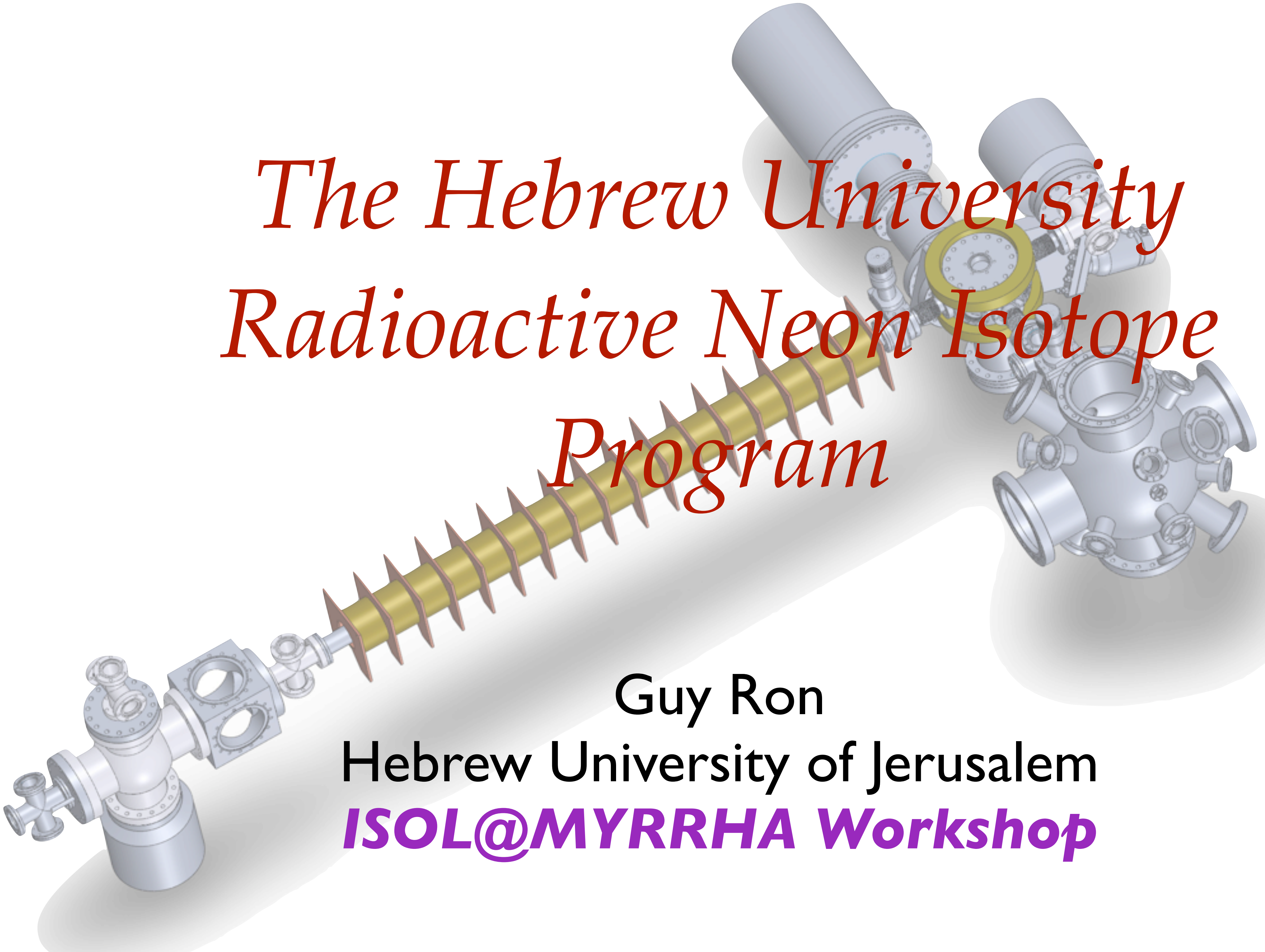
האוניברסיטה העברית בירושלים
The Hebrew University of Jerusalem

The Hebrew University Radioactive Neon Isotope Program



Guy Ron
Hebrew University of Jerusalem

ISOL@MYRRHA Workshop

Outline

- (Very) short intro
- Why neon?
- Some technical aspects of the HUJI program
- Production schemes and relevance to MYRRHA.

