Excitation Cross Sections in Xenon

Terry Buck

Introduction:

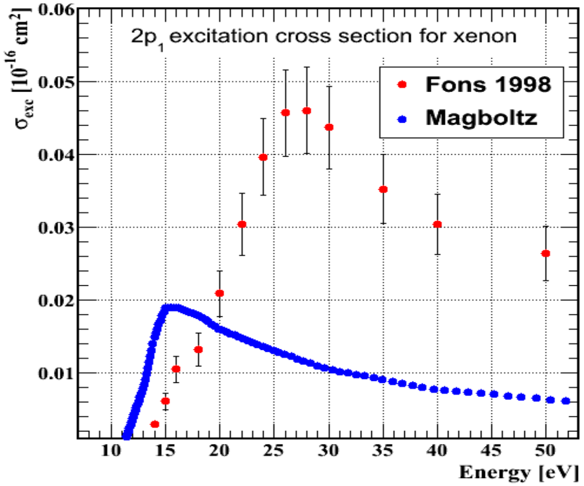
- Problem faced when using MAGBOLTZ to find transfer rates in xenon
- Recent measurements of Xenon cross sections
- Comparison between recent measurements and MAGBOLTZ data
- Background information on the shape of excitation cross sections (mechanisms, types of transitions..)
- Comparing to theory

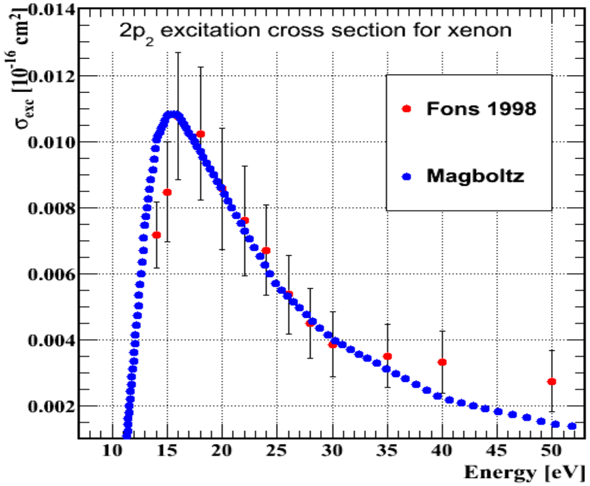
The Problem: Unreasonable transfer rates obtained

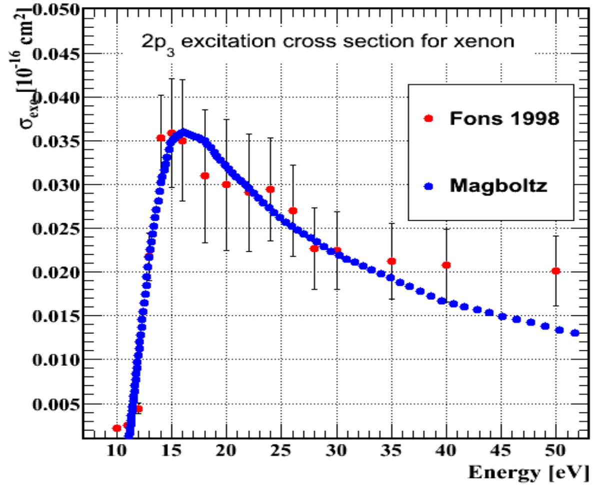
Gas mixtures in which an attempt was made to find transfer rates :

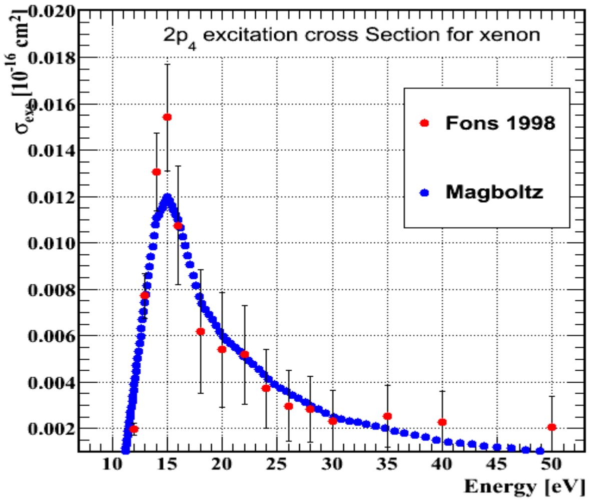
1-Xe–CH_4
2-Xe–CO_2
3-Xe–Ar
4-Xe–Ar–CH_4
5-Xe–C_2H_2
6-Xe–iC_4H_{10}
7-Xe–iC_2H_4

