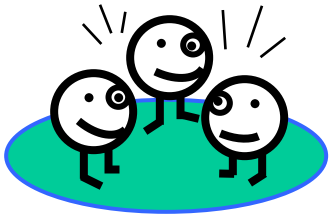
Workshop on Data Compilation, IAEA, Vienna, *May 25th, 2011*

"Systematic studies of nuclear reactions using EXFOR" --- from a viewpoint of a database user ---

- Contents:
  - Introduction
    - EXFOR and σ_R etc
  - An ex. of systematic analyses: necessity of "HE" data
    - BS Approxi. of nuclei
  - σ_{NN}^{total} in EXFOR
  - Summary

The black-sphere picture as a reference frame

A. Kohama (RIKEN Nishina C.)

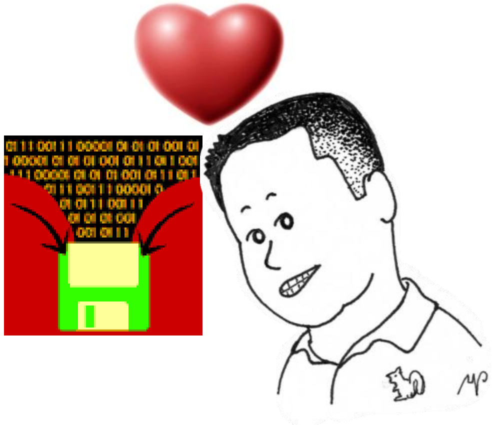


Ref. *Phys. Rev.* **C69,** 064316 (2004).
Phys. Rev. **C72**, 024602 (2005).
J. Phys. Soc. Japan **76**, 044201 (2007).
Phys. Rev. **C78**, 061601 (2008).

Self-introduction

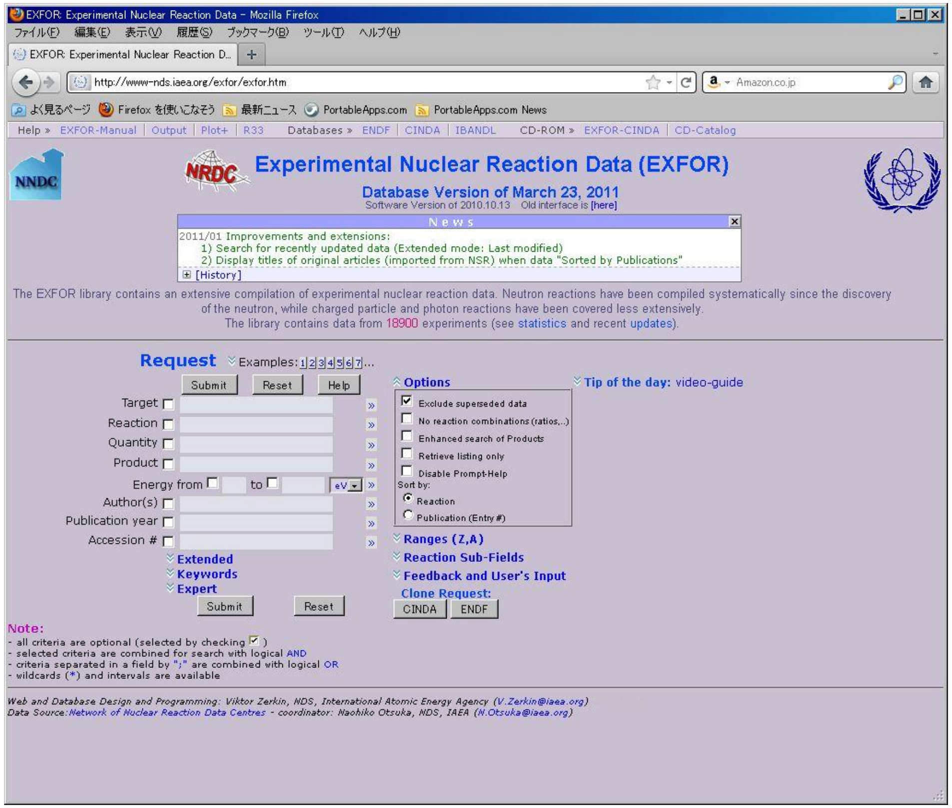
- I am …
  - a nuclear theorist majoring nuclear reactions.
- Research interest:
  - Nuclear radii, density distributions, …
- Approach:
  - Based on the systematic analyses of plenty of reaction data involving stable nuclei, we lighten up the structure and reaction mechanism of unstable nuclei.

- I am a "Data lover".
  - One of the heavy-users of EXFOR.
  - Members of JCPRG and N. Otsuka helped me in collecting data including "missing" data.
  - Prof. Kato has suggested me to join this WS.



EXFOR is powerful

- Databases support systematic analyses
  - use EXFOR
  - Data: $d\sigma_{\mathrm{el}}(p+\mathrm{A})/d\Omega$, $\sigma_{\mathrm{R}}(p+A)$, $\sigma_{\mathrm{R}}(A+A)$, …
- EXFOR is very powerful for our systematic analyses.



Key Quantities

- ☆ Scattering amplitude: $f_{\mathrm{pA}}(q)$.

- Differentiated quantities:
  - Differ. cross sec.: $d\sigma_{\mathrm{el}}/d\Omega = |f_{\mathrm{pA}}(q)|^2$. sensitive to density distribution (radius, diffuseness)
  - Analyzing power: A_y.

- Integrated quantities:
  - Total elas. scat. cross sec.: $\sigma_{\mathrm{el}} = \int d\Omega\, |f_{\mathrm{pA}}(q)|^2$.
  - Total cross sec.: $\sigma_{\mathrm{tot}} = (4\pi/k)\, Im\, f_{\mathrm{pA(pN)}}(q)$.
  - Total reac. cross sec.: $\sigma_R = \sigma_{\mathrm{tot}} - \sigma_{\mathrm{el}}$. sensitive to radius and diffuseness. Tail?
  - Interaction cross sec.: $\sigma_I = \sigma_R - \sigma_{\mathrm{inel}}$. structure info.!

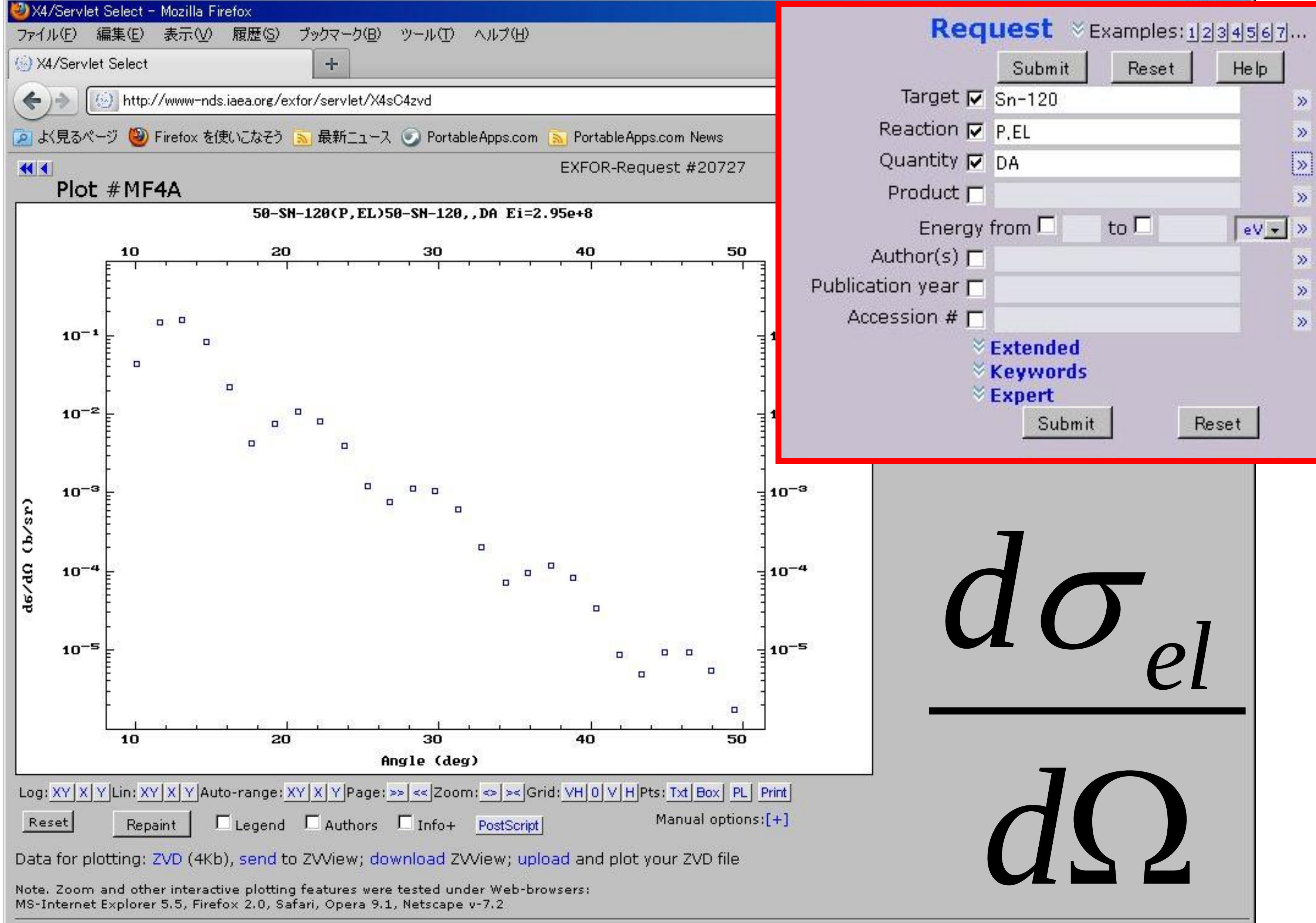
Importance of σ_R

- Physics side:
  - Nuclear geometrical size, eg., r_m
  - Isotope dep. of r_m
    → Sym. Energy coef. L
  - Energy dependence
    → density distribution?
- Practical side:
  - Estimation of the reaction rate in simulation codes:
    - eg., FULKA, GEANT, PHITS (Particle and Heavy Ion Transport code System). http://phits.jaea.go.jp/

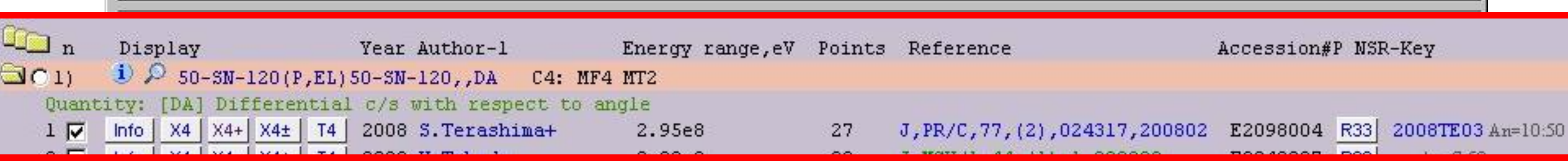
For PHITS, see

 # H. Iwase, K. Niita and T. Nakamura, J. Nucl. Sci. Technol. 39, 1142 (2002).

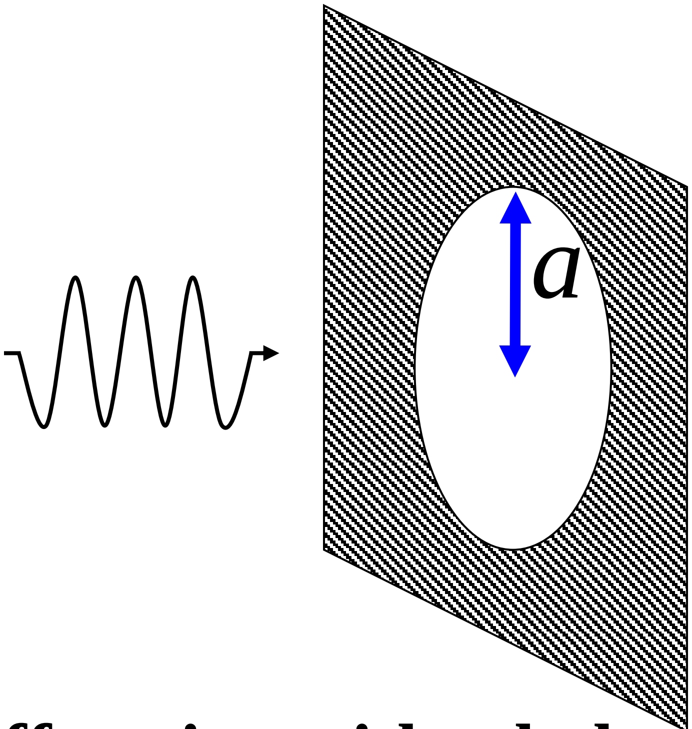
 # K. Niita, T. Sato, H. Iwase, H. Nose, H. Nakashima, L. Sihver, Radiat. Meas. 41, 1080 (2006).



$$\frac{d\sigma_{el}}{d\Omega}$$

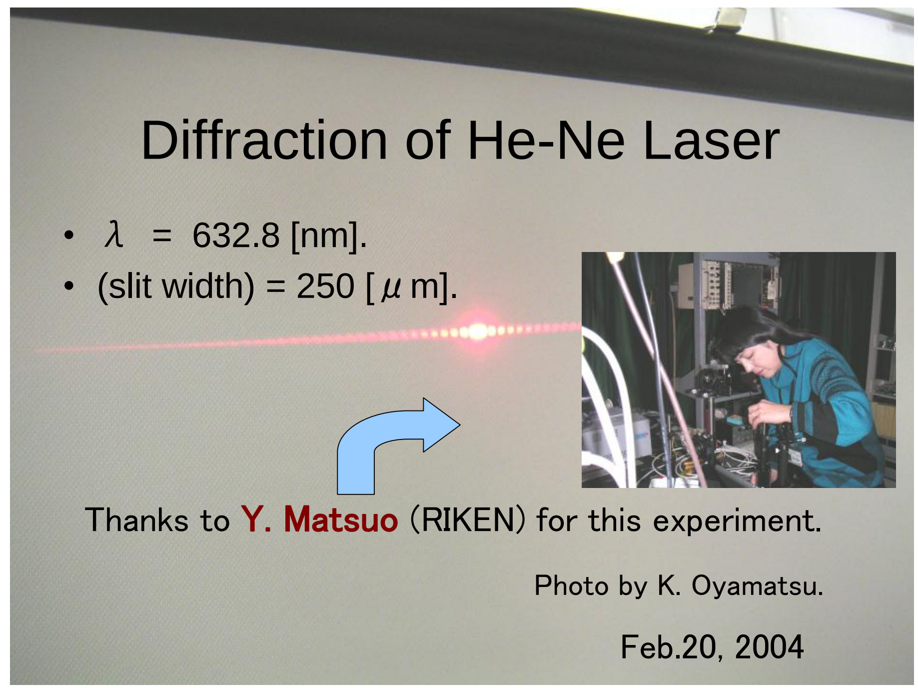


Fraunhofer diffraction in Optics



Diffraction with a hole embedded in an infinitely extended screen.

- Diffract. pattern: $|f(q)|^2$

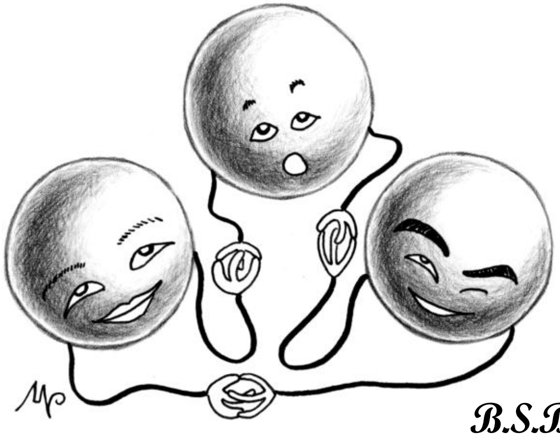


$$f(q) = ipa\,J_1(qa)/q.$$

Ref. “The Classical theory of fields” L. D. Landau & E. M. Lifshitz

The contemporary black-sphere model
and
the black-sphere cross section formula

in collaboration with
K. Iida (Kochi U.) and K. Oyamatsu (Aichi Shukutoku U.)

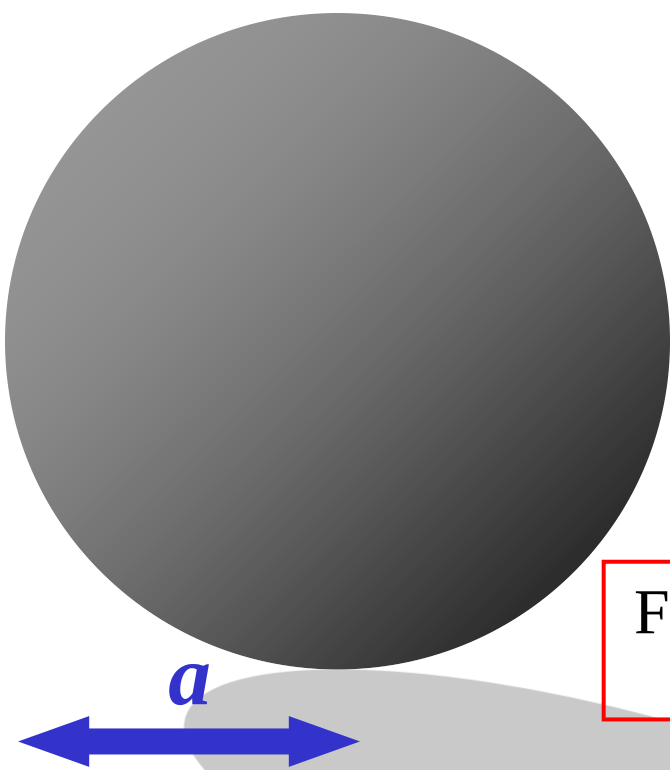


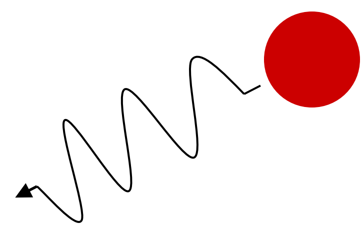
B.S.B.

Black-sphere approxi. of nuclei

$T_p \geqq 800$ [MeV].

"Black" Nucleus





proton

$\lambda_p / a \ll 1.$

- We assume that the target nucleus is strongly absorptive.

$i.e., \ a/(1/\rho_0 \sigma_{pN}) \gg 1.$

e.g., L. Ray, *Phys. Rev.* **C20**, 1857 (1979).

Fraunhofer diffraction formula is applicable.
G. Placzek and H.A. Bethe (1940).

Ref. A.K., K. Iida, and K. Oyamatsu, *Phys. Rev.* **C69,** 064316 (2004).

