V-03-Meigo

Particle-transport Calculation

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Introduction

Neutronics calculation are performed for MLF design with NMTC/JAM such as shielding and property of spallation neutron source(intensity, pulse structure, heat deposition and so on)

NMTC/JAERI: Standard calculation for JKJ
Spallation neutron source, Transmutation (ADS)
Beam line (3N BT), Shielding calculation for 50GeV synchrotron

As for shielding, MCNPX is employed as well.

For assurance of prediction capability of the particle transport code.

NMTC/JAM and MCNPX are compared with the experimental data.

NMTC/JAM

NMTC: Nucleon Meson Transport Code
- Monte Carlo technique
- (Intra nuclear cascade + evaporation) ＋inter transport
- Bertini Cascade model (up to 3.5 GeV)

JAM：Jet AA Microscopic transport model, Phys. Rev. C61,024901(1999)
- Developed by research group for hadron science at JAERI
- Applicable energy ~1 TeV
- All kind of hadrons can be transported.

NMTC/JAM:
- Above 3.5 GeV: JAM   Below 3.5 GeV: Bertini
- Not only installed JAM, but also the following modified.
  - Revised the nucleon-nucleus cross section
  - New evaporation model (GEM: Generalized Evaporation Model)
  - Charged particle transport in magnetic field calculation

History of NMTC/JAM

Downsizing
- PC(Linux)
- DEC-Alpha(Unix)
- Sun(Solaris)

1951	NMTC(ORNL)	Intranuclear cascade model Evaporation model
1983	NMTC/JAERI	Implemented high energy fission model
1997	NMTC/JAERI97	N-nucleus cross section revised(1) Level density parameter Simplify of geometry (CG geometry) Importance sampling
2000	NMTC/JAM	JAM model N-nucleus cross section revised (2) Transport in magnetic field

Now available: Automatic parallel calculation
GG geometry
QMD (Quantum Molecular Dynamics) model

NMTC/JAM code system

Solaris, DEC, Linux

NMTC/JAM

Input
- Target material
- Geometry
- Particle, tally

p,π,K
E_n>20MeV

E_n<20MeV
γ

Output
- Spectrum
- Residual nuclide
- Heat deposition
- Dose
- DPA

MCNP
or
TWODANT, DORT

Contribution for
E_n<20MeV, γ

Merge

Output for all particle

DCHAIN-SP

Residual activity
Radiation Dose

2 input cards required

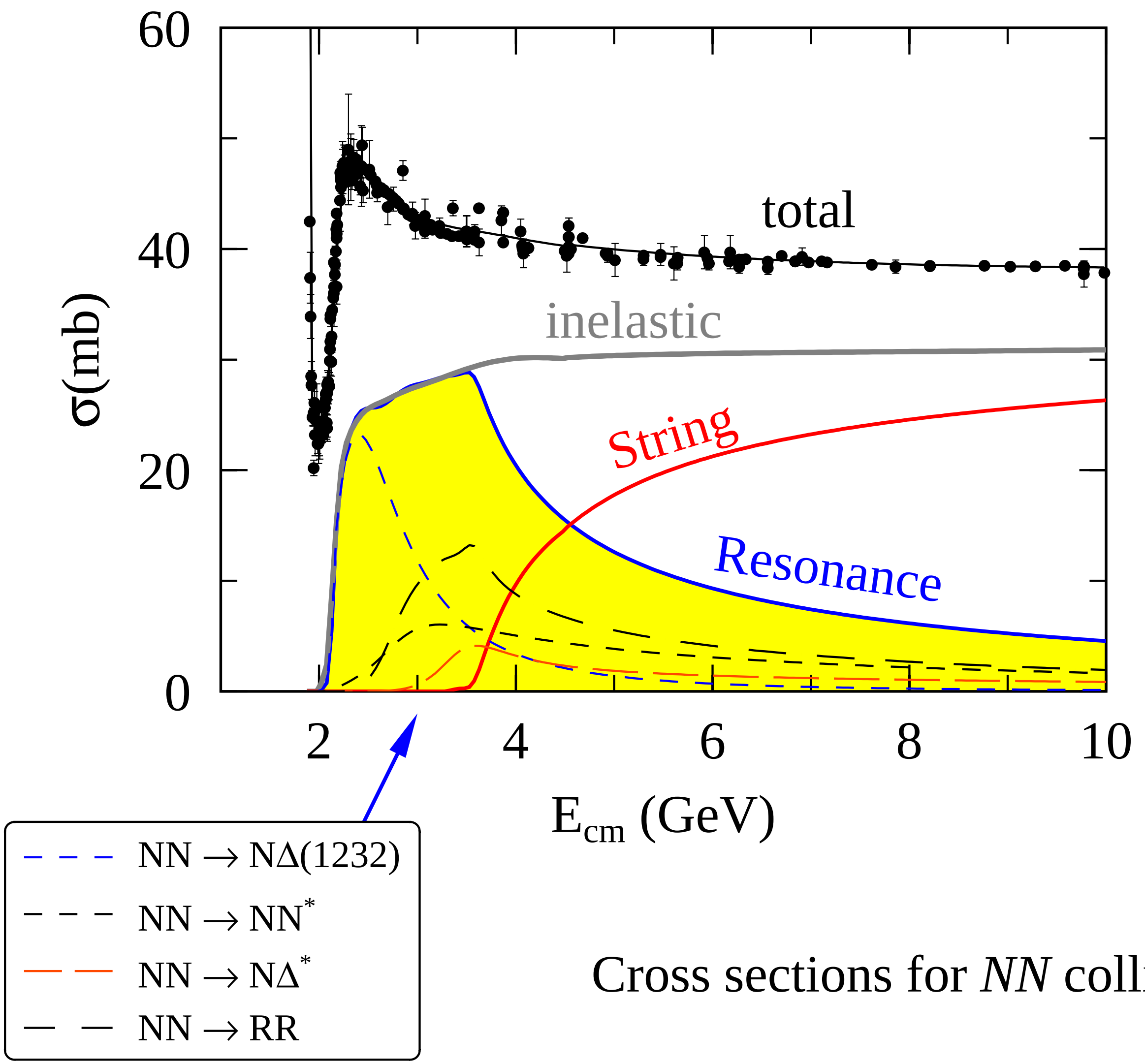
NMTC/JAM
MCNP
- material, geometry

DCHAIN-SP
- Time
- (irradiation, cooling)

Every physical quantity can be obtained.

JAM: Inelastic cross section for NN

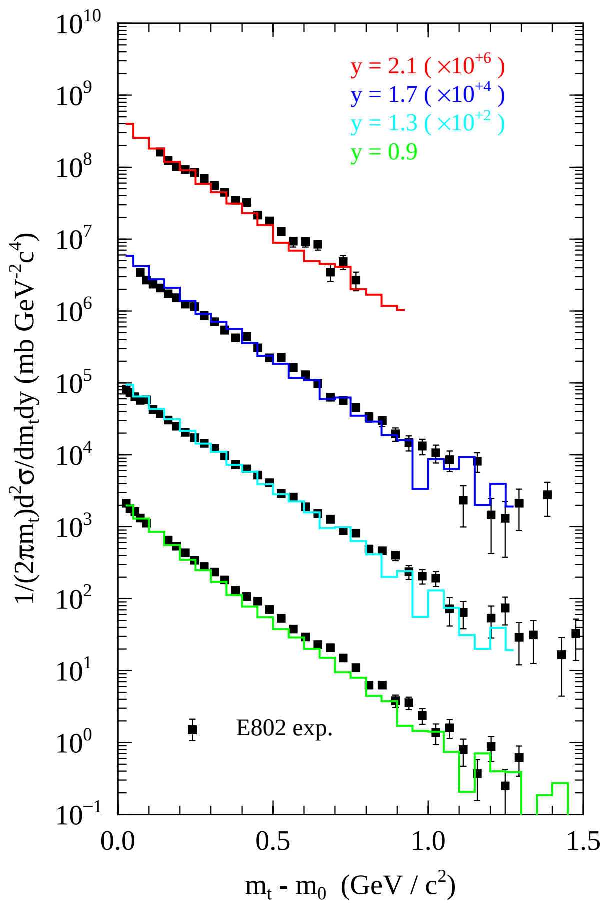
Proton-Proton Inelastic Cross Section



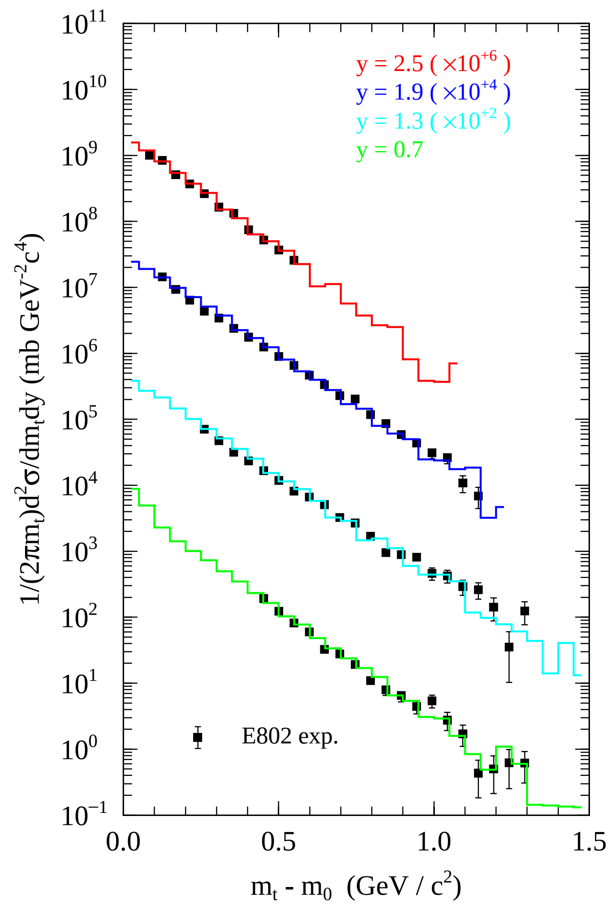
Cross sections for *NN* collision parameterized.

