AccApp2009

Vienna, Austria

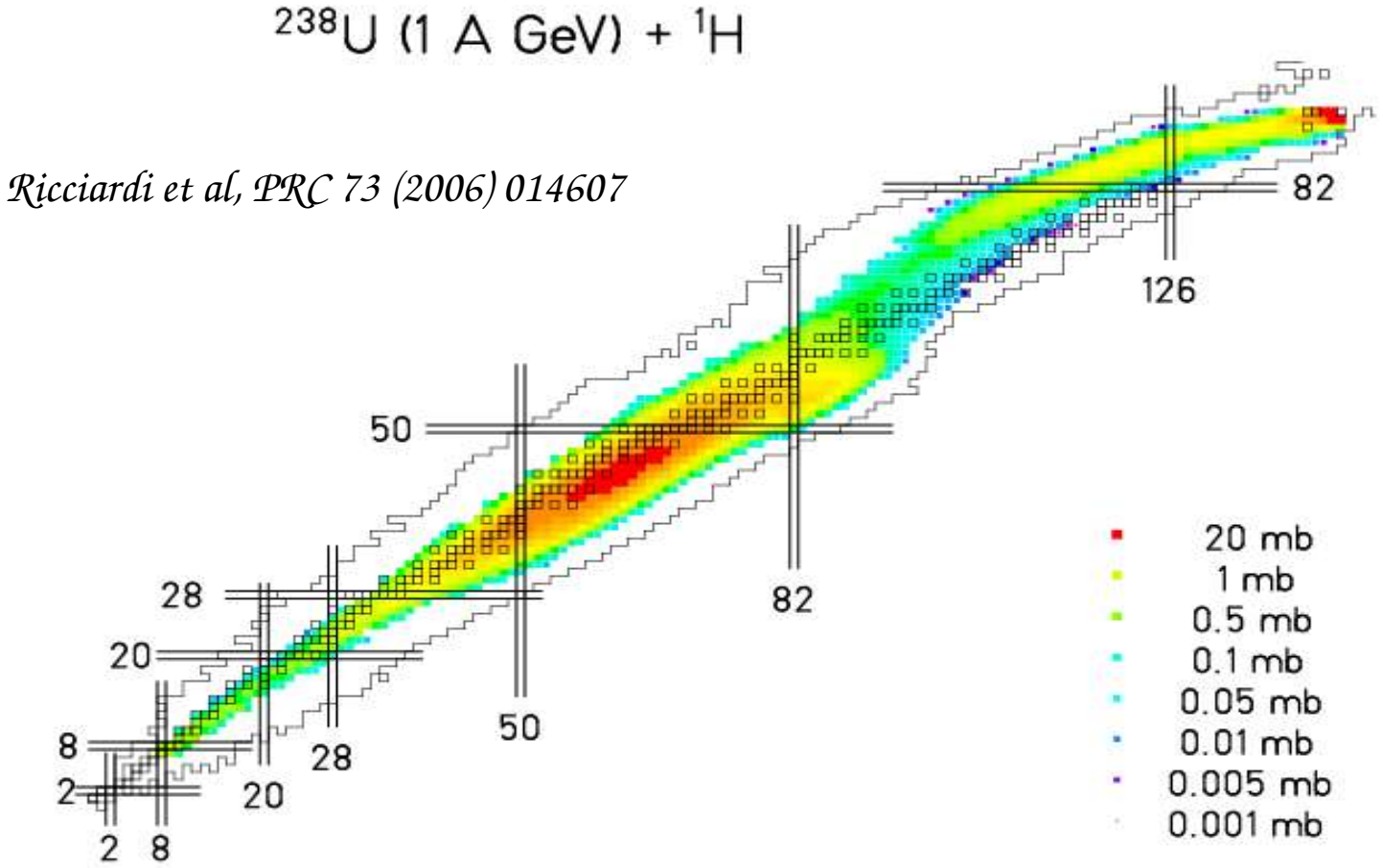
Production of A+1 and Z+1 isotopes in p-^{A}Z reactions. Application to p-^{208}Pb and p-^{209}Bi.

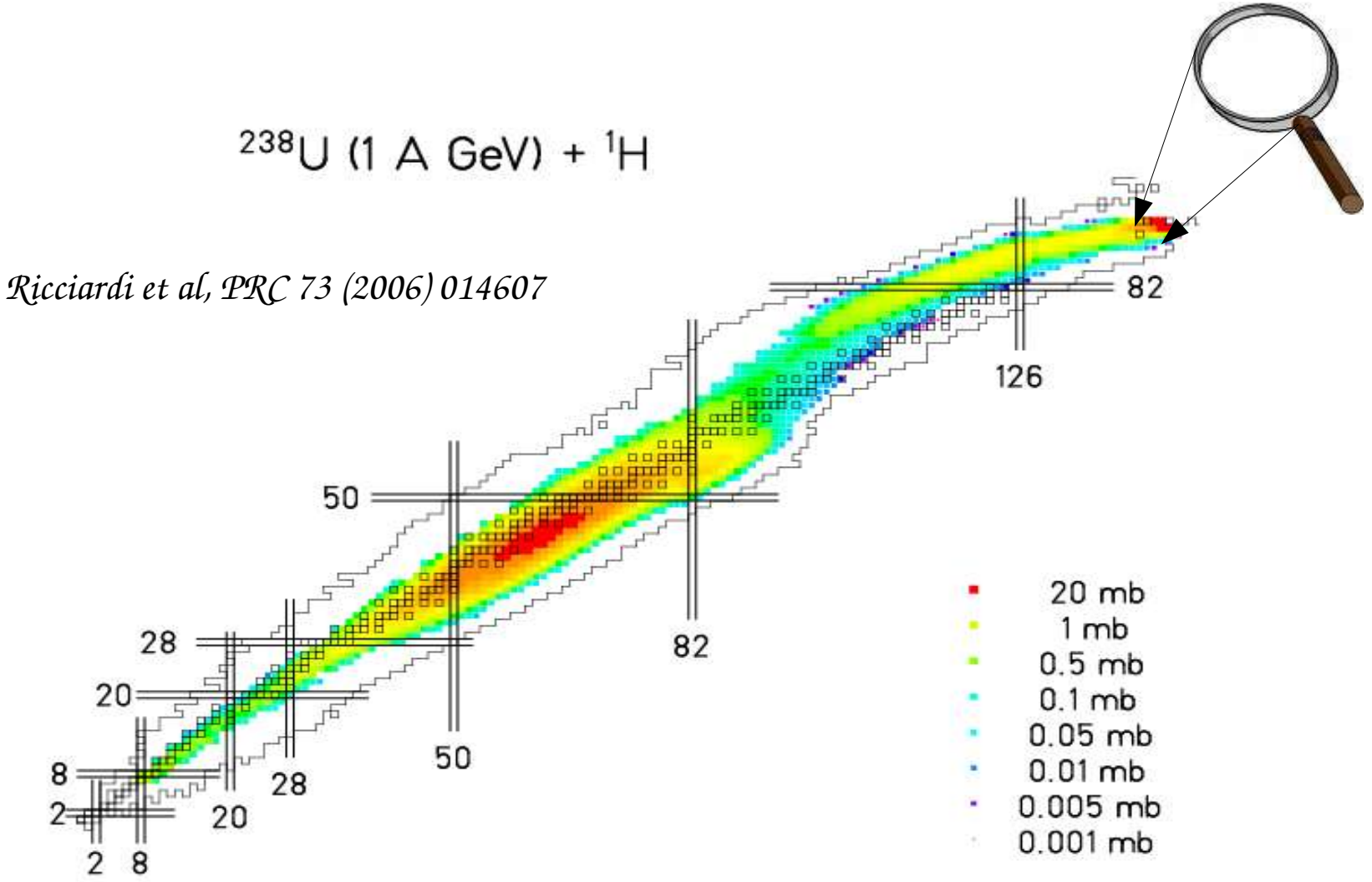
J. CUGNON (ULg), Th. AOUST (SCK-CEN &AVN-Belgium)

