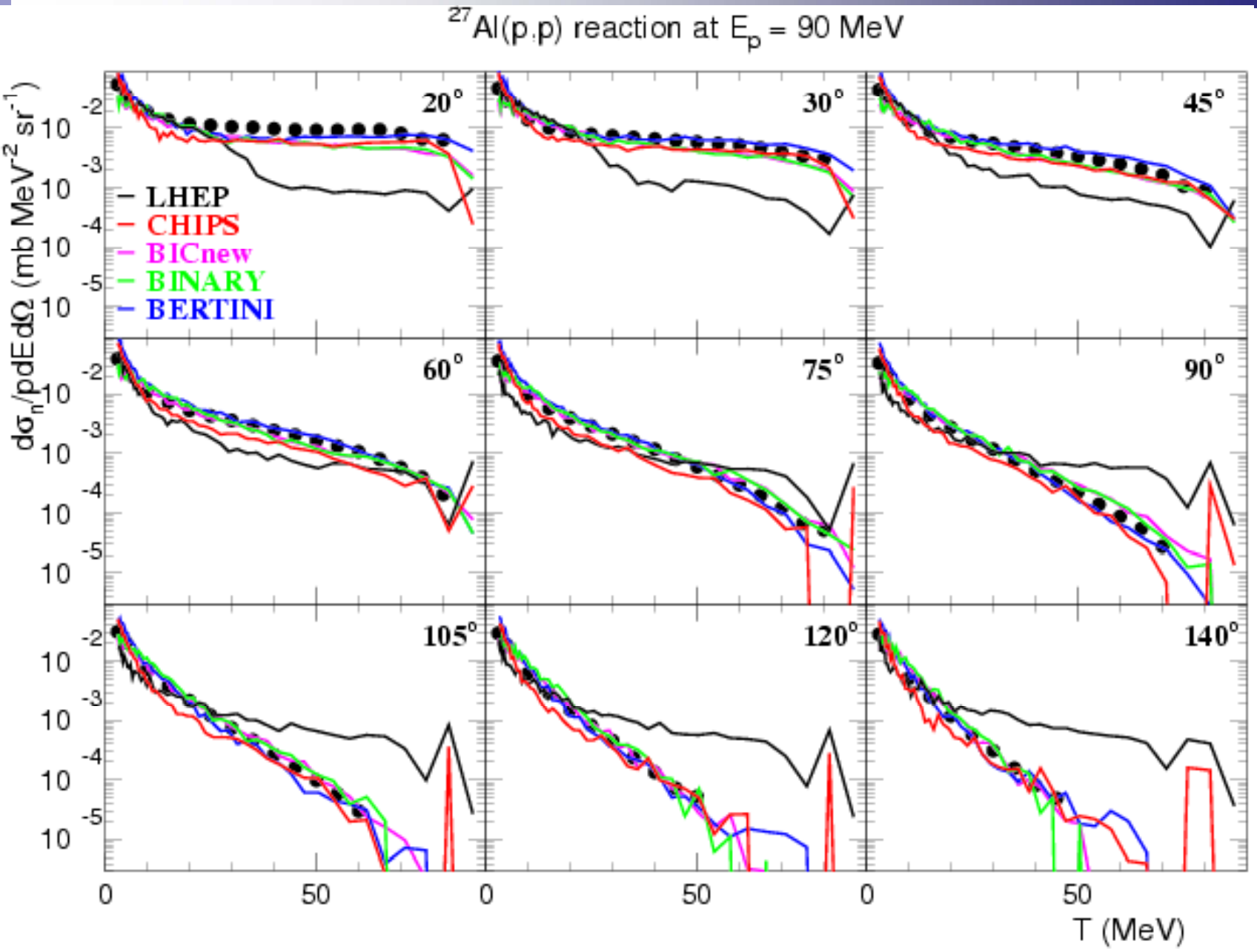
- Data: A.M.Kalend et al., Phys.Rev.C28(1983)105.
  - Targets: Al, Bi (other targets: Ni, Zr, Pb, Th).
  - Spectra of neutrons, protons, d, t, He^3, and α .
  - θ: 20^o,30^o,45^o,60^o,75^o, 90^o,105^o,120^o ,140^o .
- The data are compared with Preco, Bertini, Binary, LEP (LHEP), CHIPS
  - Preco satisfactory describes n,p,d but not t,He^3,α
  - On Al Binary is close to Preco, on Bi loses θ-dep.
  - Bertini is good for p&n (no fragments, no CoulBar).
  - LHEP is angular independent, does not have He^3.
  - CHIPS is good in all the scope.

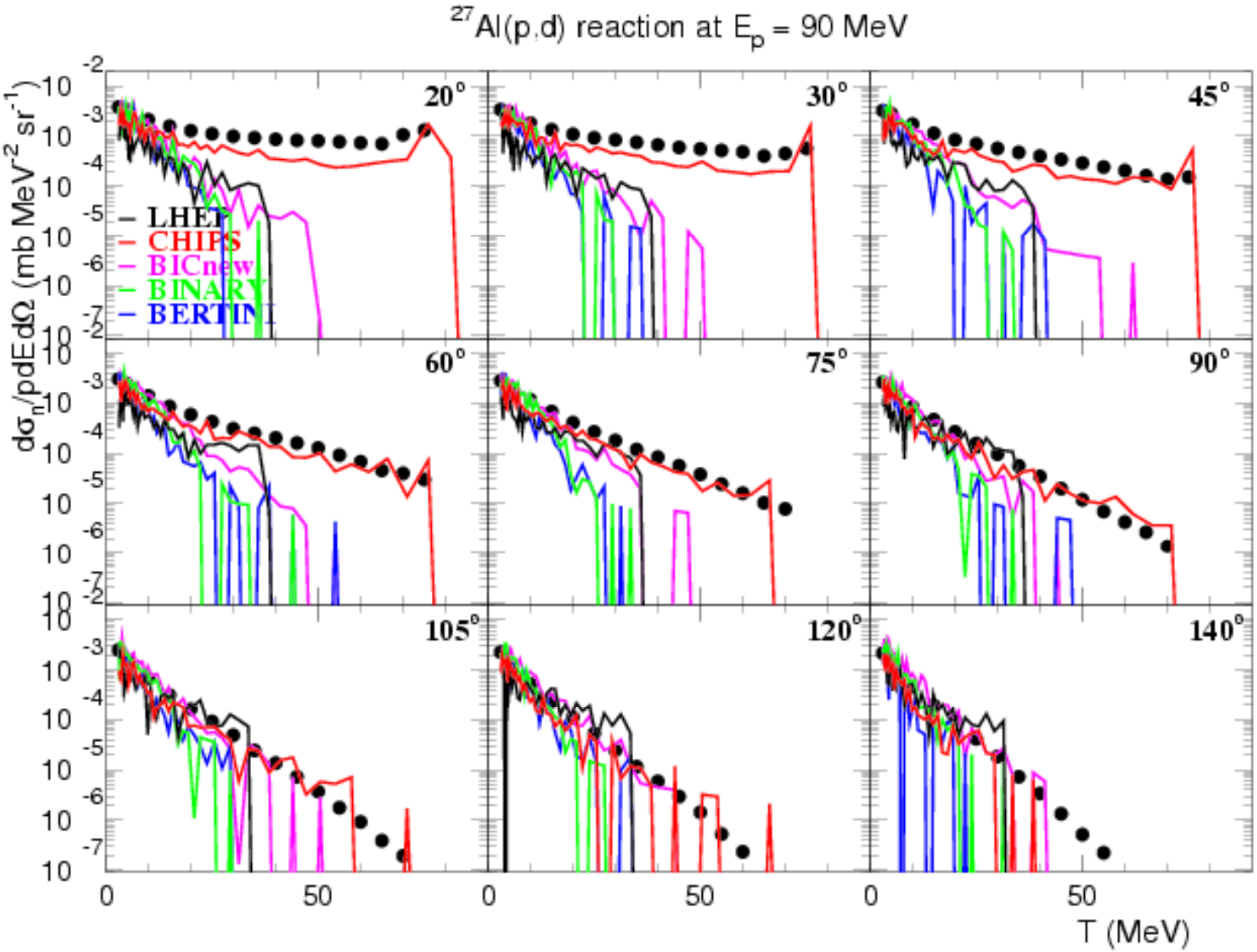

CHIPS improvement of pAl inelastic cross-section
σ, mb
800
700
600
500
400
pAl_tot - pAl_el(CHIPS)
pAl_inel
pC G4-QGSP
pC G4-LHEP
pC ENDF-VI
pAl CHIPS inel
Si28
90MeV
10^-1
1
10
10^2
P, GeV/c