Where to search for beyond SM Physics?

- Brute force ("*Swifter, Higher, Stronger*"):
  - Go higher in energy/luminosity.
  - LHC/Tevatron/ILC.
- Finesse:
  - High precision experiments.
  - Detect the effect of beyond SM on low energy observables.
  - "Table top" experiments: $0\nu\beta\beta$, atomic PNC, EDM, $\nu\beta$ correlation.
  - Accelerator based: Proton/Neutron weak charge (Q_{weak}, PRex, ...).

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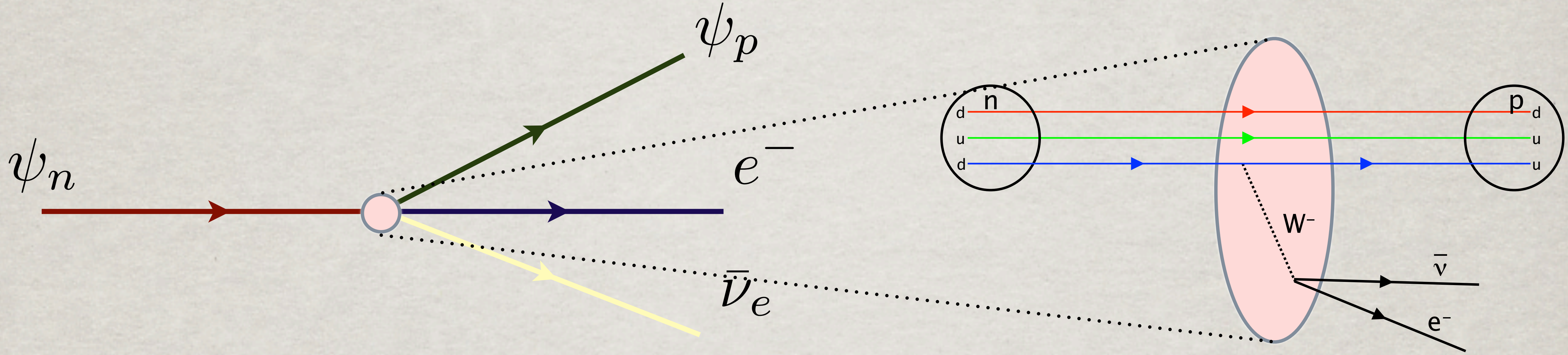
Weak Interaction

