



The image is a vibrant collage of scientific and technical terms. In the foreground, the words "Burnup", "Spacetime", "PCA", "Material Science", "The Elements", and "Inventory" are arranged in a cluster. Above them, "Depletion" and "Source terms" are prominently displayed. Interspersed among these words are various chemical symbols such as "Hg", "Pt", "Kr", "Uub", and "Uut". The background features a large, semi-transparent periodic table of elements. Overlaid on the table are several large, semi-transparent spheres of different colors (green, blue, red, orange) and a molecular model composed of spheres connected by lines, representing atoms and bonds. The overall composition is dynamic and visually rich, suggesting a complex scientific or technological field.

FISPACT-II

Self shielding of resonant channels

Thin and thick target yields - High fidelity resonance
Applications: beam, accelerator, isotope production

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- thin and thick target yields
- accounts approximately for target geometry
- applicable to thick targets
- handles foils, wires, spheres and finite cylinders
- uses one physical length scale to represent the target: the “effective length” y

Type ID	Geometry	Dimension(s)	Y
1	foil	thickness (t)	$y=1.5t$
2	wire	radius (r)	$y=2r$
3	sphere	radius (r)	$y=r$
4	cylinder	radius (r), height (h)	$y=1.65rh(r+h)$



- theory of radioisotope production
- production rates and cross-sections
- saturation factors and practical yields
- model uses resonance parameters from the Resolved Resonance Range
- model includes the effects of neutron loss through radiative capture
- model includes effects of neutron energy diffusion through elastic scattering