INCL4 Collaboration

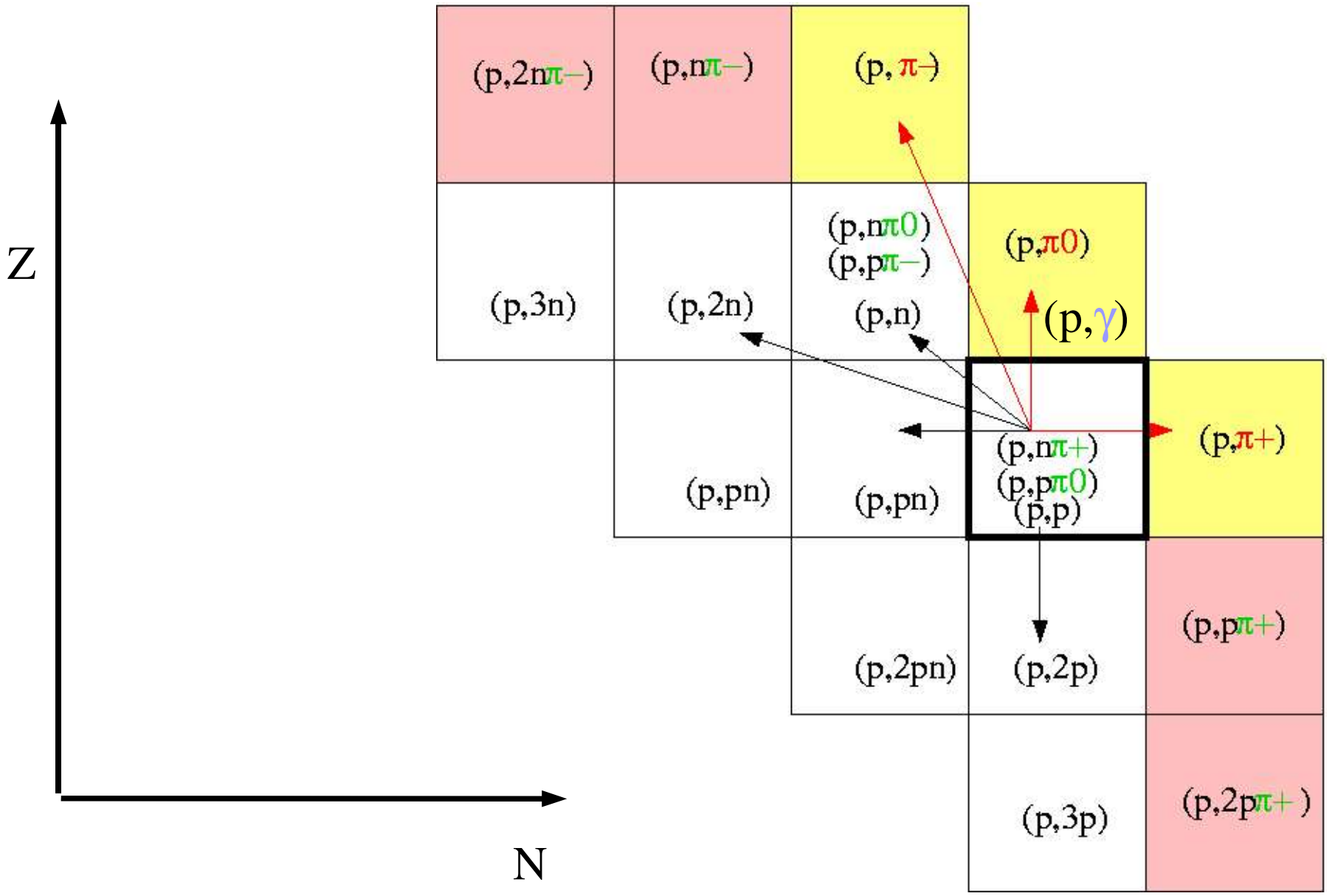
- Introduction
- Special channels and special dynamics for special isotopes
- Importance of pion-producing channels
- Test of INCL4.4.3: Emphasis on the energy-dependence of the nuclear mean field
- Importance for radiotoxicity
- Conclusion

1. Introduction

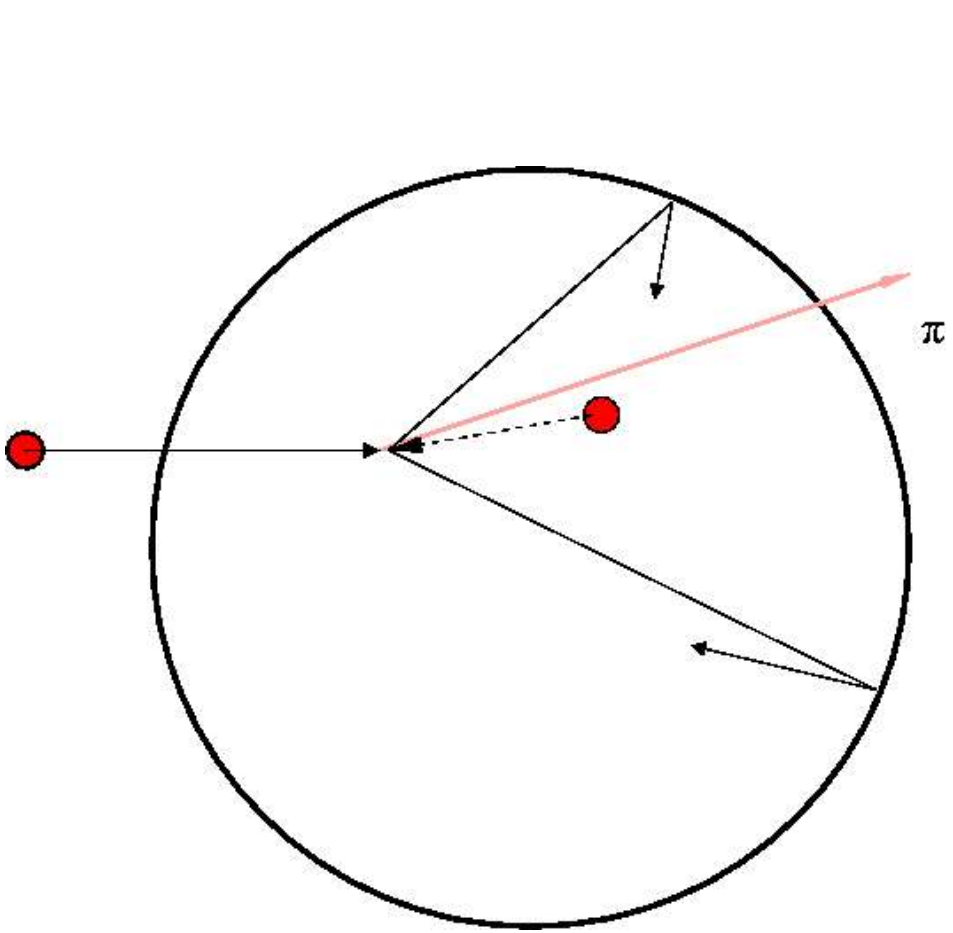


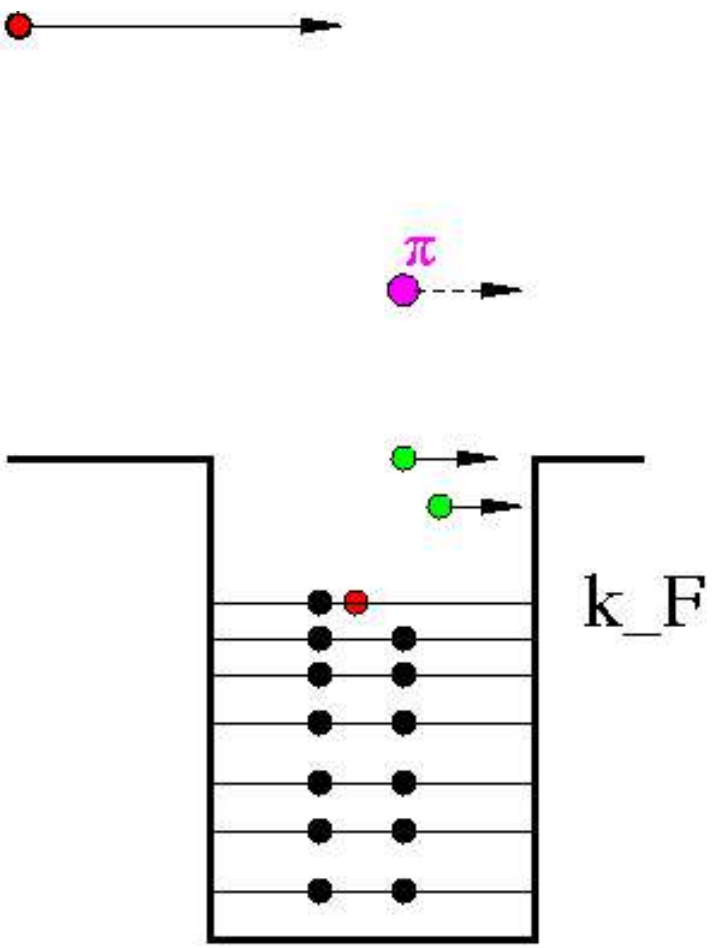

^{238}U (1 A GeV) + ^{1}H
Ricciardi et al, PRC 73 (2006) 014607
82
126
50
28
20
8
2
2
8
20
28
50
82
20 mb
1 mb
0.5 mb
0.1 mb
0.05 mb
0.01 mb
0.005 mb
0.001 mb