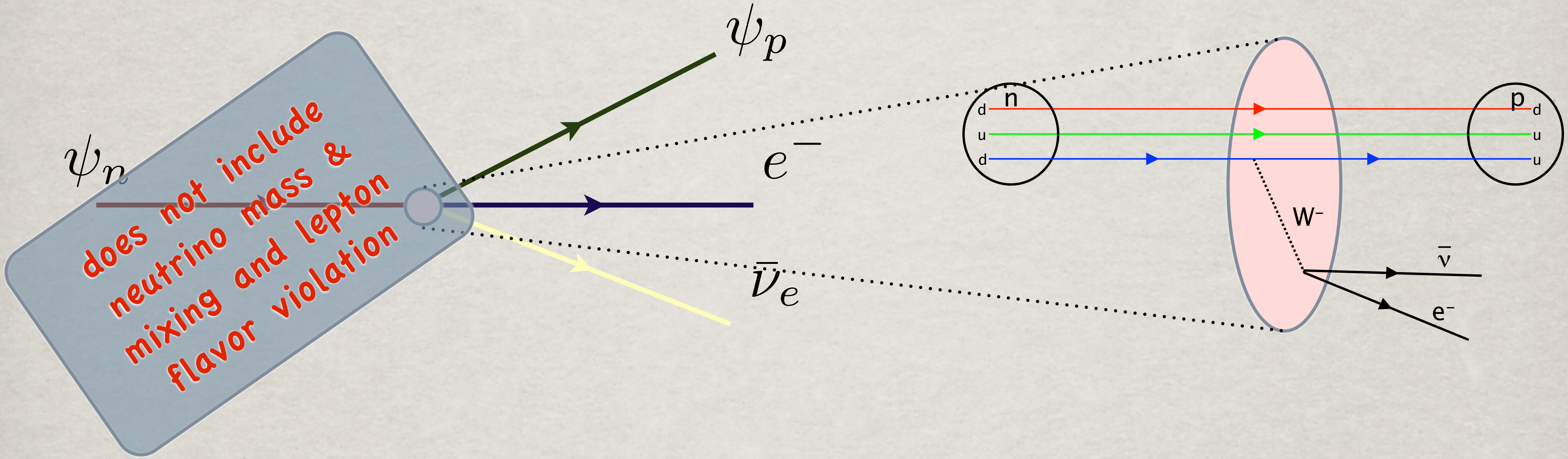
Nuclear β decay



$$
\begin{aligned}
H_\beta = \quad & (\bar{\psi}_n\psi_p)(C_s\bar{\psi}_e\psi_\nu + C'_s\bar{\psi}_e\psi_\nu\gamma_5\psi_\nu) \\
& +(\bar{\psi}_n\gamma_\mu\psi_p)(C_V\bar{\psi}_e\gamma^\mu\psi_\nu + C'_V\bar{\psi}_e\gamma^\mu\gamma_5\psi_\nu) \\
& +\frac{1}{2}(\bar{\psi}_n\sigma_{\lambda\nu}\psi_p)(C_T\bar{\psi}_e\sigma^{\lambda\nu}\psi_\nu + C'_T\bar{\psi}_e\sigma^{\lambda\nu}\gamma_5\psi_\nu) \\
& -(\bar{\psi}_n\gamma_\mu\gamma_5\psi_p)(C_A\bar{\psi}_e\gamma^\mu\gamma_5\psi_\nu + C'_A\bar{\psi}_e\gamma^\mu\psi_\nu) \\
& +(\bar{\psi}_n\gamma_5\psi_p)(C_P\bar{\psi}_e\gamma_5\psi_\nu + C'_P\bar{\psi}_e\psi_\nu)
\end{aligned}
$$

19 free parameters
(10 complex couplings
- arbitrary phase)

Nuclear β decay



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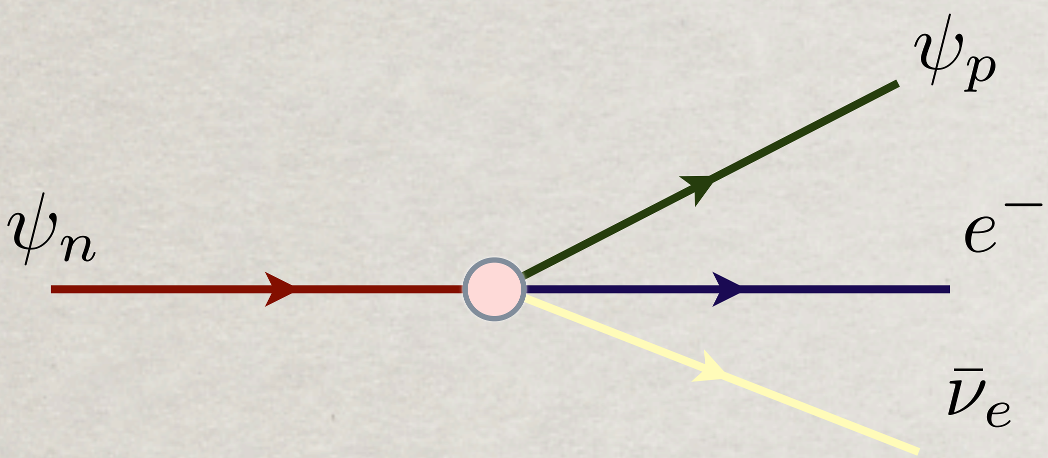
$$