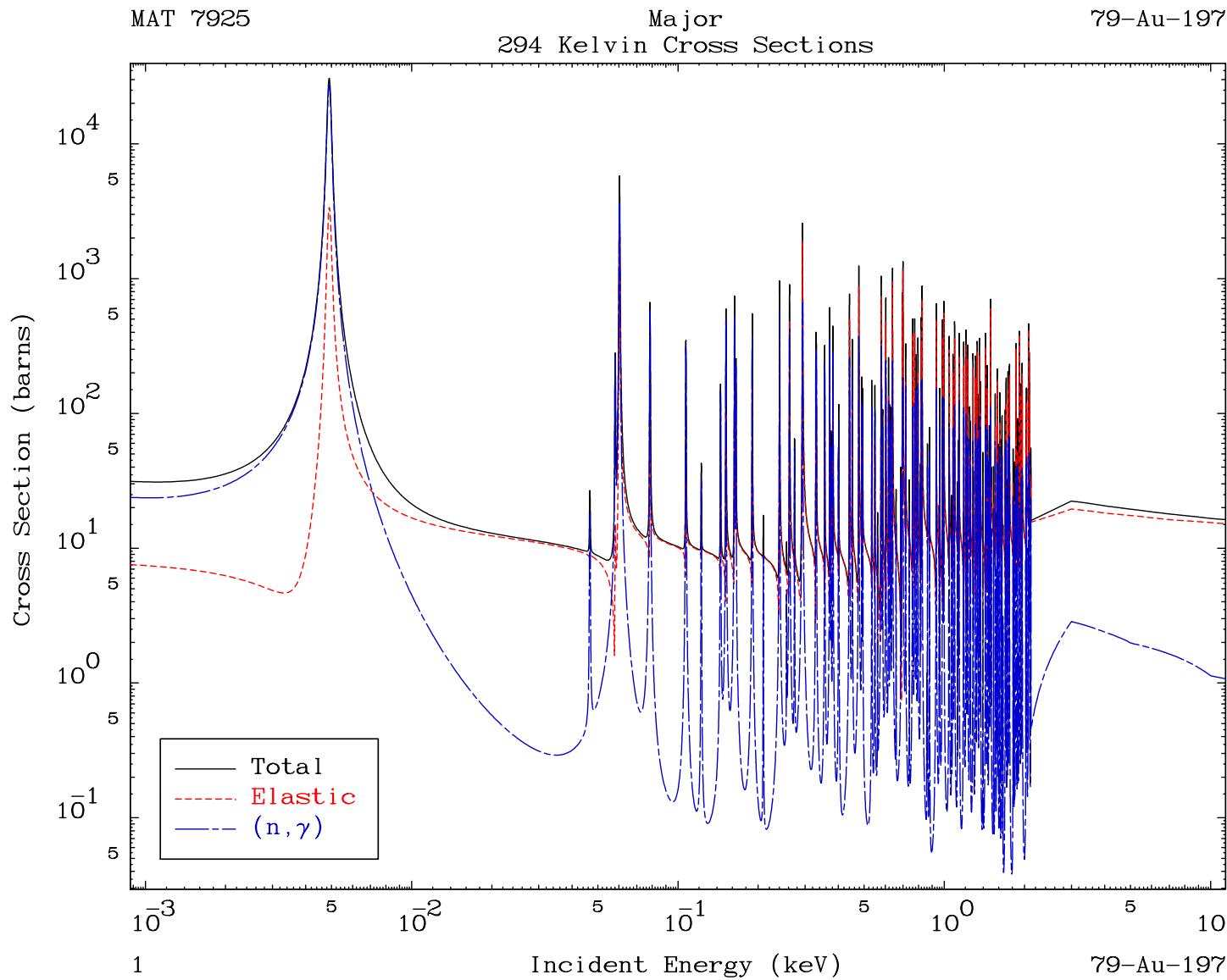


- one resonance in a pure target
- dimensionless parameter to combine the physical effective length