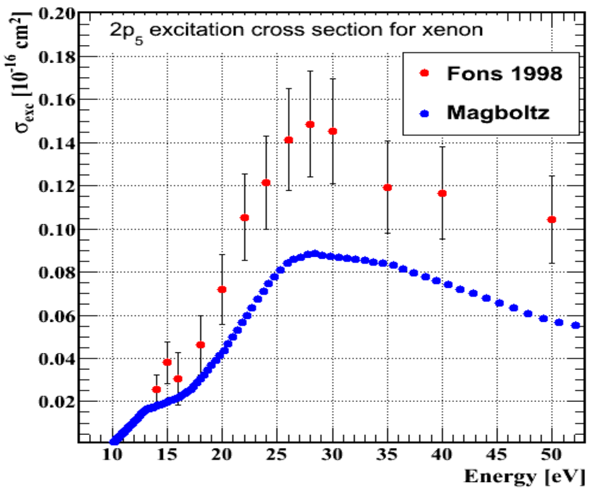
Difference in Shape between Magboltz and Experimental Data:

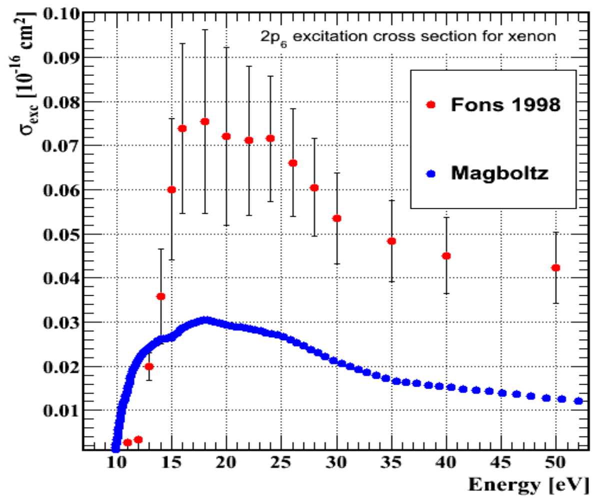












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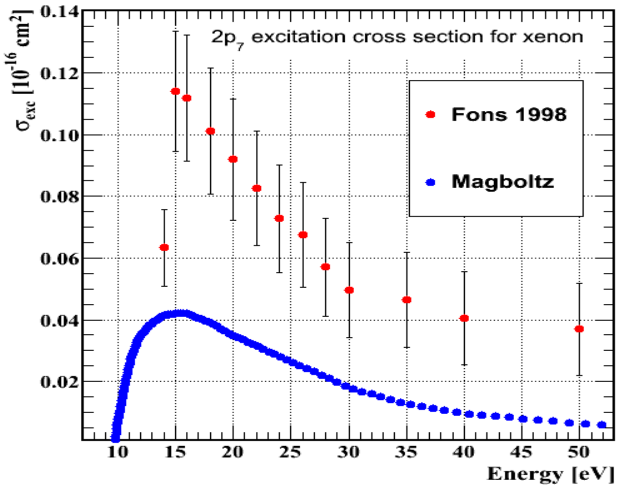
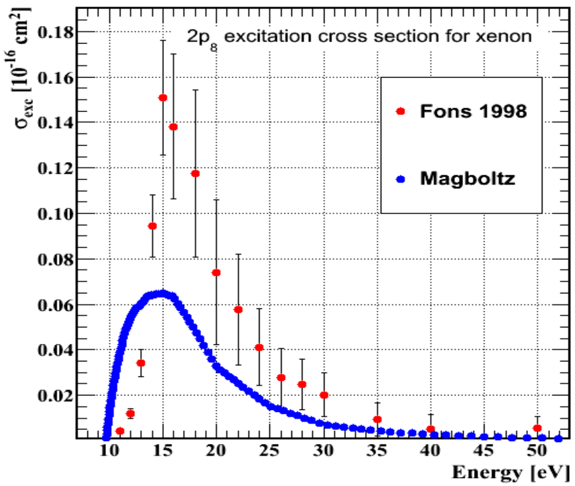
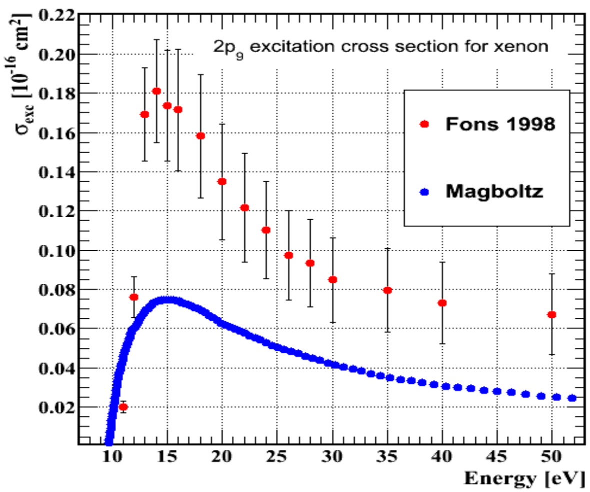
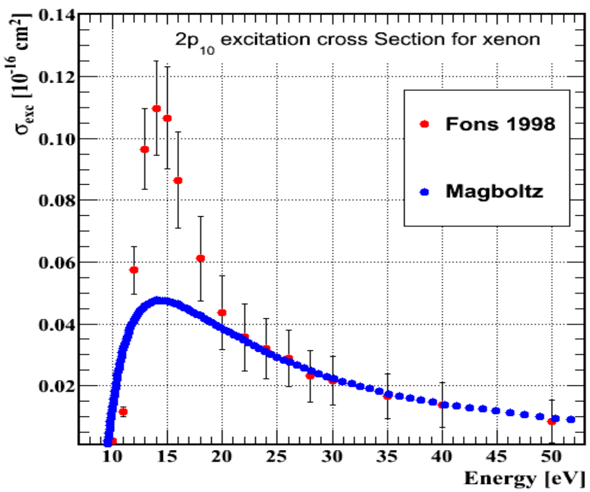

2p7 excitation cross section for xenon
Fons 1998
Magboltz
σexc [10-16 cm2]
Energy [eV]


2p8 excitation cross section for xenon
Fons 1998
Magboltz
σexc [10-16 cm2]
Energy [eV]


2p9 excitation cross section for xenon
Fons 1998
Magboltz
σexc [10-16 cm2]
Energy [eV]


2p10 excitation cross Section for xenon
Fons 1998
Magboltz
σexc [10-16 cm2]
Energy [eV]

Two Mechanisms:

- Electromagnetic Interaction
- Electron exchange
  - Low probability at high energy

Three Types of Transitions:

- Dipole Allowed
- Spin Allowed Dipole Forbidden
- Spin Forbidden

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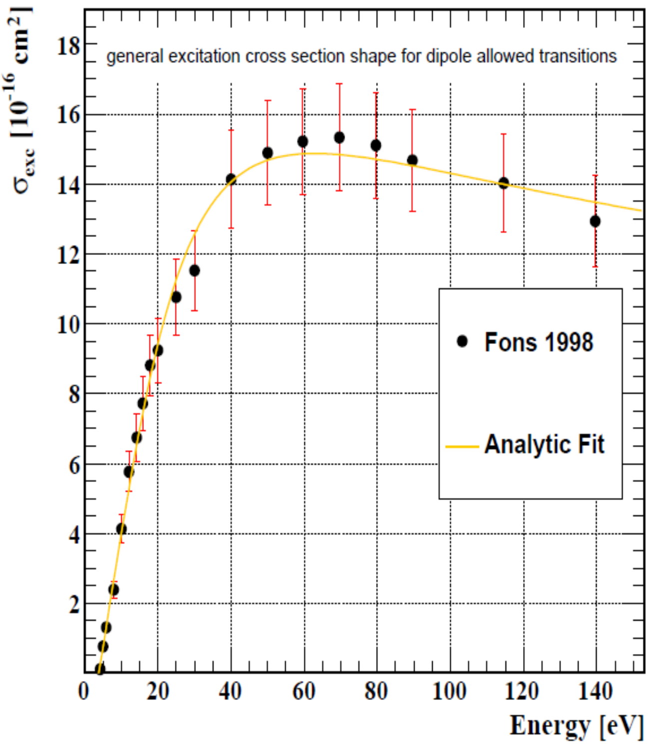
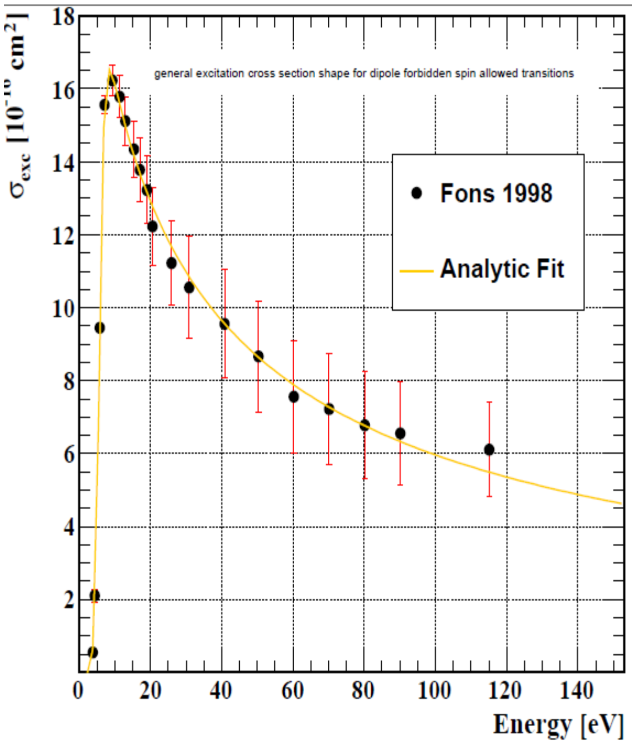
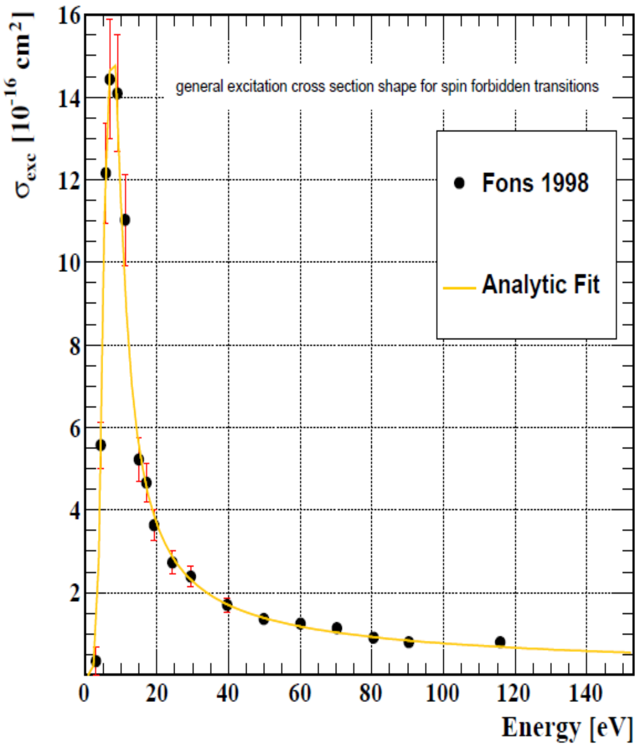


Dipole Allowed



Spin Allowed



Spin Forbidden

Mixed L-S coupled states for the 2p levels of xenon:

	1S0	3S1	1P1	3P0	3P1	3P2	1D2	3D1	3D2	3D3
2p1	0.4	-	-	0.6	-	-	-	-	-	-
2p2	-	.22	.15	-	.57	-	-	.06	-	-
2p3	-	-	-	-	-	.19	.34	-	.47	-
2p4	-	.02	.24	-	-	-	-	.74	-	-
2p5	0.6	-	-	0.4	-	-	-	-	-	-
2p6	-	-	-	-	-	.75	.23	-	.02	-
2p7	-	.02	.95	-	.20	-	-	.19	-	-
2p8	-	-	-	-	-	-	-	-	-	1.00
2p9	-	-	-	-	-	.06	.43	-	.51	-
2p10	-	.74	.03	-	.23	-	-	-	-	-