This is Standard Model

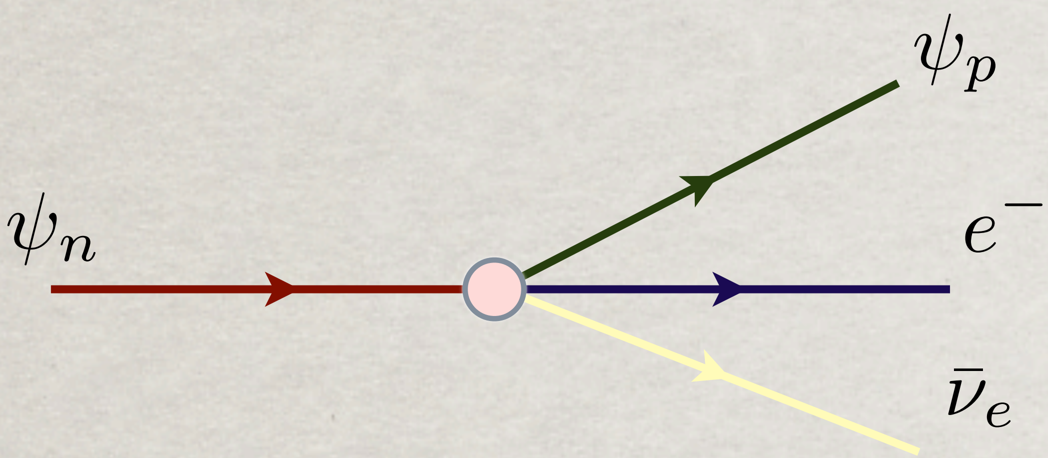


$$H_\beta = (\bar{\psi}_n \gamma_\mu \psi_p)(C_V \bar{\psi}_e \gamma^\mu \psi_\nu + C'_V \bar{\psi}_e \gamma^\mu \gamma_5 \psi_\nu) - (\bar{\psi}_n \gamma_\mu \gamma_5 \psi_p)(C_A \bar{\psi}_e \gamma^\mu \gamma_5 \psi_\nu + C'_A \bar{\psi}_e \gamma^\mu \psi_\nu)$$