with the nuclear parameters

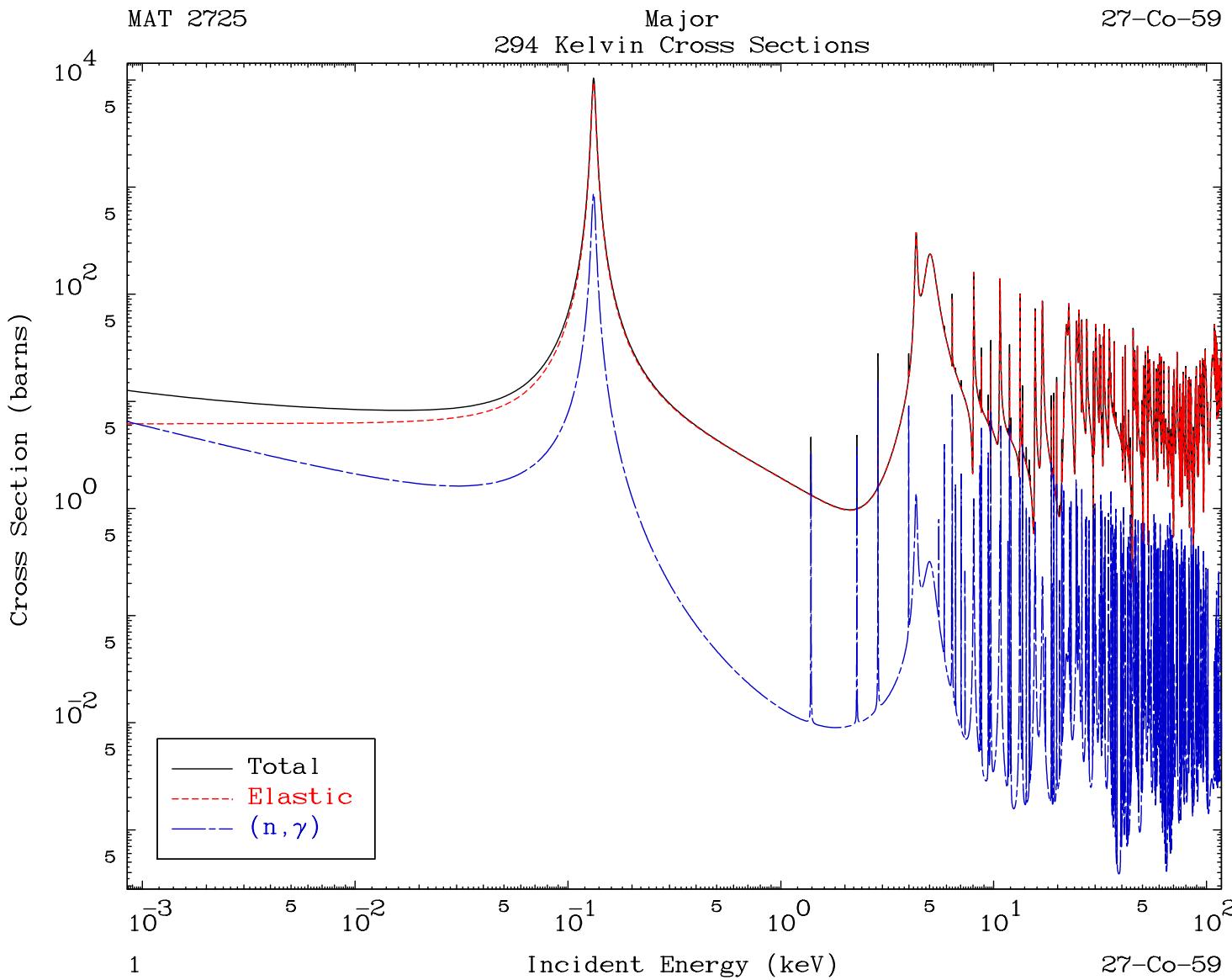
$$z = \sum_{tot} (E_{res}) y \sqrt{\frac{\Gamma_\gamma}{\Gamma}}$$