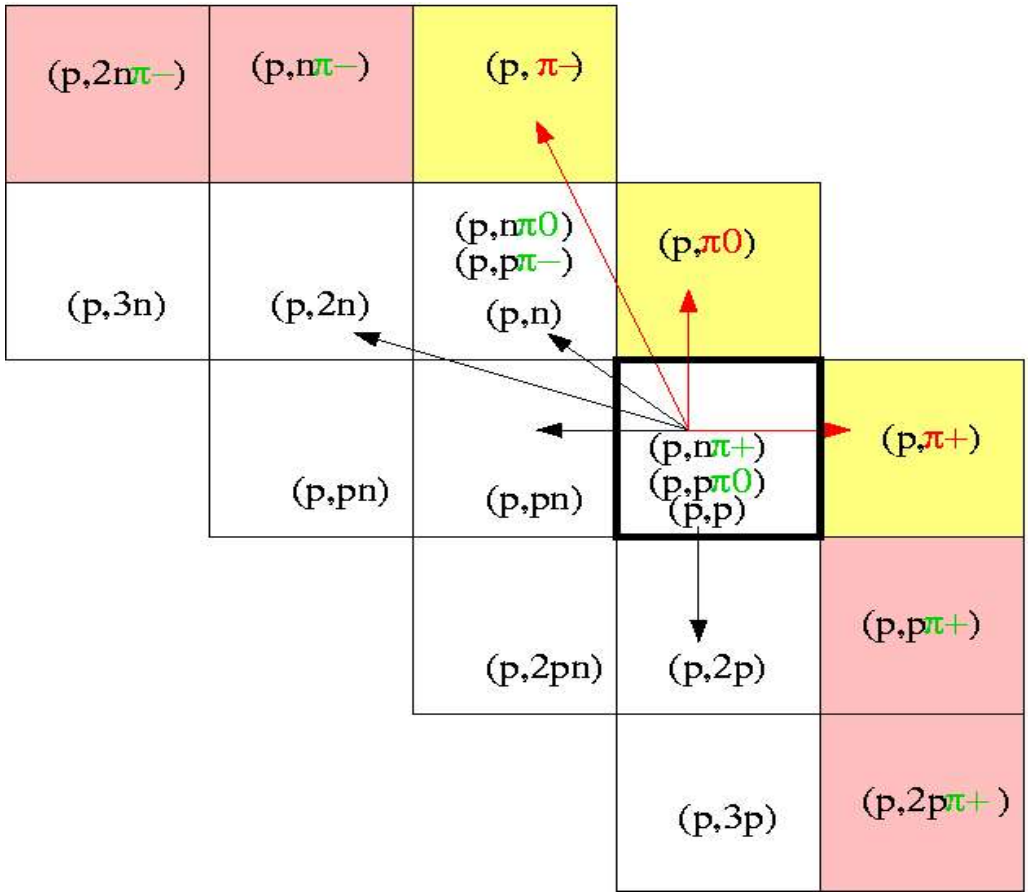
2. Special channels



Production of A+1 isotopes = single scattering with stringent kinematical conditions



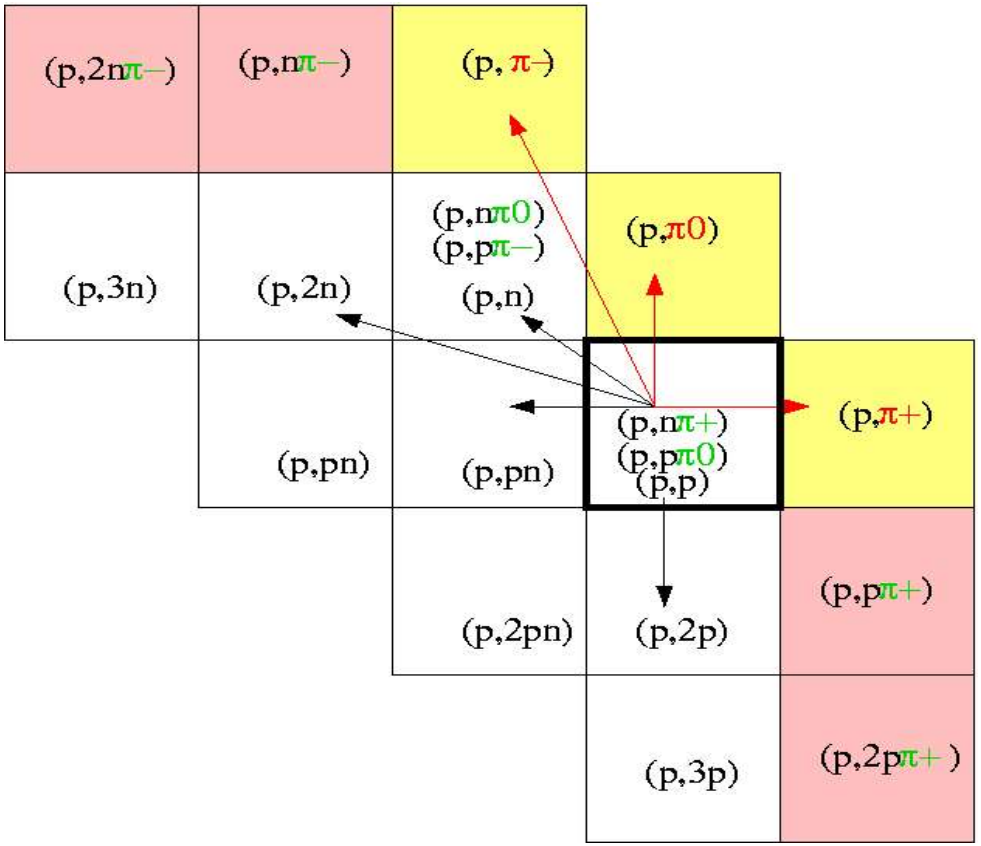




Production of Z+2 isotopes = at least one inelastic scattering

- Production of $^{A}(Z+2)$= one single inelastic scattering with constraints: no further interaction for the pion and one nucleon trapped (only)

- Production of $^{(A-1)}(Z+2)$= two scatterings with constraints: no further interaction for the pion and one nucleon trapped (only)



Production of Z+1 isotopes =
more dynamical paths, less constraint

- Production of $^{A}(Z+1)$= one single elastic scattering with constraints: no further interaction for one of the nucleons; but also one inelastic collisions with no further interaction for the pion and one of the nucleons

- Production of $^{(A-1)}(Z+1)$= two elastic scatterings or one elastic and one inelastic collisions

3. Importance of pion production

1. production of a given isotope

↕

single channel

↕

simple dynamical path

2. importance of pion production channels

A good test for INC models

4. INCL4

brief description of INCL4.2=standard version:

- ordered & separated NN collisions
- elastic or inelastic
- subject to Pauli blocking†
- potential well†
- transmission, reflection, (refraction)†
- stochasticity†
- relativistic kinematics
- isospin degree of freedom

INCL4.4.3

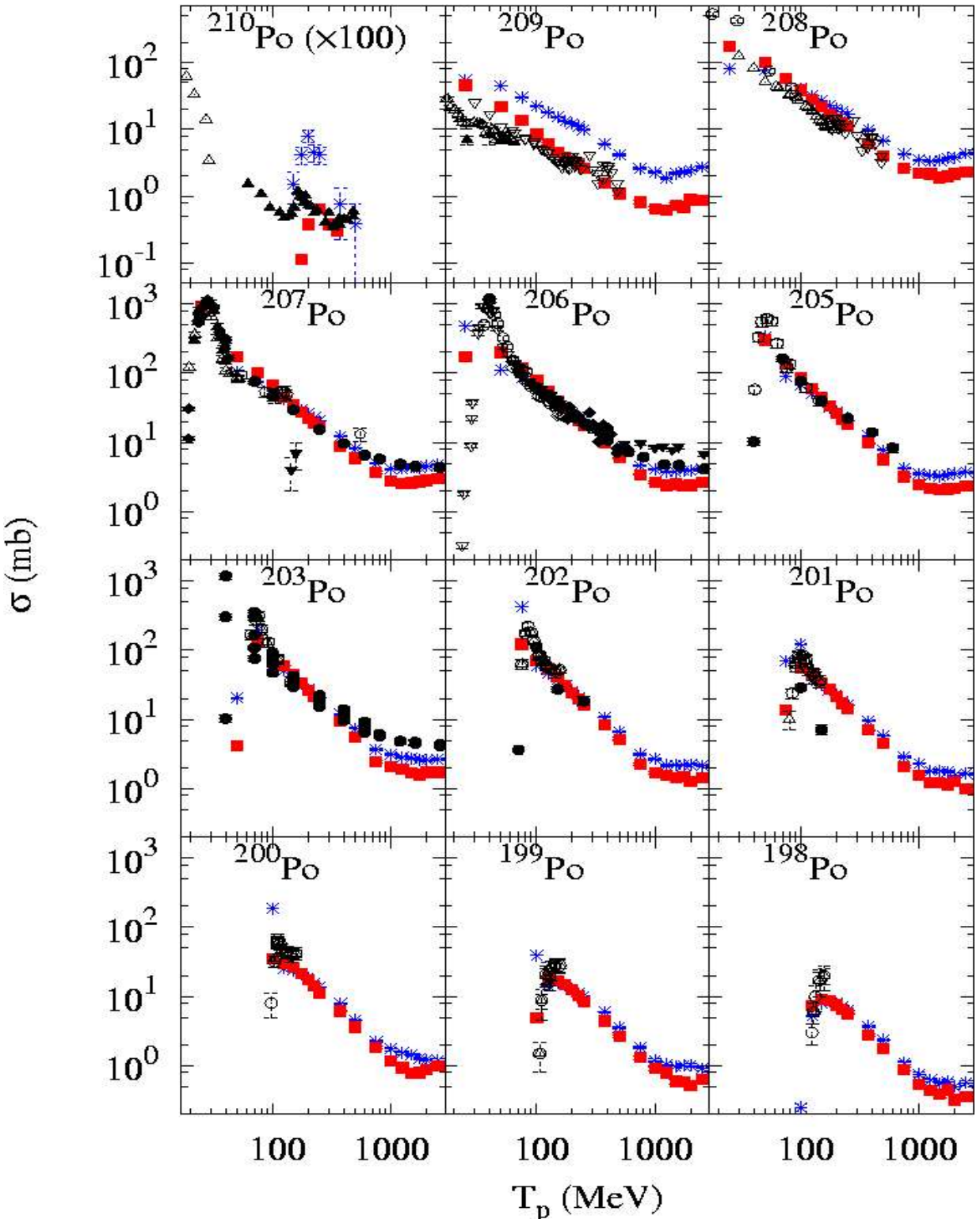
- isospin and energy-dependence of the potential well depth
- average potential well for pions
- strict Pauli blocking on the first collision

INCL4.5 (composites+low energy features): see satellite meeting

Here: coupled to ABLA fission-evaporation code.