JAM: Comparison of particle production cross section (1)

p (13.7 GeV) + Au → p



p (13.7 GeV) + Au → π^-



JAM agrees with the experiment for 13.7-GeV proton incidence.

JAM: Comparison of double differential cross section (DDX)

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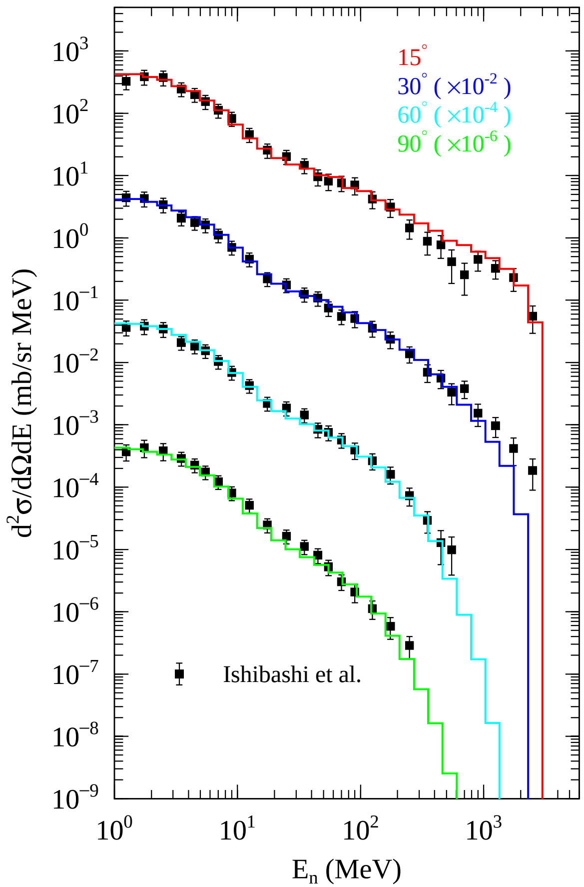
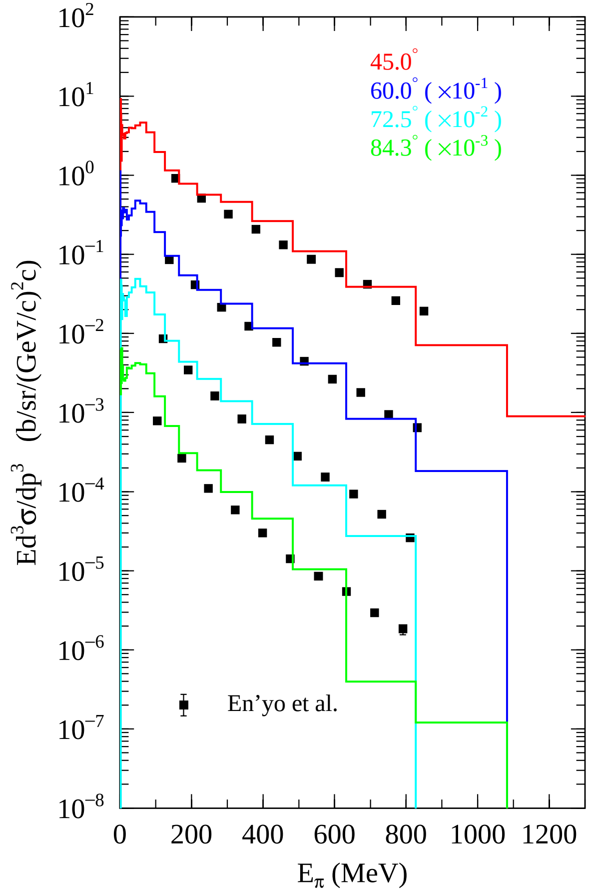
High Intensity Proton Accelerator Project
大強度陽子加速器計画

p (3.0 GeV) + Pb → n



p (3.17 GeV) + Pb → π⁻



JAM shows good agreement with experiment for 3-GeV protons.
Also Bertini cascade is in good agreement so that Bertini used less than 3.5 GeV.

JAM: Decay of particle

Name	kf-code	mass (MeV)	charge	baryon
p	2212	938.3	1	1
n	2112	939.6	0	1
π^+	211	139.6	1	0
π^0	111	135.0	0	0
π^-	-211	139.6	-1	0
μ^+	-13	105.7	1	0
μ^-	13	105.7	-1	0
K^+	321	493.6	1	0
K^0	311	497.7	0	0
K^-	-321	493.6	-1	0
ν_e	12	0.0	0	0
ν_μ	14	0.0	0	0
η	221	547.5	0	0
η'	331	957.8	0	0
Λ^0	3122	1115.7	0	1
Σ^+	3222	1189.4	1	1
Σ^0	3212	1192.5	0	1
Σ^-	3112	1197.4	-1	1
Ξ^0	3322	1314.9	0	1
Ξ^-	3312	1321.3	-1	1
Ω^-	3334	1672.4	-1	1

π^0	$\rightarrow \gamma + \gamma$	100%
π^+	$\rightarrow \mu^+ + \nu_\mu$	100%
π^-	$\rightarrow \mu^- + \nu_\mu$	100%
μ^+	$\rightarrow e^+ + \overline{\nu_e} + \nu_\mu$	100%
μ^-	$\rightarrow e^- + \overline{\nu_e} + \nu_\mu$	100%
K^0	$\rightarrow \pi^+ + p$	68.61%
	$\rightarrow \pi^0 + \pi^0$	31.39%
	$\rightarrow \gamma + \gamma$	other
K^+	$\rightarrow \mu^+ + \nu_\mu$	63.51%
	$\rightarrow \pi^+ + \pi^-$	other
K^-	$\rightarrow \mu^- + \nu_\mu$	63.51%
	$\rightarrow \pi^+ + \pi^-$	other
η	$\rightarrow \gamma + \gamma$	38.9%
	$\rightarrow \pi^0 + \pi^0 + \pi^0$	31.9%
	$\rightarrow \pi^+ + \pi^- + \pi^0$	23.7%
	$\rightarrow \pi^+ + \pi^- + \gamma$	other

η'	$\rightarrow \pi^+ + \pi^- + \eta$	44.1%
	$\rightarrow \pi^0 + \pi^0 + \eta$	20.5%
	$\rightarrow \pi^+ + \pi^- + \gamma$	30.1%
	$\rightarrow \gamma + \gamma$	other
Λ^0	$\rightarrow p + \pi^-$	64.1%
	$\rightarrow n + \pi^0$	other
Σ^+	$\rightarrow p + \pi^0$	51.57%
	$\rightarrow n + \pi^+$	other
Σ^0	$\rightarrow \Lambda^0 + \gamma$	100%
Σ^-	$\rightarrow n + \pi^-$	100%
Ξ^0	$\rightarrow \Lambda^0 + \pi^0$	100%
Ξ^-	$\rightarrow \Lambda^0 + \pi^-$	100%
Ω^+	$\rightarrow \Lambda^0 + K^-$	67.8%
	$\rightarrow \Xi^0 + \pi^-$	23.6%
	$\rightarrow \Xi^- + \pi^0$	other

All decay mode of hadrons is taken into account.