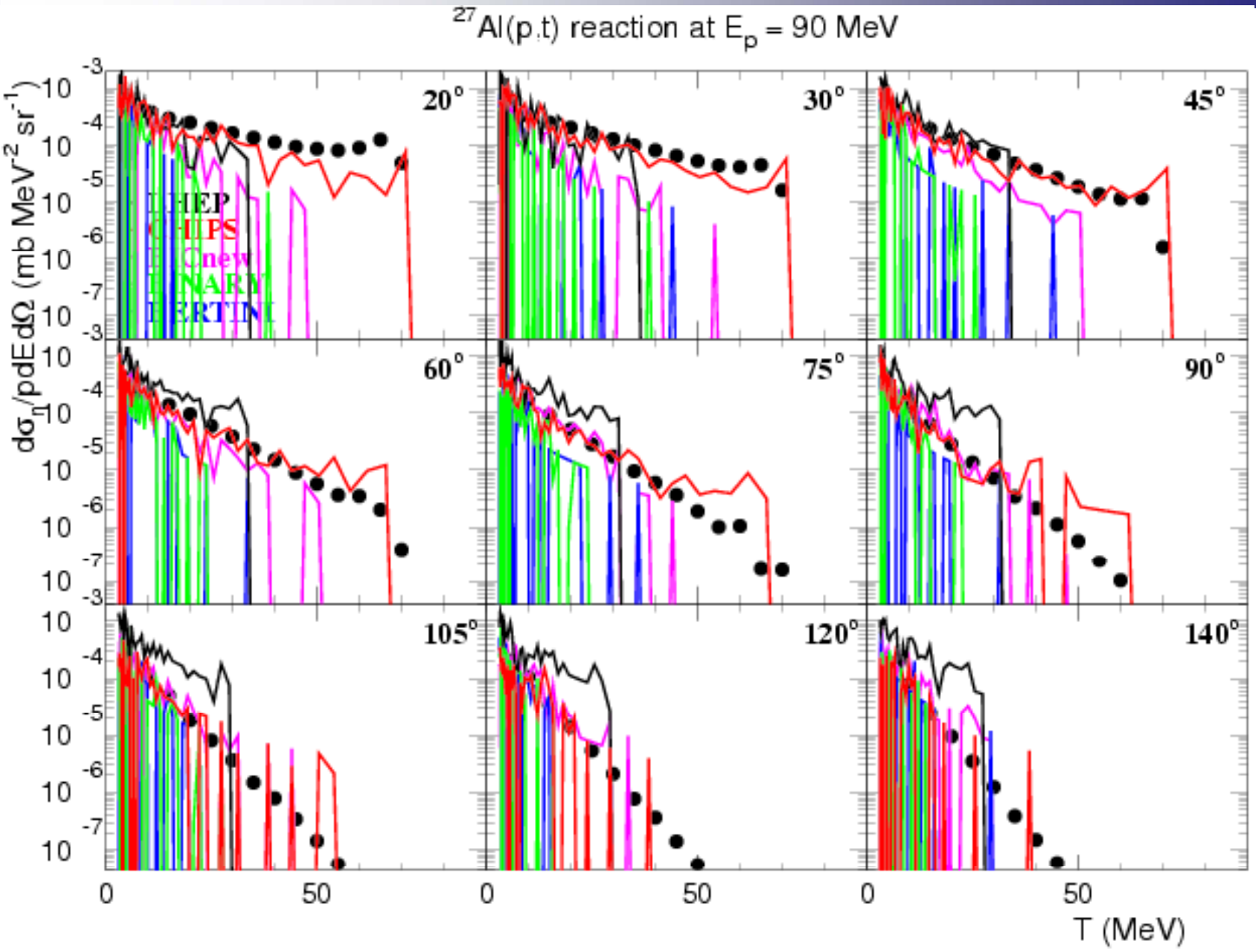
CHIPS improvement of pPb inelastic cross-section