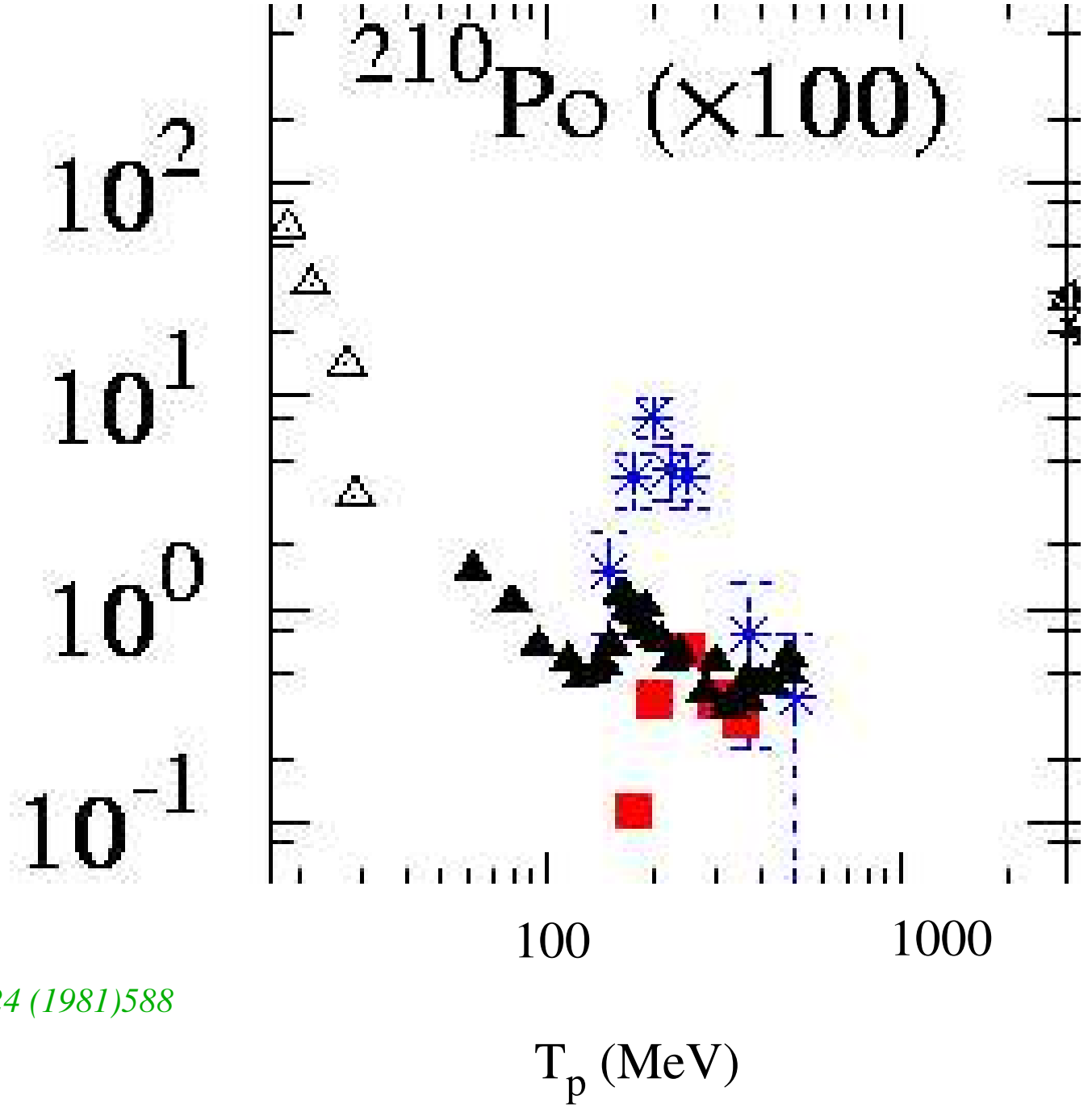
5. Results

- Production of A+1 isotopes in p+^{209}Bi: ^{210}Po
- Production of Z+1 isotopes in p+^{209}Bi: ^{209}Po,^{208}Po, ...
- Production of Z+1 isotopes in p+^{208}Pb: Bi

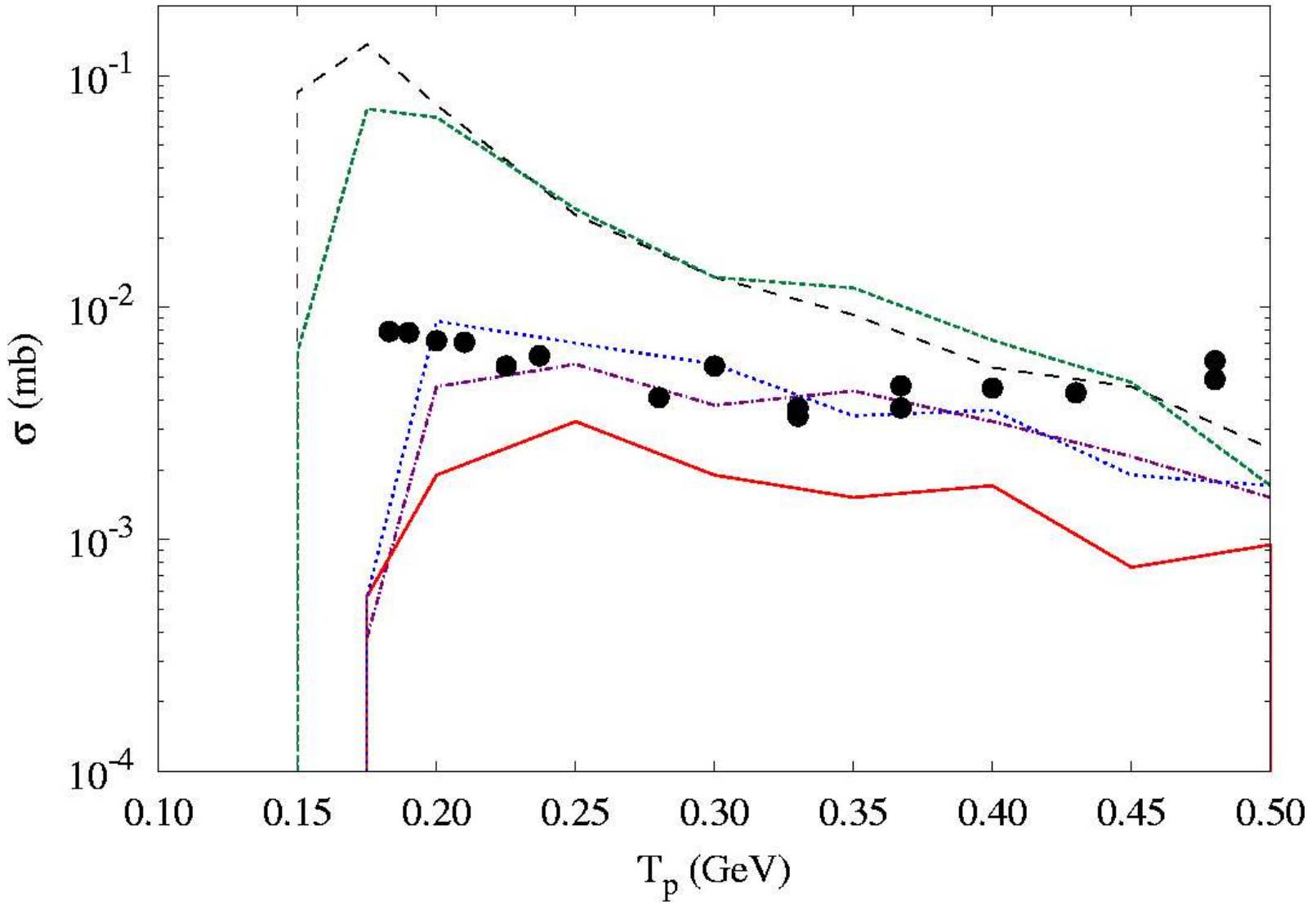

210Po (×100)
209Po
208Po
207Po
206Po
205Po
203Po
202Po
201Po
200Po
199Po
198Po
σ (mb)
T_p (MeV)
100
1000