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Optical Cross Section:

$$Q_{ij}^{opt} = \frac{4\pi ekT}{hc}\frac{H\lambda_{ij}F(\lambda_{ij})}{\Omega S_{ij}^{lamp}}\frac{S_{ij}^{exc}}{IP}$$

Shape function:

$$q_i(E) = \frac{Q_{ij}^{opt}(E)}{Q_{ij}^{opt}(E_{ref} = 50\text{eV})}$$

Shape function approximation:

$$q(E) = q^C(E) + q^D(E)$$

$$q^C(E) = \frac{C1(\frac{E-E_{TH}}{E_R})^{C2}}{1+(\frac{E-E_{TH}}{C3})^{C2+C4}}$$

$$q^D(E) = \frac{D1(\frac{E-E_{TH}}{E_R})^{D2}}{1+(\frac{E-E_{TH}}{D3})^{D2+D4}}$$

- Q_{ij}^{opt} is the optical emission cross section
- λ_{ij} is the wavelength of the transition
- S_{ij}^{exc} is the observed electron-excitation signal recorded by a PMT, integrated over the width of the band pass of a monochromator
- S_{ij}^{lamp} is the signal from a standard lamp which has spectral irradiance F(ij
- H is the height of an auxiliary slit used in the lamp calibration portion of the e Ω eriment
- is the solid angle of the collision region collected by the optical System
- I is the electron beam current
- P is the target gas pressure
- T is the gas temperature,