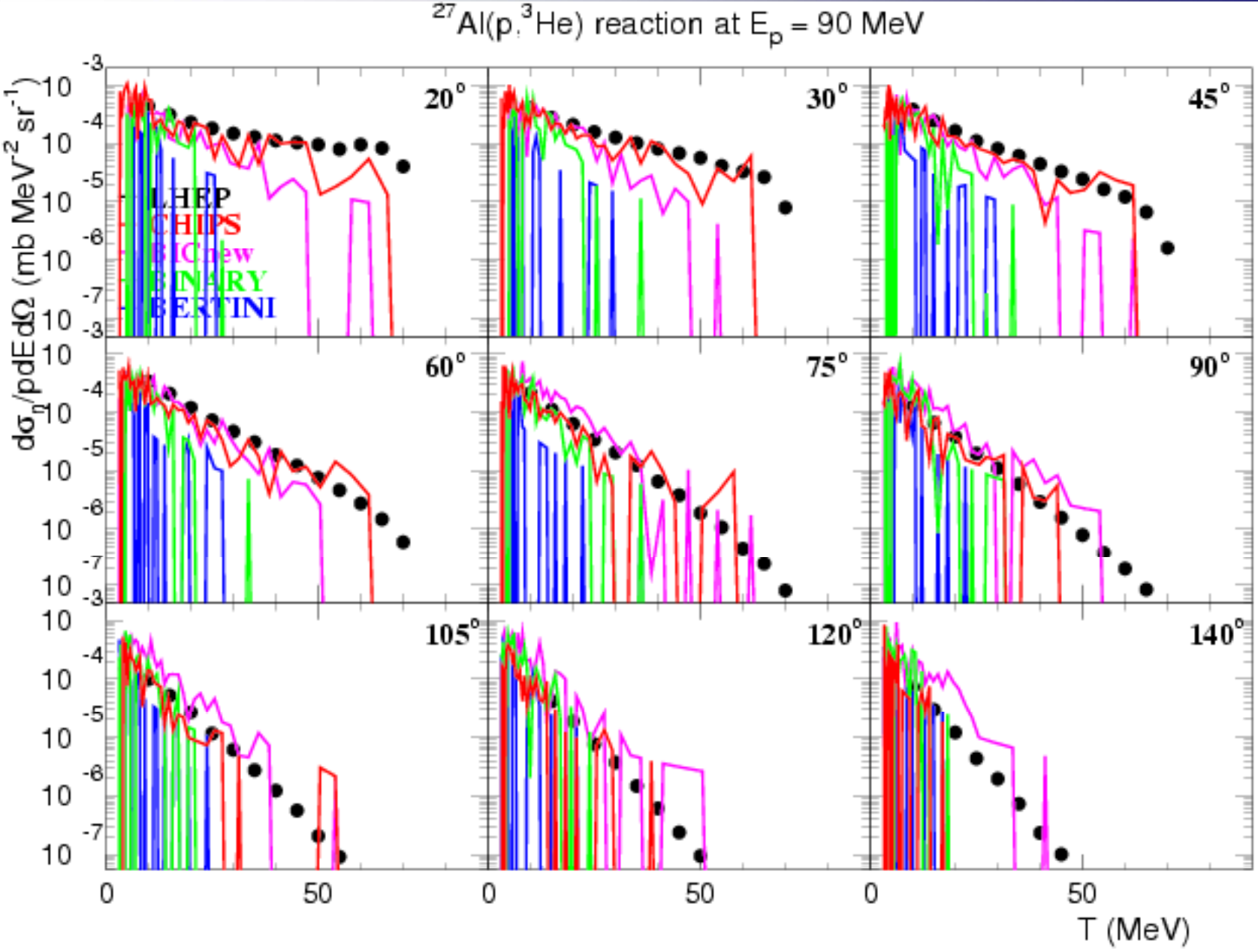


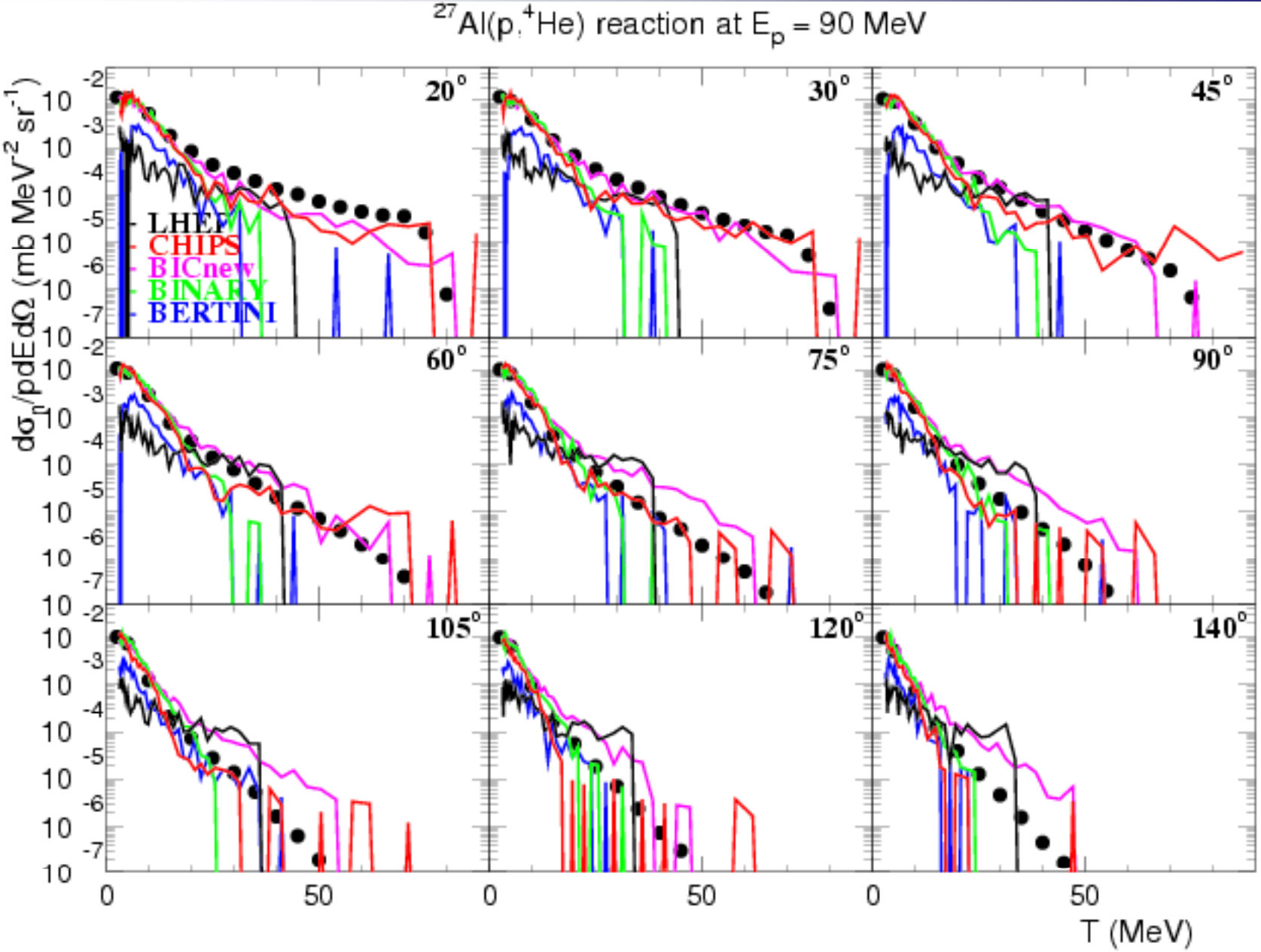

^{27}Al(p,n) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI
T (MeV)

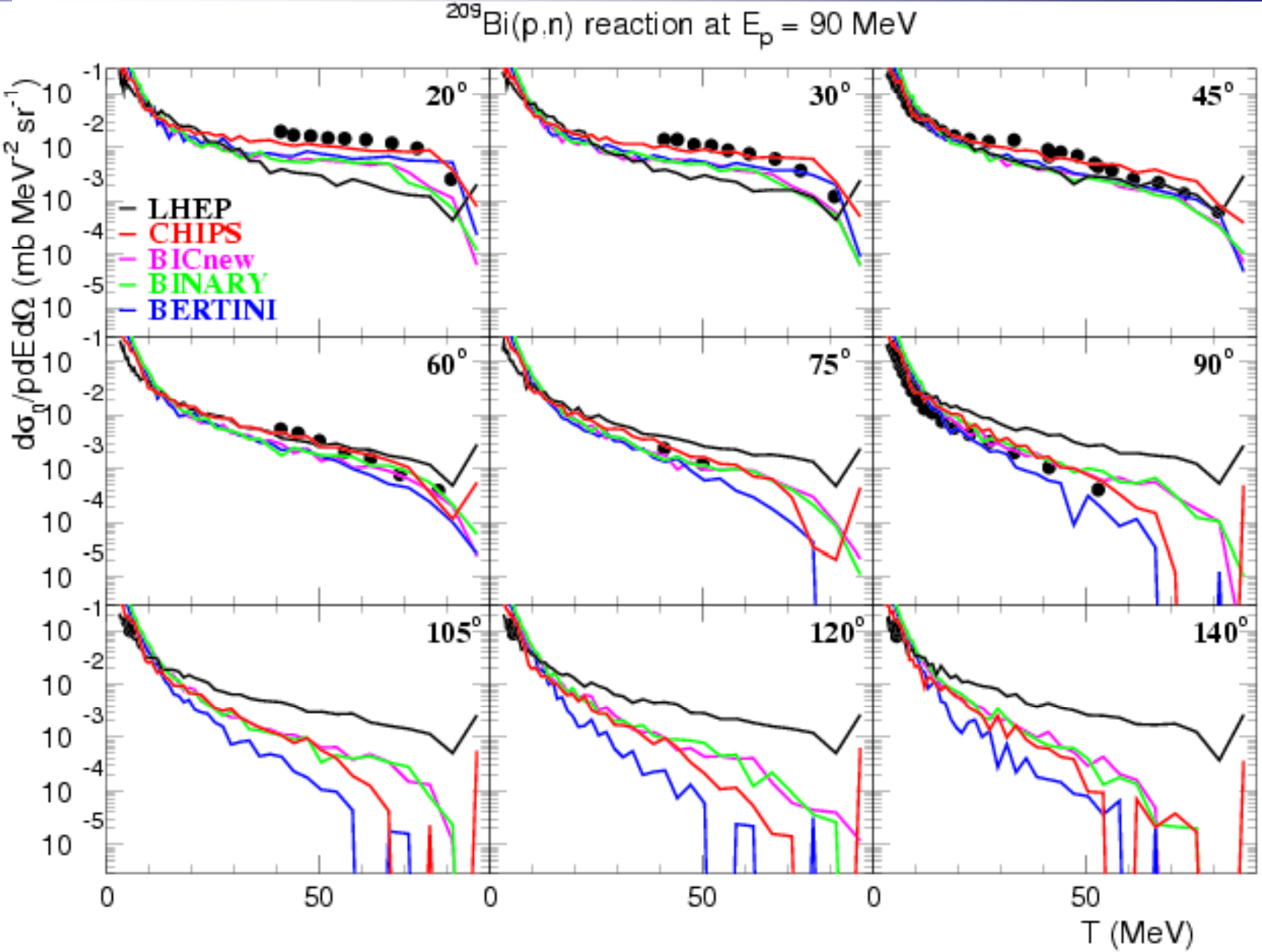

^{27}Al(p,p) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI
T (MeV)

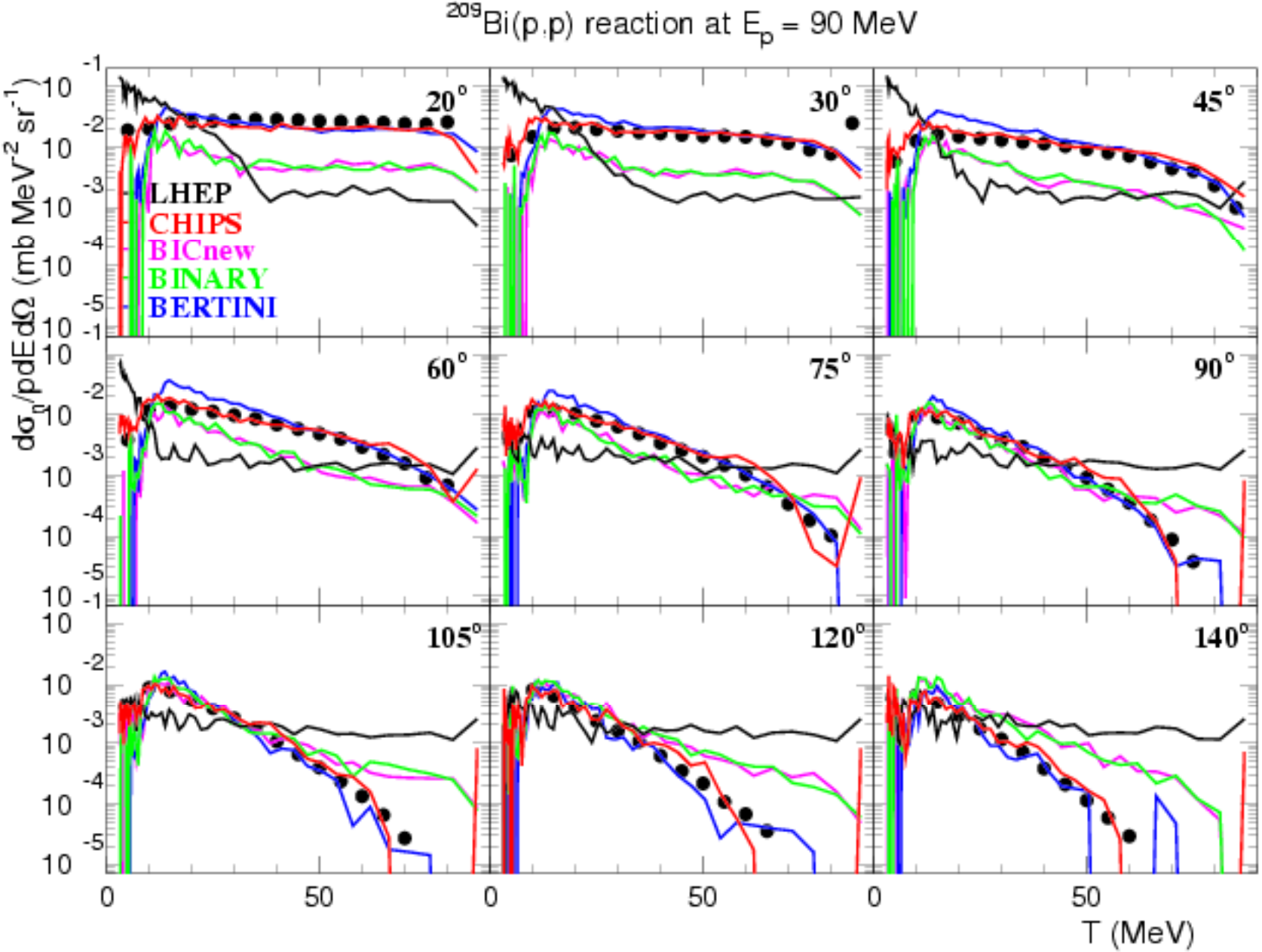

^{27}Al(p,d) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI
0
50
T (MeV)