- where
 - $\sum_{tot}(E_{res})$ is the macroscopic cross-section at the energy E_{res} of the resonance peak
 - Γ_γ is the radiative capture width
 - Γ is the total resonance width
 - y “effective length”
- Self-shielding factor G_{res} is defined in terms of z only

Giant isolated resonance

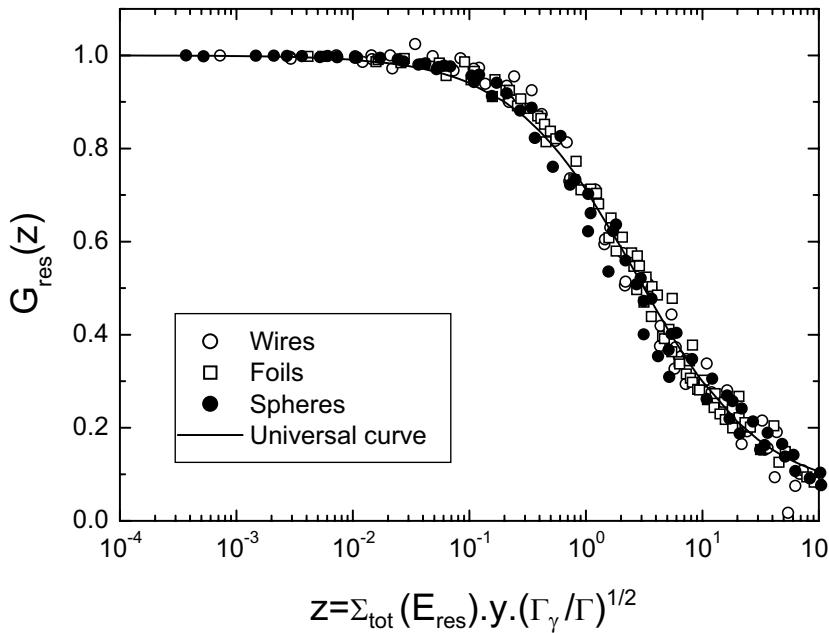


Giant isolated resonance



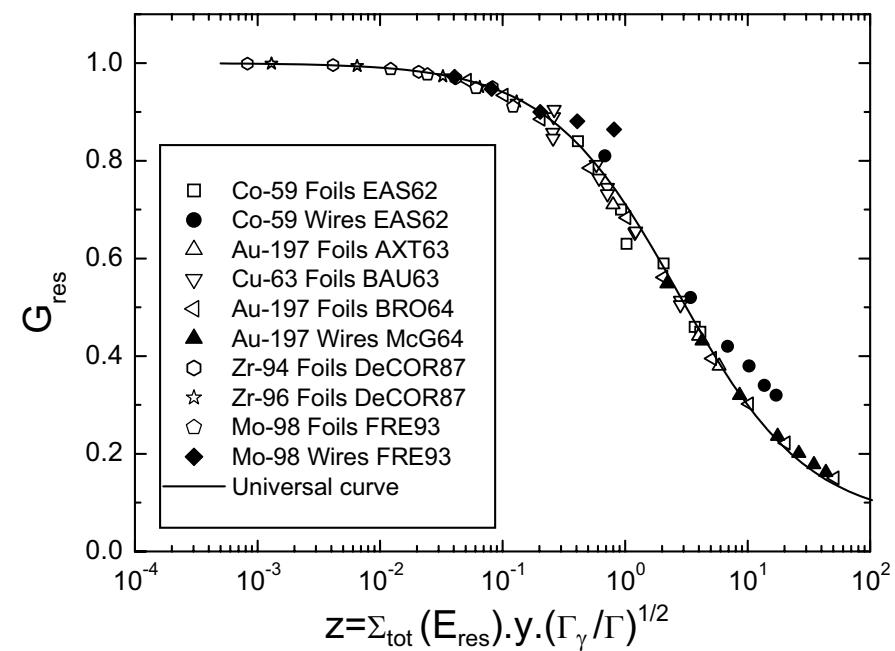
Model development, first step (1)

Baumann, 1963; Yamamoto and Yamamoto, 1965; Lopes, 1991



Target geometry

Experimental self shielding factor





$$G_{res}(z) = \frac{A_1 - A_2}{1 + \left(\frac{z}{z_0}\right)^p} + A_2$$

- this is the “universal sigmoid curve” for the model
- the parameters have been determined empirically to be a good fit to experimental data
- preferred values are:
 - $A_1 = 1.000 \pm 0.005$
 - $A_2 = 0.060 \pm 0.011$
 - $Z_0 = 2.70 \pm 0.09$
 - $p = 0.82 \pm 0.02$



- extend model to a group of separated resonances
- still considering a pure target: one nuclide
- assign a weight to each resonance

$$w_i = \left(\frac{\Gamma_\gamma}{E_{res}^2} \cdot \frac{g\Gamma_n}{\Gamma} \right)_i$$

where

- Γ_n is the neutron scattering width
- g is the statistical factor, $(2J + 1)/(2(2I + 1))$
- J is the spin of the resonance state
- I is the spin of the target nucleus
- form an average self-shielding factor from all resonances of interest