“Kurotama” in Japanese

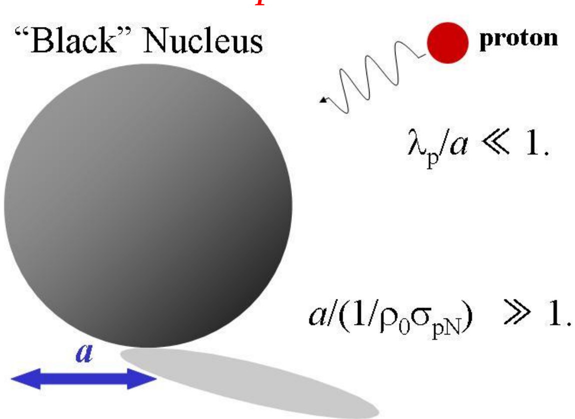
The contemporary black-sphere model

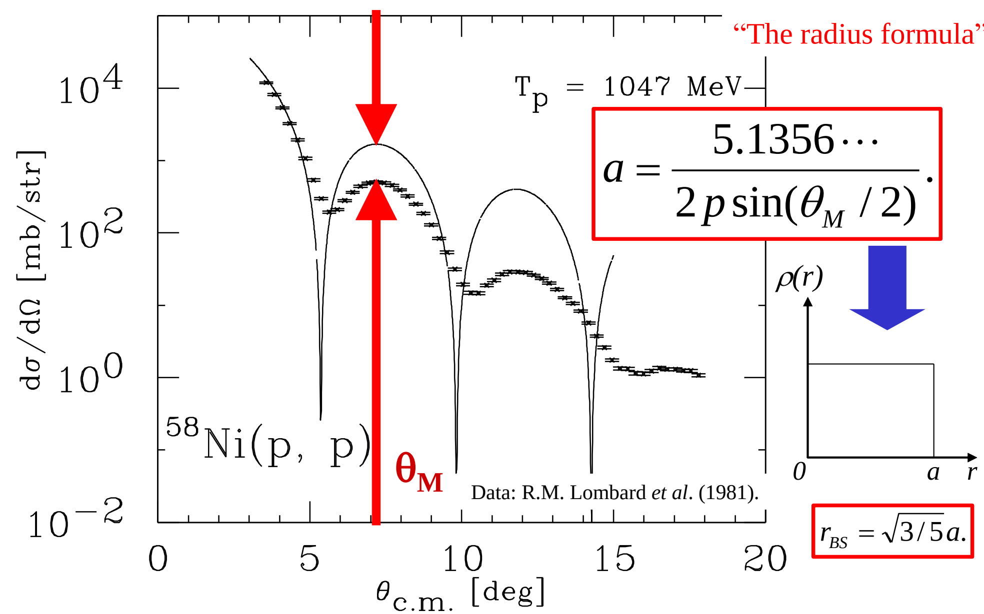
Estimate only the strong interac. contribution.

- Determine the black-sphere radius as;
- Geometrical cross section: $\sigma_{BS} = \pi a^2$.
  - $a = 1.2135\, A^{1/3}$ fm for $T_p > 800$ MeV.

$$a = \frac{5.1356\cdots}{2p\sin(\theta_M/2)}.$$

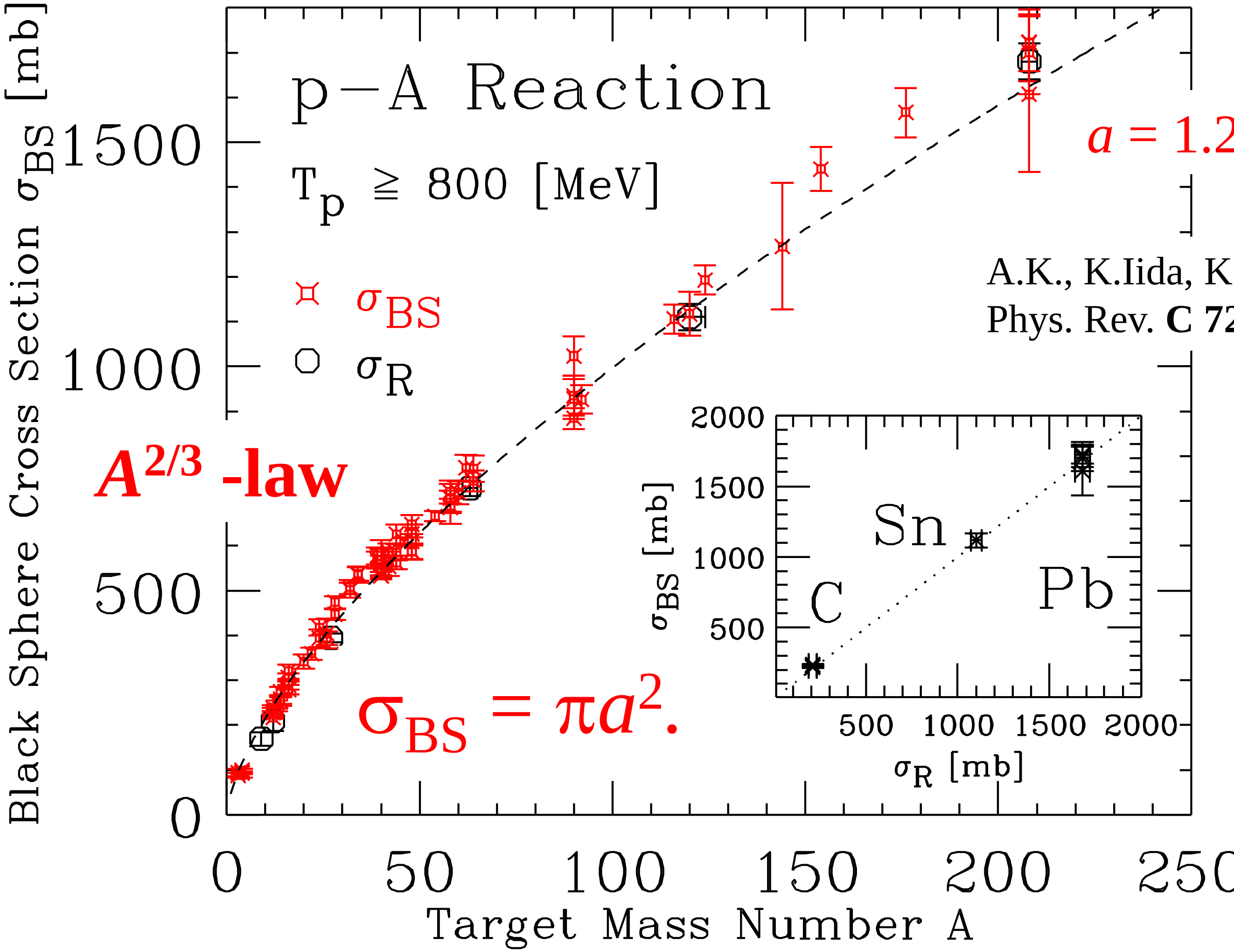
How to determine “a” ?





No parameter!

σ_{BS} as a function of A ($\geqq 3$)



$A^{2/3}$ -law

$\sigma_{BS} = \pi a^2.$

$a = 1.2135\, A^{1/3}$ [fm].

A.K., K.Iida, K.Oyamatsu,
Phys. Rev. **C 72**, 024602 (2005).

Data: ^{9}Be, ^{12}C, ^{27}Al, ^{natu}Cu, ^{natu}Sn, ^{natu}Pb.

The agreement of σ_{BS} with the data is persistent down to 100 MeV.

σ_R in EXFOR

- Total reaction cross section
  = non-elastic cross section (NON)
  = total cross section (TOT)
  - total elastic cross section ("EL")

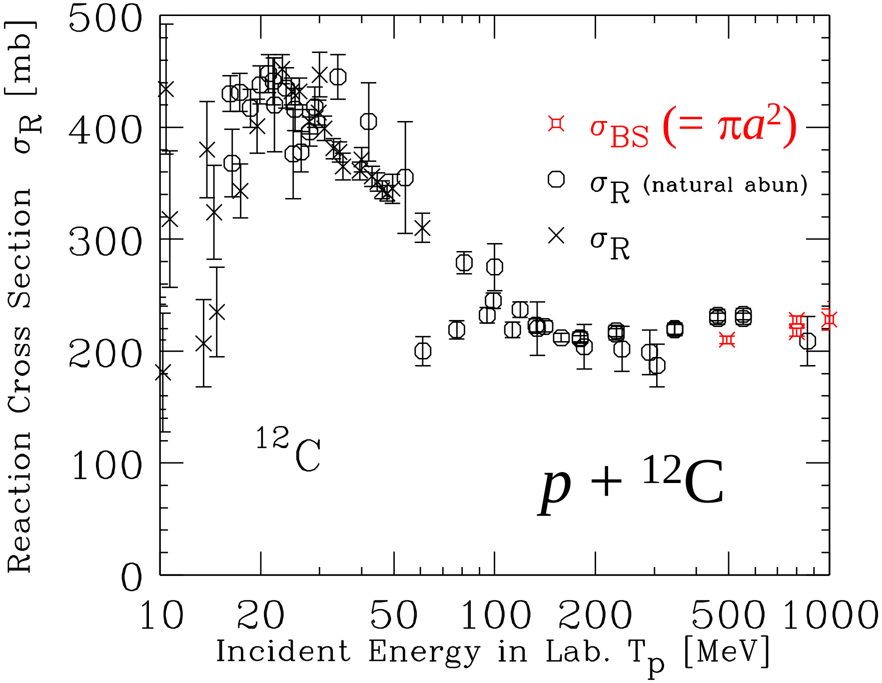
- Lots of data have been already compiled incl. very recent ones.

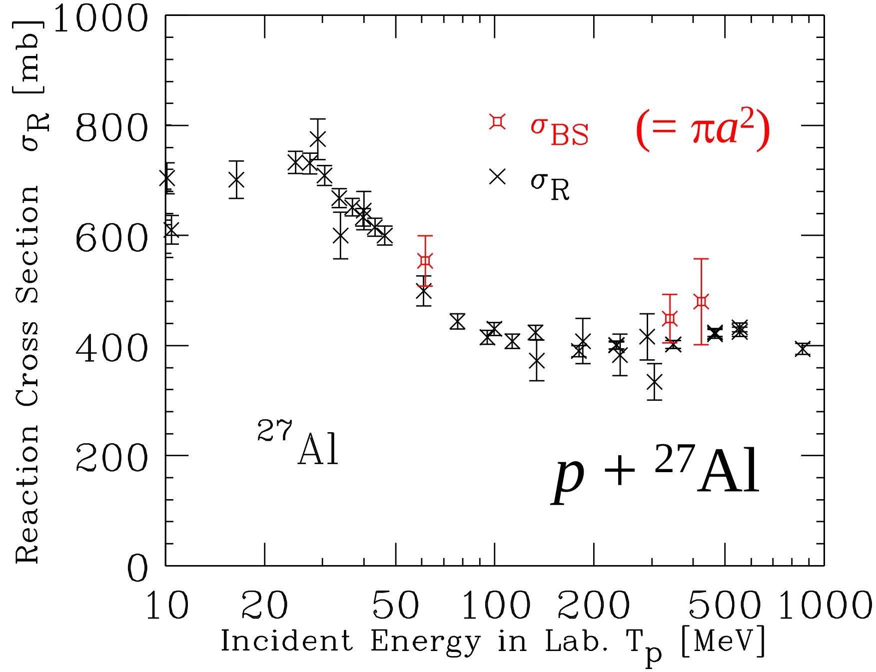
- *cf*. antiproton data
  - Recently compiled thanks to the effort of N. Otsuka and JCPRG.

σ_{BS} *vs.* σ_R : Energy Dependence

$\boxed{\sigma_R \cong \sigma_{BS}}$

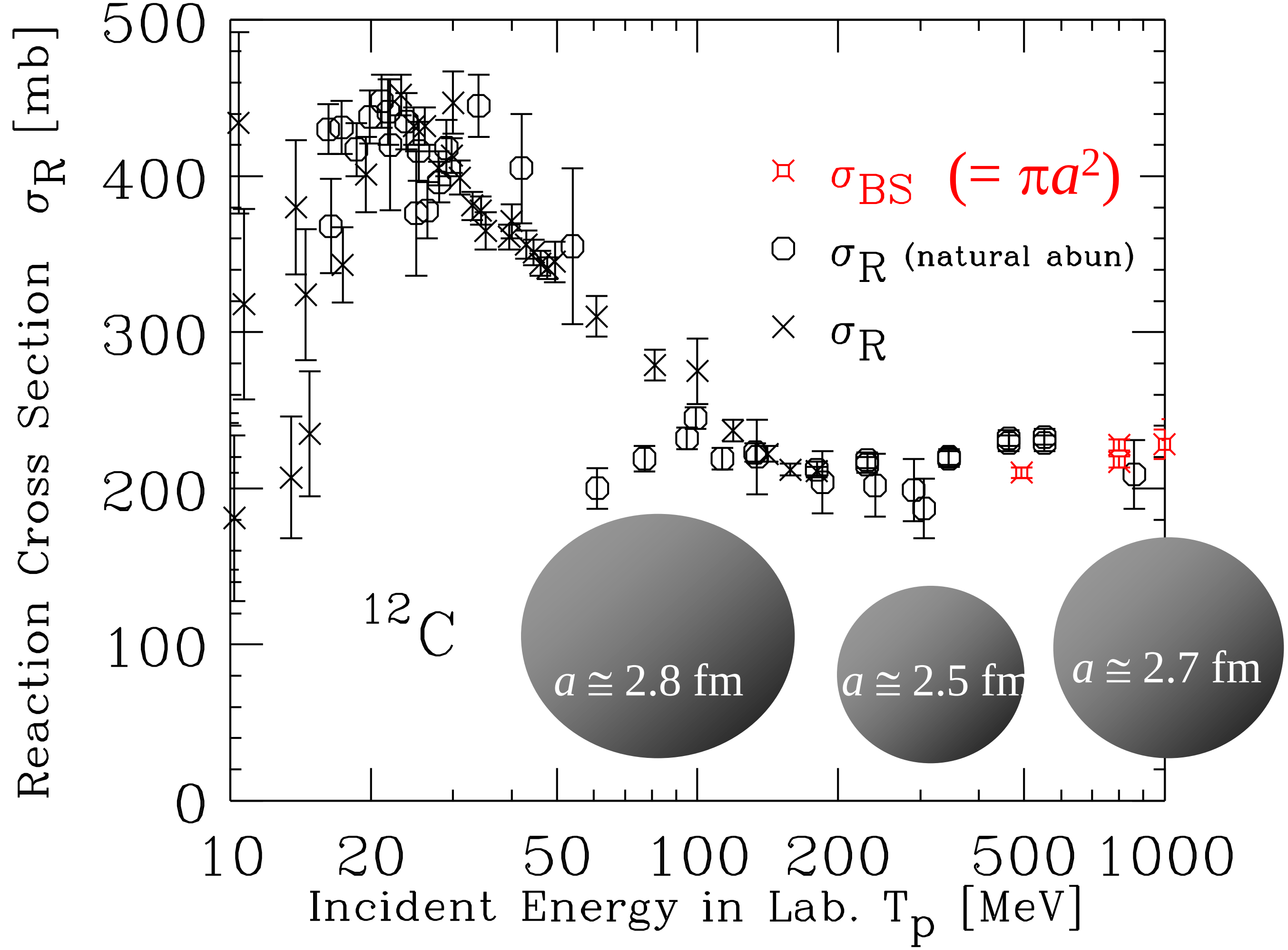
The empirical relation holds even for T_p < 800 MeV.





Data: W. Bauhoff, *At. Data Nucl. Data Tables*, **35**, 429 (1986).
A. Auce *et al.*, *Phys. Rev.* **C 71**, 064606 (2005).

The size of the black sphere changes with T_p

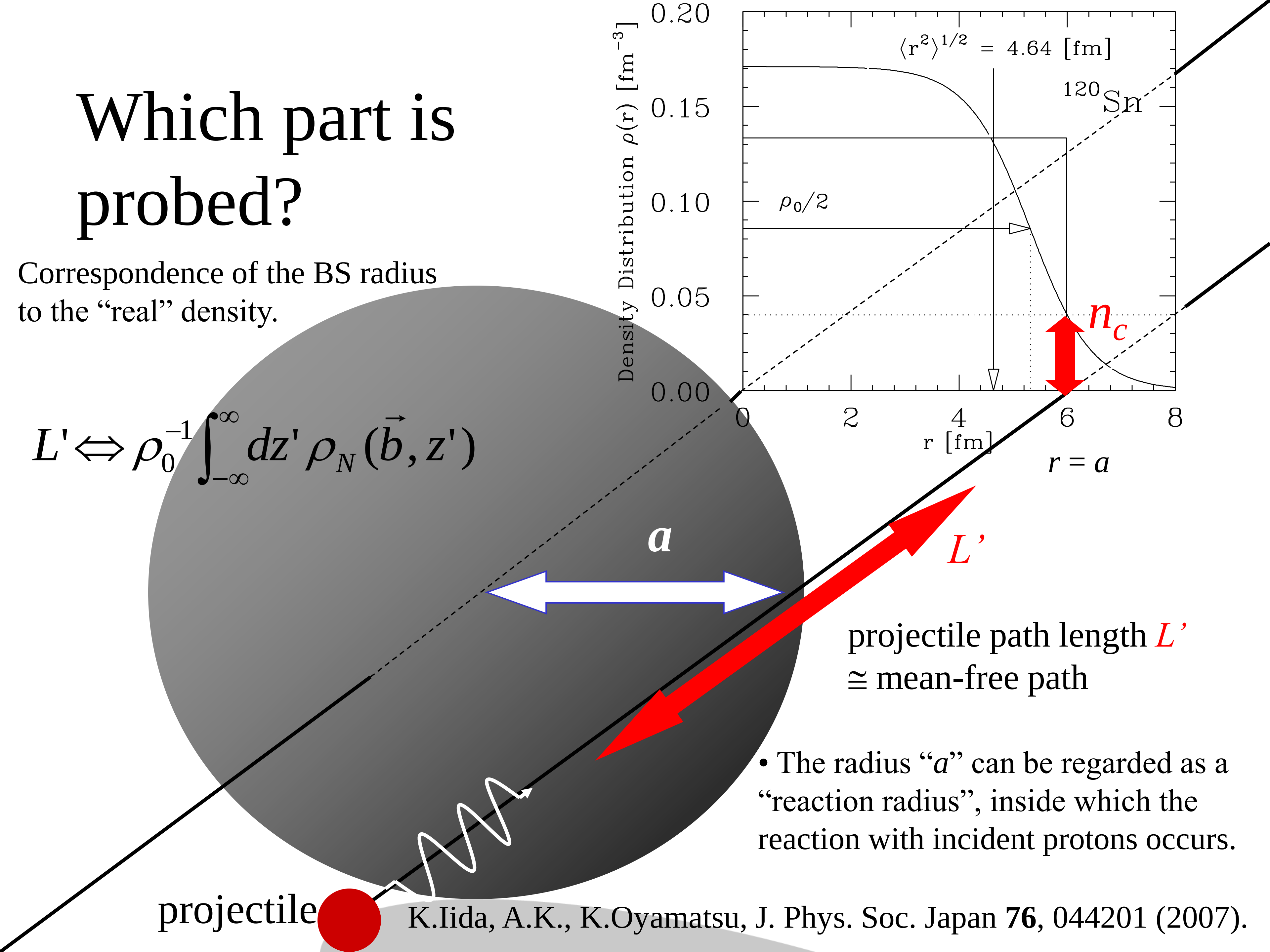


The region where incident proton probes will change according to the change of the black-sphere radius.