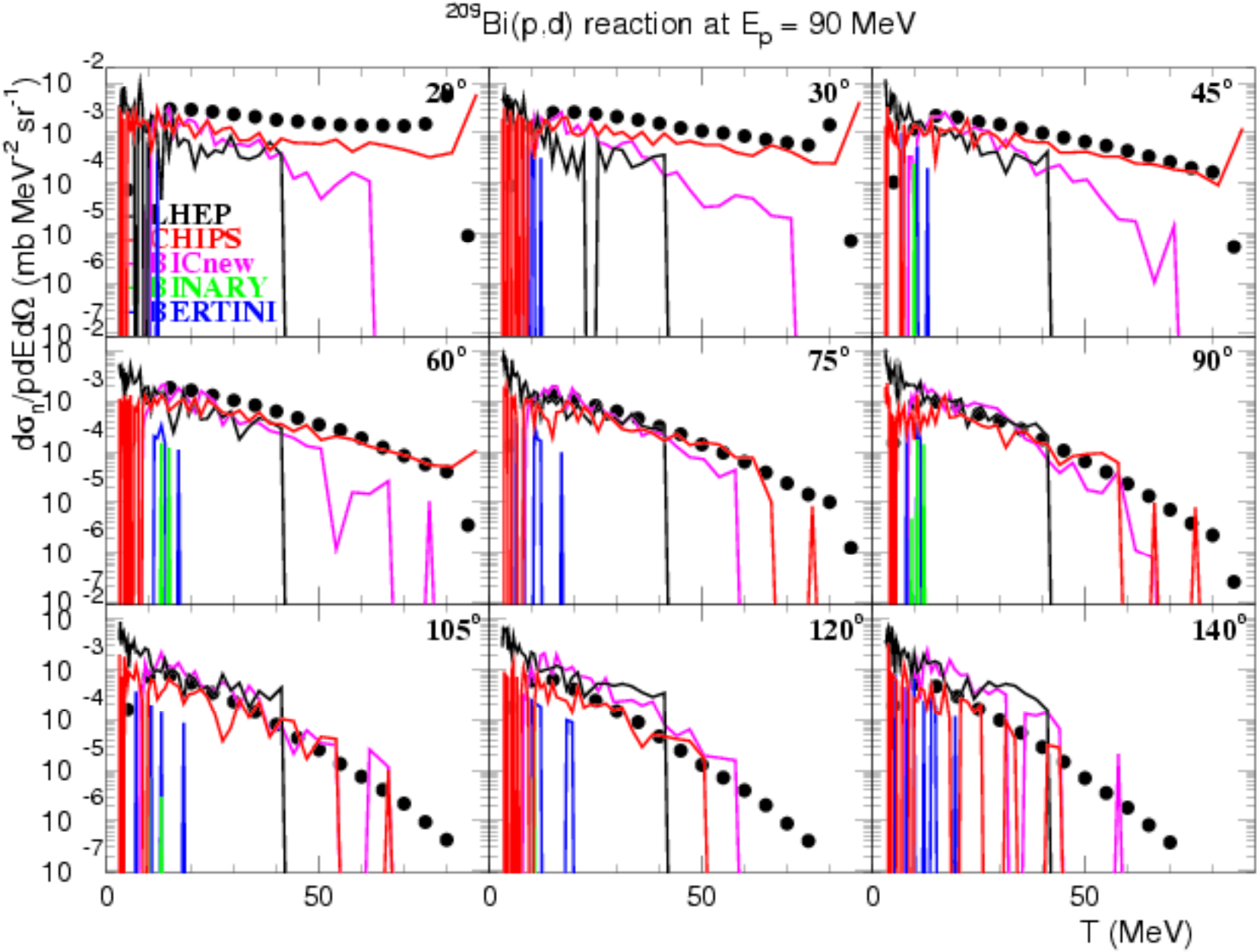

^{27}Al(p,t) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
20°
30°
45°
60°
75°
90°
105°
120°
140°
HEP
IUPS
Cnew
NARY
BERTINI
0
50
T (MeV)

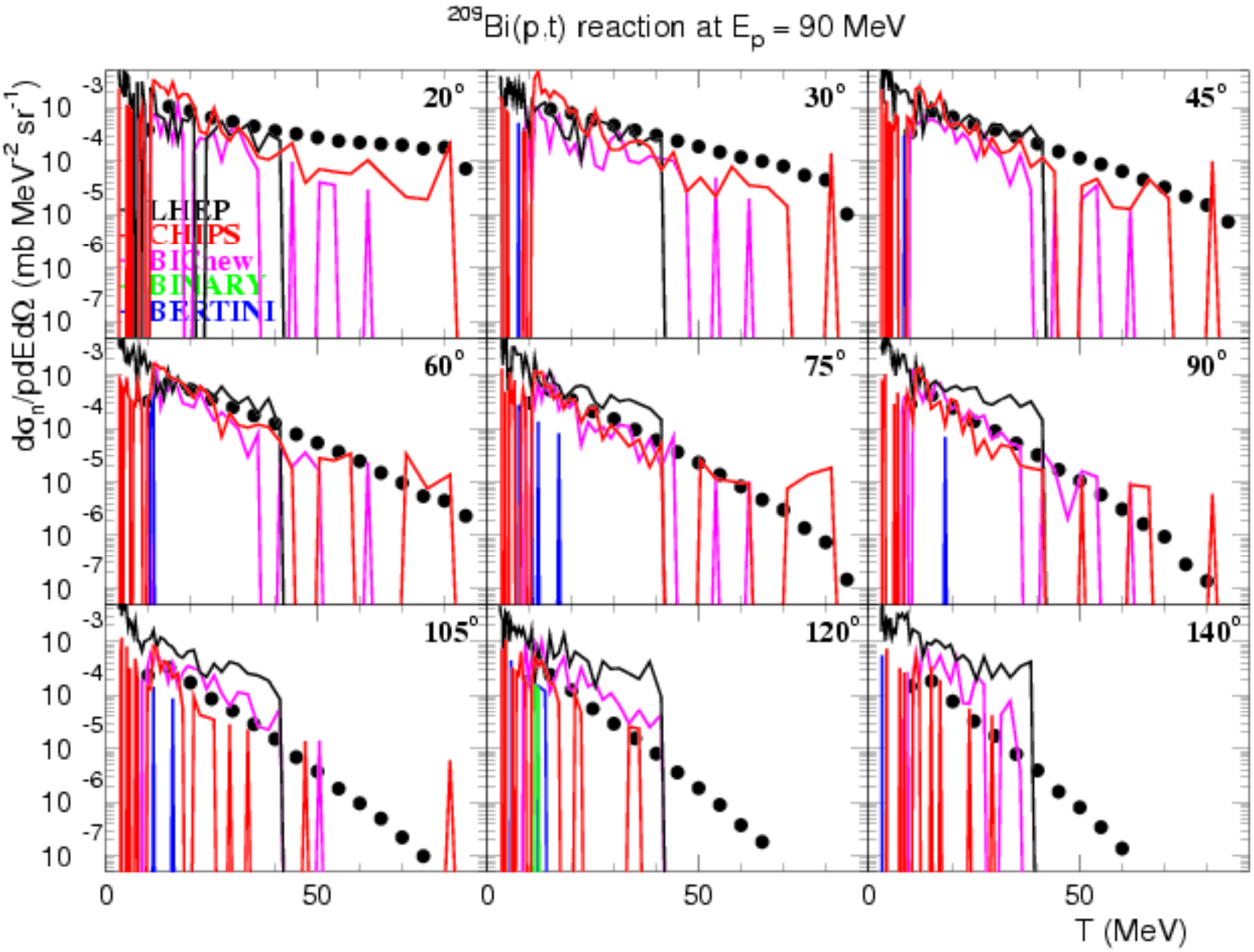

^{27}Al(p,^{3}He) reaction at E_p = 90 MeV
LHEP
CHIPS
BIC new
BINARY
BERTINI
20°
30°
45°
60°
75°
90°
105°
120°
140°
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
T (MeV)