$$C_V = C'_V = 1$$

$$C_A = C'_A = 1.26$$

This is Standard Model



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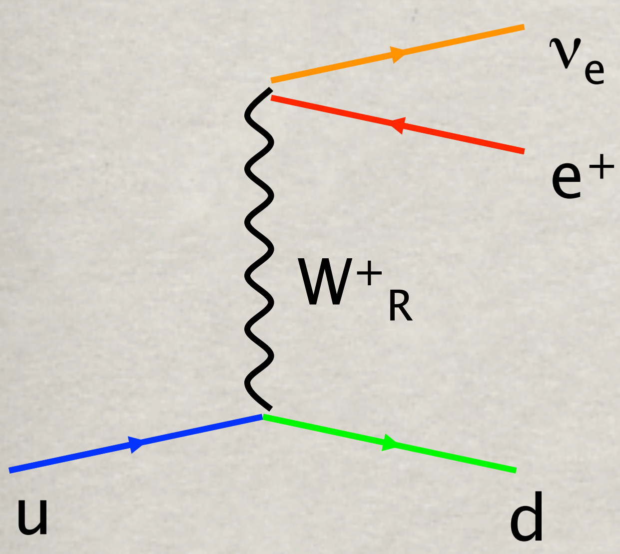
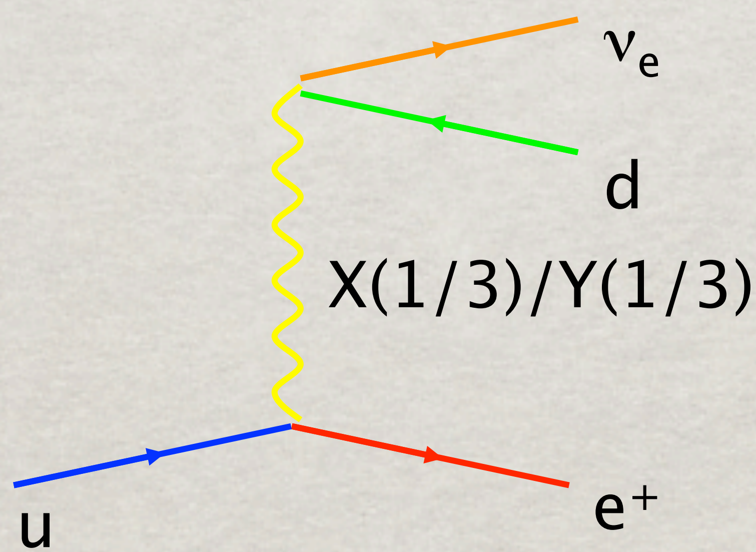
This is Not....



Right handed bosons

$$C \neq C'$$



Scalar or Tensor Leptoquarks

$$C_T \neq 0$$

$$C_S \neq 0$$

- SUSY slepton flavor mixing.
- SUSY LR mixing.
- many more (with different C's)...

β decay 101

Total decay rate (electron polarization not detected)

$$\frac{d\Gamma}{dE_\beta d\Omega_\beta d\Omega_\nu} \propto \xi \left\{ 1 + a\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + b\frac{m}{E_e} + c\left[\frac{1}{3}\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} - \frac{(\vec{p}_e \cdot \vec{j})(\vec{p}_\nu \cdot \vec{j})}{E_e E_\nu}\right] \right.$$

$$\left. \left[\frac{J(J+1) - 3 < (\vec{J} \cdot \vec{j})^2 >}{J(2J-1)}\right] + \frac{< \vec{J} >}{J} \cdot \left[A\frac{\vec{p}_e}{E_e} + B\frac{\vec{p}_\nu}{E_\nu} + D\frac{\vec{p}_e \times \vec{p}_\nu}{E_e E_\nu}\right] \right\}$$

J.D. Jackson, S.B. Treiman, & H.W. Wyld, Phys. Rev. 106, 517 (1957)

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Electron-neutrino correlation

$$\begin{aligned} \xi a &= |M_F|^2 \left(-|C_S|^2 + |C_V|^2 - |C'_S|^2 + |C'_V|^2\right) + \\ &\quad \frac{|M_{GT}|^2}{3}\left(|C_T|^2 - |C_A|^2 + |C'_T|^2 - |C'_A|^2\right) \\ \xi &= |M_F|^2 \left(|C_S|^2 + |C_V|^2 + |C'_S|^2 + |C'_V|^2\right) + \\ &\quad |M_{GT}|^2 \left(|C_T|^2 + |C_A|^2 + |C'_T|^2 + |C'_A|^2\right) \end{aligned}$$

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Electron-neutrino correlation