Which part is probed?

Correspondence of the BS radius to the "real" density.

$$L' \Leftrightarrow \rho_0^{-1} \int_{-\infty}^{\infty} dz' \, \rho_N(\vec{b}, z')$$



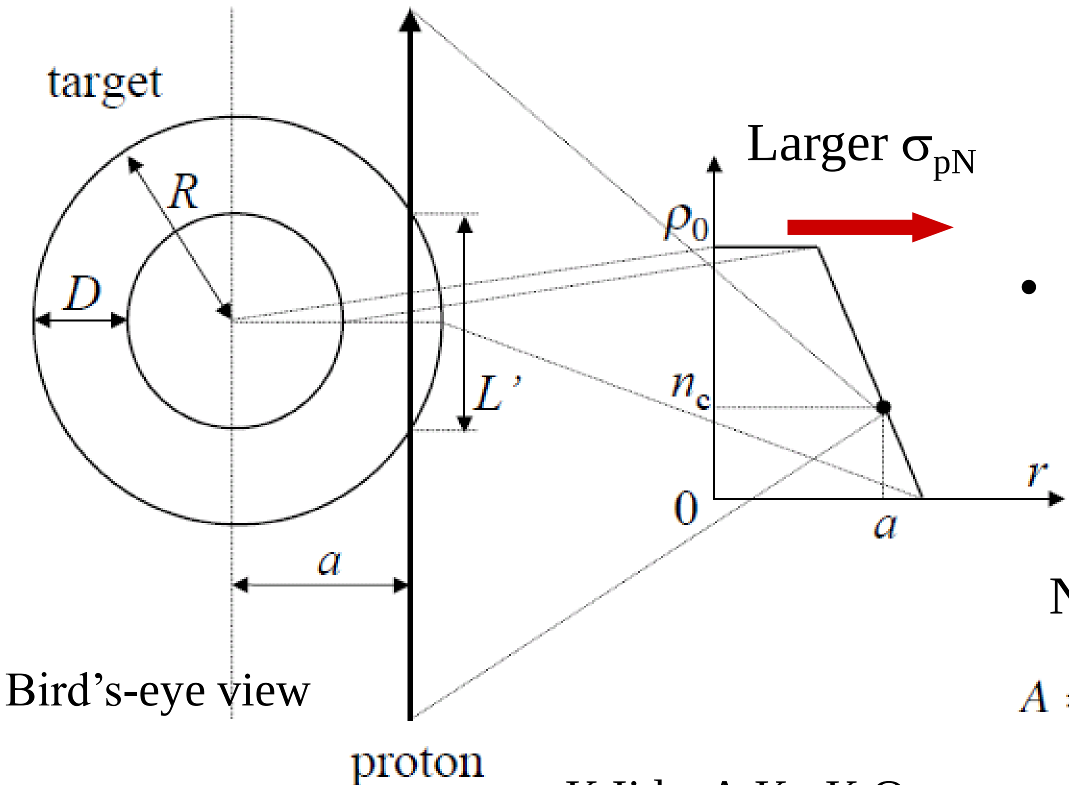
projectile path length L'
≃ mean-free path

• The radius "a" can be regarded as a "reaction radius", inside which the reaction with incident protons occurs.

K.Iida, A.K., K.Oyamatsu, J. Phys. Soc. Japan **76**, 044201 (2007).

Estimation of the path length *L'*

$$L' = 2\sqrt{R^2 - a^2}.$$



- The "real" density is approximated by *the trapezoidal density* with the standard diffuseness.

- *D*: the surface thickness (= 2.2 fm)

Normalization:

$$A = \frac{4\pi\rho_0}{3}\left(R^3 - \frac{3}{2}DR^2 + D^2R - \frac{1}{4}D^3\right).$$

K.Iida, A.K., K.Oyamatsu, J. Phys. Soc. Japan **76**, 044201 (2007).

"Optical" depth of nuclei is the key

τ = (path length)/(mean-free path).

- Introduce nuclear optical depth:
  $\tau = L'/\{1/(\sigma_{pN}\, n_c)\} = \sigma_{pN}\, n_c\, L'$,
  which is assumed to be T_p-*in*dependent.
  - This is similar to $\int_l \mathrm{d}l[\sigma_{pn} n_n(\mathbf{r}) + \sigma_{pp} n_p(\mathbf{r})]$,
  - Assume: $\tau = \mathcal{O}(1)$, *i.e.*, The black-sphere radius "*a*" corresponds to a radius at which the mean-free path of incident protons is of the order of the length of the penetration.

K.Iida, A.K., K.Oyamatsu, J. Phys. Soc. Japan **76**, 044201 (2007).

Construction of BS-cross-sect. formula

$$\sigma_R \cong \pi a(T_p)^2 \cong \pi a_0^2\left(1+\frac{\Delta a}{a_0}\right)^2.$$

- Express $\Delta a/a_0$ in terms of $\Delta\sigma_{pN}/\sigma_{pN0}$ using τ being T_p-indep. *i.e.*, $\Delta\tau = 0$, and

$$\Delta\left(\frac{\tau}{\bar{\sigma}_{pN}}\right) = \Delta(n_c L').$$

- $\Delta a = a(T_p) - a_0$.
  - a_0 is fixed to the value at 800 MeV.
- $\Delta X = X - X_0$,
  - X_0 is X (= a, σ_{pN}, n_c, L') at 800 MeV.

Destination: $\Delta a/a_0 = \Delta\sigma_{pN}/\sigma_{pN0} \times$ (T_p-*in*dependent terms).

K.Iida, A.K., K.Oyamatsu, J. Phys. Soc. Japan **76**, 044201 (2007).

Formula for reaction cross section

Proton - stable nucleus

T_p-dep. is driven by σ_{pN} through the nucl. optical depth.

$$\sigma_R(T_p, A) = \pi a^2(T_p, A) = \pi a_0^2 \left(1 + \frac{\Delta a}{a_0}\right)^2, \; T_p > 100 \text{ MeV}$$

$$\Delta a = \left(\frac{\rho_0 a_0}{D n_{c0}} - \frac{a_0}{L'_0} \frac{dL'}{da}\bigg|_0 \right)^{-1} \frac{\Delta \bar{\sigma}_{pN}}{\bar{\sigma}_{pN0}} a_0$$

$$\bar{\sigma}_{pN} = (Z/A)\sigma_{pp} + (1 - Z/A)\sigma_{pn}$$

$$X_0 : X(= \bar{\sigma}_{pN}, a, n_c, L') \text{ at } T_\mathrm{p} = 800 \text{ MeV}$$

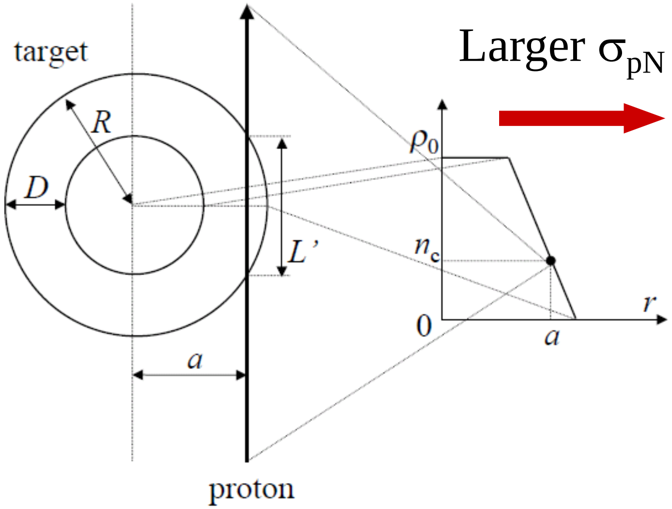
$$\Delta X = X - X_0$$

$$L' = 2\sqrt{R^2 - a^2}$$

$$R = R_0 + D/2 - R_0\left(1 + 12R_0^2/D^2\right)^{-1}$$

$$D = 2.2 \text{ fm}, \; \rho_0 = 0.16 \text{ fm}^{-3}, \; R_0 = \left(3A/4\pi\rho_0\right)^{1/3}$$

$$n_{c0} = 0.9\left(\bar{\sigma}_{pN0} L'_0\right)^{-1}$$



Bird's-eye view

$$\Delta \bar{\sigma}_{pN}^{total} = \bar{\sigma}_{pN}^{total}(T_p) - \bar{\sigma}_{pN0}^{total}.$$

is small for $T_p > 100$ MeV.

No energy dependent adjustable parameter

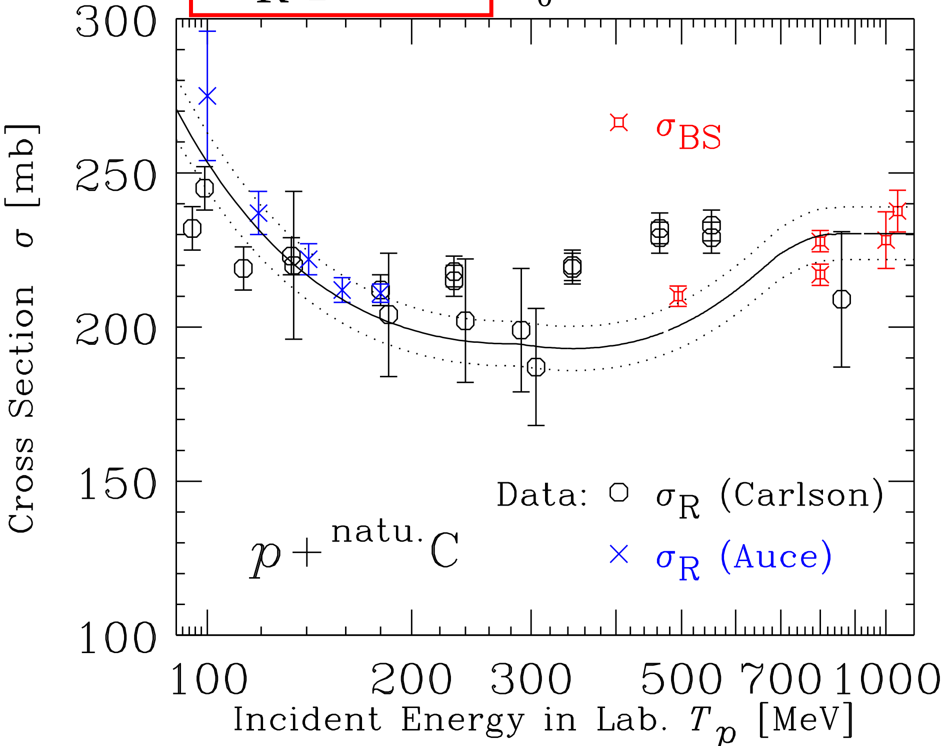
——— different from fitting formulas

From K. Iida

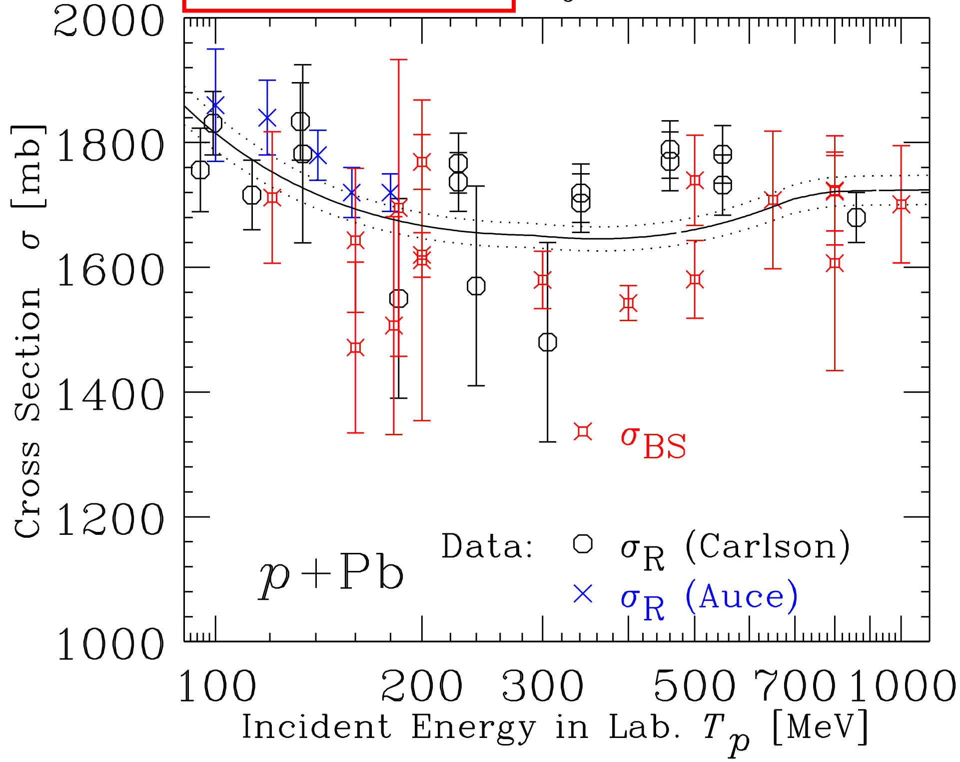
Comparison for *stable* nuclei

BS-cross-sect. formula works well

$\boxed{\sigma_R(p+\mathrm{C})}$ a_0 = 2.70 +/- 0.05 fm



$\boxed{\sigma_R(p+\mathrm{Pb})}$ a_0 = 7.40 +/- 0.05 fm



Data:

R. F. Carlson, *At. Data Nucl. Data Tables*, **63**, 93 (1996).

A. Auce *et al*., *Phys. Rev.* **C 71**, 064606 (2005).

T_p > 100 MeV

Coulomb int. can be neglected.

cf. PHITS

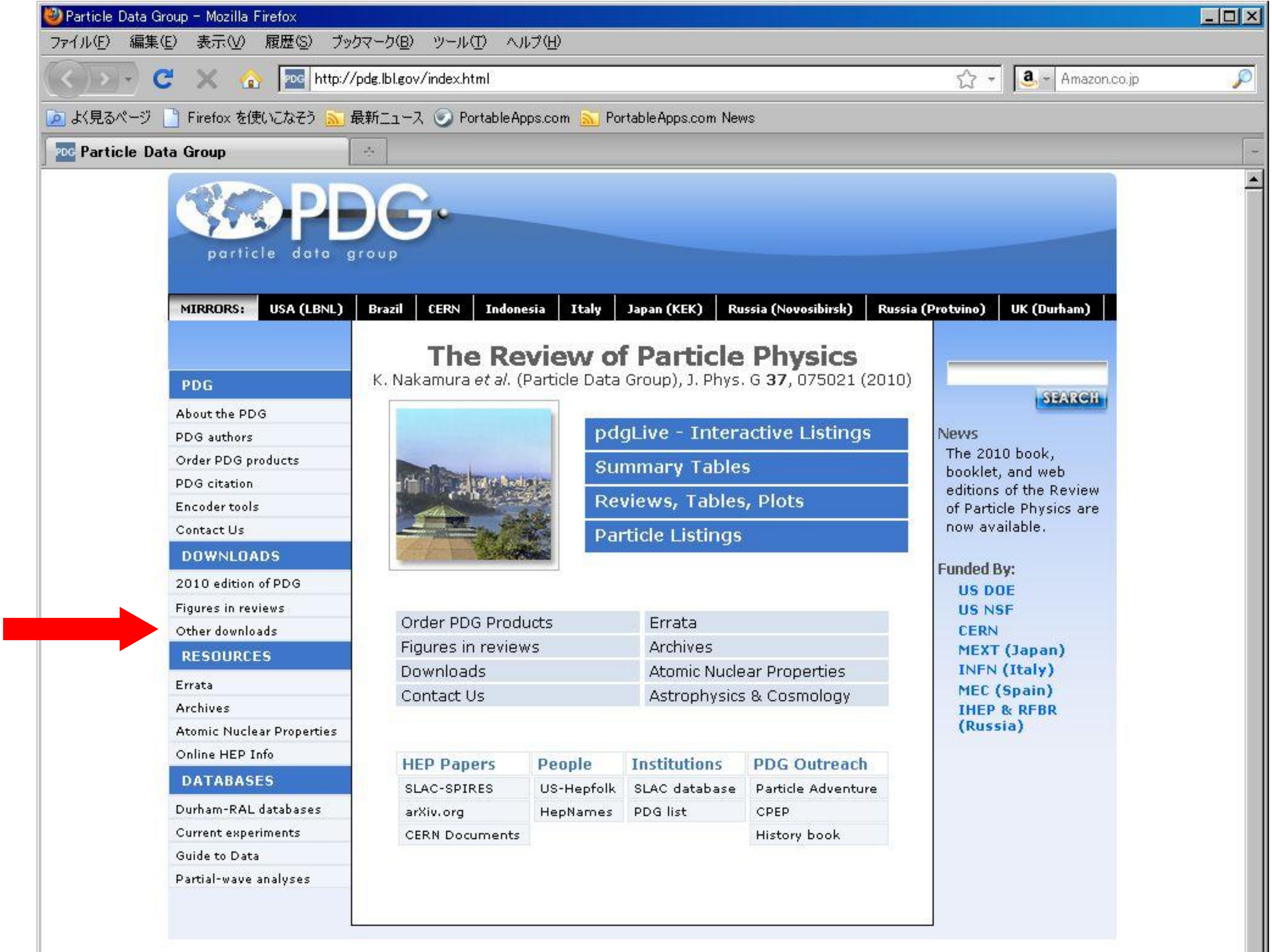
K.Iida, A.K., K.Oyamatsu, J. Phys. Soc. Japan **76**, 044201 (2007).

Compile or not to compile, that is ...

$$\sigma^{total}_{NN}$$

In the EXFOR manual,
"a less complete compilation of charged-particle-induced reaction data."