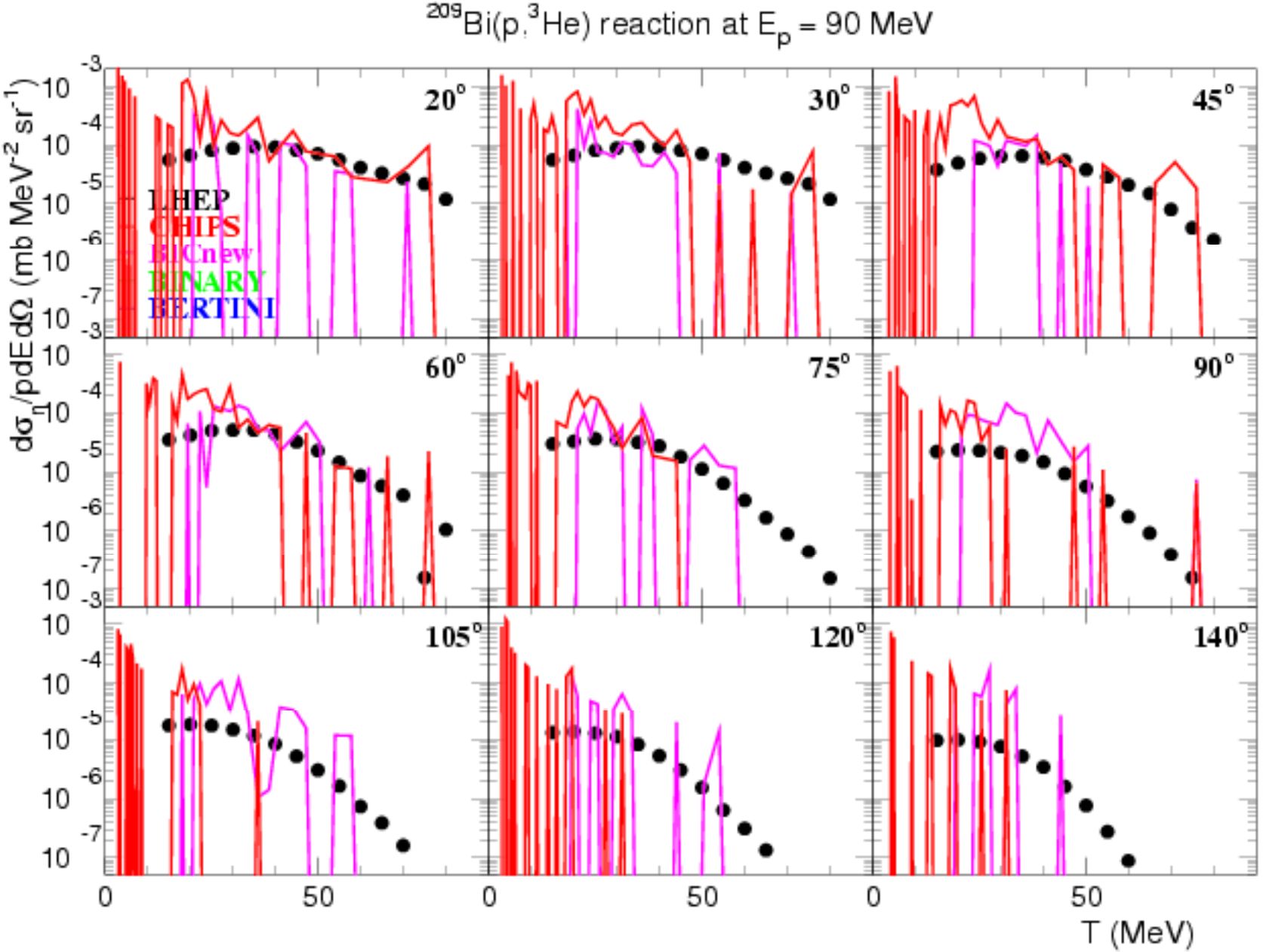

^{27}Al(p,^{4}He) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI
T (MeV)

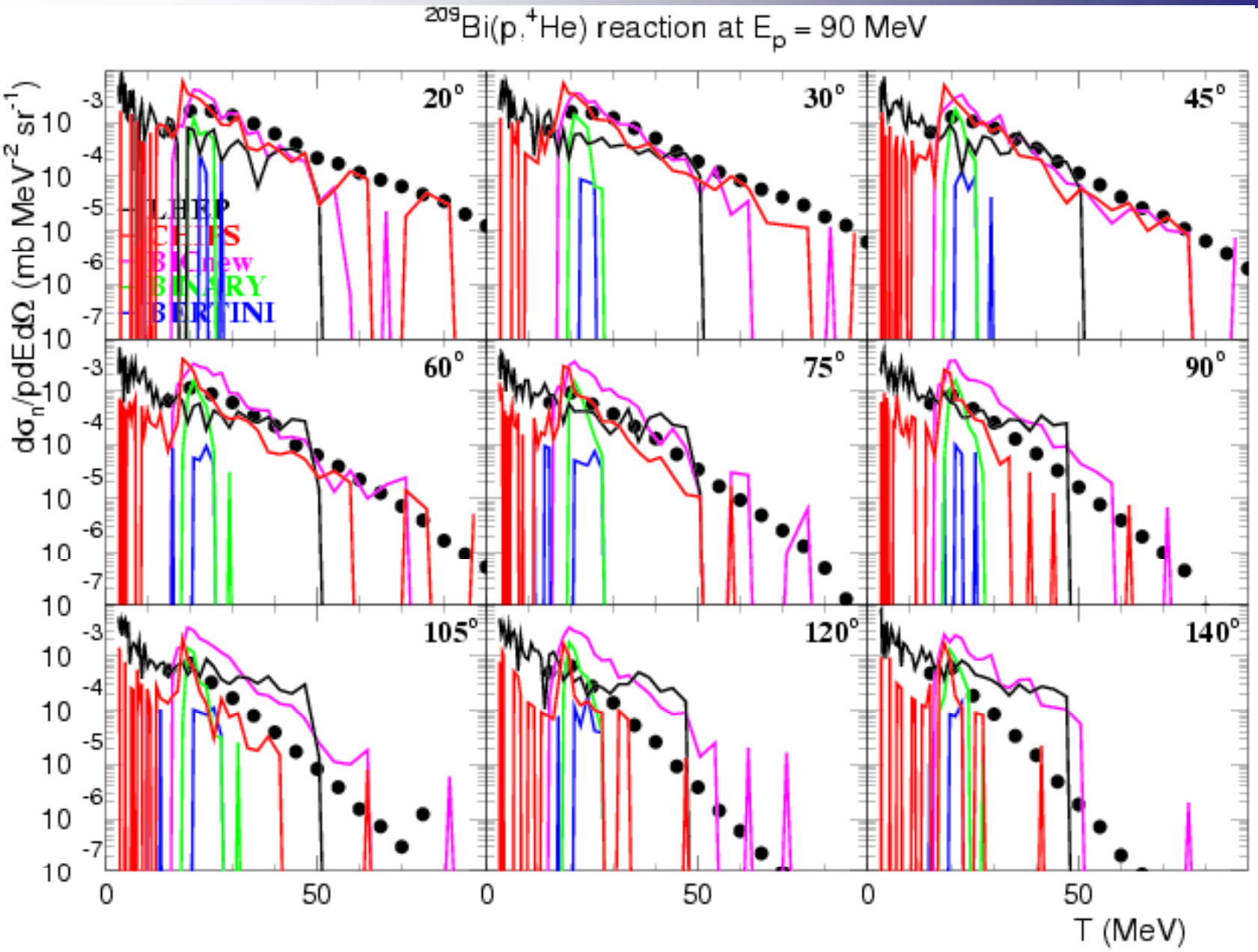

^{209}Bi(p,n) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CHIPS
BICnew
BINARY
BERTINI
T (MeV)


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


^{209}Bi(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
T (MeV)


^{209}Bi(p,t) 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)