$p+^{209}Bi$

A+1



T.E. Ward et al, PRC24 (1981)588



_____ INCL4.2

_____ + Isospin-dependent N potential

_____ + E-dependent N potential

_____ + pion potential

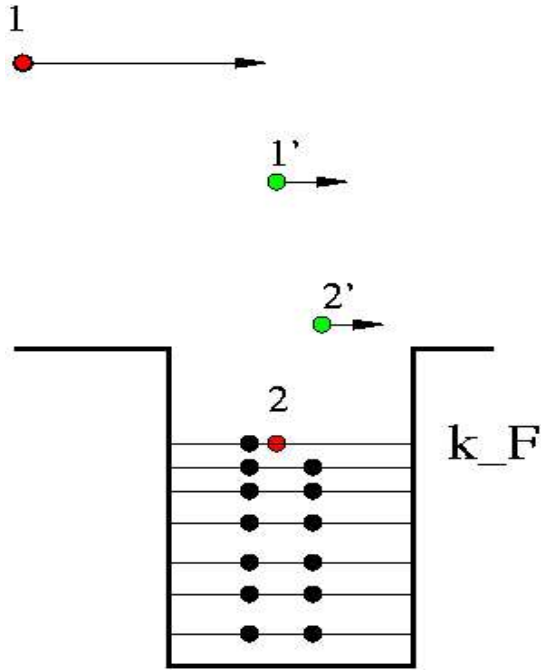
_____ + strict Pauli blocking on 1st collision =INCL4.4.3

Conservation of energy for collisions of particles moving in potential well

Optical model: linear dependence in V(E)