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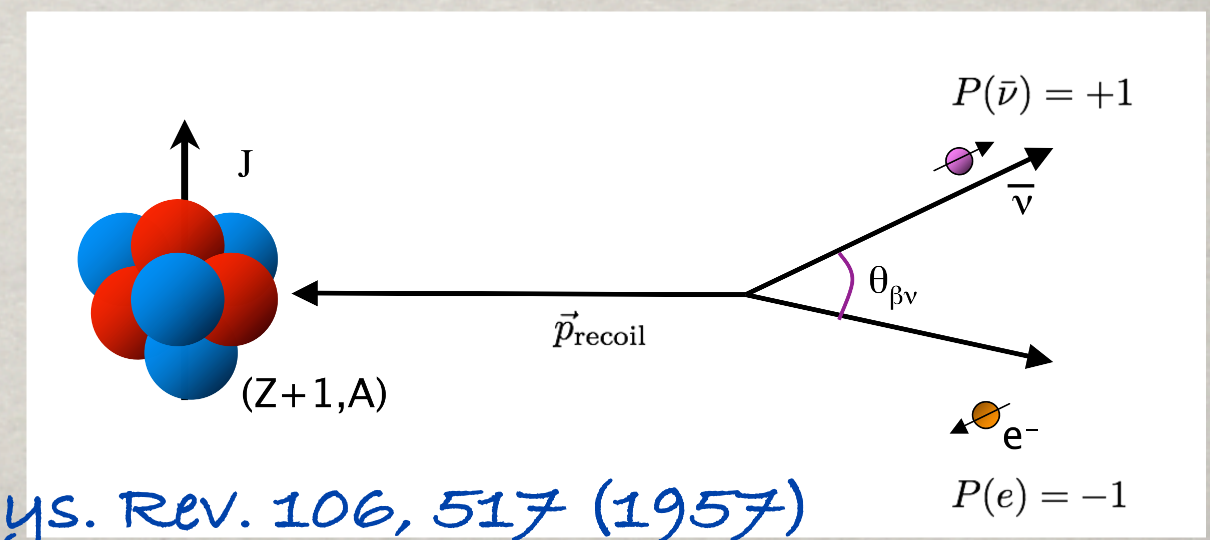
β + ν carry no AM → emitted in same direction (opposite helicities)

Pure Fermi: a = 1



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β DECAY 101

Total decay rate (electron polarization not detected)

$$\frac{d\Gamma}{dE_\beta d\Omega_\beta d\Omega_\nu} \propto \xi \left\{ 1 + a\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + b\frac{m}{E_e} + c\left[\frac{1}{3}\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} - \frac{(\vec{p}_e \cdot \vec{j})(\vec{p}_\nu \cdot \vec{j})}{E_e E_\nu}\right] \left[\frac{J(J+1) - 3 < (\vec{J}\cdot\vec{j})^2 >}{J(2J-1)}\right] + \frac{< \vec{J} >}{J} \cdot \left[A\frac{\vec{p}_e}{E_e} + B\frac{\vec{p}_\nu}{E_\nu} + D\frac{\vec{p}_e \times \vec{p}_\nu}{E_e E_\nu}\right] \right\}$$