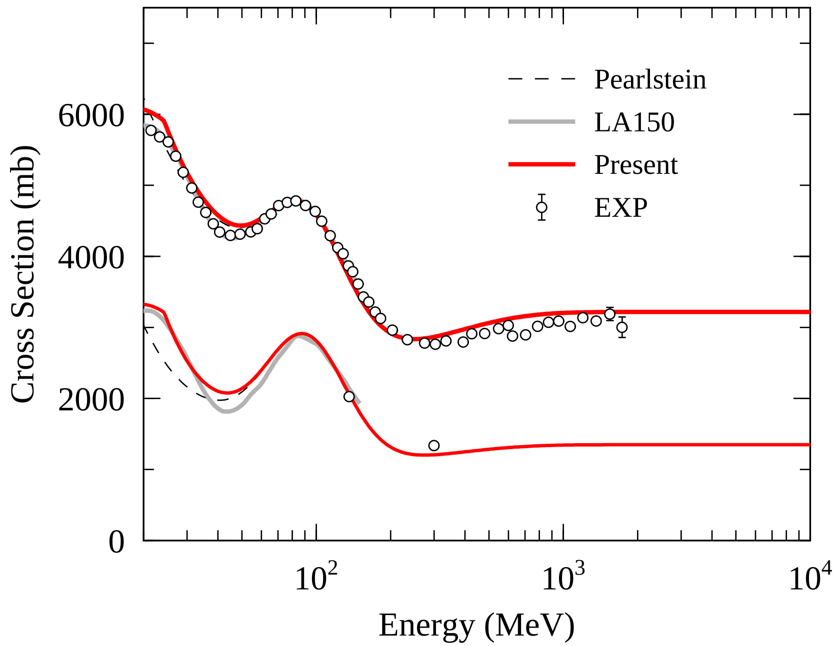
↓

Transport caluculation of all hadrons available.

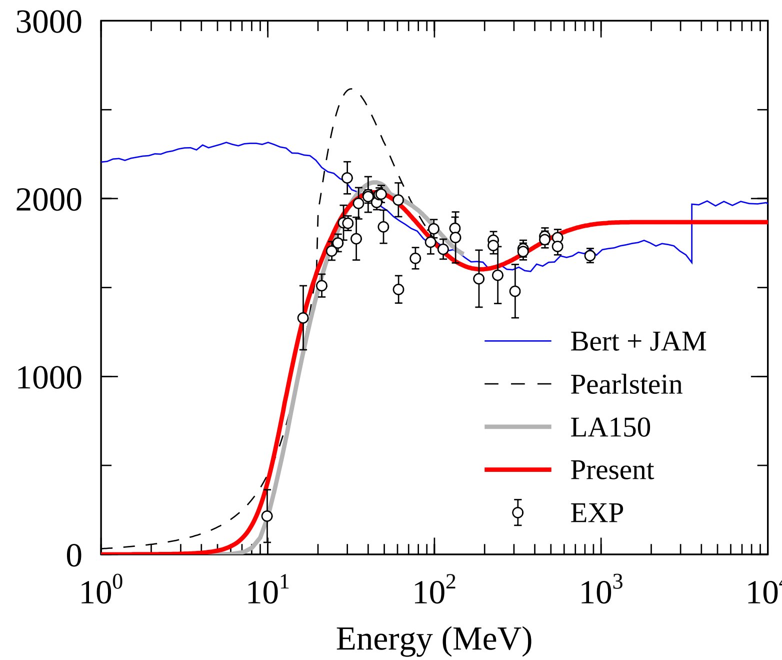
JAM: Nucleon nucleus cross section

Niita’s systematics

^{208}Pb (n,tot) and (n,ela)



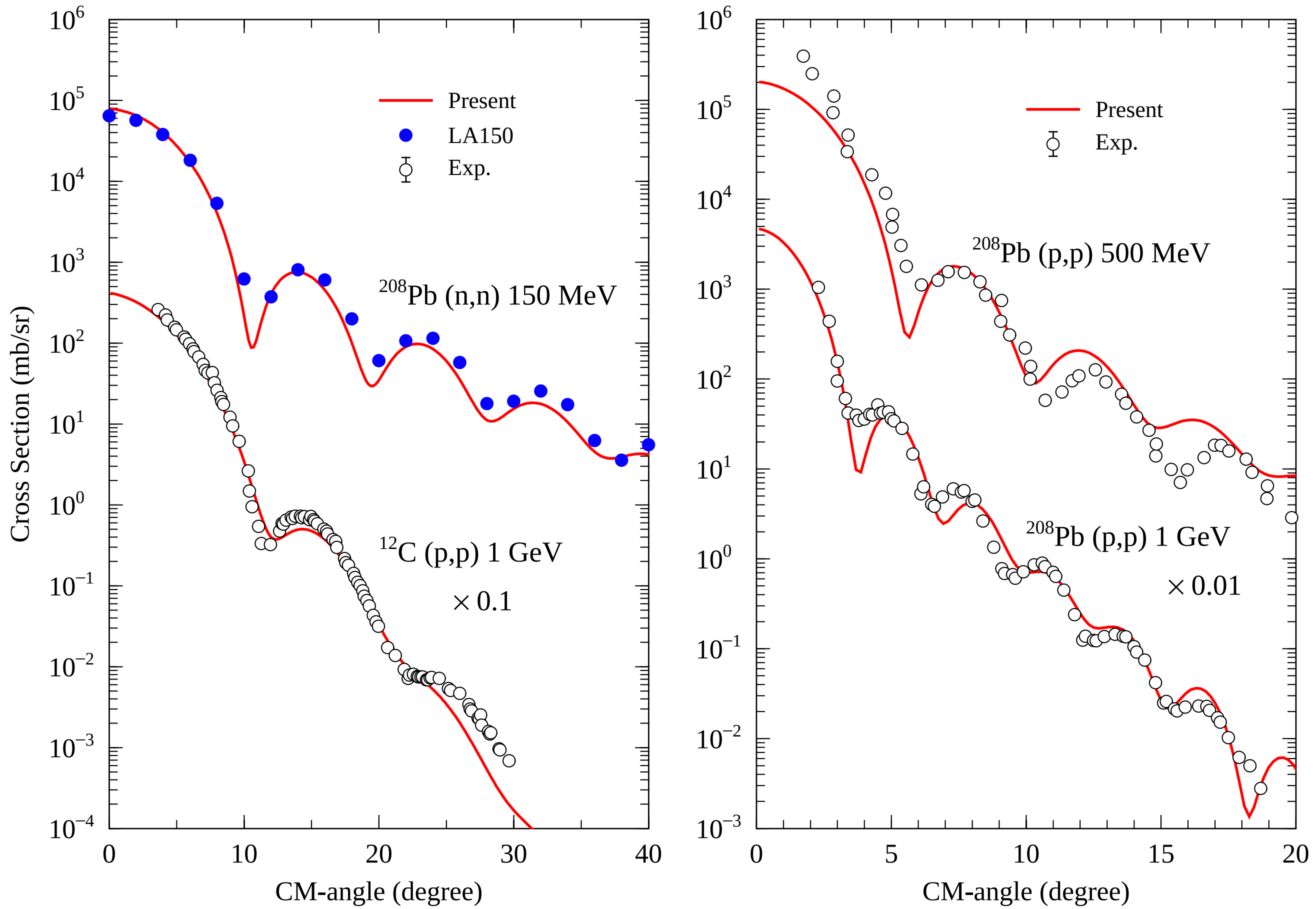
^{208}Pb (p,non)



Good agreement with experiment

JAM: Angular distribution for elastic

Also systematics by Niita is used.