EL

$$E_1 + V(E_1) + E_2 + V(E_2) = E_1' + V(E_1') + E_2' + V(E_2')$$

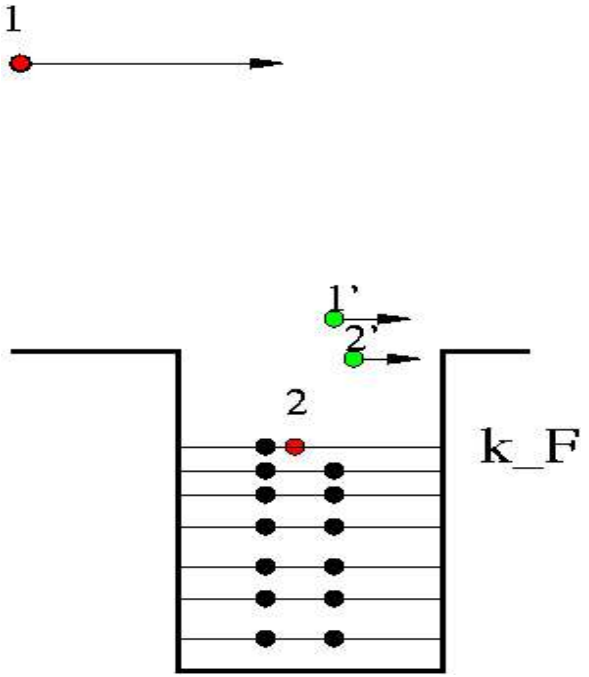


$$E_1' + E_2' \approx E_1 + E_2$$

$$V(E_1') + V(E_2') \approx V(E_1) + V(E_2)$$

INEL

$$E_1 + V(E_1) + E_2 + V(E_2) = E_1' + V(E_1') + E_2' + V(E_2') + \Delta M c^2$$



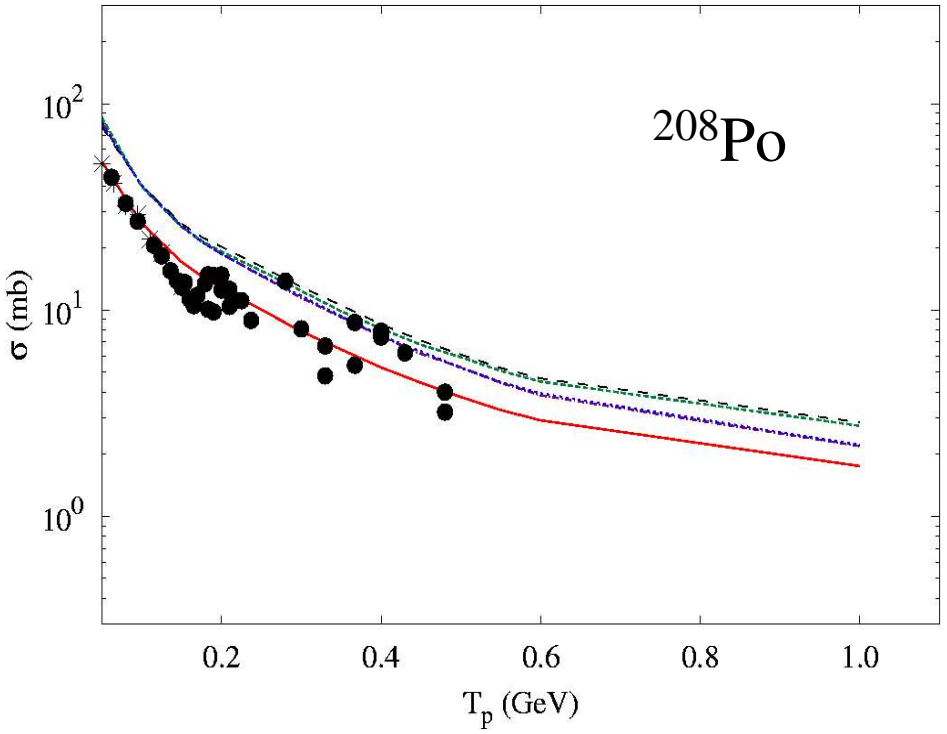
$$E_1' + E_2' < E_1 + E_2$$

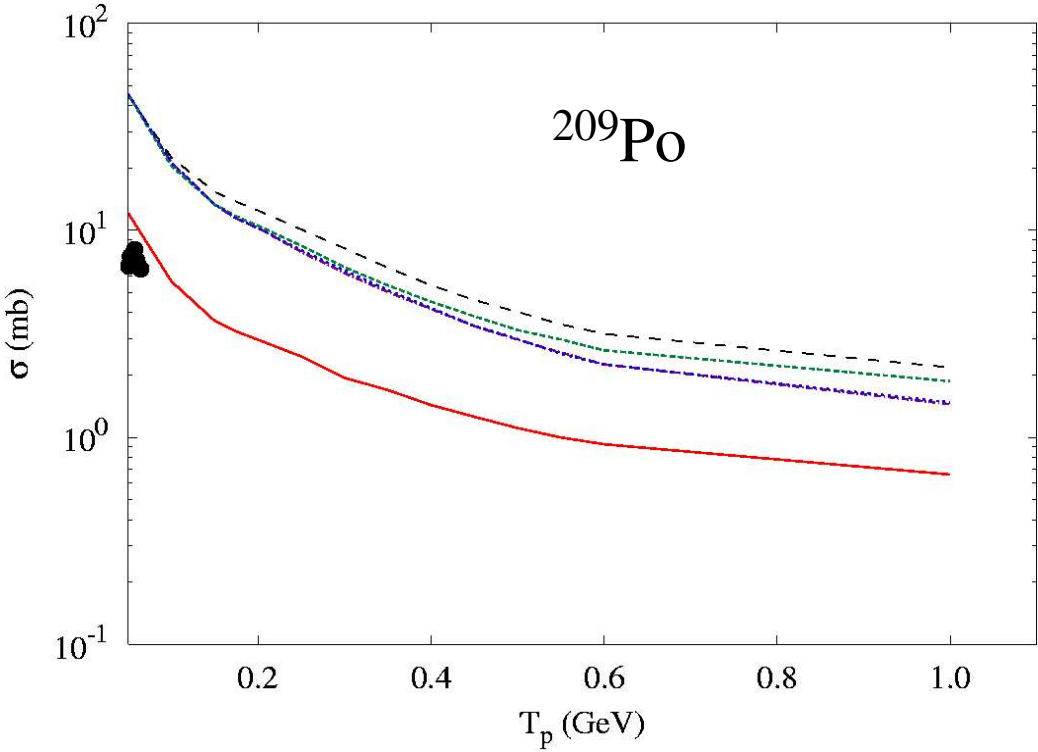
$$V(E_1') + V(E_2') > V(E_1) + V(E_2)$$

Effective negative extra Q-value

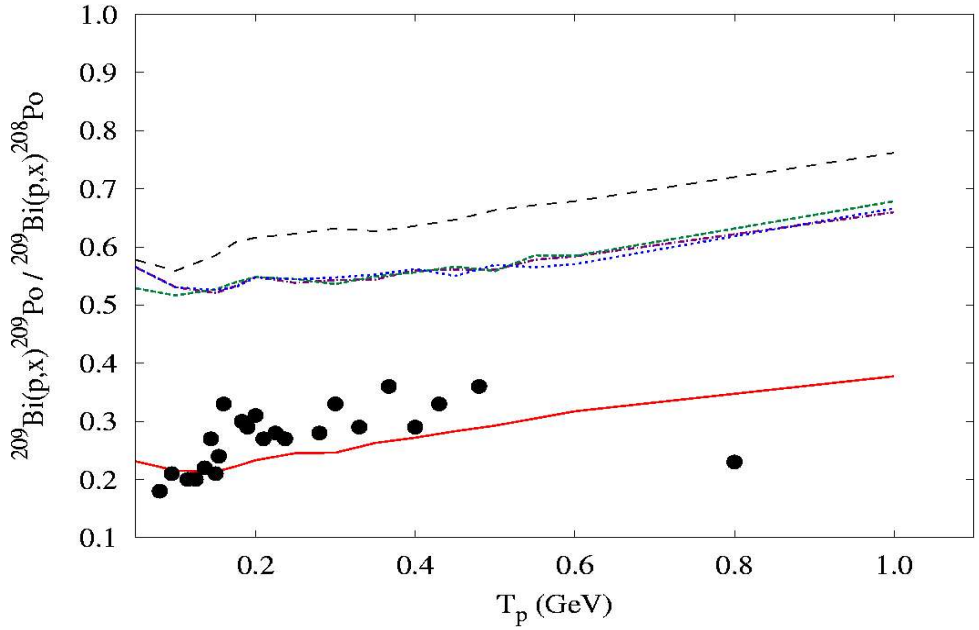
The energy-dependence leaves a fingerprint in single-inelastic scattering events

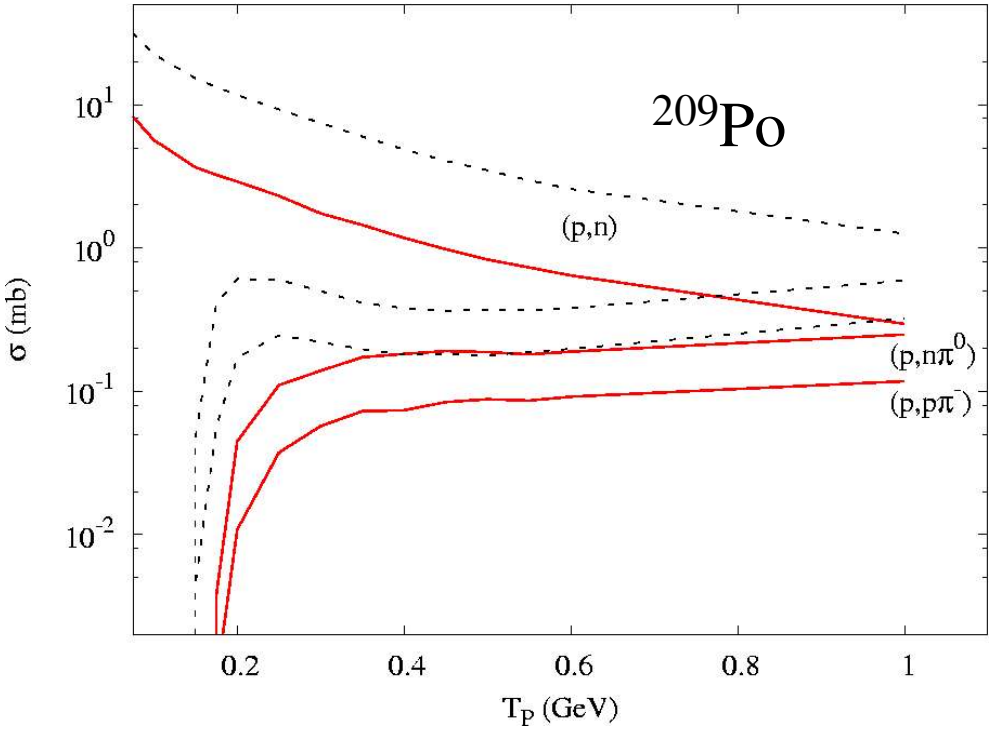
It is washed out in other events

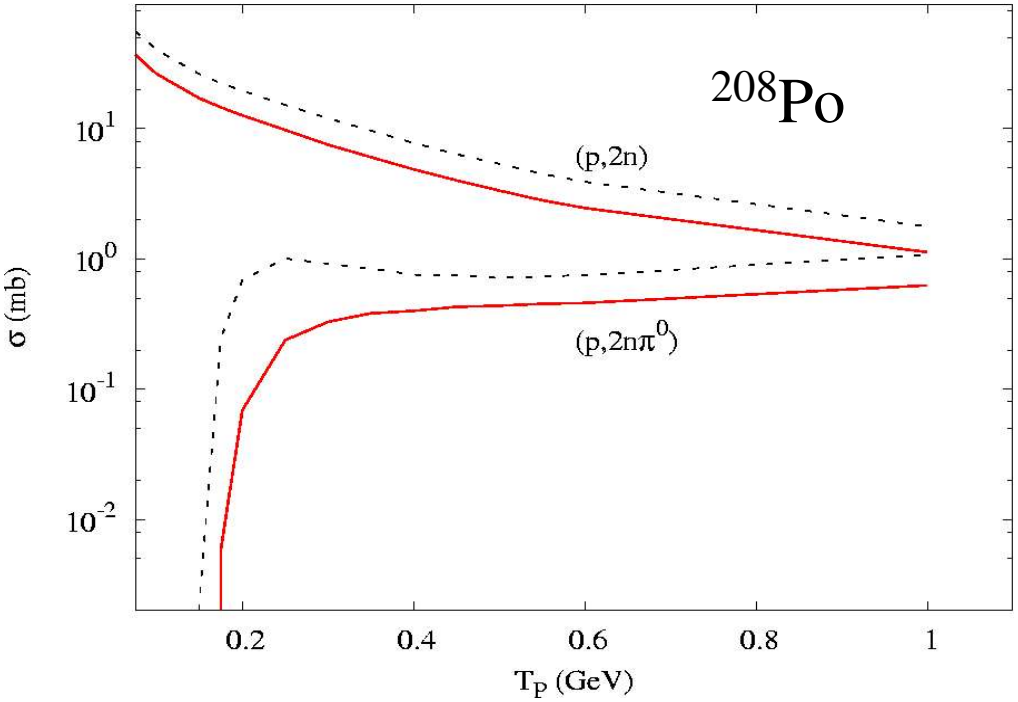

^{208}Po
σ (mb)
T_p (GeV)

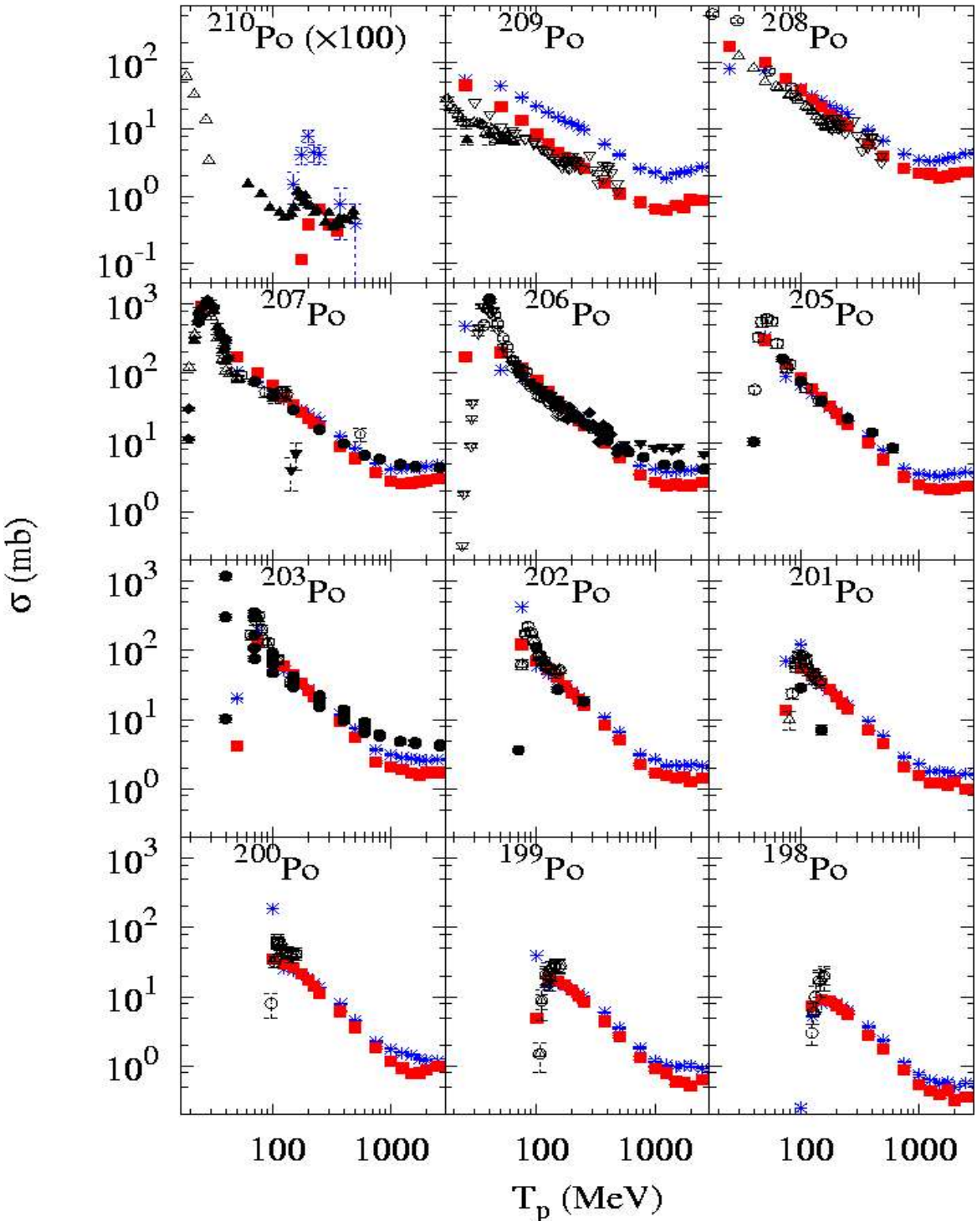

^{209}Po
σ (mb)
T_p (GeV)