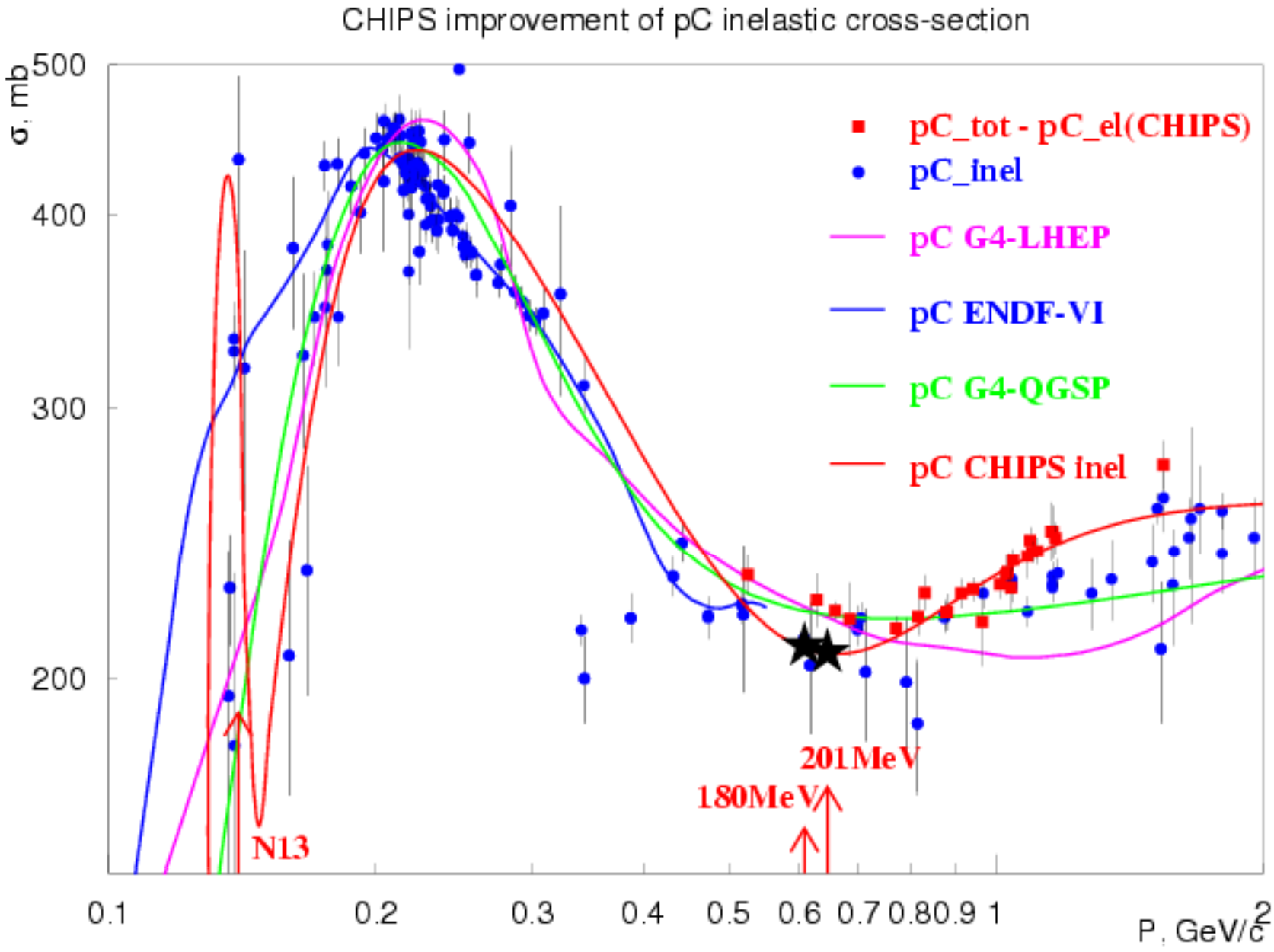

209Bi(p,3He) reaction at Ep = 90 MeV
LAHEP
CHIPS
INCnew
BINARY
BERTINI
20°
30°
45°
60°
75°
90°
105°
120°
140°
dσn/pdEdΩ (mb MeV-2 sr-1)
T (MeV)

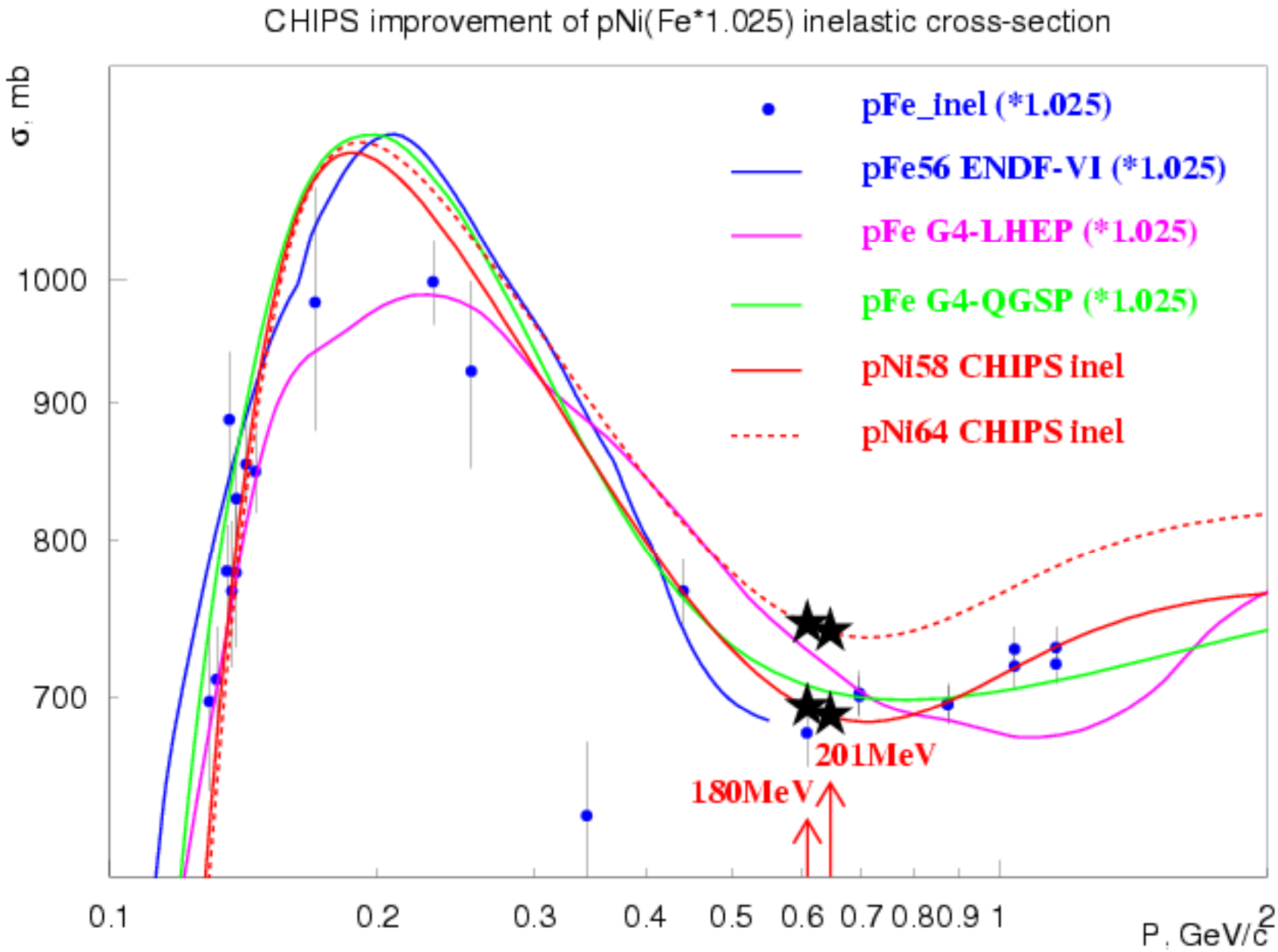

^{209}Bi(p,^{4}He) reaction at E_p = 90 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
20°
30°
45°
60°
75°
90°
105°
120°
140°
LHEP
CEM
BIC new
BINARY
BERTINI
T (MeV)