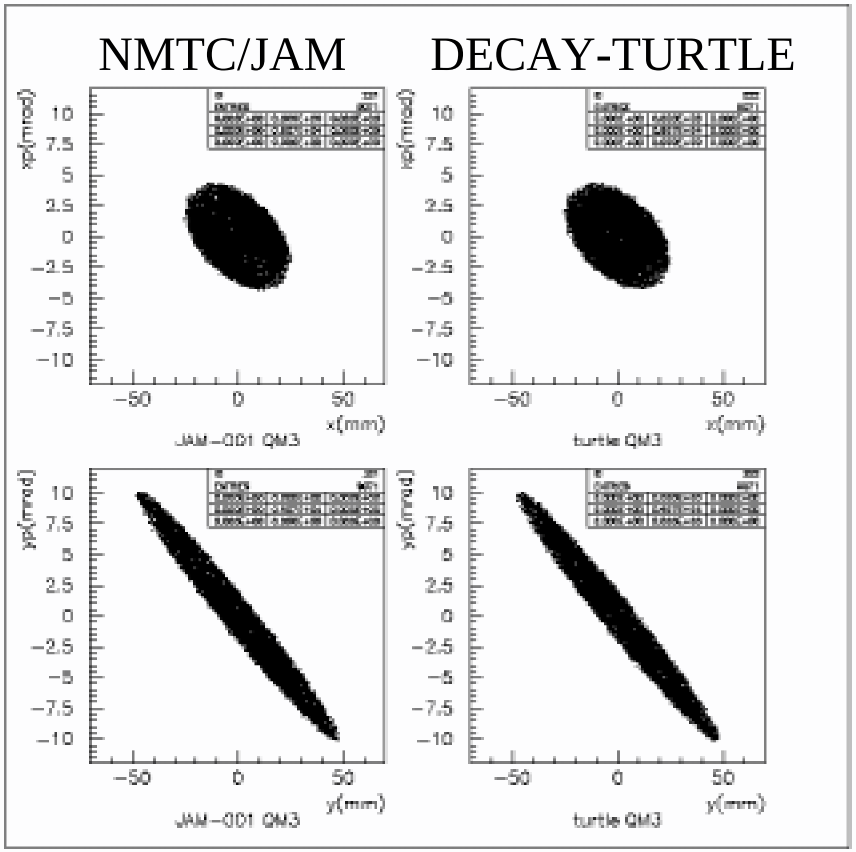
Good agreement with experiment

NMTC/JAM: Charged particle transport in magnetic field

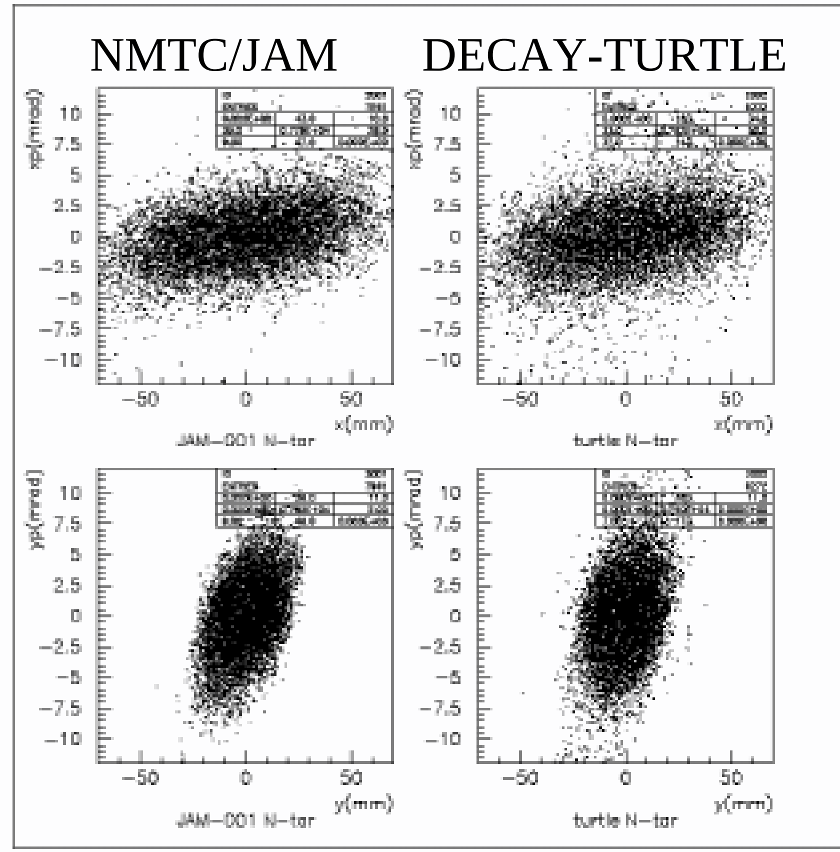
Compared with DECAY-TURTLE(Beam tracking)

Horizontal

Vertical



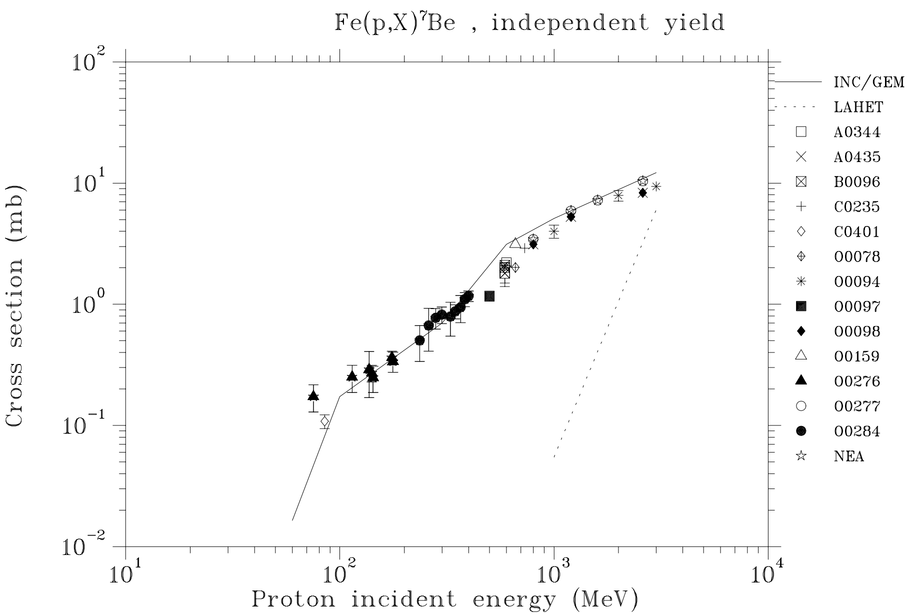
Phase space distribution at C-target.

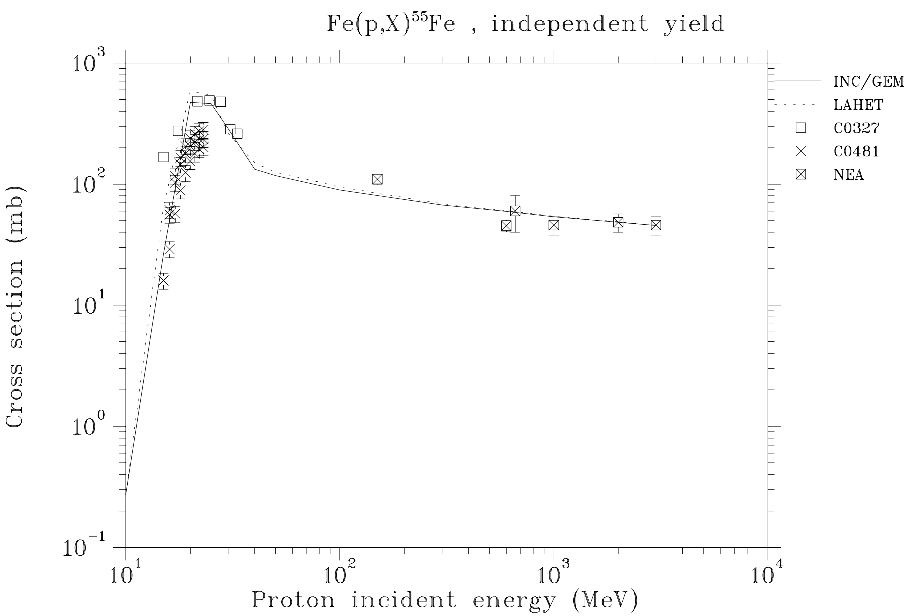


Phase space distribution at Hg-target.

NMTC/JAM gives good agreement with DECAY-TURTLE.