and e, k, h, and c are the standard atomic constants

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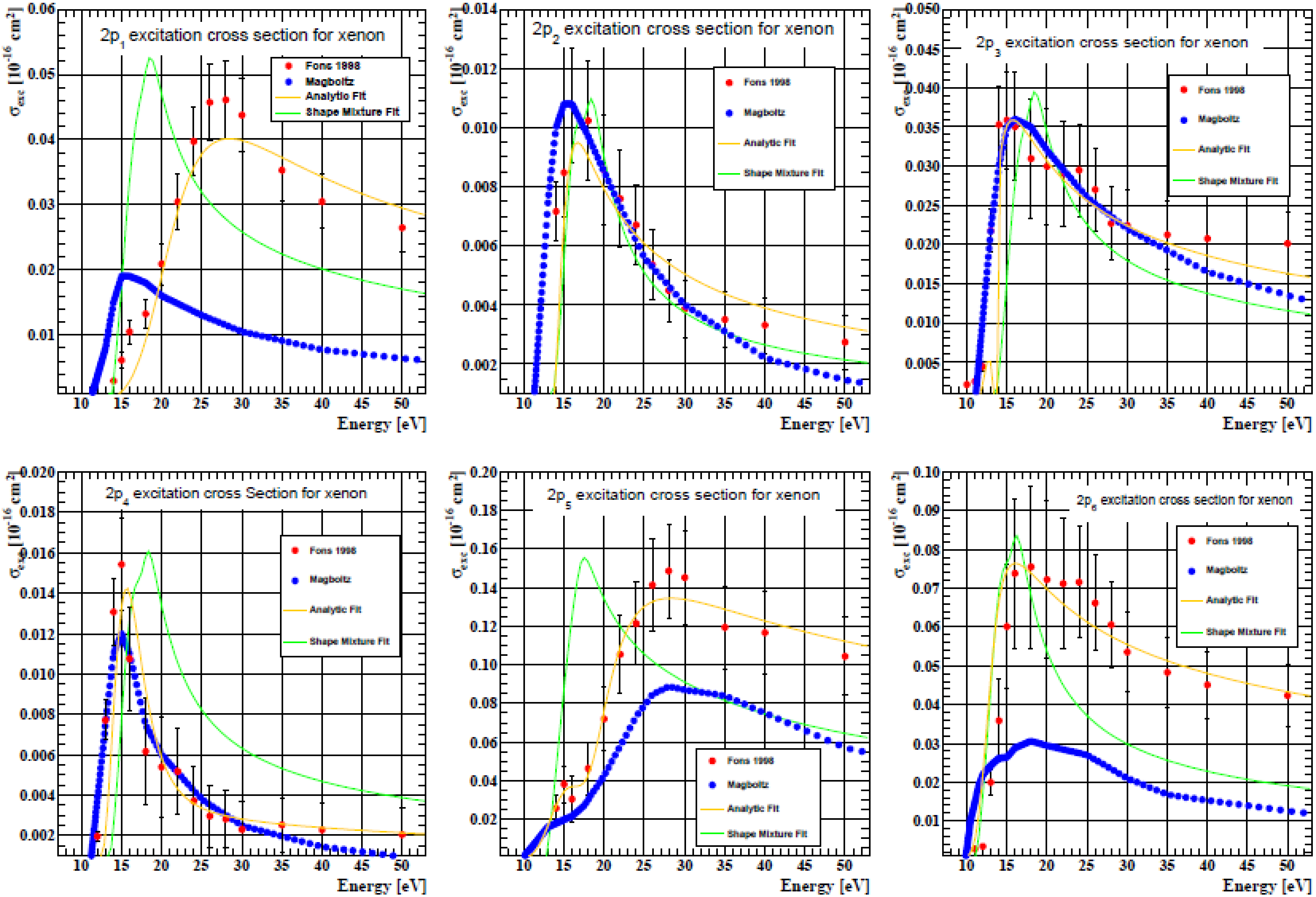
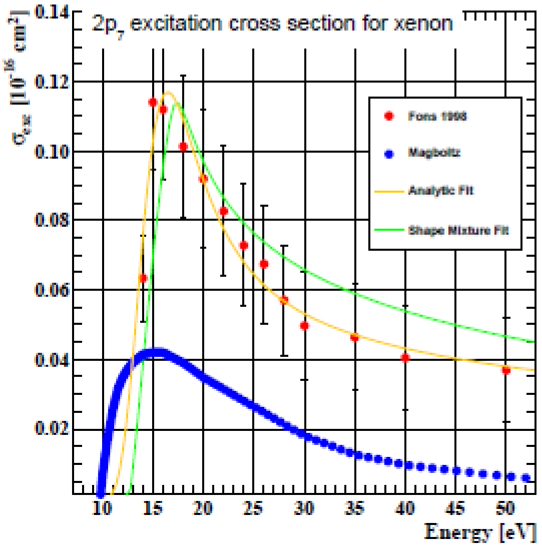
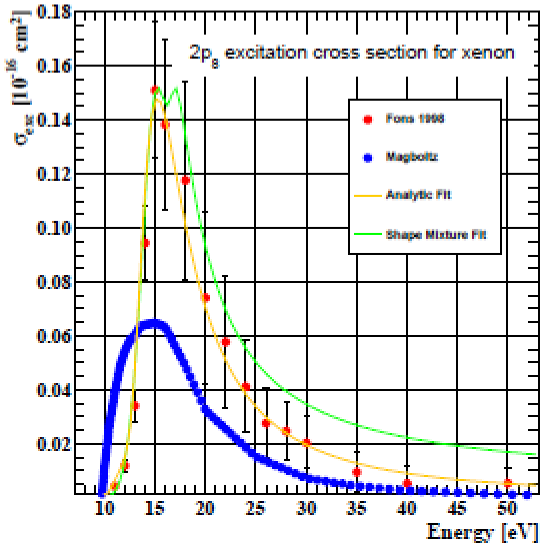