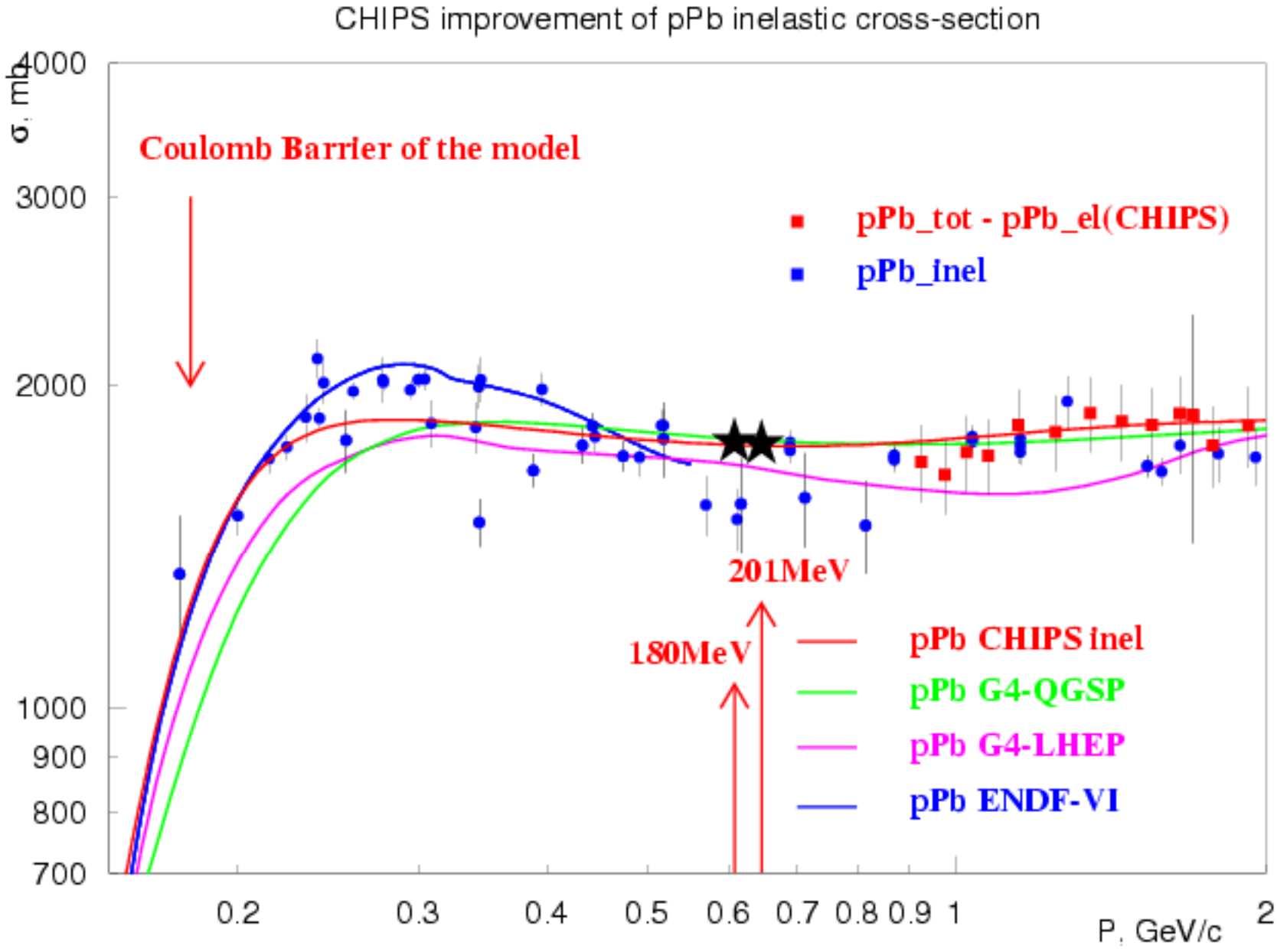
Production of subthreshold pions (E<290 MeV) in the A(p,π)X reaction @ 201 MeV

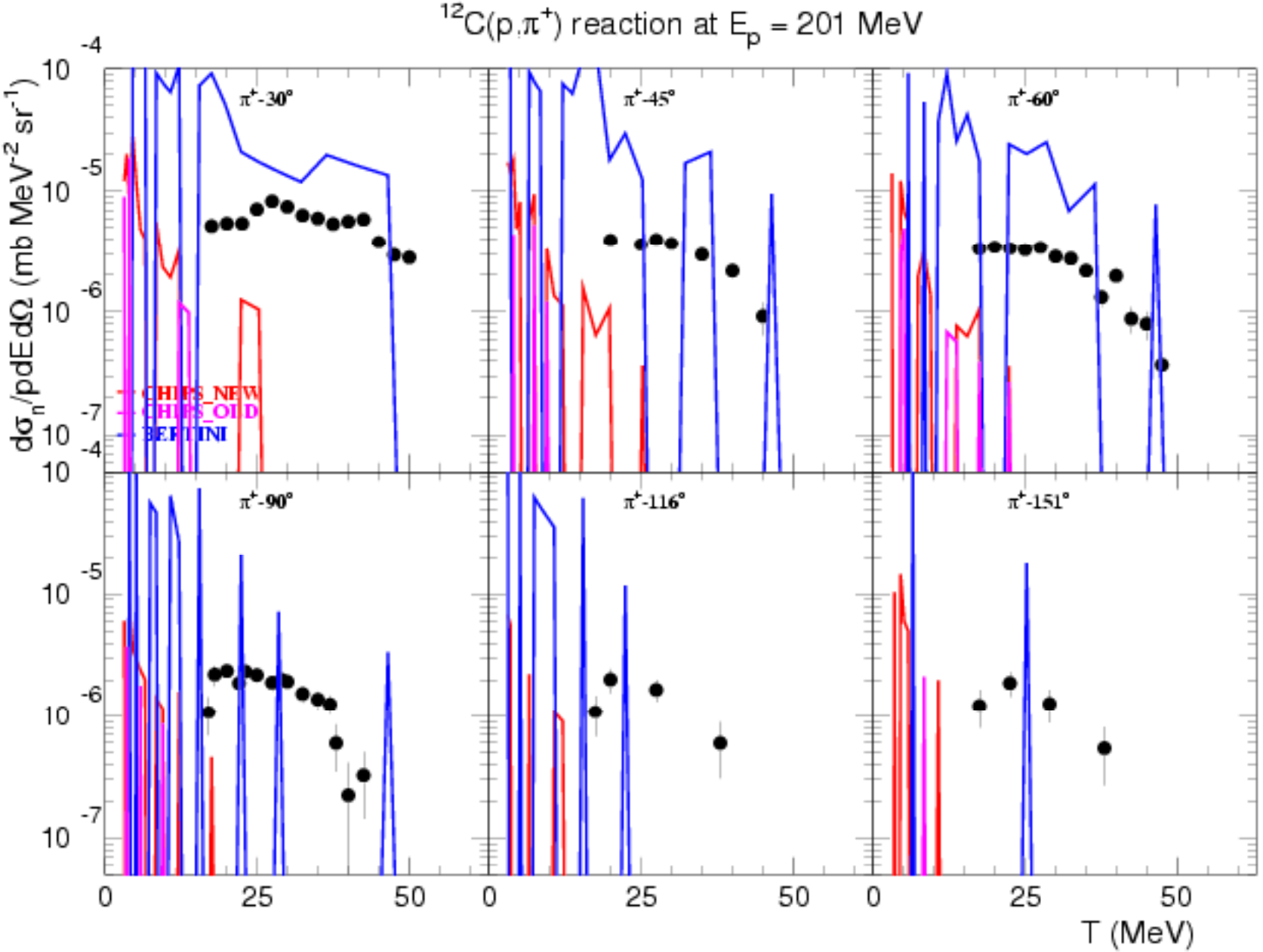
First estimate with the 201 MeV dataset

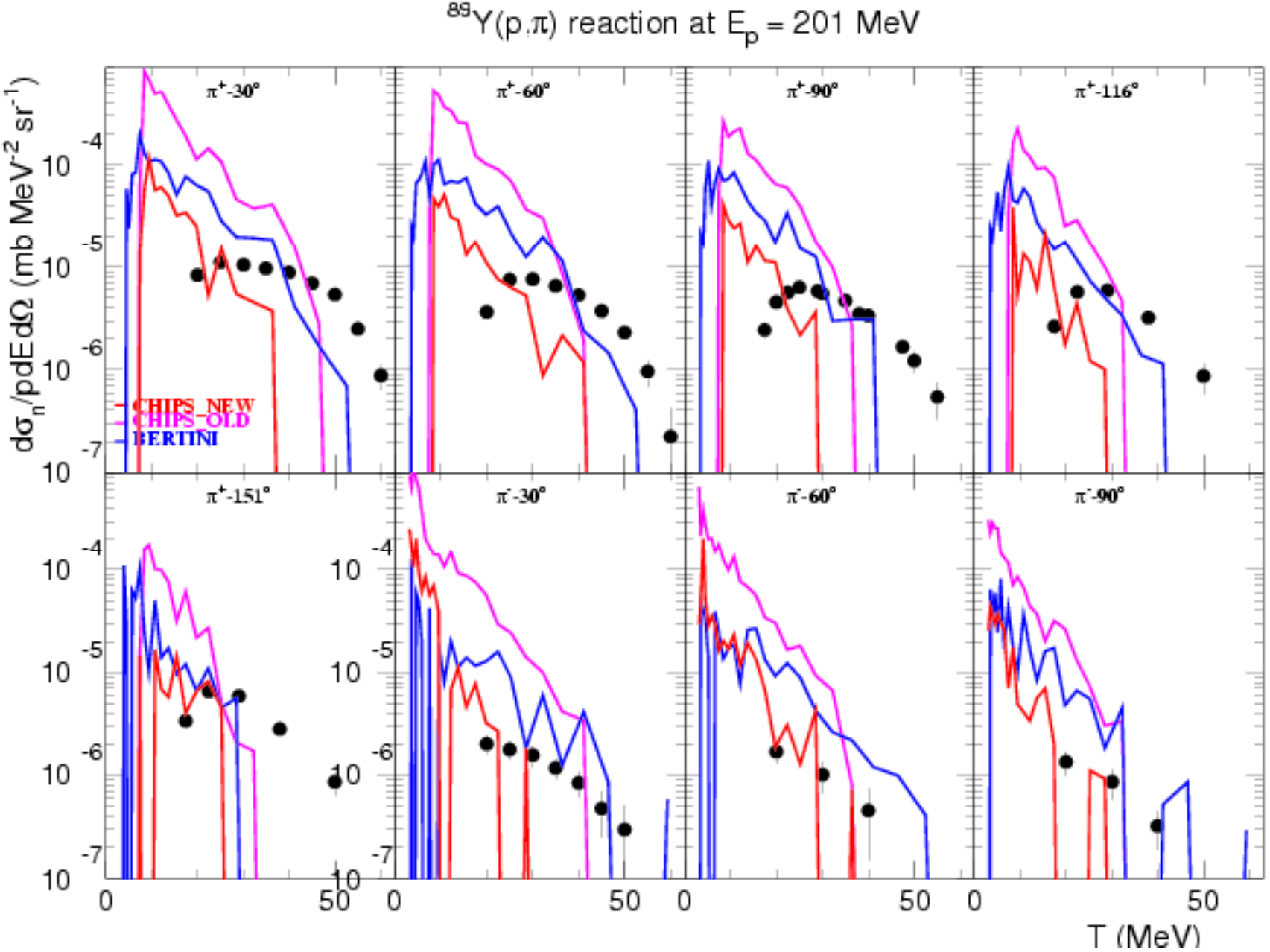
- Data: L.Bimbot et al.,Nucl.Phys.A440(1985)636
  - C,Y,Pb;π^+,π^-;θ:30^0,45^0,60^0,90^0,116^0,151^0(E=180,201MeV)
- Data: A.Badala et al., Phys. Rev. C 46(1992)604
  - ^{56}Ni,^{64}Ni;π^+,π^-;θ:22^0,35^0,55^0,72^0,90^0,105^0,120^0,138^0,155^0
- The data are compared with Preco, Bertini, Binary, LEP, CHIPS (C,Y,Pb @ 201 MeV)
  - Preco/Binari practically don't produce subthreshold pions
  - LEP (LHEP) does not produce subthreshold pions at all
  - Bertini produces too mamy subthreshold pions
  - CHIPS: before tuning is comparable with Bertini, but for C the spectra of pions are too soft. Needs improvement.