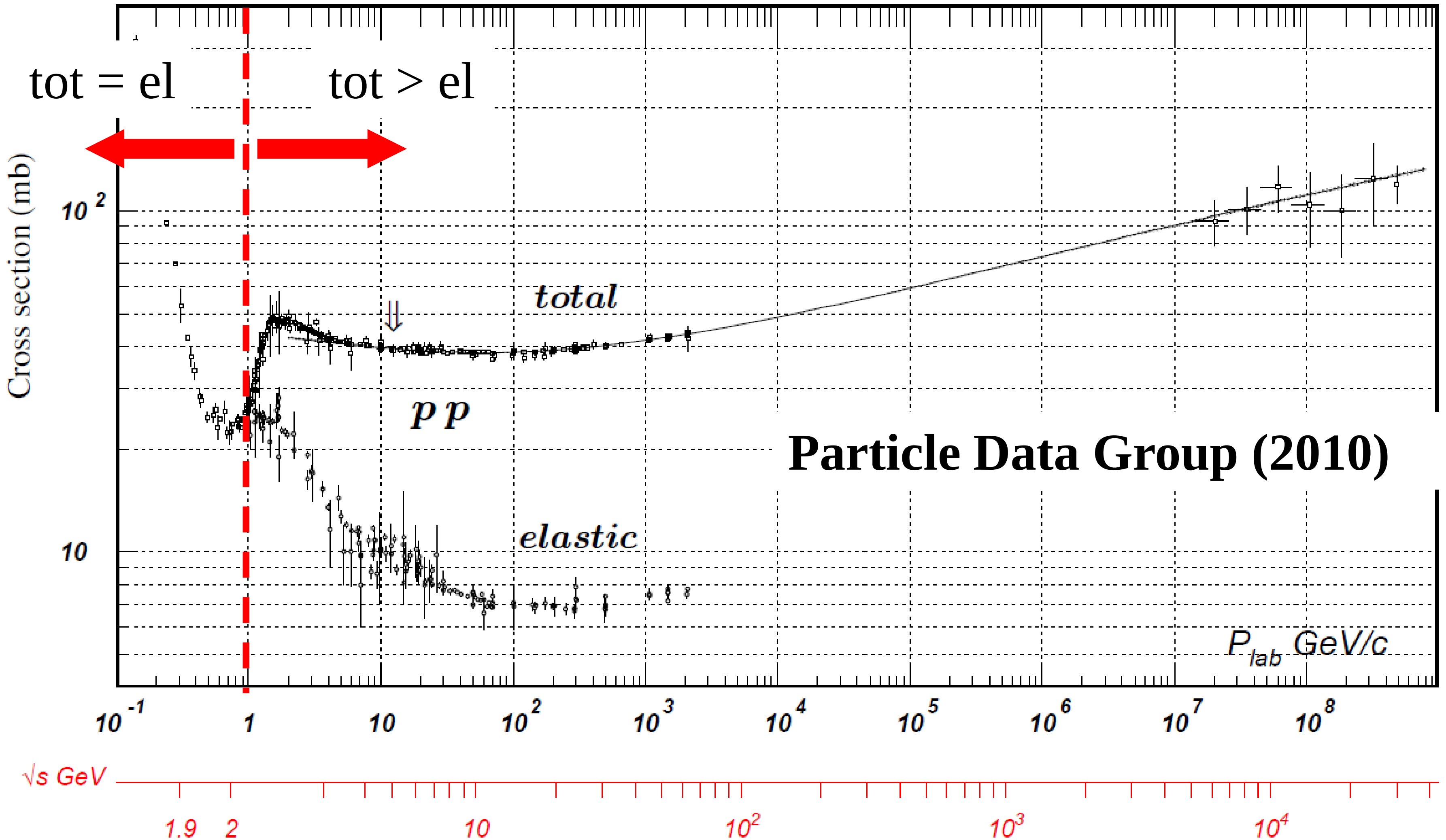
Based on the discussion with N. Otsuka (IAEA)



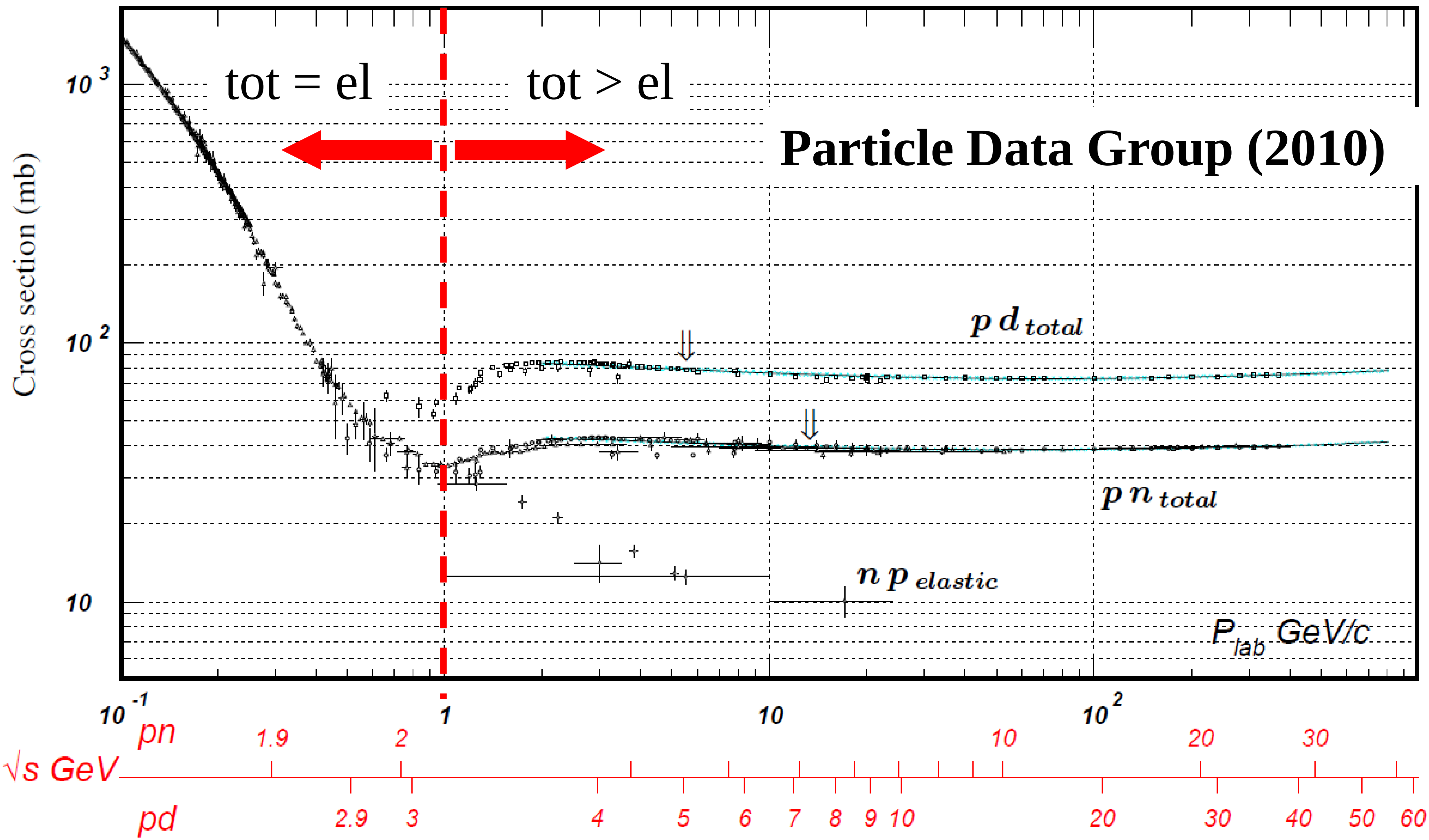
You will find “Cross Sections and related quantities”.

http://pdg.lbl.gov/

E-dep. of *p*+*p* total cross sections



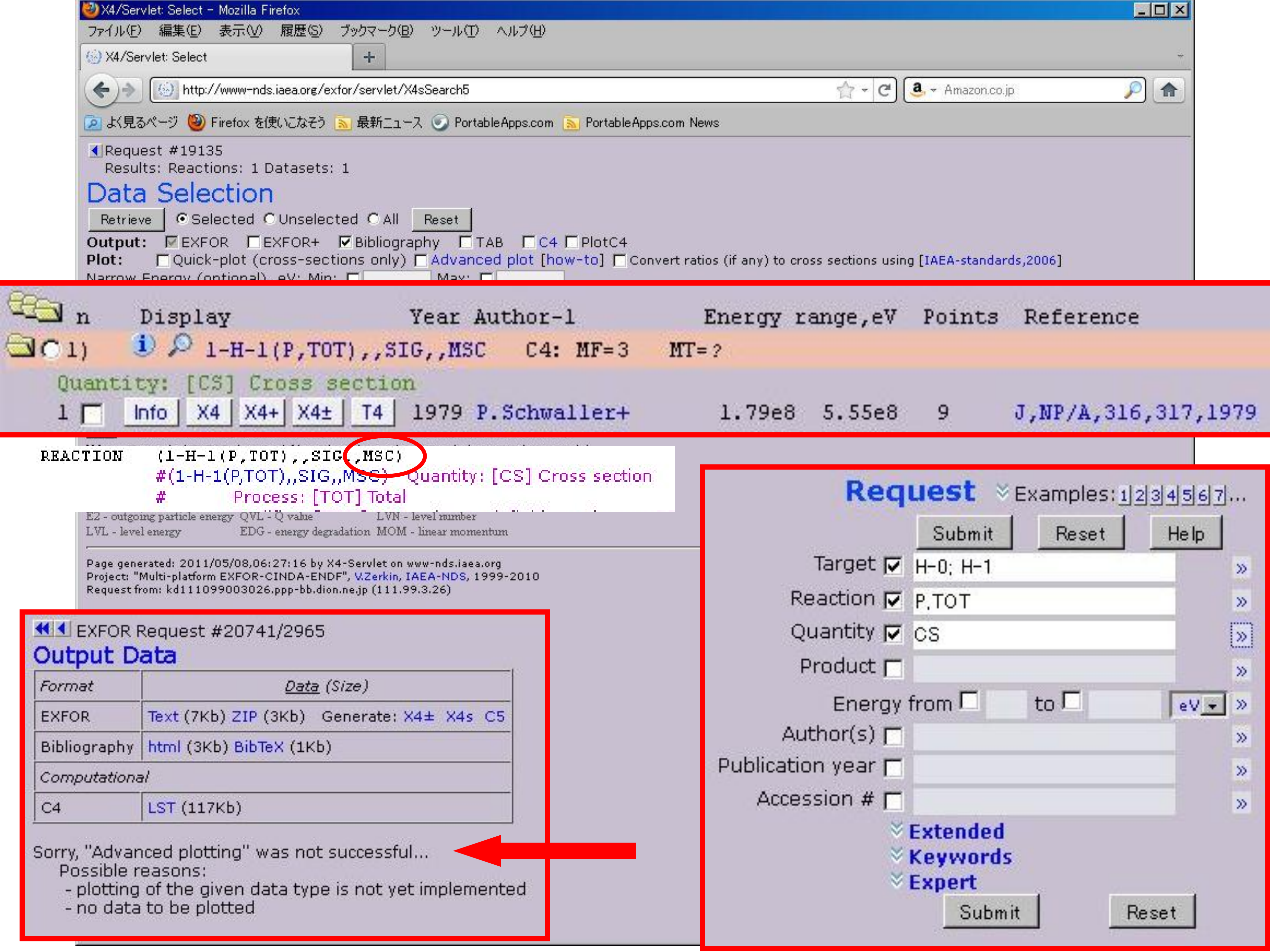
E-dep. of *p*+*n* total cross sections



“observable” or “deduced value”?

- σ_{pp}^{total}
  - ➢ It is an ill-defined quantity, not an observable.
    It is a deduced quantity.
    - Due to the coulomb interaction, it must be diverge.
    - Procedure of Coulomb subtraction should be accompanied by some uncertainties.

- σ_{np}^{total} or σ_{pp}^{total}
  - ➢ “n on p” is an observable.
    - This serves as the standard values of cross sections.
    - The highest incident energy is limited.
  - ➢ “p on n” is not an observable.
    It is a deduced quantity.
    - The target will be deuterons. The contribution from the target proton should be subtracted out.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Plot: Quick-plot (cross-sections only) Advanced plot [how-to] Convert ratios (if any) to cross sections using [IAEA-standards,2006]
n Display Year Author-1 Energy range,eV Points Reference
1) 1-H-1(P,TOT),,SIG,,MSC C4: MF=3 MT=?
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1 Info X4 X4+ X4± T4 1979 P.Schwaller+ 1.79e8 5.55e8 9 J,NP/A,316,317,1979
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Process: [TOT] Total
E2 - outgoing particle energy QVL - Q value LVN - level number
LVL - level energy EDG - energy degradation MOM - linear momentum
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- plotting of the given data type is not yet implemented
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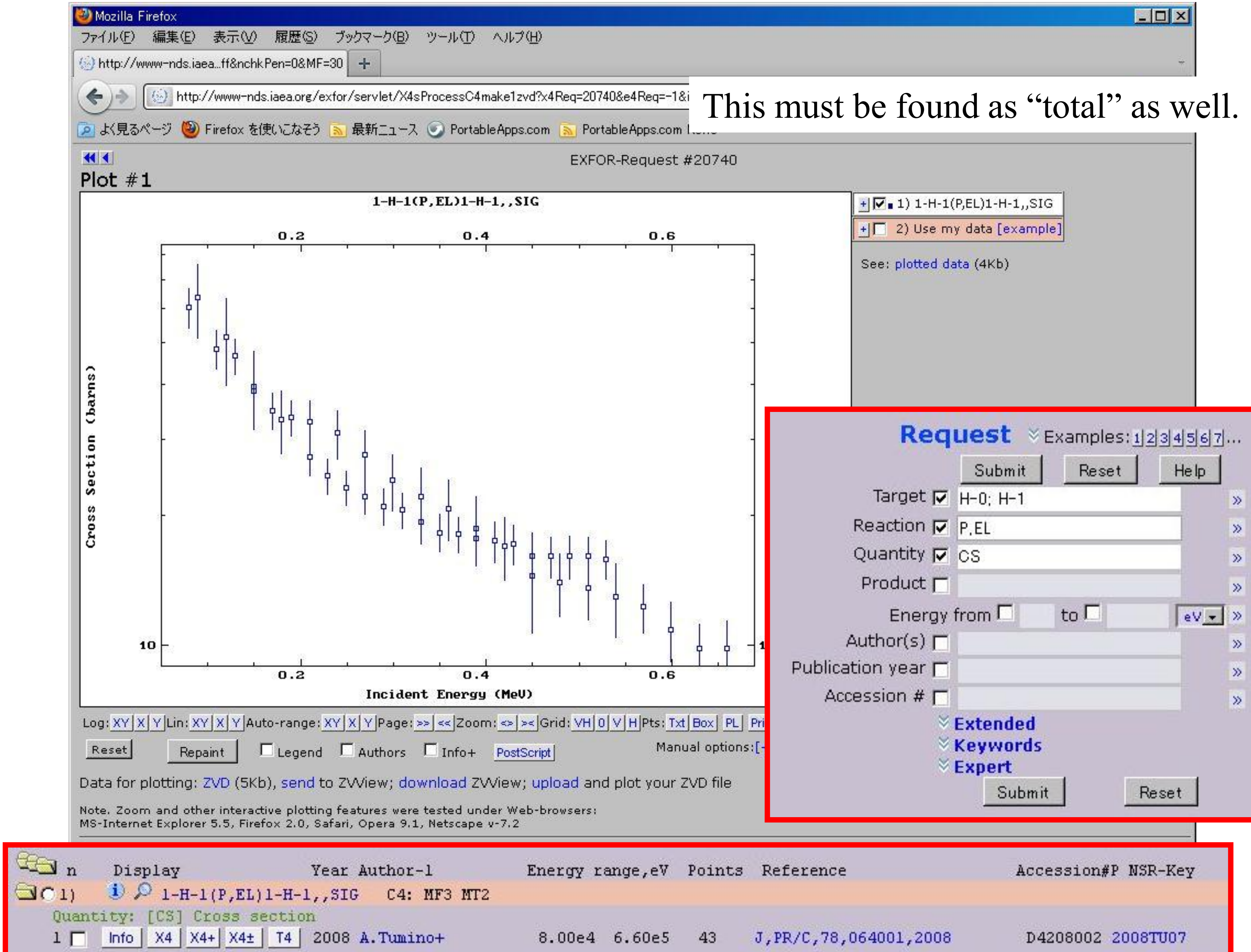
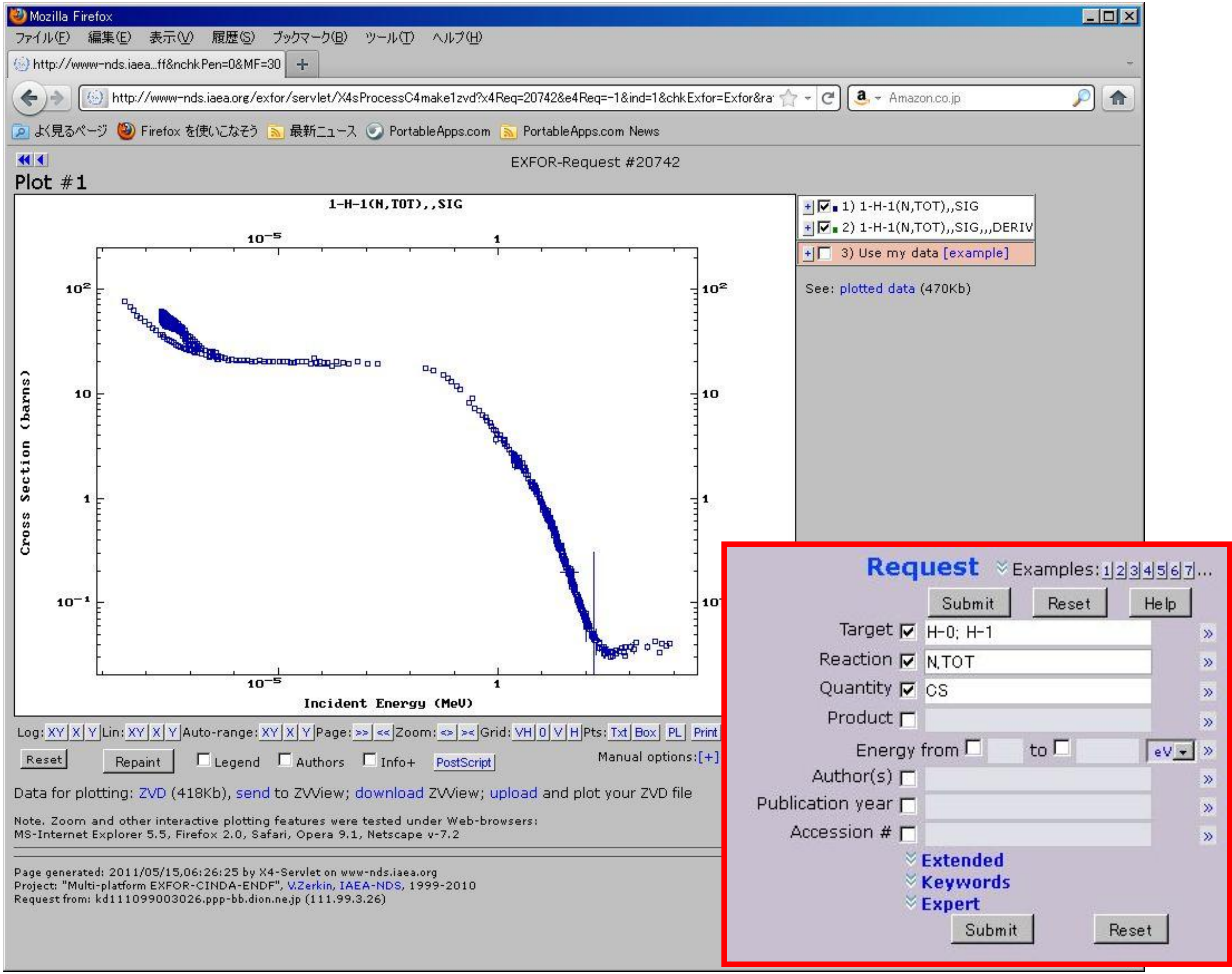
This must be found as “total” as well.