Electron-neutrino correlation

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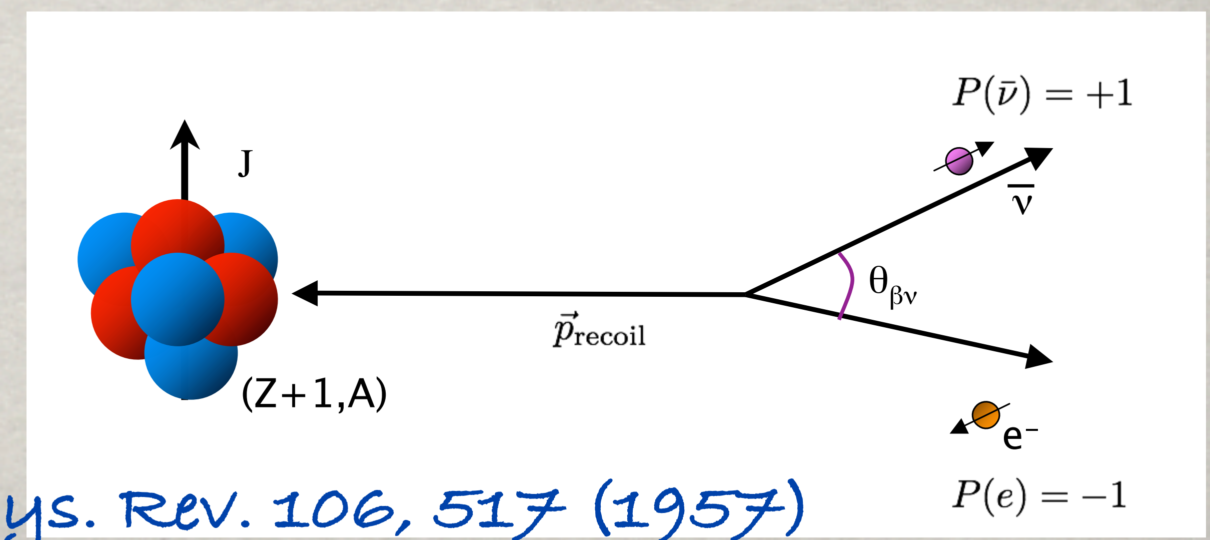
$$\xi = |M_F|^2 \left(|C_S|^2 + |C_V|^2 + |C'_S|^2 + |C'_V|^2\right) + |M_{GT}|^2\left(|C_T|^2 + |C_A|^2 + |C'_T|^2 + |C'_A|^2\right)$$

β + ν carry 1 unit AM → emitted in opposite directions (factor of 3 from spin directions)

Pure GT: $a = -1/3$



J.D. Jackson, S.B. Treiman, & H.W. Wyld, Phys. Rev. 106, 517 (1957)

β DECAY 101

Possible observables in nuclei

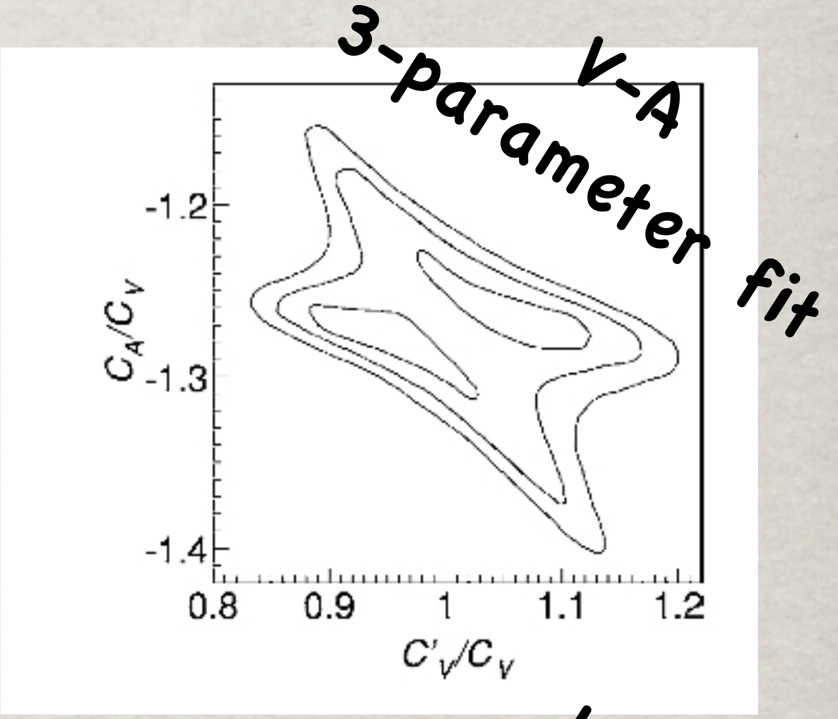
$$\frac{d\Gamma}{dE_\beta d\Omega_\beta d\Omega_\nu} \propto \xi \left\{ 1 + a\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + b\frac{m}{E_e} + c\left[\frac{1}{3}\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} - \frac{(\vec{p}_e \cdot \vec{j})(\vec{p}_\nu \cdot \vec{j})}{E_e E_\nu}\right] \left[\frac{J(J+1) - 3 < (\vec{J} \cdot \vec{j})^2 >}{J(2J-1)}\right] + \frac{< \vec{J} >}{J} \cdot \left[A\frac{\vec{p}_e}{E_e} + B\frac{\vec{p}_\nu}{E_\nu} + D\frac{\vec{p}_e \times \vec{p}_\nu}{E_e E_\nu}\right] \right\}$$