NMTC/JAM
New evaporation model: GEM

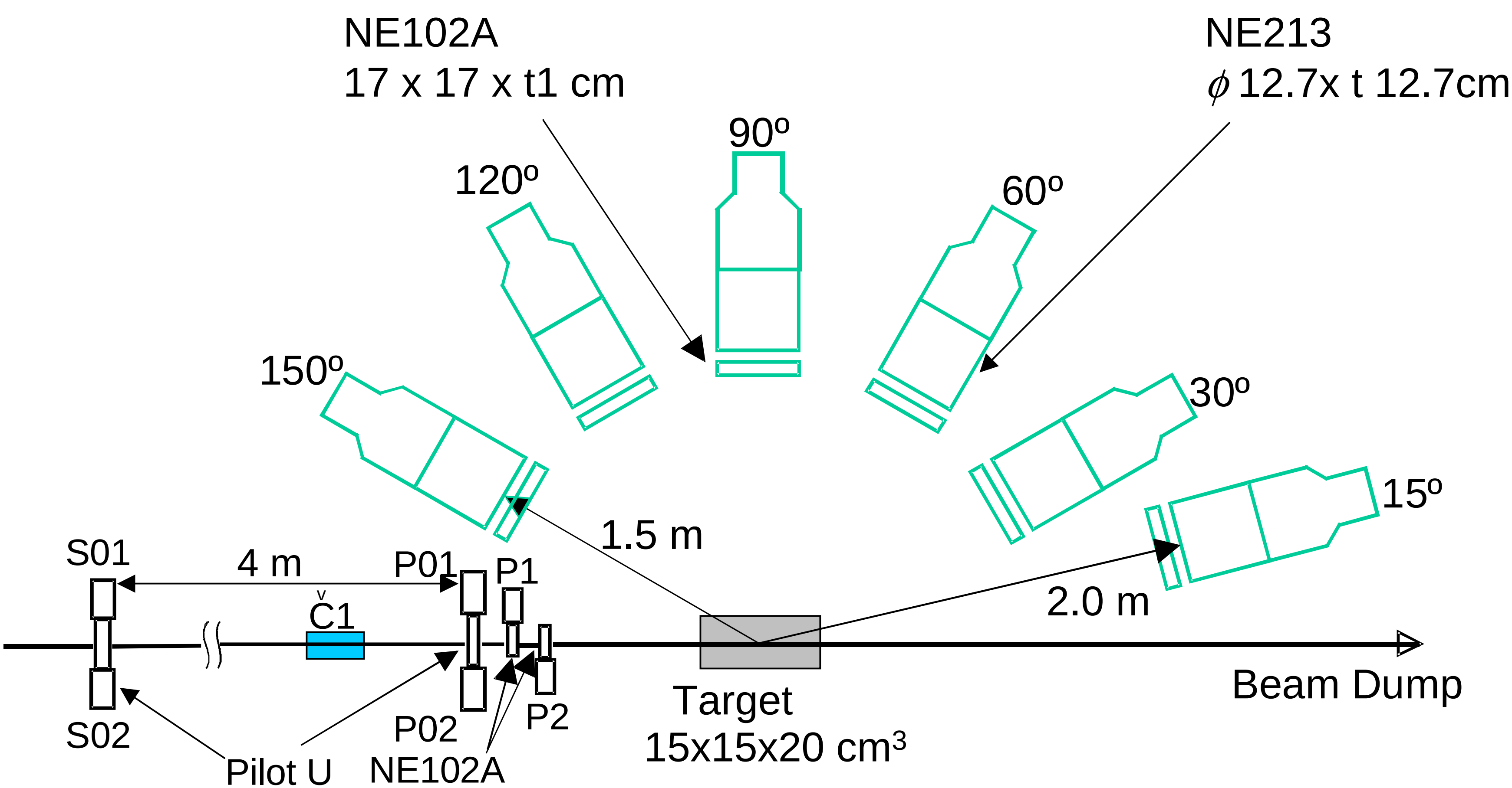




Good agreement with the experiment.
Especially for ^{7}Be production cross section

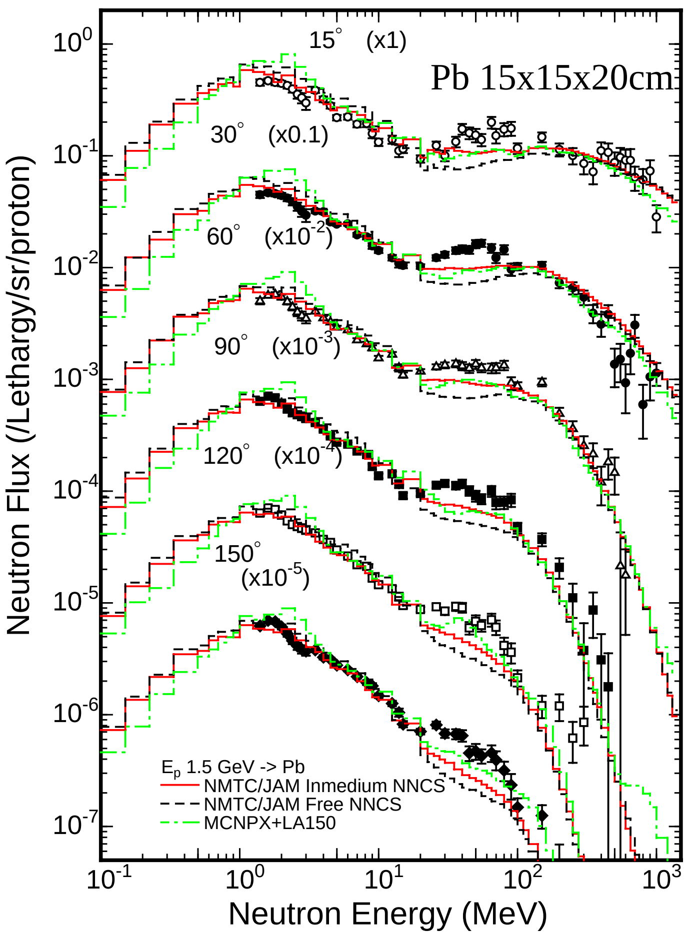
Spectrum of neutron produced from thick target by 0.5, 1.5 GeV p

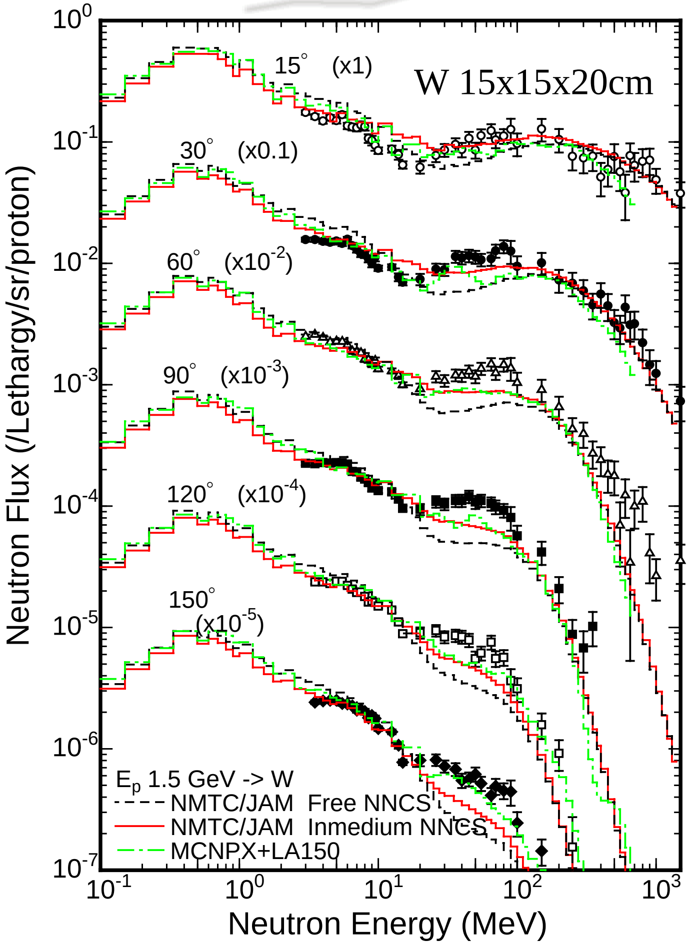
Meigo et al., Nucl. Instr. and Meth A431 (1999) 521



KEK PS π2 beam line

Neutron spectra from Pb, W targets



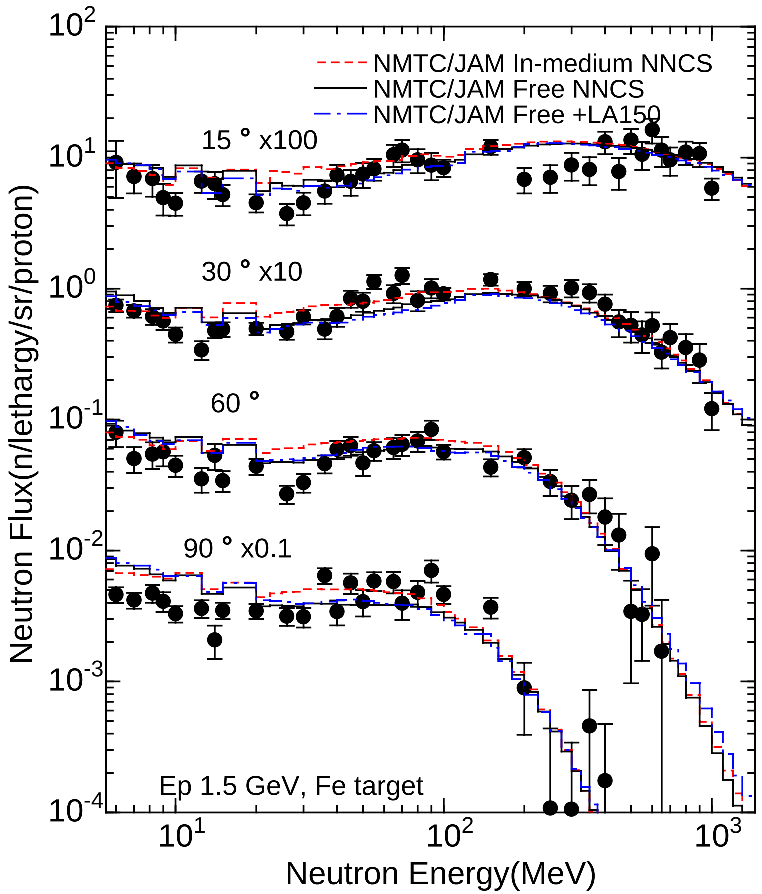


NMTC/JAM Free *N-N* cross section (black) → Generally good agreement
underestimate in 20~80 MeV