2p7 excitation cross section for xenon
σexc [10^-16 cm^2]
Energy [eV]
Fons 1998
Magboltz
Analytic Fit
Shape Mixture Fit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σexc [10^-16 cm^2]
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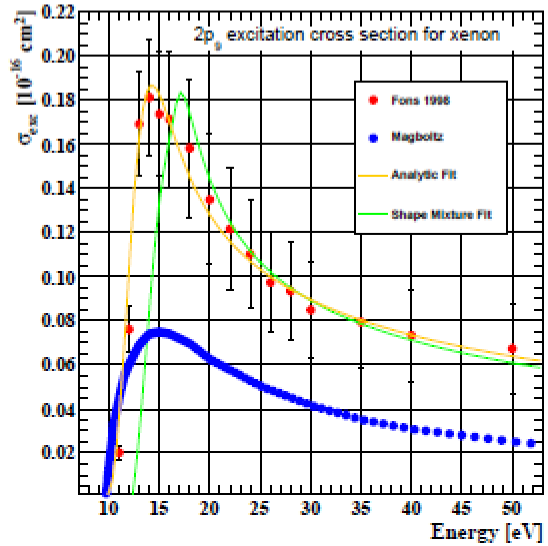
2p9 excitation cross section for xenon
σexc [10^-16 cm^2]
Energy [eV]
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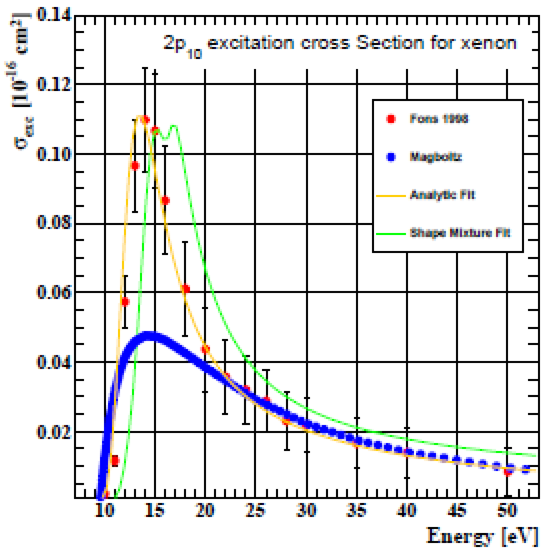
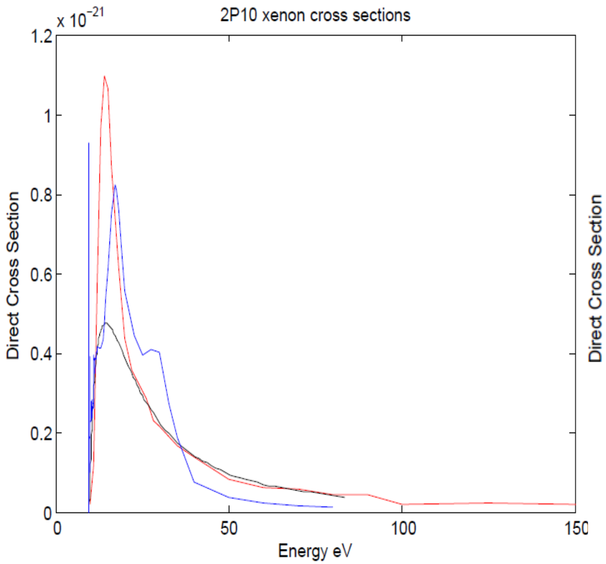
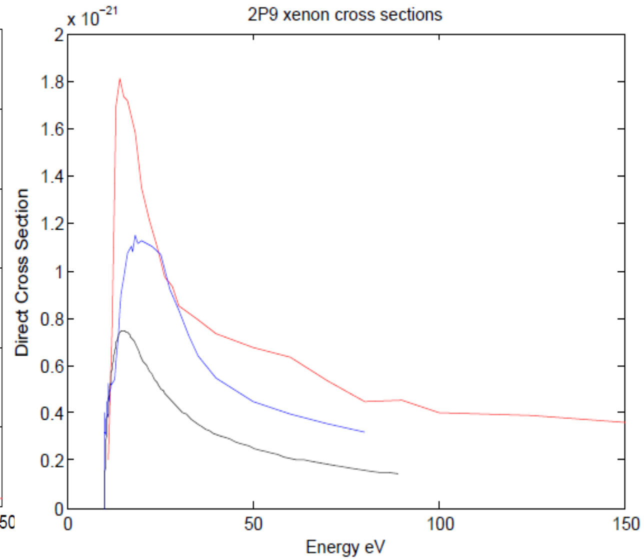

2p10 excitation cross Section for xenon
σexc [10^-16 cm^2]
Energy [eV]
Fons 1998
Magboltz
Analytic Fit
Shape Mixture Fit

“the sharp increase near threshold is almost certainly real -- it also comes out in all good theories. How accurate the absolute numbers are is hard to tell. We have some theoretical predictions for the direct cross sections, which should be quite accurate”.
-Dr. Klaus Bartschat