$$\langle G_{res} \rangle = \frac{\sum w_i G_{res}(z_i)}{\sum w_i}$$

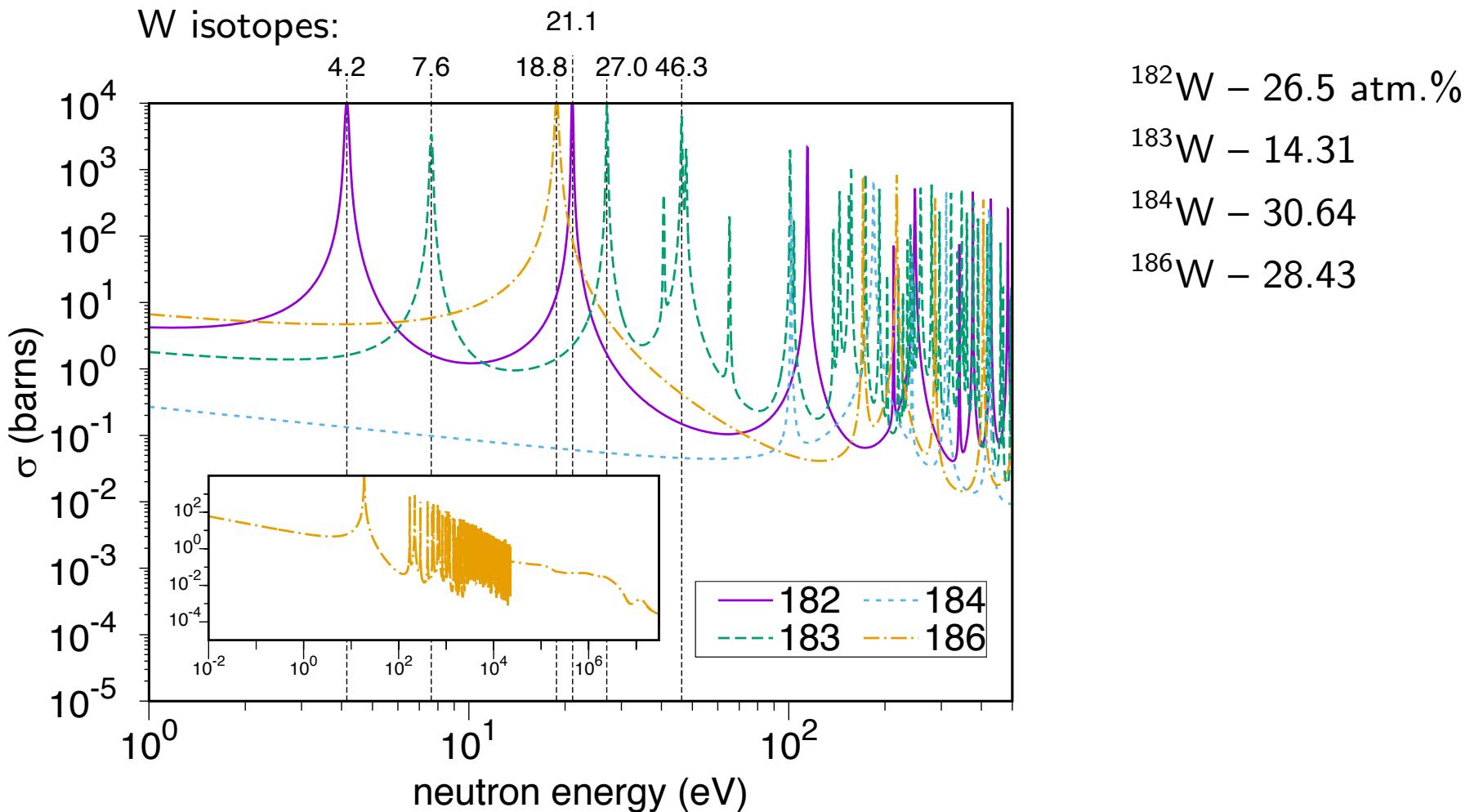


- extend $\langle G_{\text{res}} \rangle$ to form the average for resonances of a mixture of nuclides
- assume the resonances of different nuclides do not overlap significantly
- make $\langle G_{\text{res}} \rangle$ energy dependent by taking averages separately for each energy bin used for the group-wise cross-sections
- use Fröhner's simple expression for the peak cross-section of each resonance (not available from the GENDF data however, in FISPACT-II gxs application forms)



- universal curve model provides an alternative to probability table self shielding
- use $\langle G_{\text{res}} \rangle(E)$ to scale down energy-dependent cross-sections before cross-section collapse
- $\langle G_{\text{res}} \rangle(E)$ reduces the neutron flux, so apply it to all cross-sections
- target geometry specified with
SSFGEOMETRY type length₁ <length₂ >
- use resonances from mixture specified with **SSFFUEL** or **SSFMASS**
- PRINTLIB 6 now generates a table of all cross-sections with $\langle G_{\text{res}} \rangle$ reduction factors

Giant multiple resonances





Application of the model in FISPACT-II

- The self shielding factors are calculated from the resonances of the materials specified with the SSFFUEL or SSFMASS keywords

Nuclide Atoms percent

W 182	26.534
W 183	14.319
W 184	30.680
W 186	28.467

parent nuclide	daughter nuclide	mt	old sigma barns	new sigma barns	self shielding factor (%)
W 181	W 182	102	1.28654E-01	1.00821E-01	78.37
W 182	W 183m	102	4.88539E-04	4.37982E-04	89.65
W 183m	W 184	102	1.22719E-01	9.19139E-02	74.90
W 185	W 186	102	4.02148E-02	2.72004E-02	67.64
W 186	W 187	102	5.91903E-02	2.45217E-02	41.43
W 182	W 183	102	6.68732E-02	2.79708E-02	41.83
W 183	W 184	102	5.68988E-02	2.03099E-02	35.69
W 184	W 185	102	9.99565E-03	6.32533E-03	63.28
W 185m	W 186	102	6.51538E-02	4.98838E-02	76.56
W 187	W 188	102	5.15139E-01	4.63582E-01	89.99