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EXFOR-Request #20742
Plot #1
1-H-1(N,TOT),,SIG
Cross Section (barns)
Incident Energy (MeV)
1) 1-H-1(N,TOT),,SIG
2) 1-H-1(N,TOT),,SIG,,,DERIV
3) Use my data [example]
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Note. Zoom and other interactive plotting features were tested under Web-browsers:
MS-Internet Explorer 5.5, Firefox 2.0, Safari, Opera 9.1, Netscape v-7.2
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Examples: 1 2 3 4 5 6 7 ...
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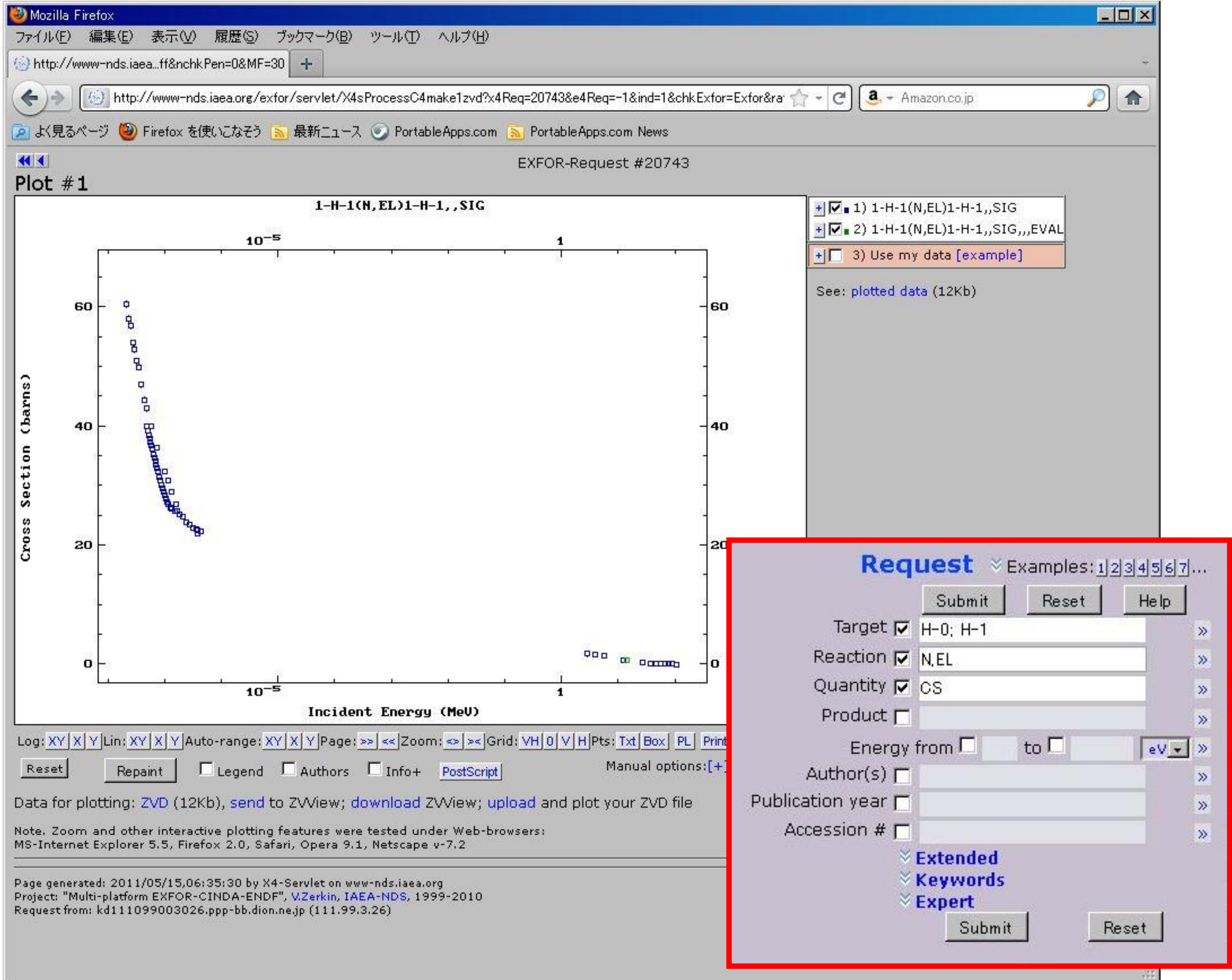

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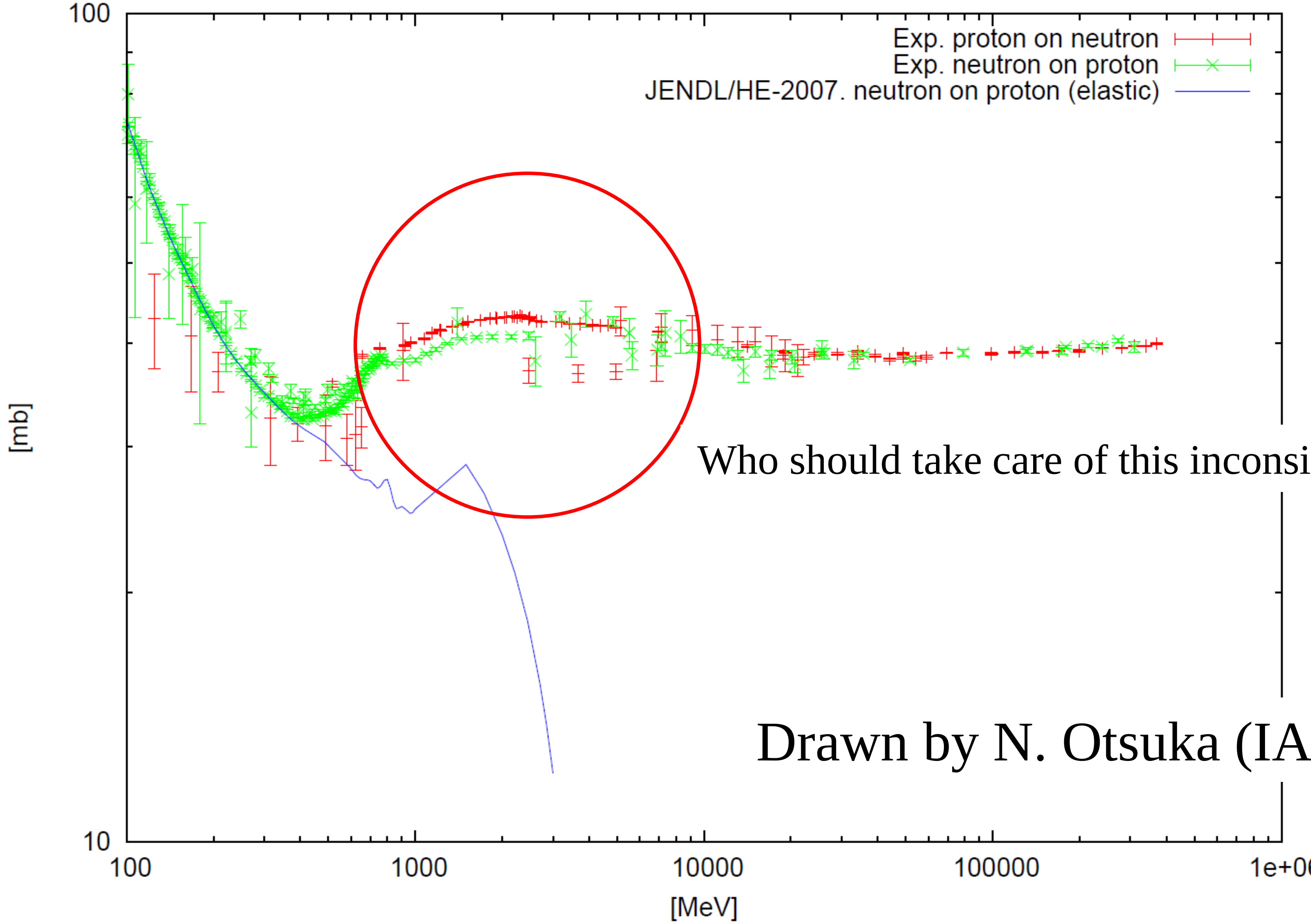
EXFOR-Request #20743
Plot #1
1-H-1(N,EL)1-H-1,,SIG
Cross Section (barns)
Incident Energy (MeV)
1) 1-H-1(N,EL)1-H-1,,SIG
2) 1-H-1(N,EL)1-H-1,,SIG,,,EVAL
3) Use my data [example]
See: plotted data (12Kb)
Log: XY X Y Lin: XY X Y Auto-range: XY X Y Page: >> << Zoom: <> >< Grid: VH 0 V H Pts: Txt Box PL Print
Reset Repaint Legend Authors Info+ PostScript
Manual options: [+]
Data for plotting: ZVD (12Kb), send to ZVView; download ZVView; upload and plot your ZVD file
Note. Zoom and other interactive plotting features were tested under Web-browsers:
MS-Internet Explorer 5.5, Firefox 2.0, Safari, Opera 9.1, Netscape v-7.2
Page generated: 2011/05/15,06:35:30 by X4-Servlet on www-nds.iaea.org
Project: "Multi-platform EXFOR-CINDA-ENDF", V.Zerkin, IAEA-NDS, 1999-2010
Request from: kd111099003026.ppp-bb.dion.ne.jp (111.99.3.26)
Request
Examples: 1 2 3 4 5 6 7 ...
Submit Reset Help
Target H-0; H-1
Reaction N,EL
Quantity CS
Product
Energy from to eV
Author(s)
Publication year
Accession #
Extended
Keywords
Expert
Submit Reset

$$\sigma_{pn}^{\text{total}} \neq \sigma_{np}^{\text{total}} \ ?$$

Data from PDG



Who should take care of this inconsistency?

Drawn by N. Otsuka (IAEA)

My current concern with σ_{NN}^{total}

- Below the π-threshold: (total) = (elastic)
- While in EXFOR even below π-threshold;
  - 1-H-1(N,EL)1-H-1,,SIG, 1-H-1(N,TOT),,SIG
  - Different data sets appear, but the same sets should appear.
- At high energy, $\sigma_{pn}^{total} \neq \sigma_{np}^{total}$?

- Extrapolation is inevitable
  - EL: integrated angular distribution of elastic differential cross section. Extrapolation to zero degree to subtract the Coulomb.
  - TOT: Extrapolation of angular distribution of elastic differential cross section to zero degree and adopt the optical theorem.

I believe that σ_{NN}^{total} is important as a measure of the strength of NN-int. and hope to be compiled properly.

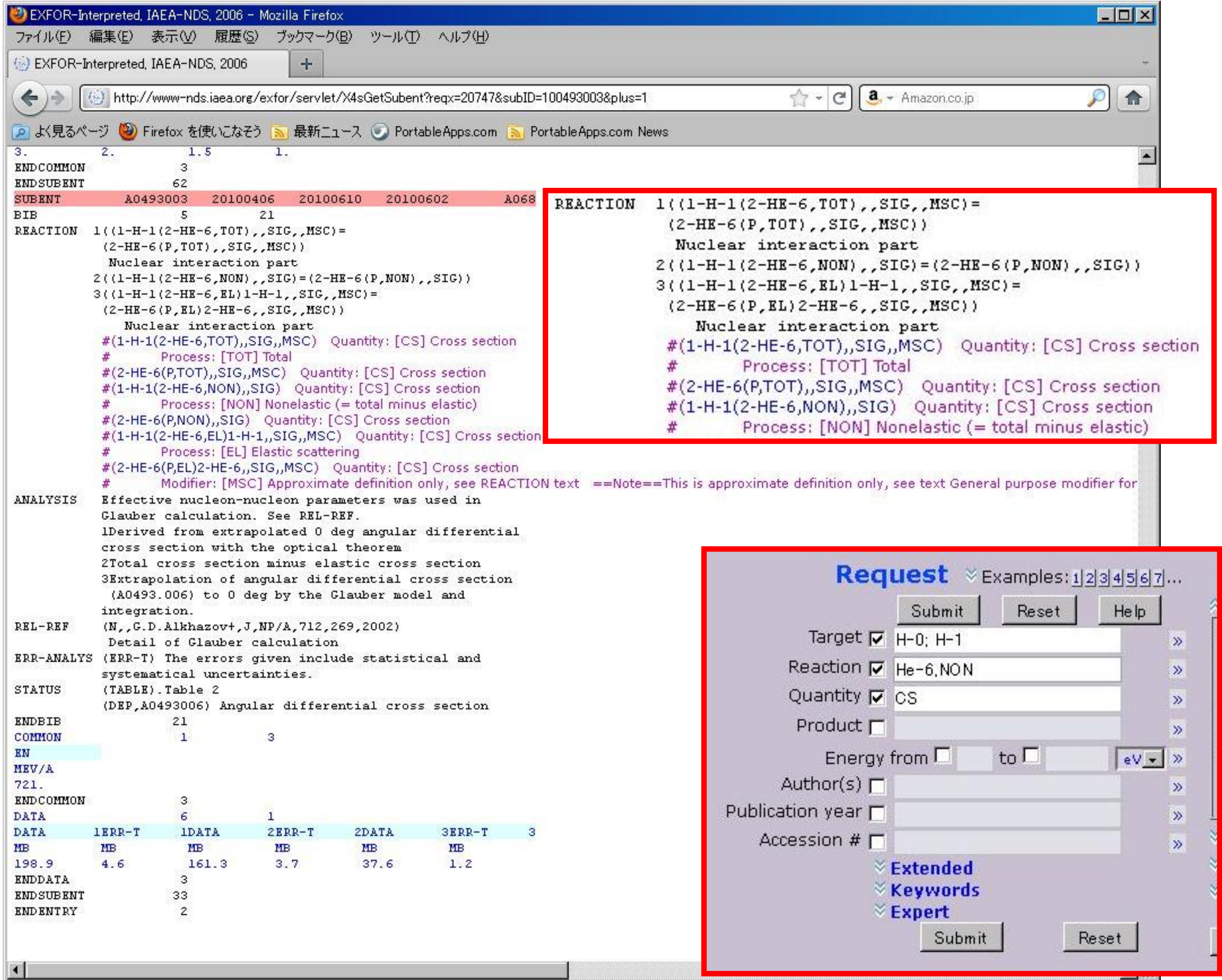
EXFOR is powerful and evolving DB

- I have illustrated an example of the systematic analyses of high energy processes using EXFOR.
  - Compilation of high energy data is very helpful.
  - Please be careful for high energy data and for reactions involving particles other than nucleons.
- Message: Databases, such as EXFOR, must be evolving forever with the users.
  - Nuclear reaction data is one of the valuable common properties of human being!

- Special thanks to N. Otsuka (IAEA) & the members of Nuclear Reaction Data Centre (JCPRG) @ Hokkaido Univ. for the data collection.

Thank you very much!

Backup slides




```
3.           2.          1.5         1.
ENDCOMMON               3
ENDSUBENT              62
SUBENT        A0493003    20100406    20100610    20100602      A068
BIB                     5          21
REACTION   1((1-H-1(2-HE-6,TOT),,SIG,,MSC)=
            (2-HE-6(P,TOT),,SIG,,MSC))
             Nuclear interaction part
           2((1-H-1(2-HE-6,NON),,SIG)=(2-HE-6(P,NON),,SIG))
           3((1-H-1(2-HE-6,EL)1-H-1,,SIG,,MSC)=
            (2-HE-6(P,EL)2-HE-6,,SIG,,MSC))
               Nuclear interaction part
            #(1-H-1(2-HE-6,TOT),,SIG,,MSC)   Quantity: [CS] Cross section
            #        Process: [TOT] Total
            #(2-HE-6(P,TOT),,SIG,,MSC)   Quantity: [CS] Cross section
            #(1-H-1(2-HE-6,NON),,SIG)   Quantity: [CS] Cross section
            #        Process: [NON] Nonelastic (= total minus elastic)
            #(2-HE-6(P,NON),,SIG)   Quantity: [CS] Cross section
            #(1-H-1(2-HE-6,EL)1-H-1,,SIG,,MSC)   Quantity: [CS] Cross section
            #        Process: [EL] Elastic scattering
            #(2-HE-6(P,EL)2-HE-6,,SIG,,MSC)   Quantity: [CS] Cross section
            #        Modifier: [MSC] Approximate definition only, see REACTION text   ==Note==This is approximate definition only, see text General purpose modifier for
ANALYSIS    Effective nucleon-nucleon parameters was used in
            Glauber calculation. See REL-REF.
            1Derived from extrapolated 0 deg angular differential
            cross section with the optical theorem
            2Total cross section minus elastic cross section
            3Extrapolation of angular differential cross section
             (A0493.006) to 0 deg by the Glauber model and
            integration.
REL-REF     (N,,G.D.Alkhazov+,J,NP/A,712,269,2002)
             Detail of Glauber calculation
ERR-ANALYS  (ERR-T) The errors given include statistical and
            systematical uncertainties.
STATUS      (TABLE).Table 2
            (DEP,A0493006) Angular differential cross section
ENDBIB                 21
COMMON                  1           3
EN
MEV/A
721.
ENDCOMMON               3
DATA                    6           1
DATA        1ERR-T      1DATA       2ERR-T      2DATA       3ERR-T      3
MB          MB          MB          MB          MB          MB
198.9       4.6         161.3       3.7         37.6        1.2
ENDDATA                 3
ENDSUBENT              33
ENDENTRY                2
```