In-medium *N-N* cross section (red) → Good agreement

MCNPX: → Good agreement

Neutron spectrum from Fe target



Fe(15x15x20cm)
irradiated by 1.5GeV protons

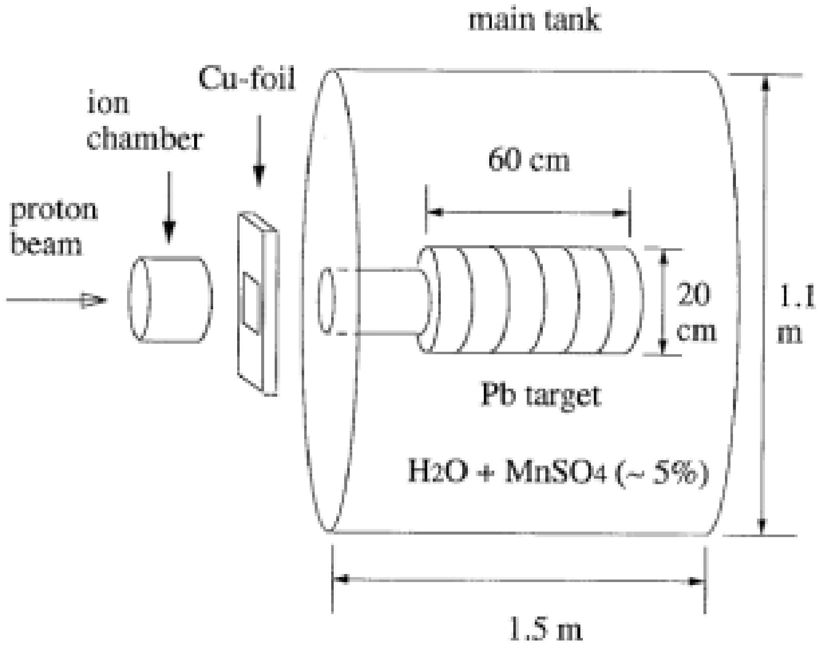
In-medium NNCS (red)
→Remarkable good agreement

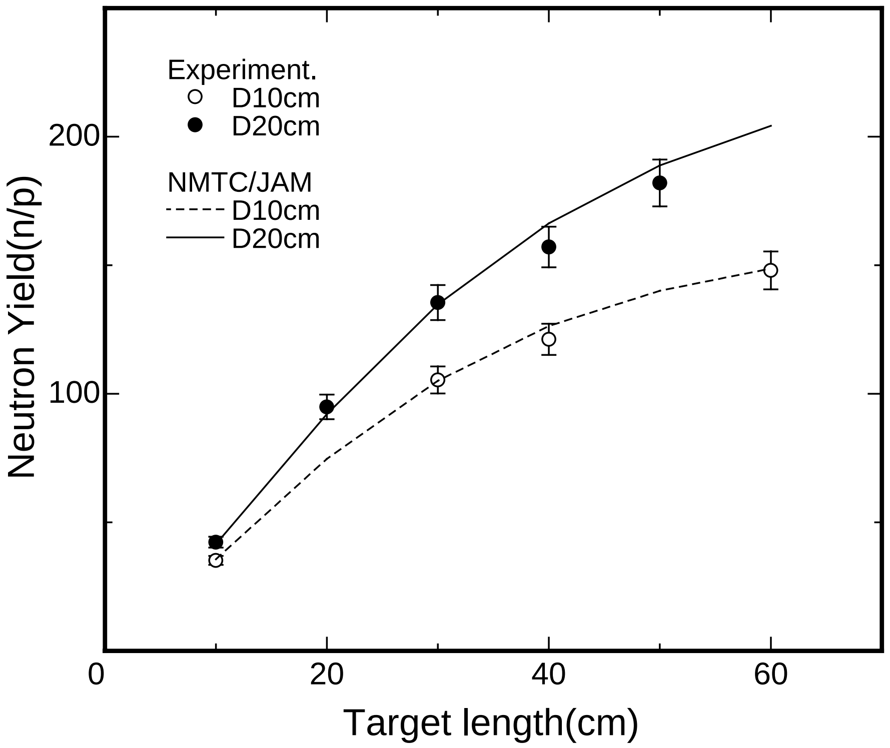
NMTC/JAM is adopted to estimate production of neutrons at beam line(3-N BT) and 3-GeV RCS in the present project.

Neutron Yield

JAERI and KEK Joint Project
High Intensity Proton Accelerator Project
大強度陽子加速器計画

12-GeV protonon lead target.Mn-bath tech.

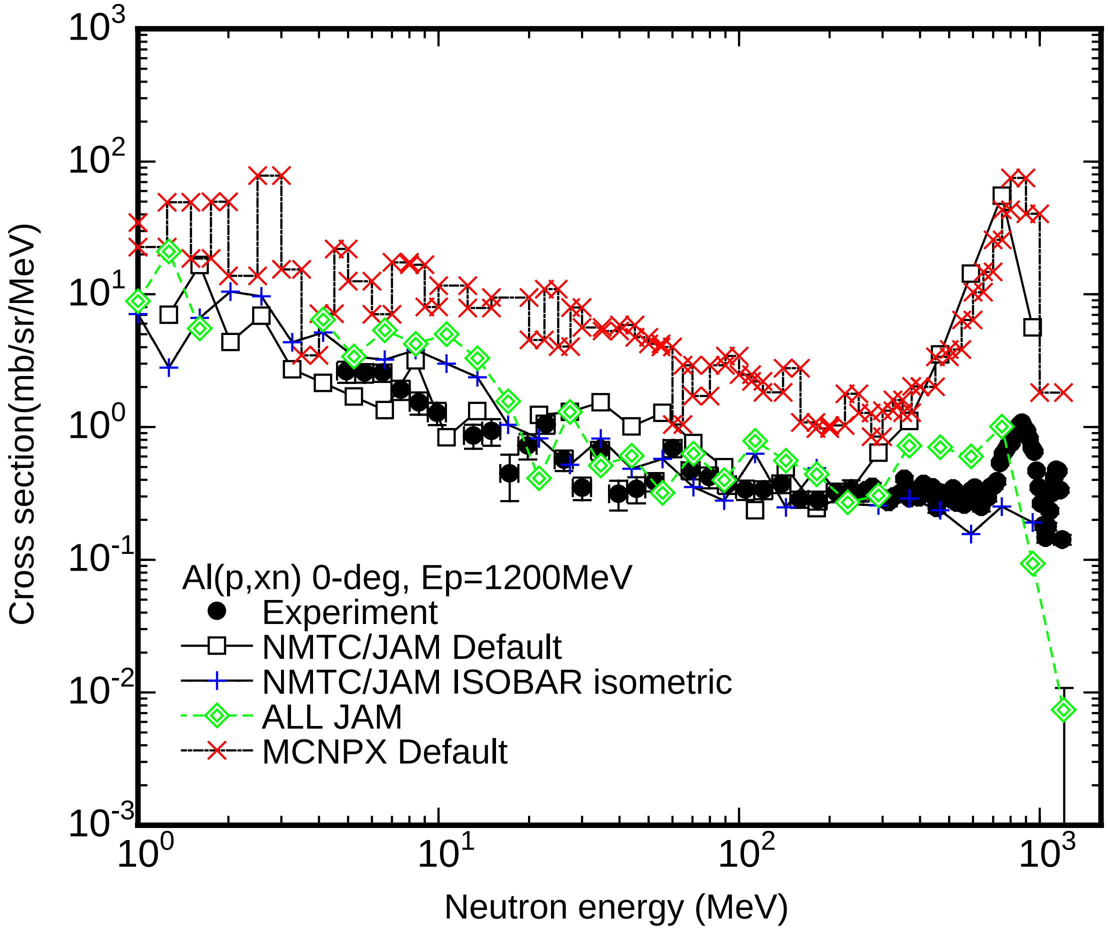




Good agreement

(p,xn) cross section at 0-deg

Important property for the design of beam line around C target



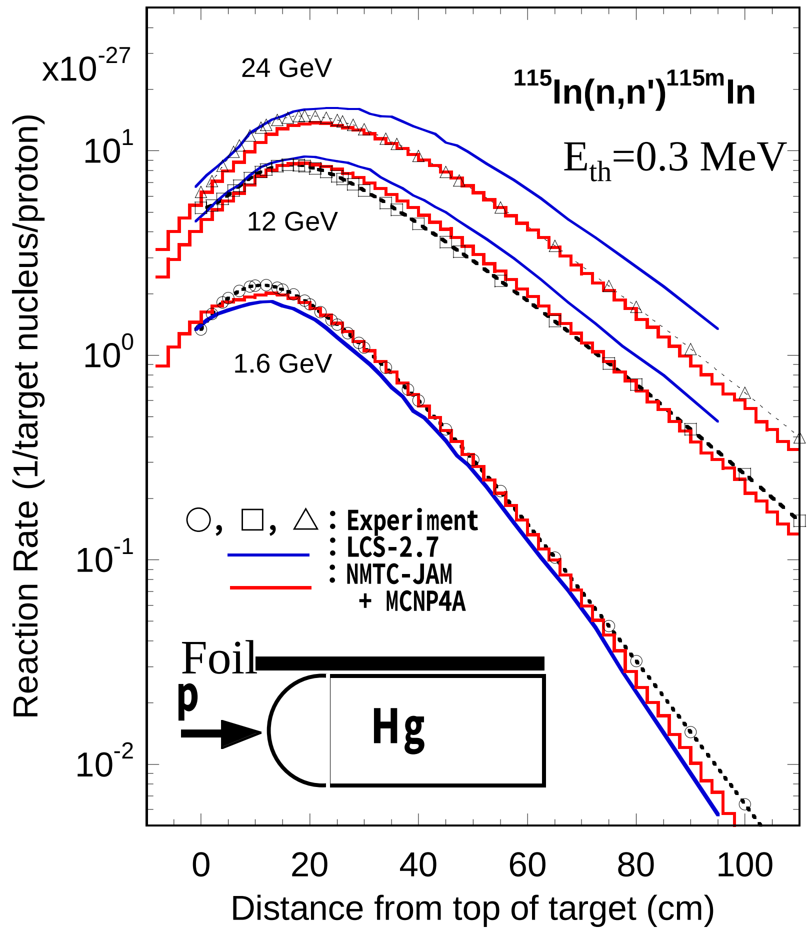
By using appropriate model for NMTC/JAM, a good agreement is obtained.