Z+1

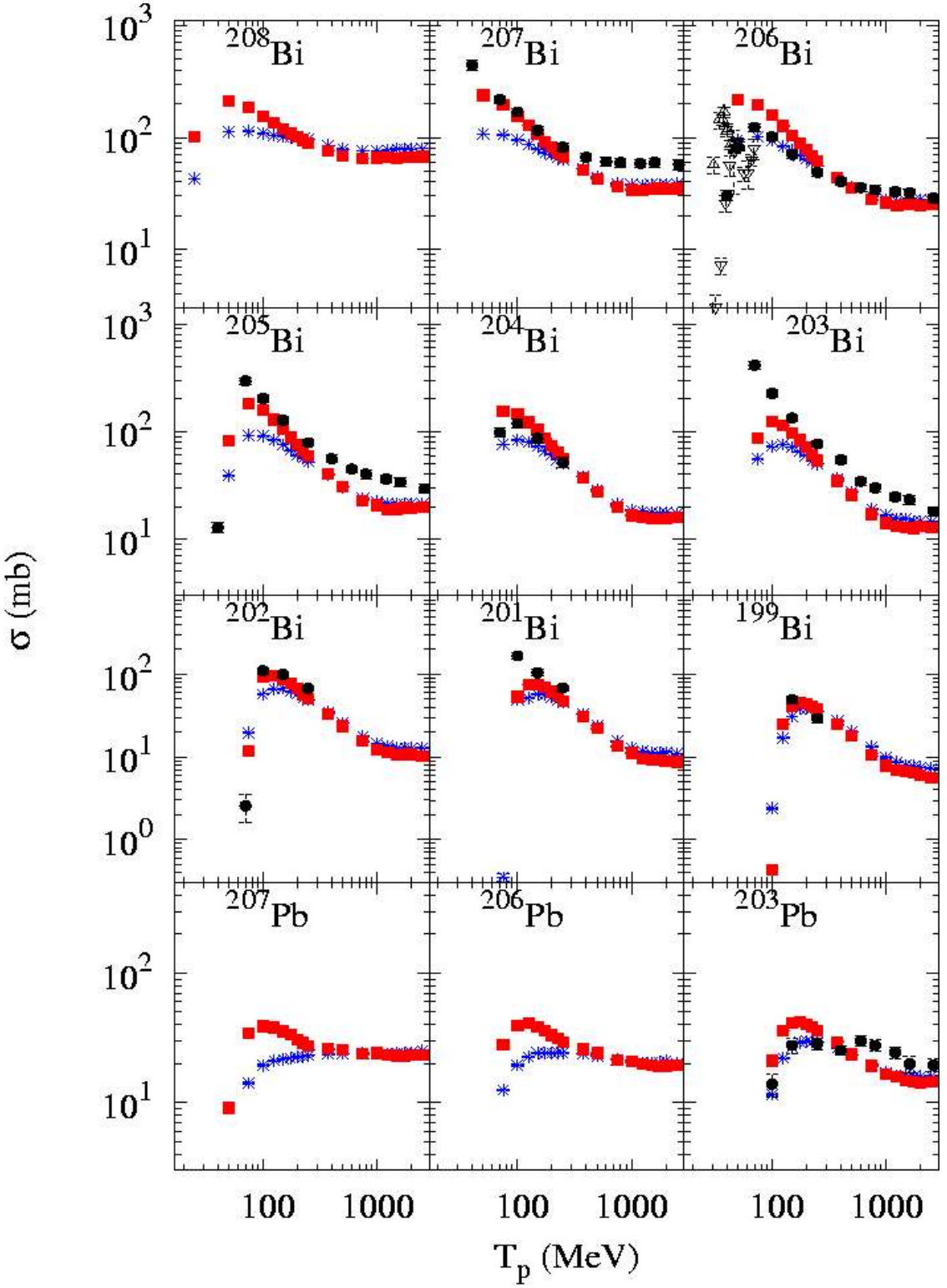

^{209}Bi(p,x)^{209}Po / ^{209}Bi(p,x)^{208}Po
T_p (GeV)


^{209}Po
(p,n)
(p,nπ^0)
(p,pπ$^-$)
σ (mb)
T_P (GeV)


^{208}Po
(p,2n)
(p,2nπ^0)
σ (mb)
T_P (GeV)


^{210}Po (×100)
^{209}Po
^{208}Po
^{207}Po
^{206}Po
^{205}Po
^{203}Po
^{202}Po
^{201}Po
^{200}Po
^{199}Po
^{198}Po
σ (mb)
T_p (MeV)

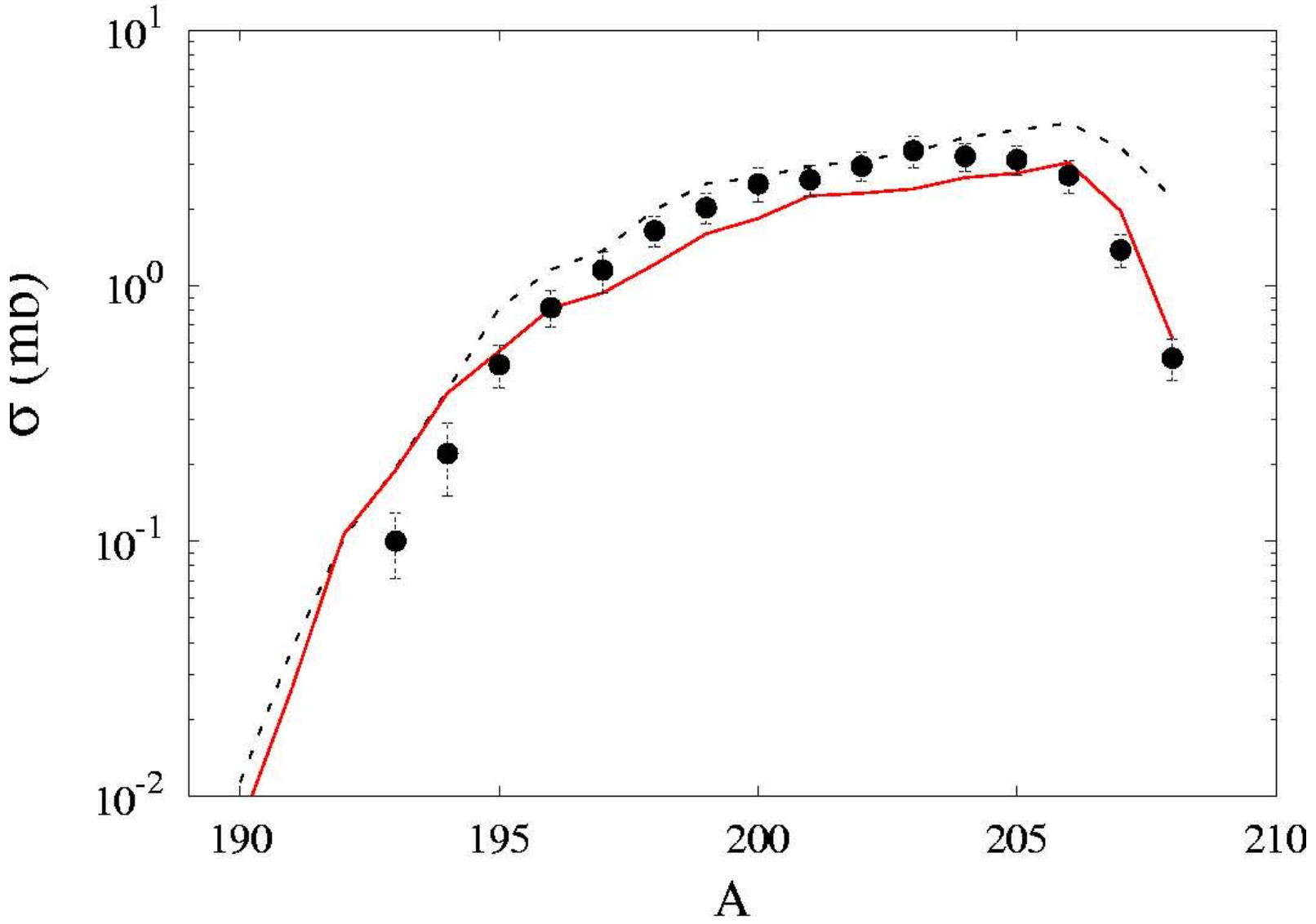
$p+^{209}Bi$


208Bi
207Bi
206Bi
205Bi
204Bi
203Bi
202Bi
201Bi
199Bi
207Pb
206Pb
203Pb
σ (mb)
T_p (MeV)
100
1000