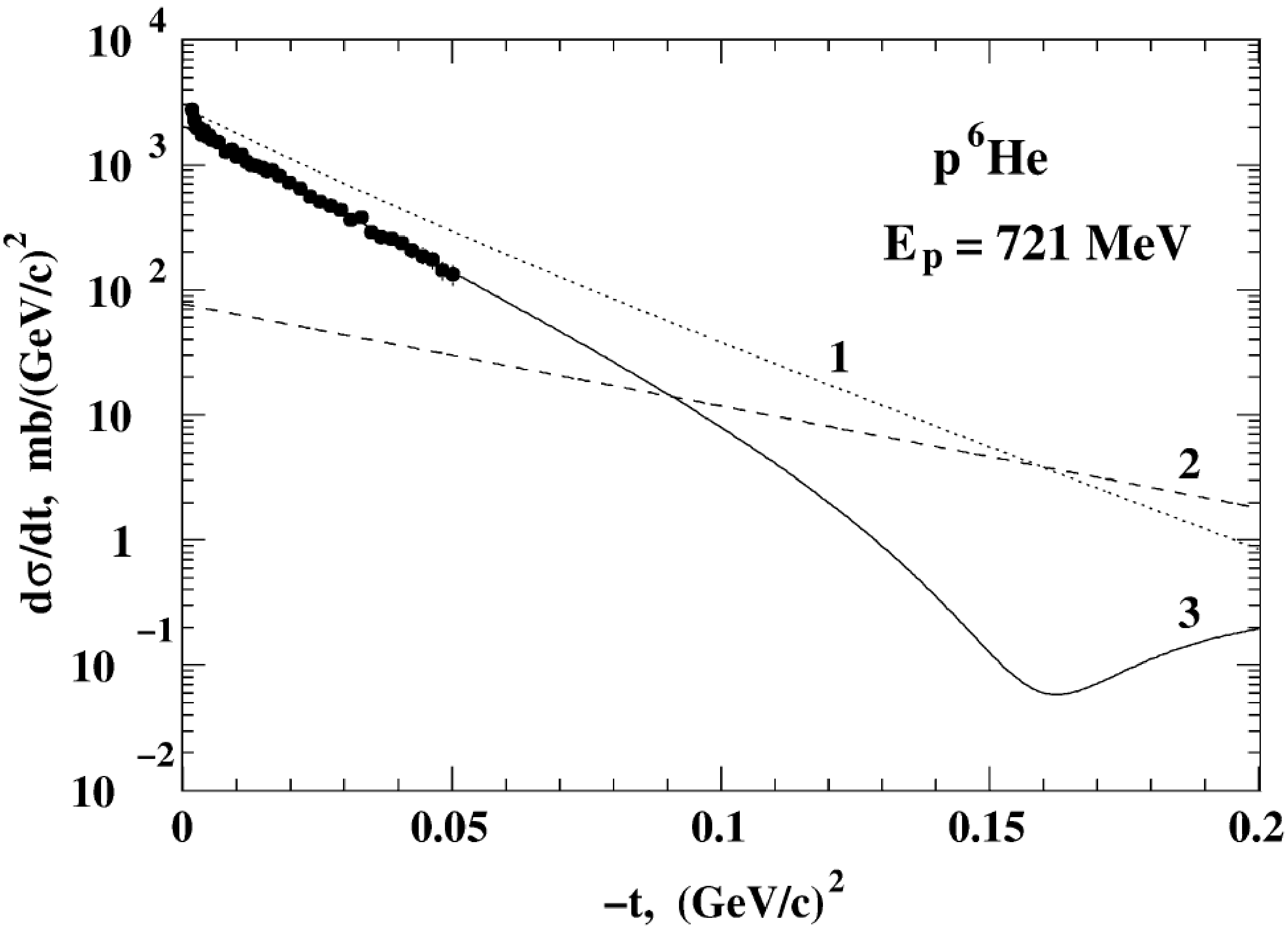
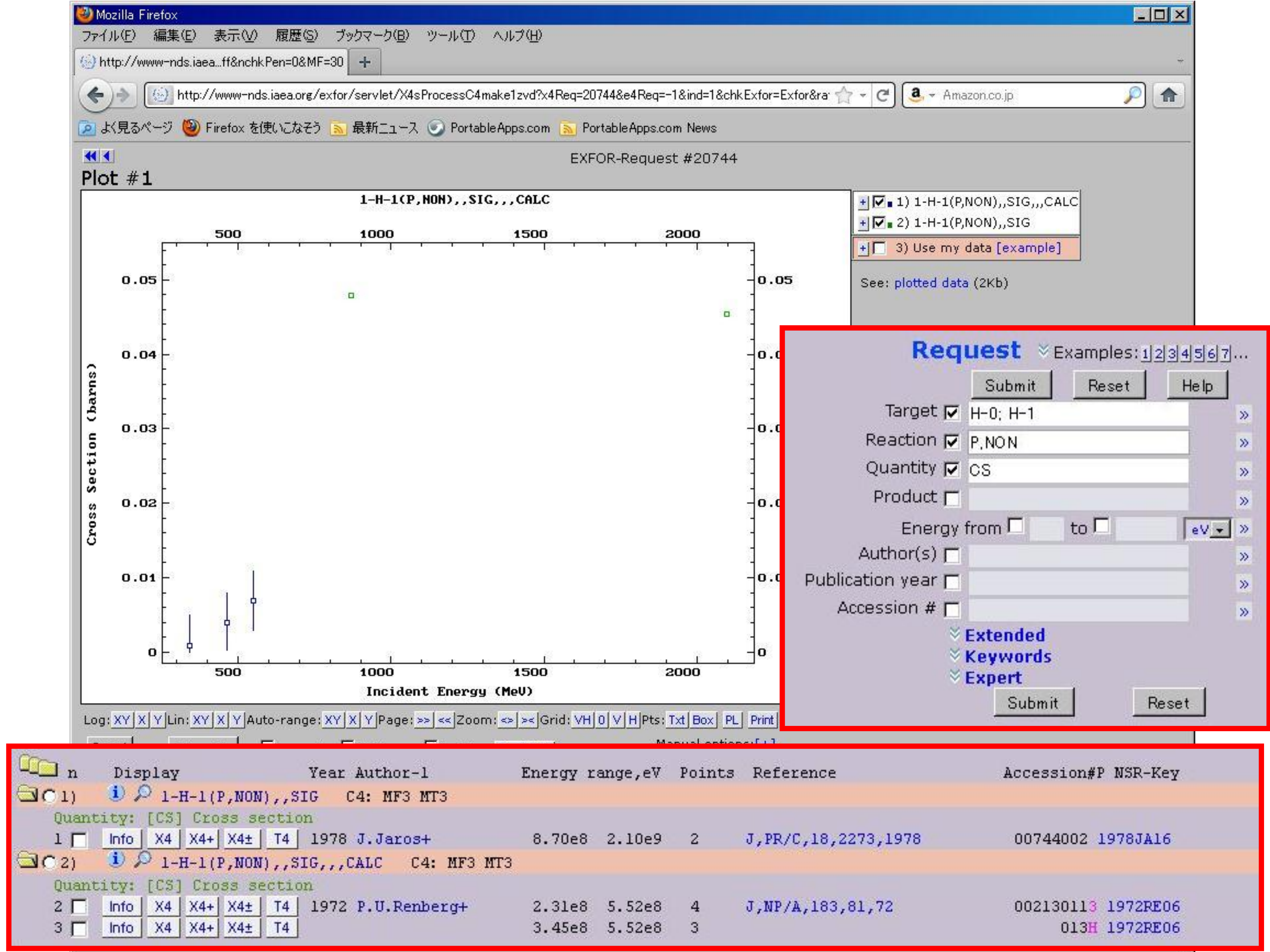


Fig. 1. Calculated $p\,^6$He elastic-scattering cross sections at $E_p = 721$ MeV versus the four-momentum transfer squared, taking into account either the single-scattering term (curve 1), or multiple-scattering terms (curve 2), or all scattering terms (curve 3). The experimental data [1,2] (dots) are also displayed.

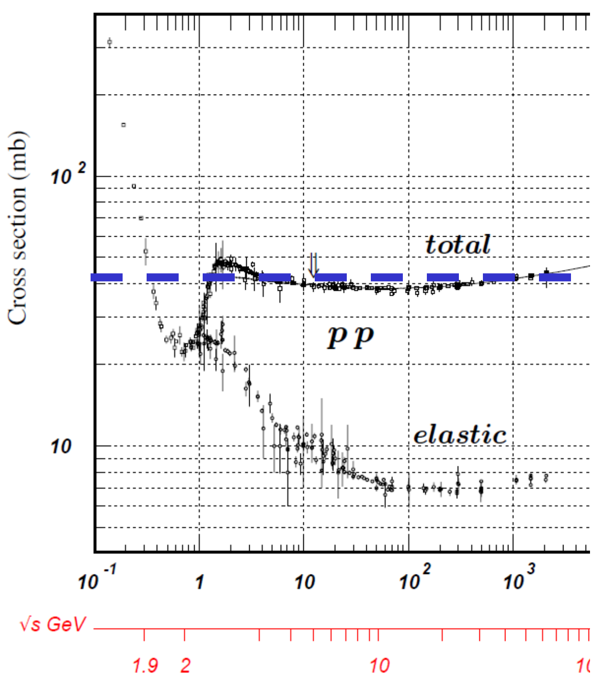

Mozilla Firefox
ファイル(F) 編集(E) 表示(V) 履歴(S) ブックマーク(B) ツール(T) ヘルプ(H)
http://www-nds.iaea.org/exfor/servlet/X4sProcessC4make1zvd?x4Req=20744&e4Req=-1&ind=1&chkExfor=Exfor&ra
Amazon.co.jp
よく見るページ Firefox を使いこなそう 最新ニュース PortableApps.com PortableApps.com News
EXFOR-Request #20744
Plot #1
1-H-1(P,NON),,SIG,,,CALC
Cross Section (barns)
Incident Energy (MeV)
1) 1-H-1(P,NON),,SIG,,,CALC
2) 1-H-1(P,NON),,SIG
3) Use my data [example]
See: plotted data (2Kb)
Log: XY X Y Lin: XY X Y Auto-range: XY X Y Page: >> << Zoom: <> >< Grid: VH 0 V H Pts: Txt Box PL Print
Request
Examples: 1 2 3 4 5 6 7 ...
Submit Reset Help
Target H-0; H-1
Reaction P,NON
Quantity CS
Product
Energy from to eV
Author(s)
Publication year
Accession #
Extended
Keywords
Expert
Submit Reset
n Display Year Author-1 Energy range,eV Points Reference Accession#P NSR-Key
1) 1-H-1(P,NON),,SIG C4: MF3 MT3
Quantity: [CS] Cross section
1 Info X4 X4+ X4± T4 1978 J.Jaros+ 8.70e8 2.10e9 2 J,PR/C,18,2273,1978 00744002 1978JA16
2) 1-H-1(P,NON),,SIG,,,CALC C4: MF3 MT3
Quantity: [CS] Cross section
2 Info X4 X4+ X4± T4 1972 P.U.Renberg+ 2.31e8 5.52e8 4 J,NP/A,183,81,72 002130113 1972RE06
3 Info X4 X4+ X4± T4 3.45e8 5.52e8 3 013H 1972RE06

Applications to other hadronic probes

σ_{pp} *vs.* σ_{pbarp}

- p + p
- pbar + p

12 *40. Plots of cross sections and related quantities*



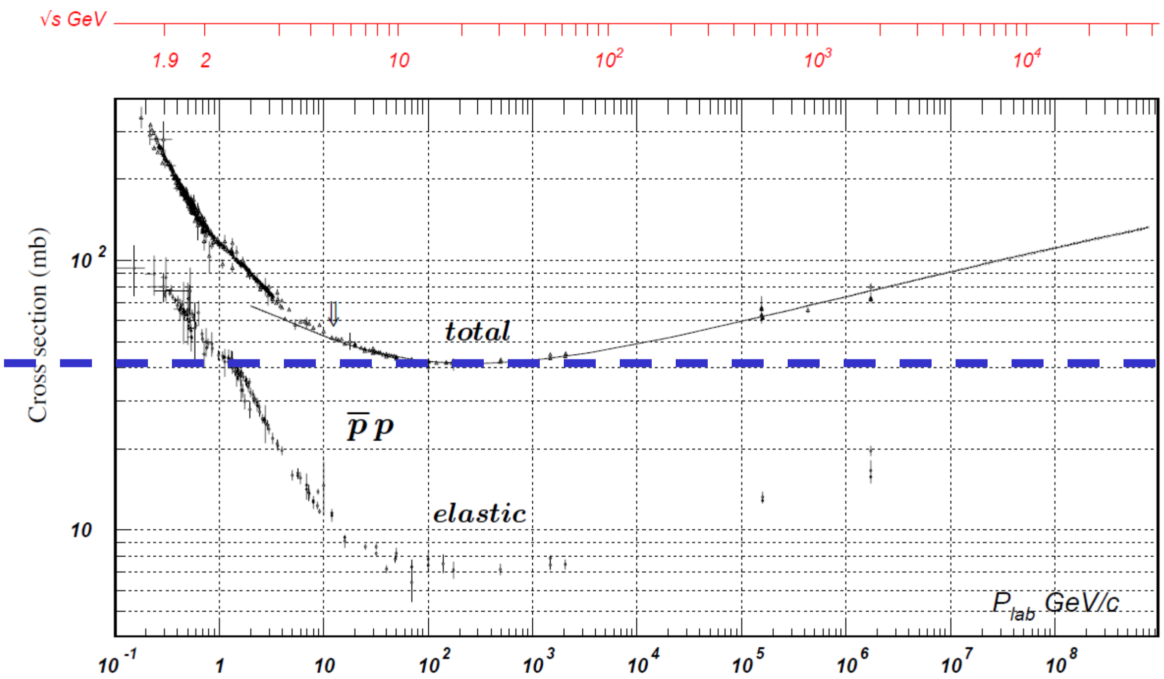
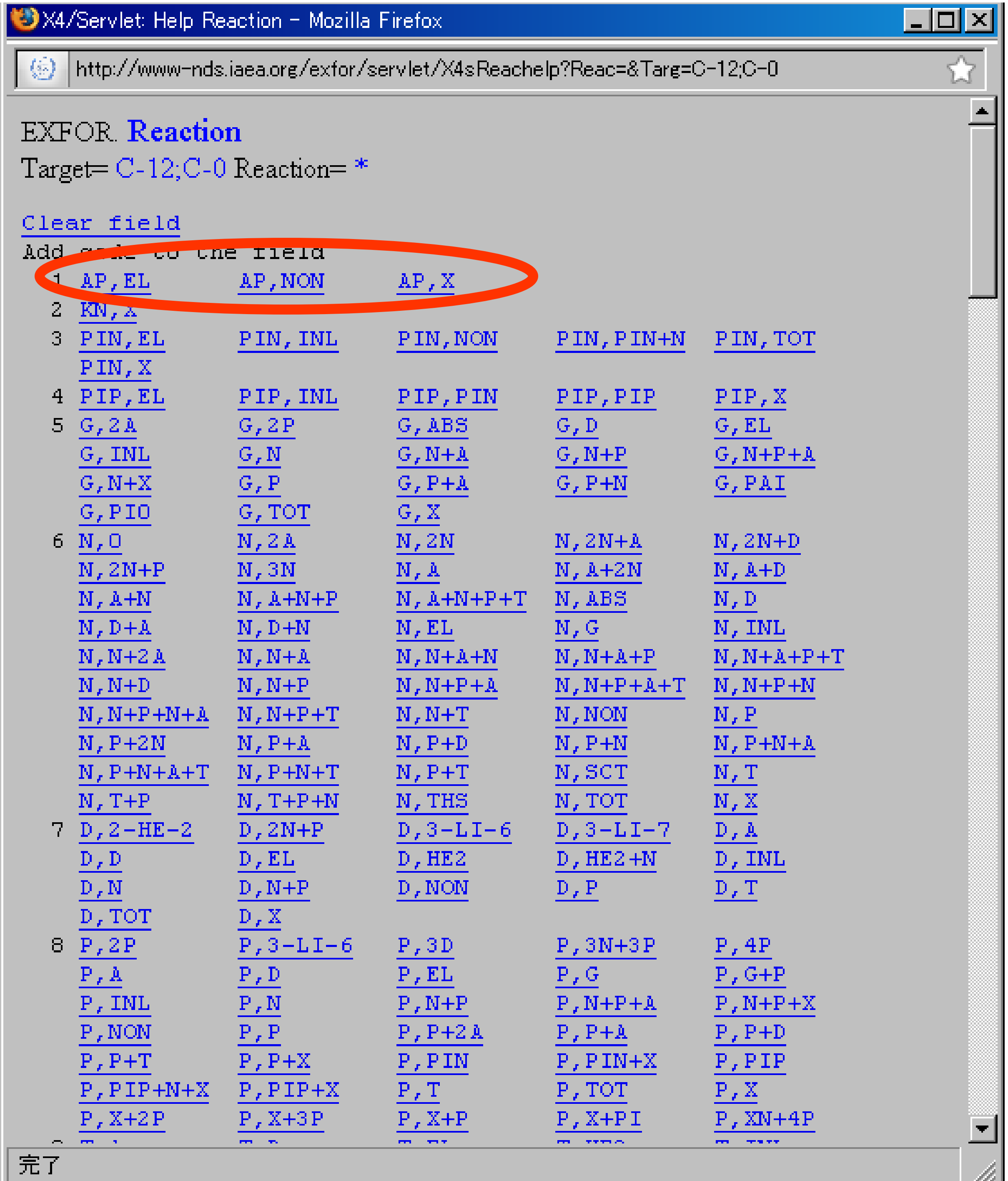


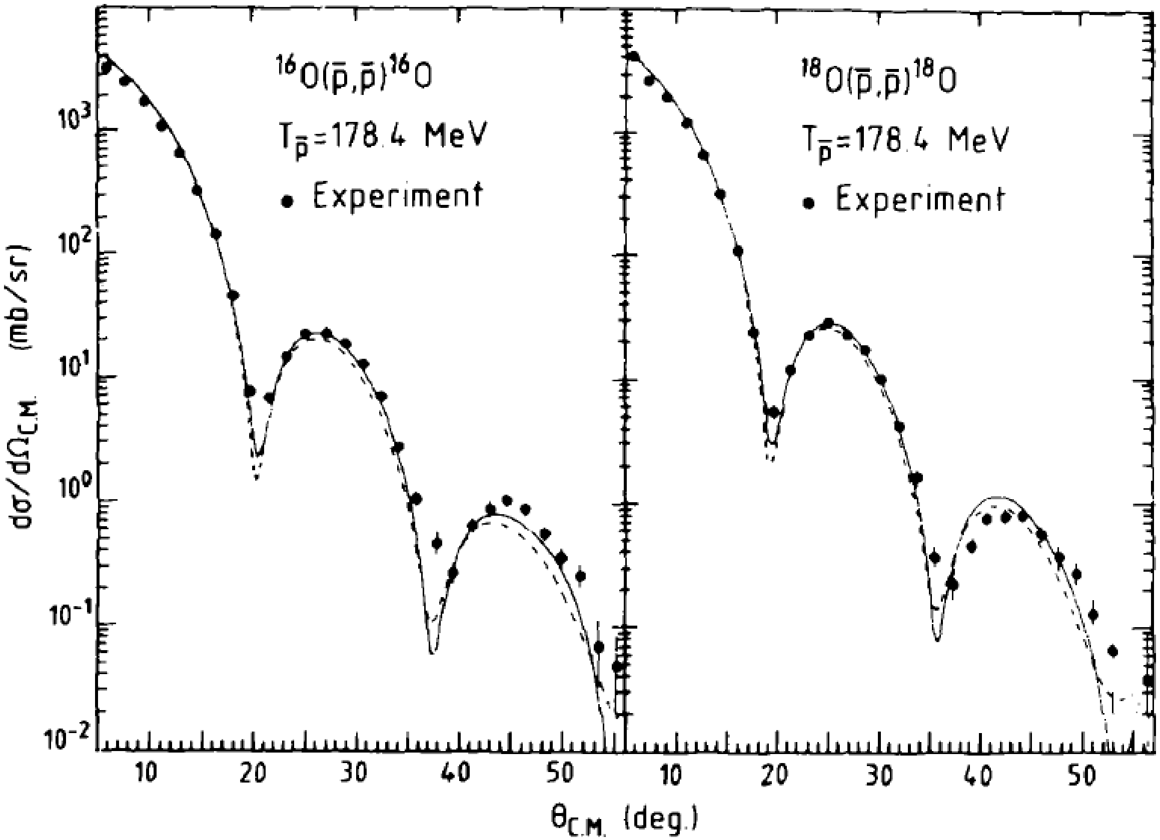
Figure 40.11: Total and elastic cross sections for pp and $\overline{p}p$ collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at `http://pdg.lbl.gov/xsect/contents.html`. (Courtesy of the COMPAS group, IHEP, Protvino, August 2005.)