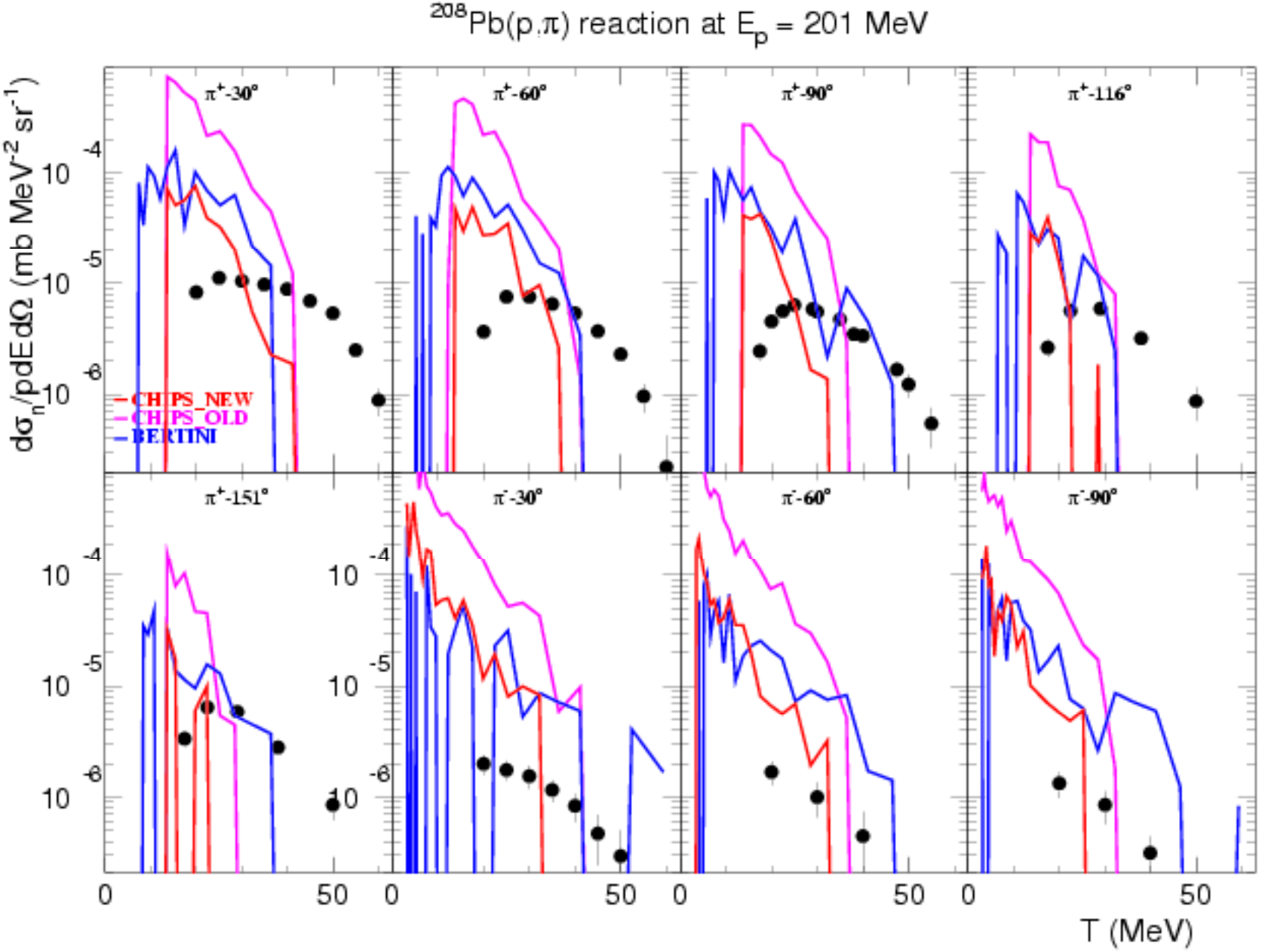

CHIPS improvement of pC inelastic cross-section
σ, mb
500
400
300
200
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
P, GeV/c
pC_tot - pC_el(CHIPS)
pC_inel
pC G4-LHEP
pC ENDF-VI
pC G4-QGSP
pC CHIPS inel
N13
180MeV
201MeV


CHIPS improvement of pNi(Fe*1.025) inelastic cross-section
σ, mb
1000
900
800
700
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
P, GeV/c
pFe_inel (*1.025)
pFe56 ENDF-VI (*1.025)
pFe G4-LHEP (*1.025)
pFe G4-QGSP (*1.025)
pNi58 CHIPS inel
pNi64 CHIPS inel
201MeV
180MeV


CHIPS improvement of pPb inelastic cross-section
σ, mb
4000
3000
2000
1000
900
800
700
Coulomb Barrier of the model
pPb_tot - pPb_el(CHIPS)
pPb_inel
201MeV
180MeV
pPb CHIPS inel
pPb G4-QGSP
pPb G4-LHEP
pPb ENDF-VI
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
P, GeV/c


$^{12}C(p,\pi^+)$ reaction at E_p = 201 MeV
$d\sigma_n/pdEd\Omega$ (mb MeV^{-2} sr^{-1})
π^+-30°
π^+-45°
π^+-60°
π^+-90°
π^+-116°
π^+-151°
CHIPS_NEW
CHIPS_OLD
BERTINI
T (MeV)


^{89}Y(p,π) reaction at E_p = 201 MeV
π⁺-30°
π⁺-60°
π⁺-90°
π⁺-116°
π⁺-151°
π⁻-30°
π⁻-60°
π⁻-90°
CHIPS_NEW
CHIPS-OLD
BERTINI
dσ_n/pdEdΩ (mb MeV⁻² sr⁻¹)
T (MeV)


208Pb(p,π) reaction at Ep = 201 MeV
π+-30°
π+-60°
π+-90°
π+-116°
π+-151°
π--30°
π--60°
π--90°
dσn/pdEdΩ (mb MeV-2 sr-1)
CHIPS_NEW
CHIPS_OLD
BERTINI
T (MeV)

Conclusion

- All G4 models but LEP satisfactory fit spectra of p & n at 90 MeV (BINARY was the worst, now PRECO is the worst)
- Now CHIPS is faster than BINARY and PRECO
- LEP & G4QLowEn are the fastest generators but LEP does not produce ^{3}He and produces too many other fragments
- Bertini is the fastest of the comprehensive models, and now for p it is the best, but it has problems with heavier fragments
- G4PreCompoundModel has been cured for d, but now it has the overestimated yield of α's on Bi (at 90 MeV)
- Enhanced forward yield of fragments is badly reproduced by all the G4 Models except for CHIPS
- CHIPS is good for yields of all nuclear fragments at 90 MeV