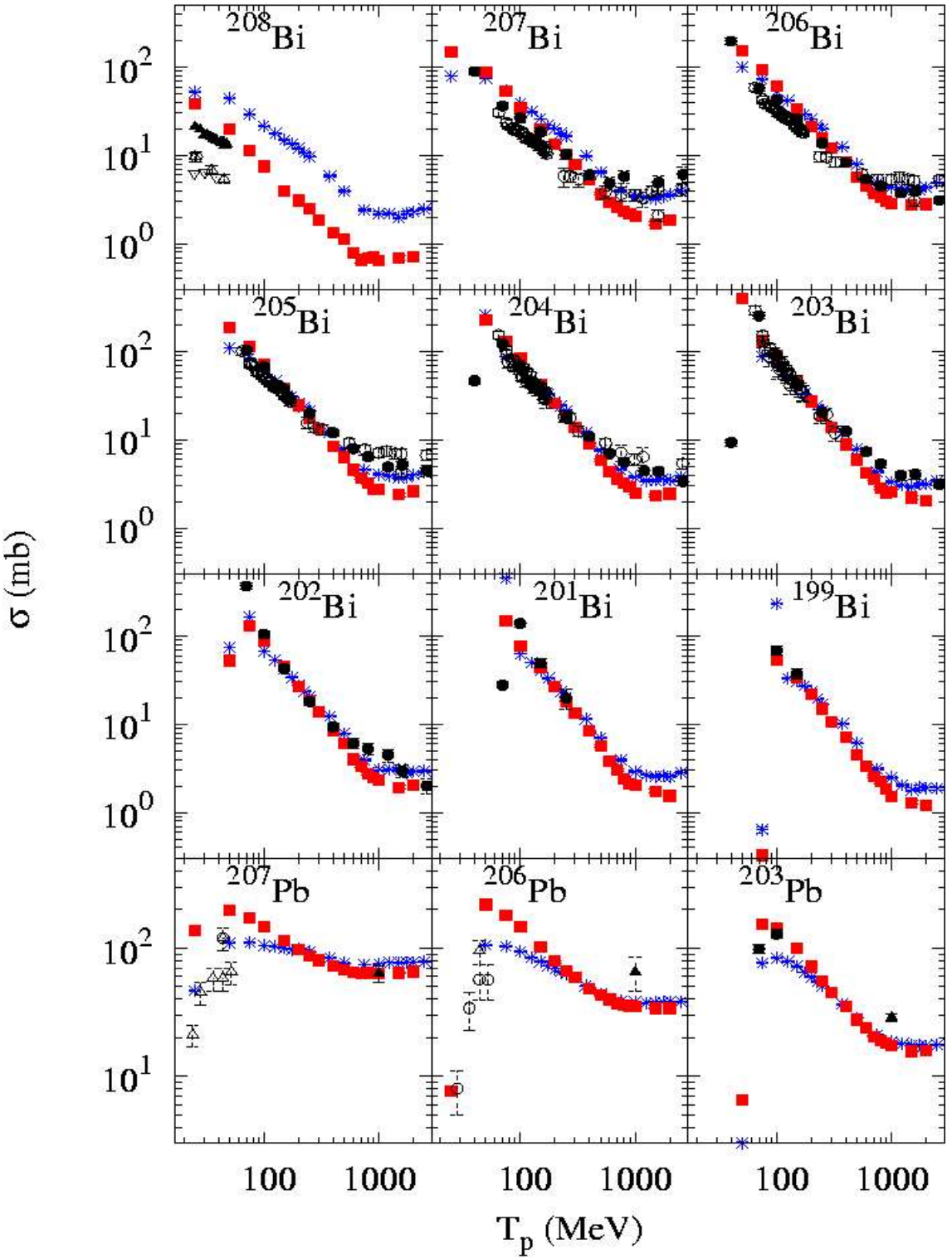
$p+^{209}Bi$

Bi isotopes: Z+1

$p(1GeV)+^{208}Pb$



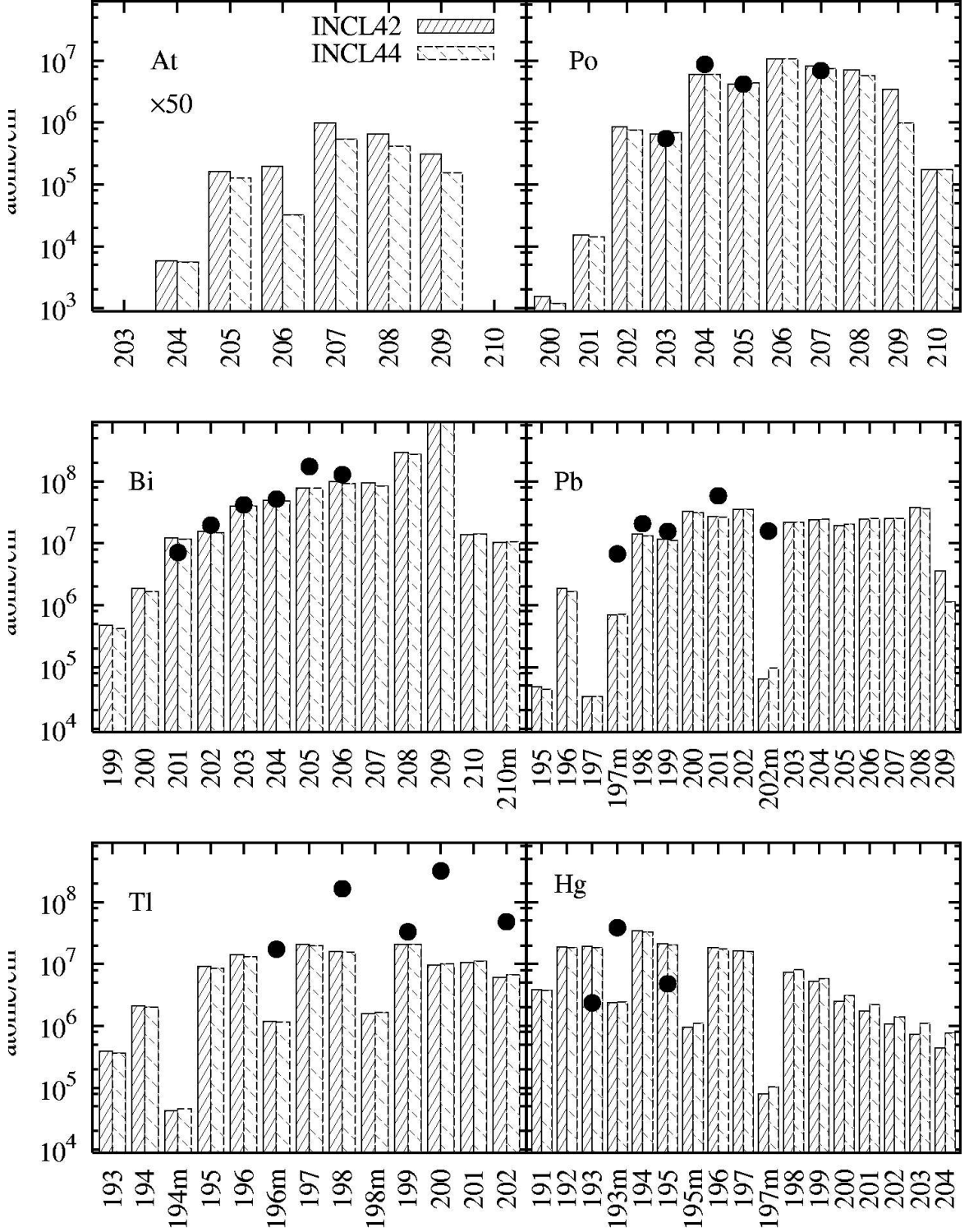
A. Kelic et al


208Bi
207Bi
206Bi
205Bi
204Bi
203Bi
202Bi
201Bi
199Bi
207Pb
206Pb
203Pb
σ (mb)
T_p (MeV)
100
1000

$p+^{208}Pb$

Z+1

6. Applications to Pb-Bi targets



alternate disks of Pb-Bi

3rd disk in Bi

K. Van der Meer et al

NIM Phys. Res. B217 (2004) 202

7. Conclusion

- For residues close to target, identification of channels and mechanisms
- Pion production channels are important
- Pion fusion (A+1) is dominated by incoherent process
- Bears the fingerprint of the energy-dependence of the nucleon potential
- Improved version of INCL4 is successful
- May be of importance for radiotoxicity studies