- These options have never been appeared before!

pbar + *A* elastic scattering

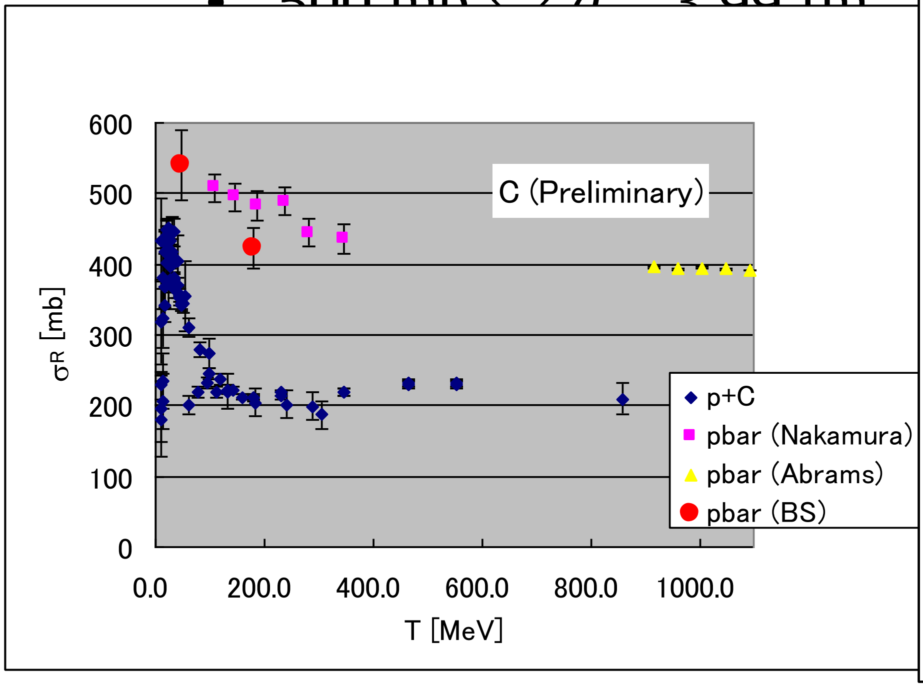
- Only the optical potentials are deduced.

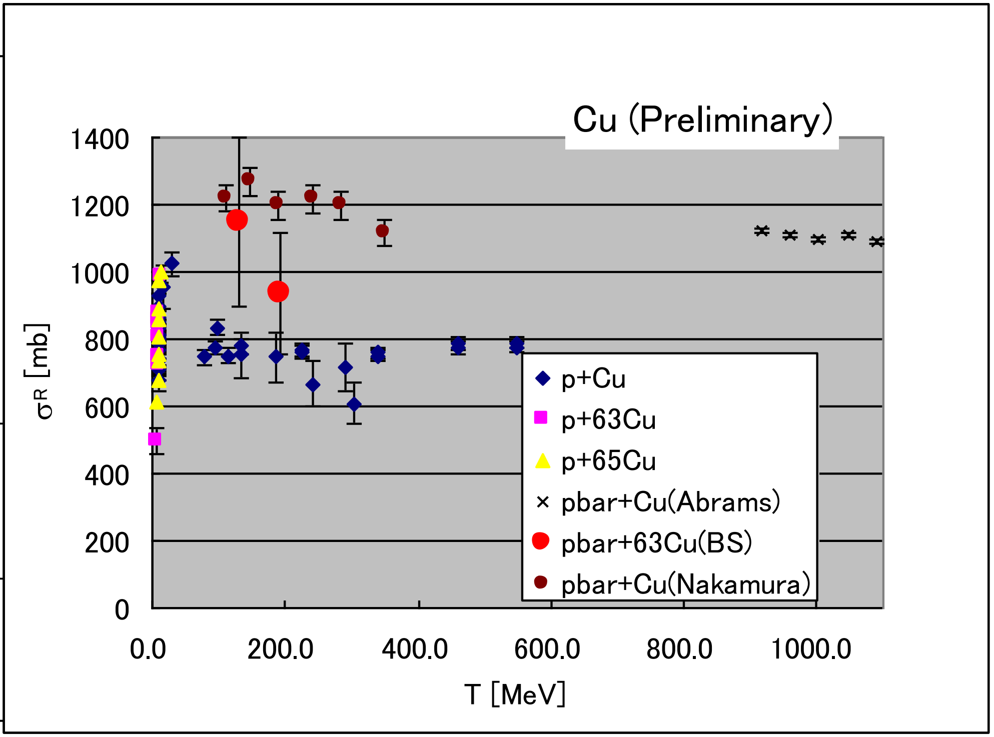


- Ref. G. Bruge et al., Phys. Lett. B169, (1986) 14

σ_R of antiproton + A

- 200 mb ⇔ a = 2.52 fm.
- 500 mb ⇔ a = 3.99 fm.
- 800 mb ⇔ a = 5.05 fm.





Data for σ_{BS}: D. Garreta et al., Phys. Lett. B135, 266 (1984).
V. Ashford et al., Phys. Rev. C 30, 1080 (1984).

Do we know σ_{NN}^{total} precisely?

- One may say "Yes!", but …
- σ_{NN}^{total} is important, because it is a measure for the strength of the NN interaction.
- Practically, we need σ_{NN}^{total} for

$$f(0) = \frac{i + c_0}{4\pi} \sigma_{\mathrm{NN}}^{\mathrm{total}} |\boldsymbol{p}|.$$

  - NN scattering amplitude in the conventional multiple scattering theories, eg., KMT, Glauber.
  - The contemporary black-sphere model needs σ_{NN}^{total} .
    - the formula is now being implemented to PHITS.

The SAID (SP07)

- The on-line Scattering Analysis Interactive Dial-in (SAID) facility.
- The SAID program gives several estimations of observables based on the partial-wave analyses of the latest compilation of nucleon-nucleon scattering data.

PHYSICAL REVIEW C **76**, 025209 (2007)

Updated analysis of *NN* elastic scattering to 3 GeV

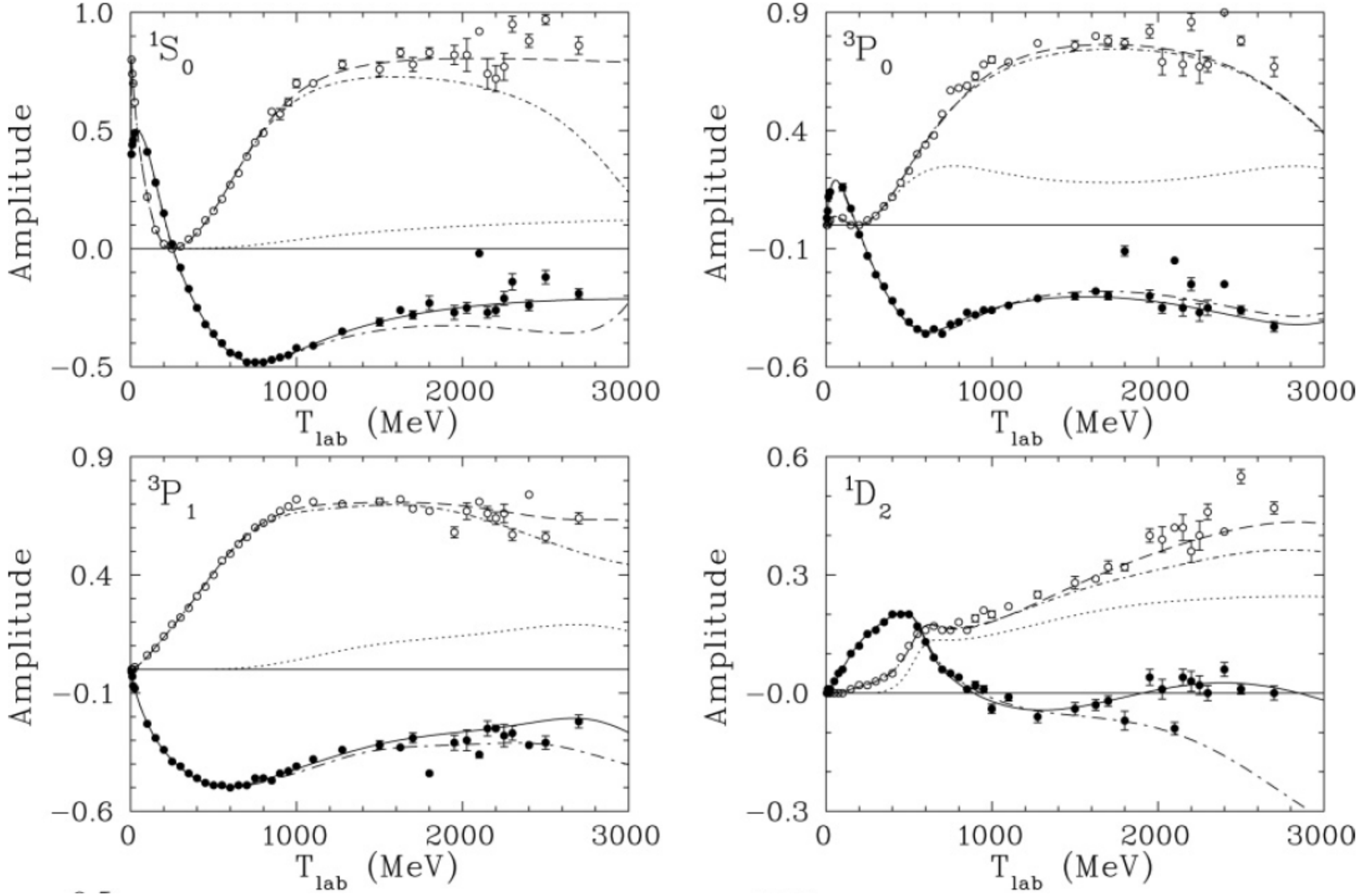
R. A. Arndt, W. J. Briscoe, I. I. Strakovsky, and R. L. Workman
Center for Nuclear Studies, Department of Physics, The George Washington University, Washington, D.C. 20052, USA
(Received 18 June 2007; published 16 August 2007)

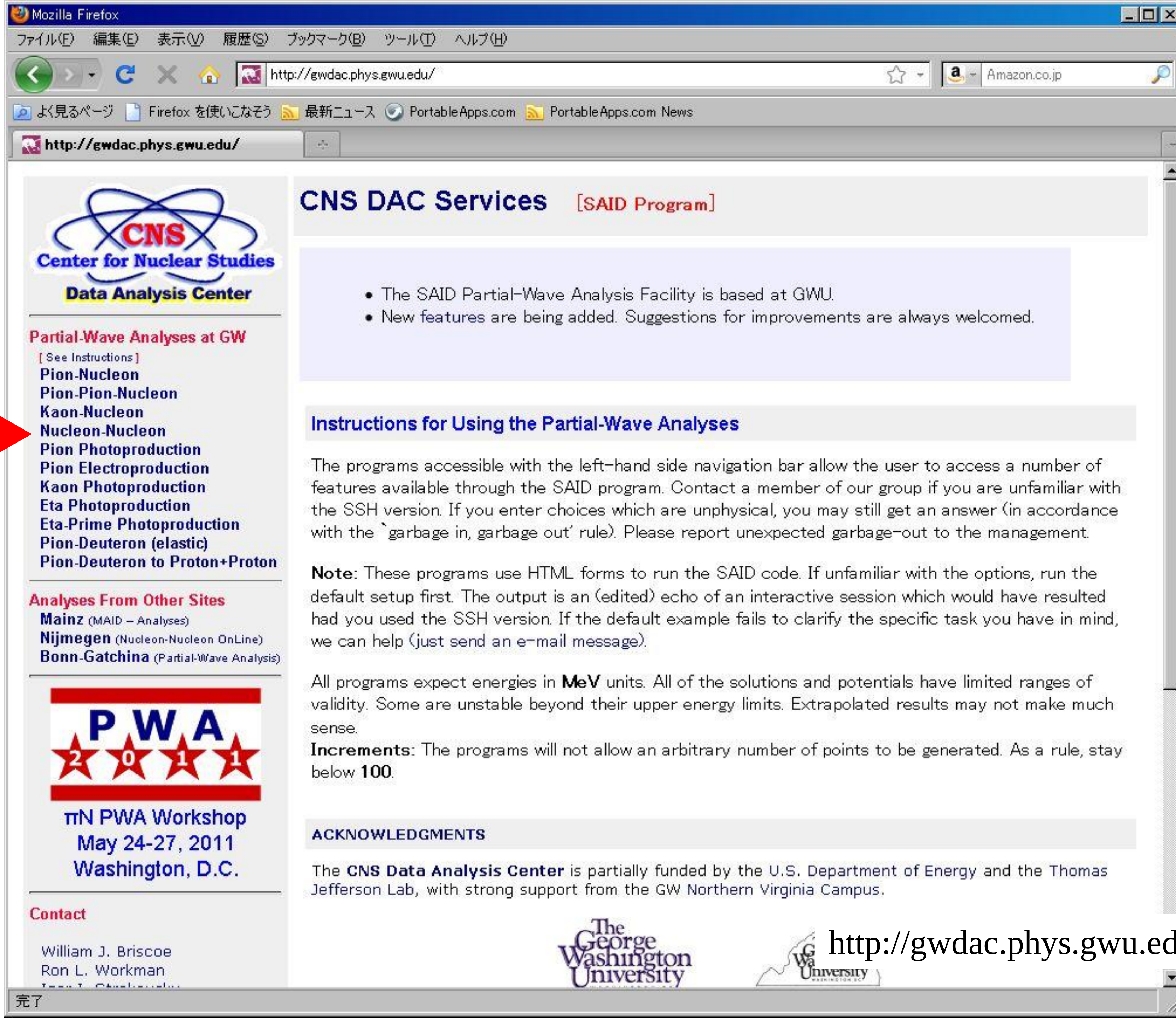
A partial-wave analysis of *NN* elastic scattering data has been updated to include a number of recent measurements. Experiments carried out at the Cooler Synchrotron (COSY) by the EDDA Collaboration have had a significant impact above 1 GeV. Results are discussed in terms of the partial-wave and direct-reconstruction amplitudes.

SAID (SP07)

ARNDT, BRISCOE, STRAKOVSKY, AND WORKMAN

PHYSICAL REVIEW C **76**, 025209 (2007)





Mozilla Firefox

ファイル(F) 編集(E) 表示(V) 履歴(S) ブックマーク(B) ツール(T) ヘルプ(H)

http://gwdac.phys.gwu.edu/

よく見るページ Firefox を使いこなそう 最新ニュース PortableApps.com PortableApps.com News

http://gwdac.phys.gwu.edu/

CNS
Center for Nuclear Studies
Data Analysis Center

Partial-Wave Analyses at GW

[See Instructions]

- Pion-Nucleon
- Pion-Pion-Nucleon
- Kaon-Nucleon
- Nucleon-Nucleon
- Pion Photoproduction
- Pion Electroproduction
- Kaon Photoproduction
- Eta Photoproduction
- Eta-Prime Photoproduction
- Pion-Deuteron (elastic)
- Pion-Deuteron to Proton+Proton

Analyses From Other Sites

- Mainz (MAID – Analyses)
- Nijmegen (Nucleon-Nucleon OnLine)
- Bonn-Gatchina (Partial-Wave Analysis)

PWA 2011

πN PWA Workshop
May 24-27, 2011
Washington, D.C.

Contact

William J. Briscoe
Ron L. Workman

CNS DAC Services [SAID Program]

- The SAID Partial-Wave Analysis Facility is based at GWU.
- New features are being added. Suggestions for improvements are always welcomed.

Instructions for Using the Partial-Wave Analyses

The programs accessible with the left-hand side navigation bar allow the user to access a number of features available through the SAID program. Contact a member of our group if you are unfamiliar with the SSH version. If you enter choices which are unphysical, you may still get an answer (in accordance with the `garbage in, garbage out' rule). Please report unexpected garbage-out to the management.

Note: These programs use HTML forms to run the SAID code. If unfamiliar with the options, run the default setup first. The output is an (edited) echo of an interactive session which would have resulted had you used the SSH version. If the default example fails to clarify the specific task you have in mind, we can help (just send an e-mail message).

All programs expect energies in **MeV** units. All of the solutions and potentials have limited ranges of validity. Some are unstable beyond their upper energy limits. Extrapolated results may not make much sense.
Increments: The programs will not allow an arbitrary number of points to be generated. As a rule, stay below **100**.

ACKNOWLEDGMENTS

The **CNS Data Analysis Center** is partially funded by the U.S. Department of Energy and the Thomas Jefferson Lab, with strong support from the GW Northern Virginia Campus.