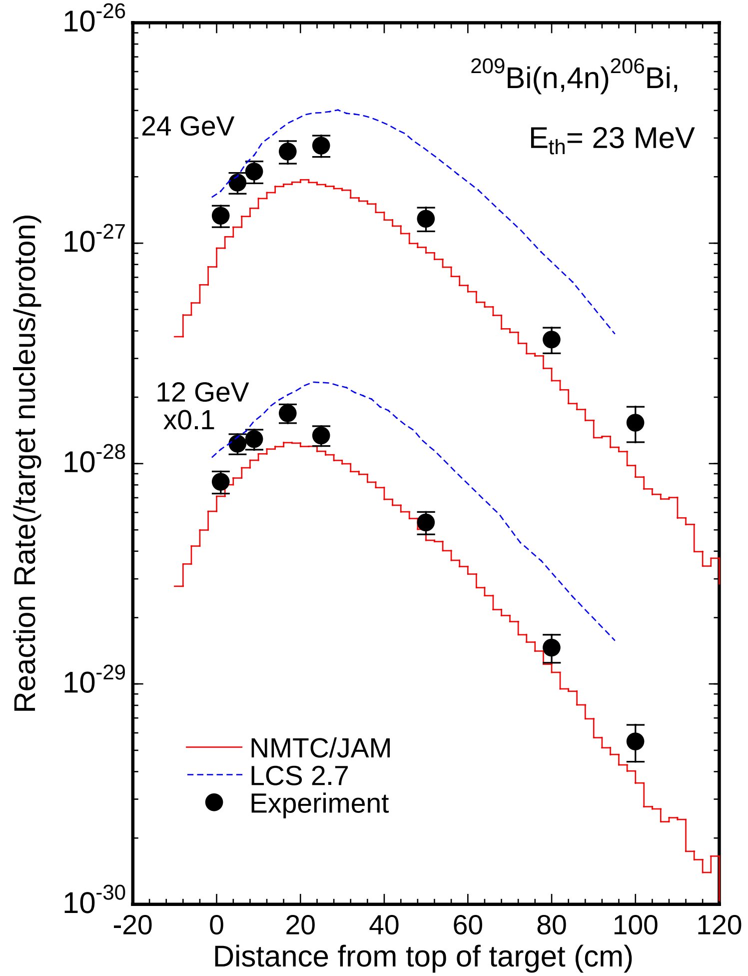
Up to now, MCNPX overestimates significantly by a factor of 100.

Activation experiment at AGS Spallation Taget Experiment (ASTE)

Activity distribution of foils placed around the target

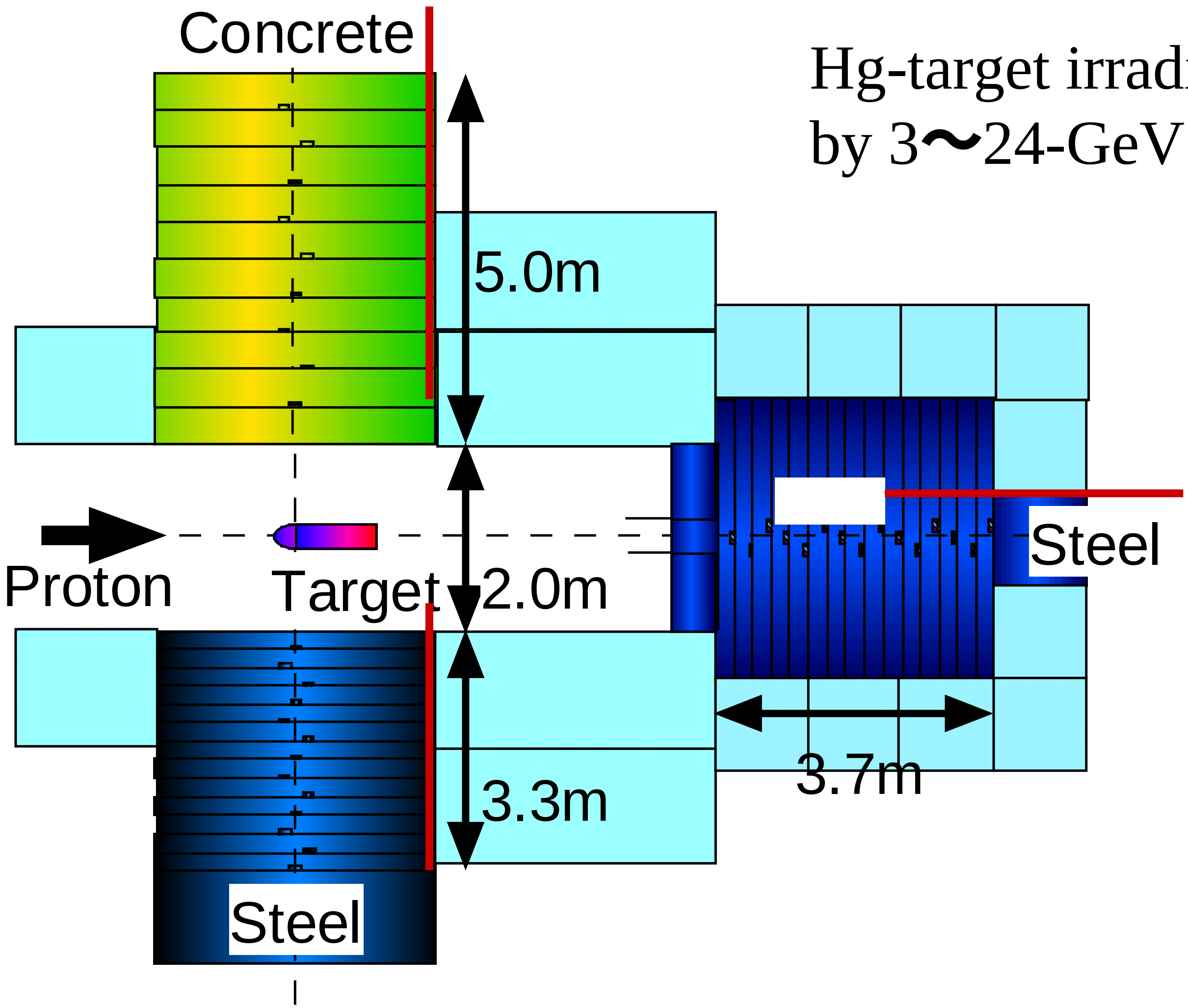
Mercury target: ϕ 20 cm ✕ 130 cm





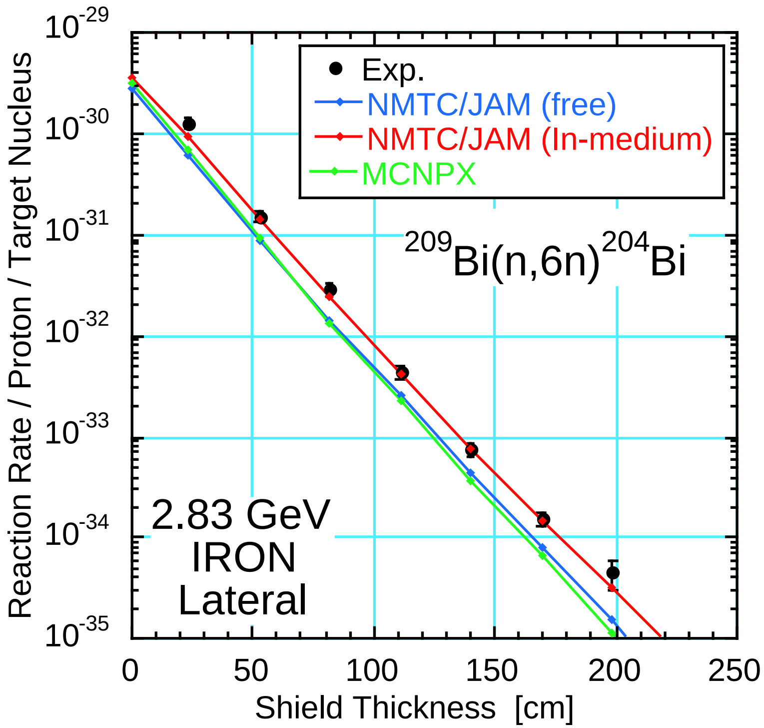
NMTC/JAM is in good agreement with experiment.