2P10 xenon cross sections
x 10^-21
Direct Cross Section
Energy eV


2P9 xenon cross sections
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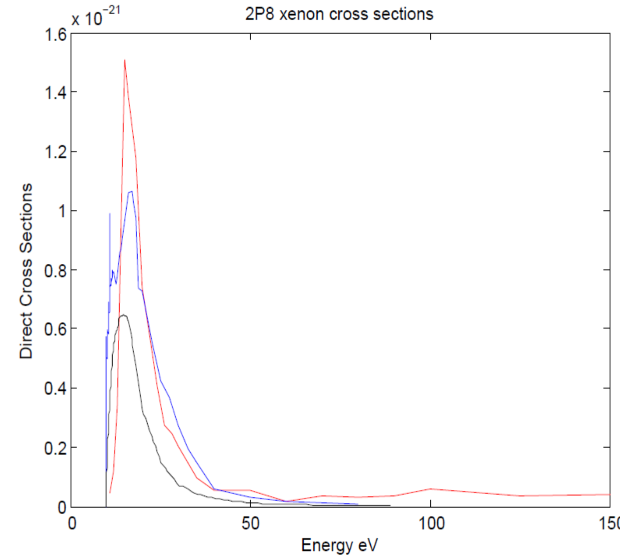
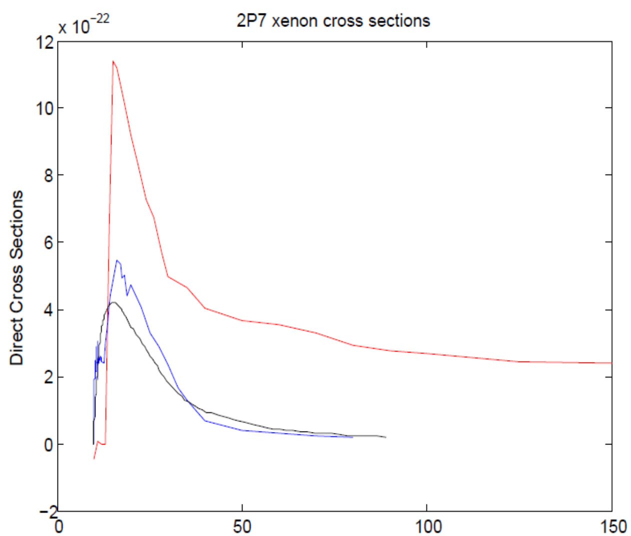
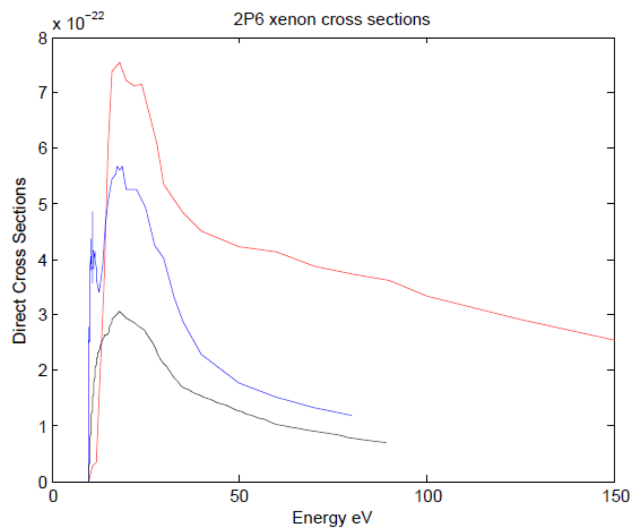
Direct Cross Section
Energy eV


2P8 xenon cross sections
x 10^-21
Direct Cross Sections
Energy eV


2P7 xenon cross sections
x 10^-22
Direct Cross Sections


2P6 xenon cross sections
x 10^-22
Direct Cross Sections
Energy eV

Conclusion:

- A correct shape model was sought in order to improve transfer rate results for xenon gas mixtures when using Magboltz
- Though the magnitude of the cross sections was not confirmed, the abrupt spike in cross section at low energy seen in the most recent set of experimental measurements was determined to be a real phenomenon caused by electron exchange interactions which dominate at low incident electron energy