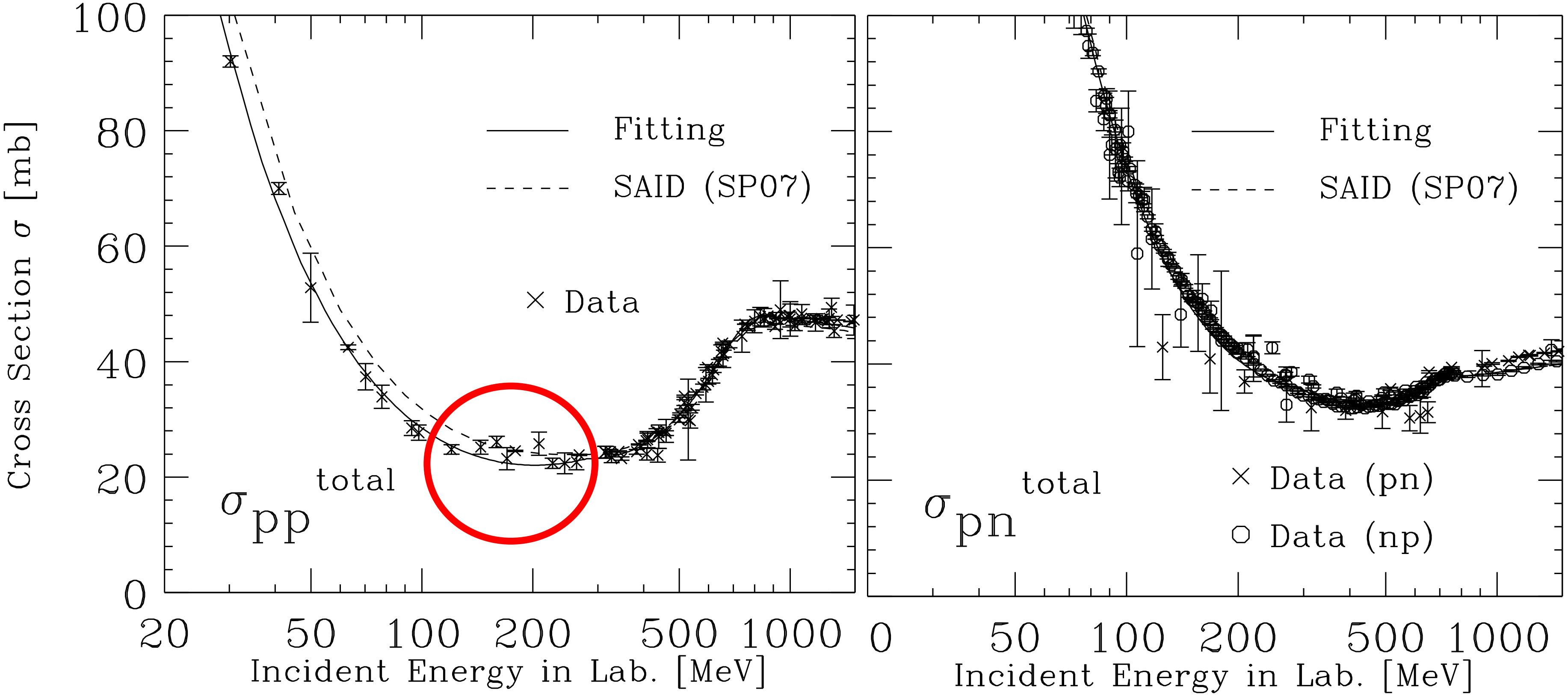
The George Washington University

完了

http://gwdac.phys.gwu.edu/

Which curve is more appropriate? Fitting *vs.* SAID

About 10 % deviation between the two!



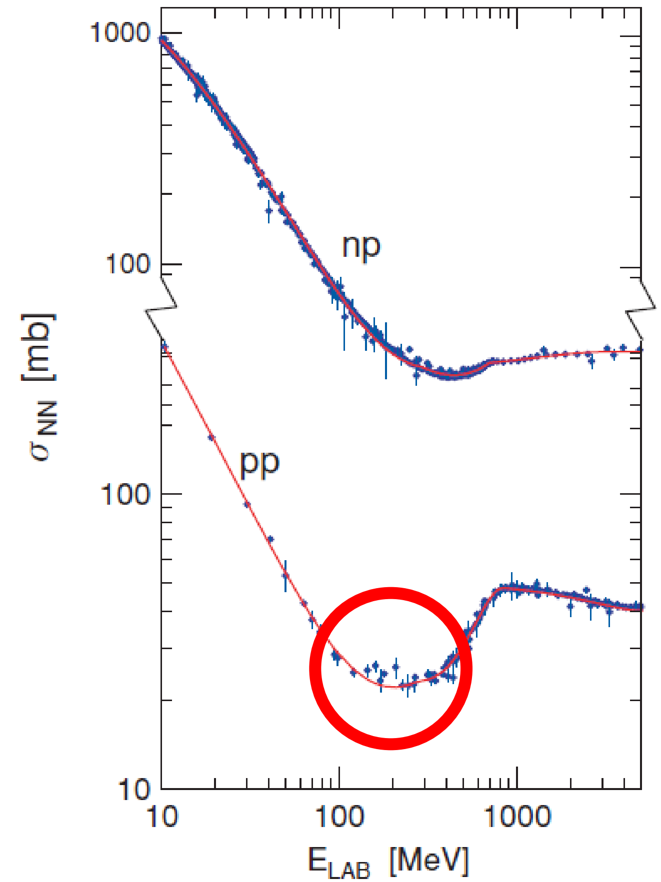
Fitting: C. A. Bertulani and C. De Conti, Phys. Rev. C 81, 064603 (2010).

PHYSICAL REVIEW C **81**, 064603 (2010)

Pauli blocking and medium effects in nucleon knockout reactions

C. A. Bertulani[1,*] and C. De Conti[2,†]
[1] *Physics Department, Texas A&M University-Commerce, Commerce, Texas 75428-3011, USA*
[2] *Campus Experimental de Itapeva, Universidade Estadual Paulista, 18409-010 Itapeva, SP, Brazi*
(Received 12 April 2010; published 3 June 2010)

Least-squares fit to the data



- “We study medium modifications of the nucleon-nucleon (*NN*) cross sections and their influence on the nucleon knockout reactions. …”

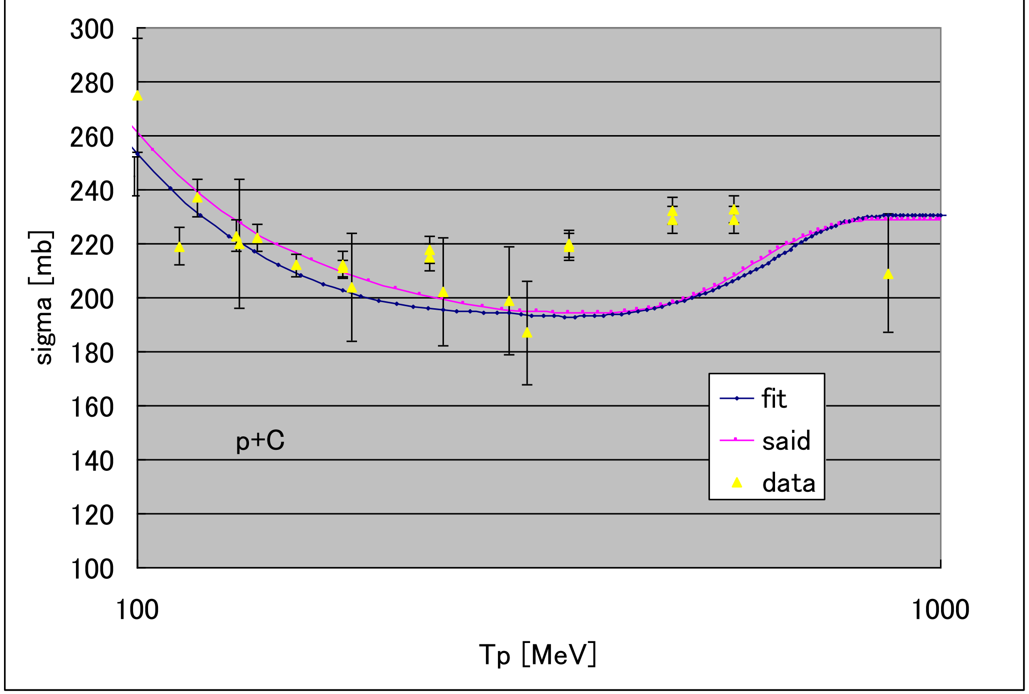
$$\sigma_{pp} = \begin{cases} 19.6 + 4253/E - 375/\sqrt{E} + 3.86 \times 10^{-2} E \\ (\text{for } E < 280 \text{ MeV}), \\ \\ 32.7 - 5.52 \times 10^{-2} E + 3.53 \times 10^{-7} E^3 \\ \qquad - 2.97 \times 10^{-10} E^4 \\ (\text{for } 280 \text{ MeV} \leqslant E < 840 \text{ MeV}), \\ \\ 50.9 - 3.8 \times 10^{-3} E + 2.78 \times 10^{-7} E^2 \\ \qquad + 1.92 \times 10^{-15} E^4 \\ (\text{for } 840 \text{ MeV} \leqslant E \leqslant 5 \text{ GeV}) \end{cases}$$

$$\sigma_{np} = \begin{cases} 89.4 - 2025/\sqrt{E} + 19108/E - 43535/E^2 \\ (\text{for } E < 300 \text{ MeV}), \\ \\ 14.2 + 5436/E + 3.72 \times 10^{-5} E^2 - 7.55 \times 10^{-9} E^3 \\ (\text{for } 300 \text{ MeV} \leqslant E < 700 \text{ MeV}), \\ \\ 33.9 + 6.1 \times 10^{-3} E - 1.55 \times 10^{-6} E^2 \\ \qquad + 1.3 \times 10^{-10} E^3 \\ (\text{for } 700 \text{ MeV} \leqslant E \leqslant 5 \text{ GeV}) \end{cases}$$

It is hard to distinguish…: p+C

- Two curves
- We use
  - the same a_0
  - Two parameterizations
    - SAID (SP07)
    - Fitting by Bertulani

$\sigma_R(p\text{+C})$ a_0 = 2.70 fm



Data:

R. F. Carlson, *At. Data Nucl. Data Tables*, **63**, 93 (1996).

A. Auce *et al*., *Phys. Rev.* **C 71**, 064606 (2005).

E > 100 MeV/nucl. Coulomb int. can be neglected.

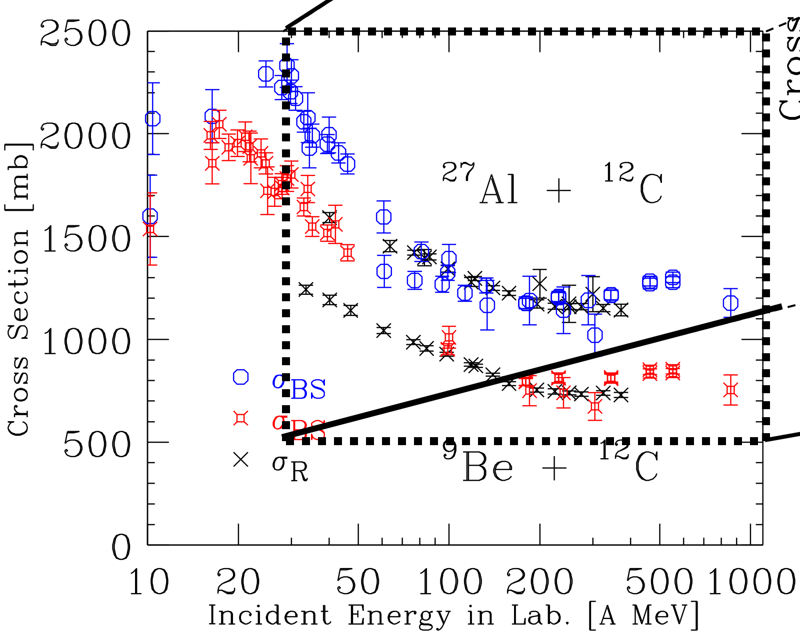
σ_{BS} for *A*+*A* Reactions

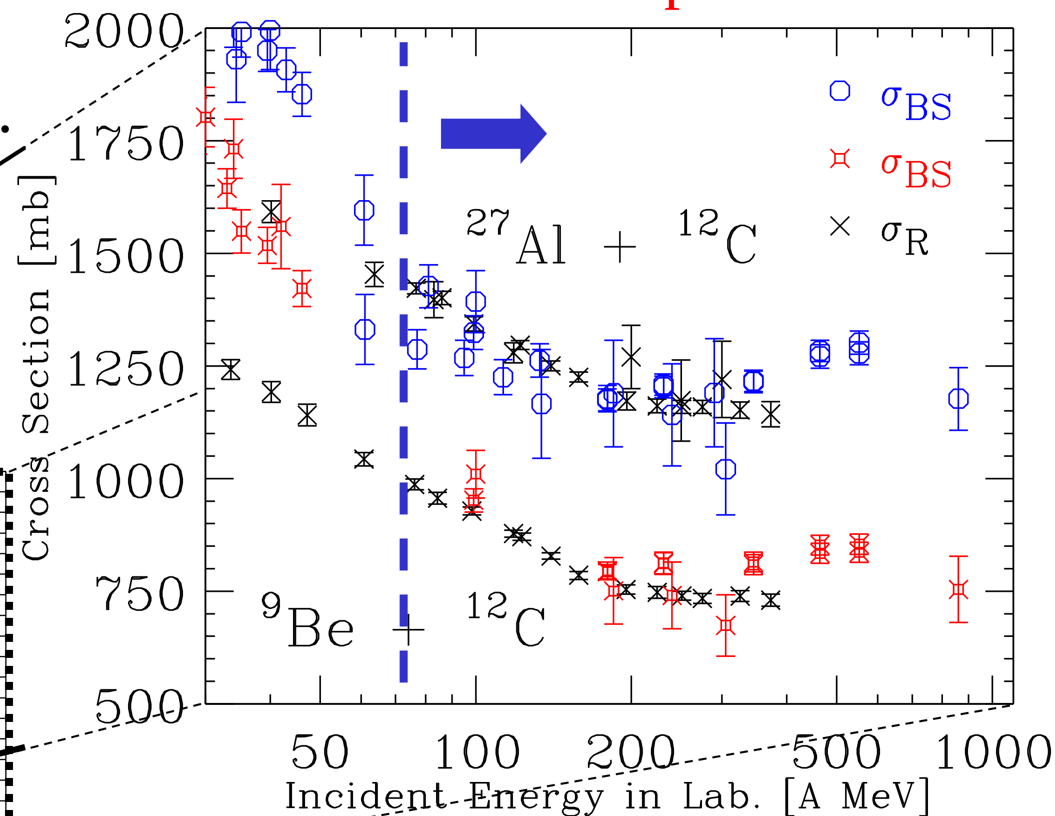
No parameter!

$\boxed{\sigma_{BS} = \pi\,(a_T + a_P)^2.}\ \cong \sigma_R\ .$

See Phys. Rev. C 78, 061601 (2008).

- ^{9}Be + C & ^{27}Al + C



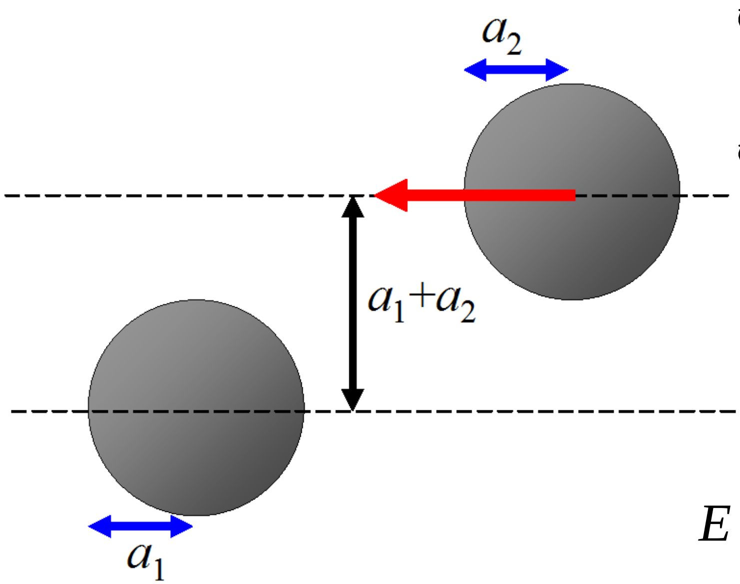


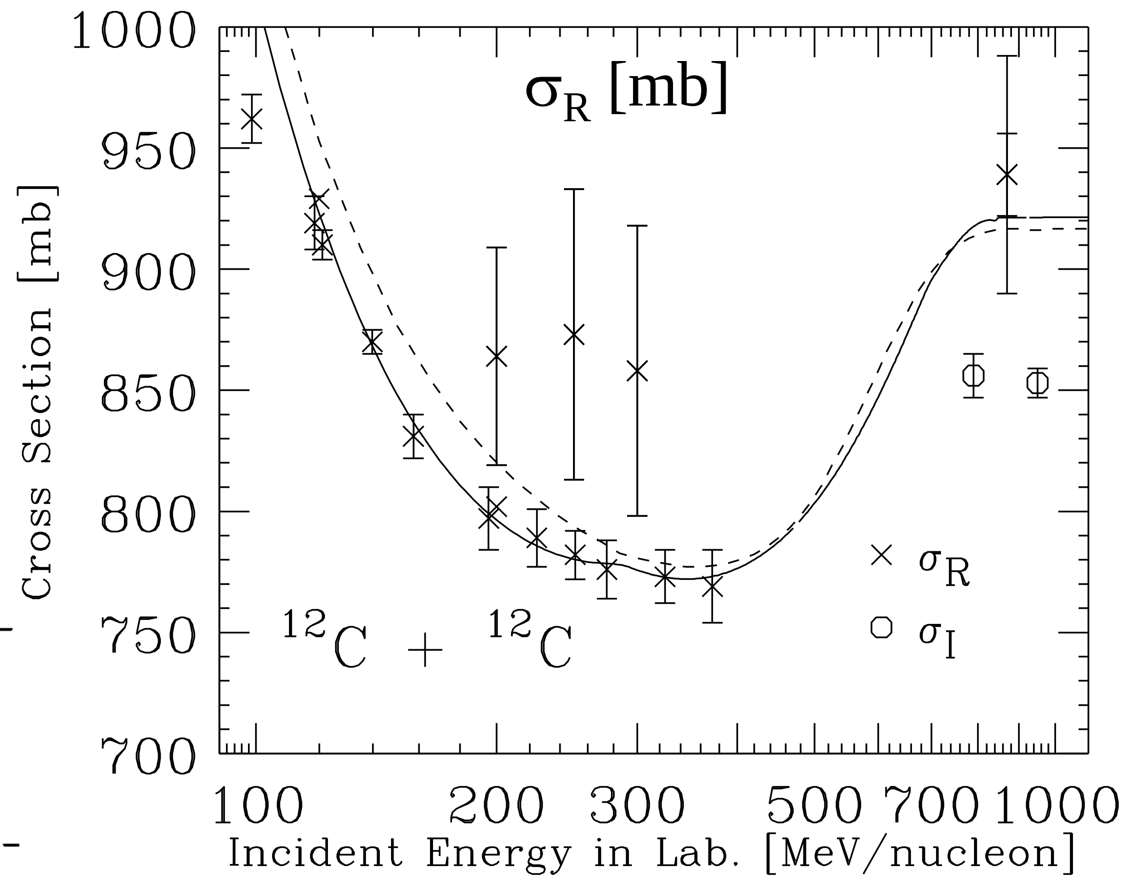
σ_{BS} is determined by two σ_R's of proton-nucleus reactions. Data of σ_R: S. Kox *et al*. (PRC35), M. Takechi *et al*. (PRC79).

Application to A+A reactions works

- Using BS cross section formula:

$$\sigma_R \cong \sigma_{BS} = \pi(a_1 + a_2)^2.$$





E > 100 MeV/nucl.   Coulomb int. can be neglected.

K. Iida, AK, K. Oyamatsu, *J. Phys. Soc. Japan* **76**, 044201 (2007).

Water diffraction

出典: フリー百科事典『ウィキペディア（Wikipedia）』

http://ja.wikipedia.org/wiki/%E6%B0%B4%E9%9D%A2%E6%B3%A2