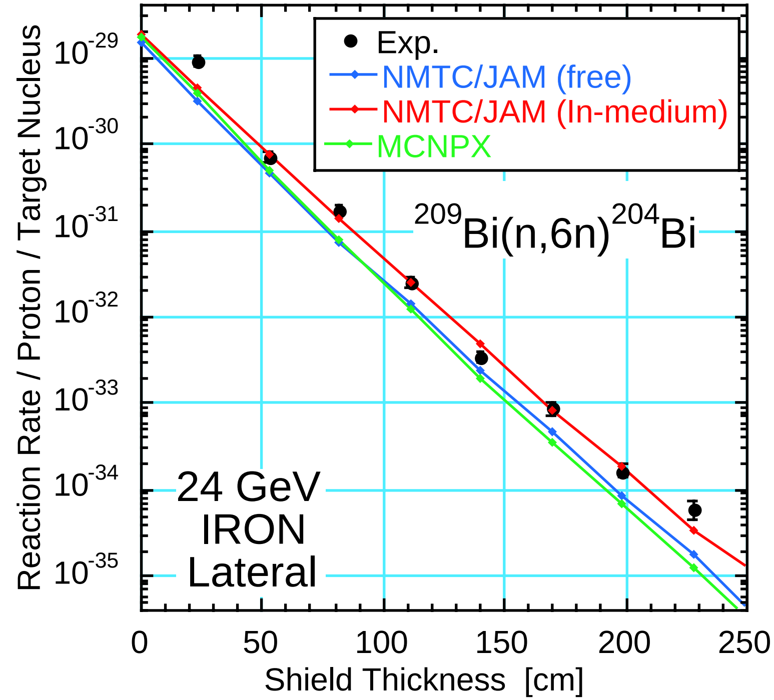
Shielding Experiment
ASTE



Hg-target irradiated
by 3〜24-GeV proton

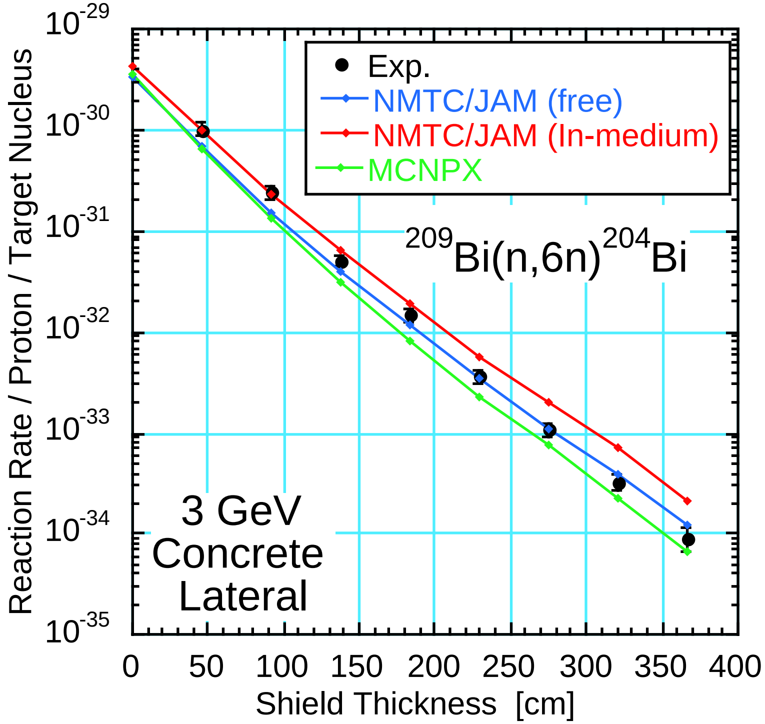
Code Calculation Results - Steel -

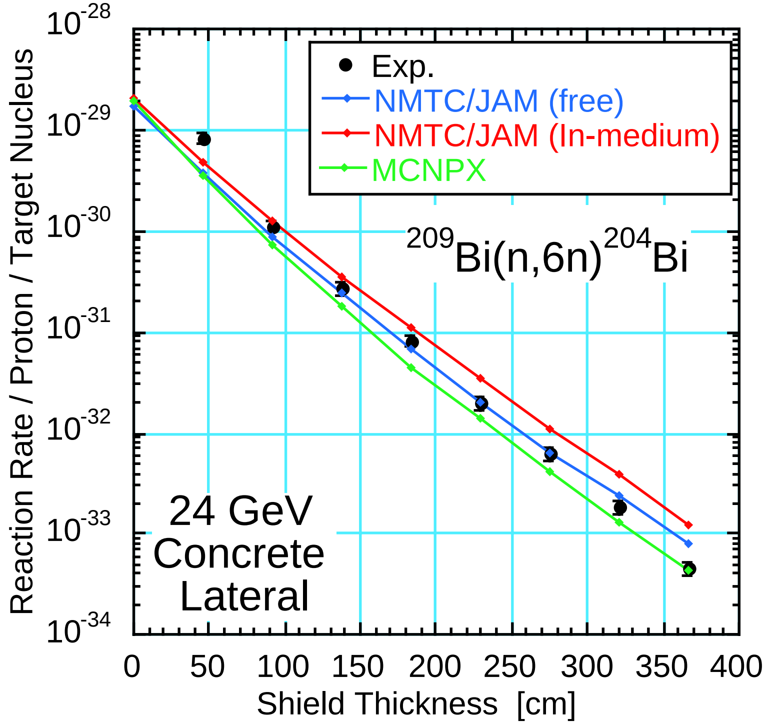




- NMTC/JAM (free)
  - Underestimation at the beginning, adequate for deep penetration
- NMTC/JAM (in-medium)
  - Adequate for overall
- MCNPX
  - Underestimation at the beginning, slightly underestimation for deep penetration

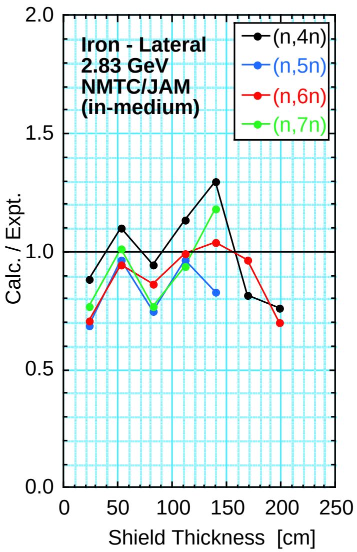
Code Calculation Results - Concrete -

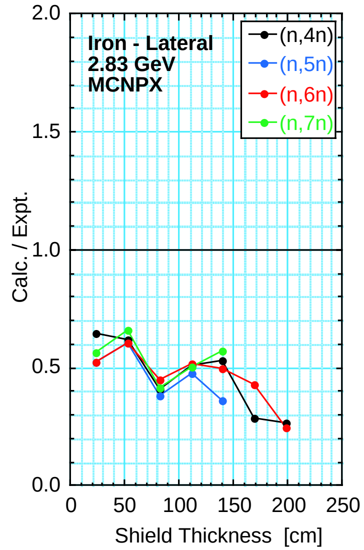


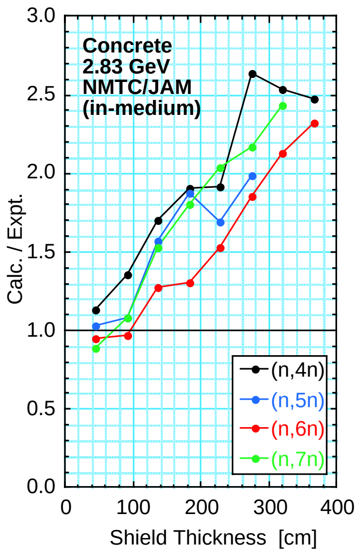


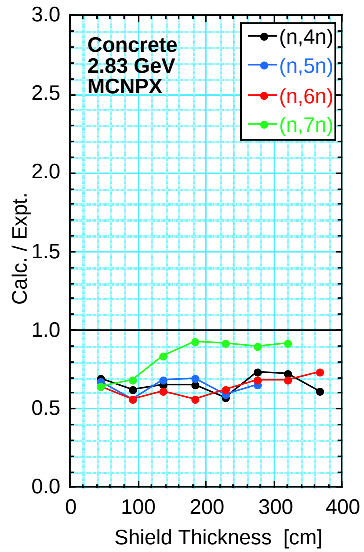
- NMTC/JAM (free)
  - Underestimation at the beginning, slightly overestimation for deep penetration
- NMTC/JAM (in-medium)
  - Overestimation for deep penetration
- MCNPX
  - Underestimation at the beginning, adequate for deep penetration

Comparison of Code/Experiment









NMTC/JAM
Fe: very well < ±20 %
Concrete overestimate factor 3

MCNPX
Fe: underestimate factor 2
Concrete underestimate factor 2

Summary

NMTC/JAM and MCNPX can predict within a factor of 2 for shielding.

NMTC/JAM and MCNPX can predict with good accuracy for the performance of neutron source property.