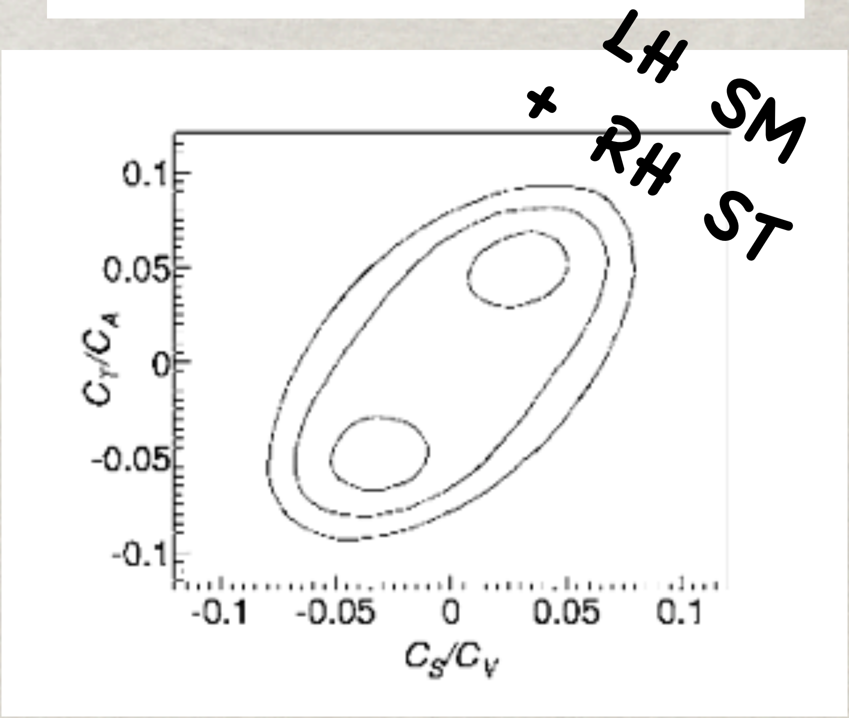
Parameter	Observable	Sensitivity	SM Prediction
a	β-ν (recoil) correlation	Tensor & Scalar terms	1 for pure Fermi -1/3 for pure GT or combination
b (Fierz term)	Comparison of β^+ to EC rate	SV/T/A interference	0
A	β asymmetry for polarized nuclei	Tensor, ST/VA Parity	Nucleus dependent
B	ν asymmetry (recoil) for polarized nuclei	Tensor,TA/ST/VA/SA/VT Parity	Nucleus dependent
D	Triple product	ST/VA Interference TRI	0

Limits on non-SM coupling

- Very large model space.
- Not spanned by collider experiments.
- Current best limits not very stringent.
- Naively $\frac{C_T}{C_A}, \frac{C_S}{C_S} \propto \left(\frac{M_W}{M_{NewPhys}}\right)^2$

  so uncertainty to 0.01 probes new physics at ~ 1TeV!
- Possible effects on high energy results (W production at D0).





N. Severijns, M. Beck, and O. Naviliat-Cuncic, Rev. Mod. Phys. 78, 991 (2006)
J. Sromki, AIP Conf Proc 338 (1995)

Anatomy of an Experiment

Produce Radioactive Atoms

(Produce, Transport, Neutralize)

↓

Trap

(MOT, Dipole, Ion, Electrostatic)

↓

Wait...

↓

Detect decay products (β, Ion)

(Scintillators, MCPs,...)

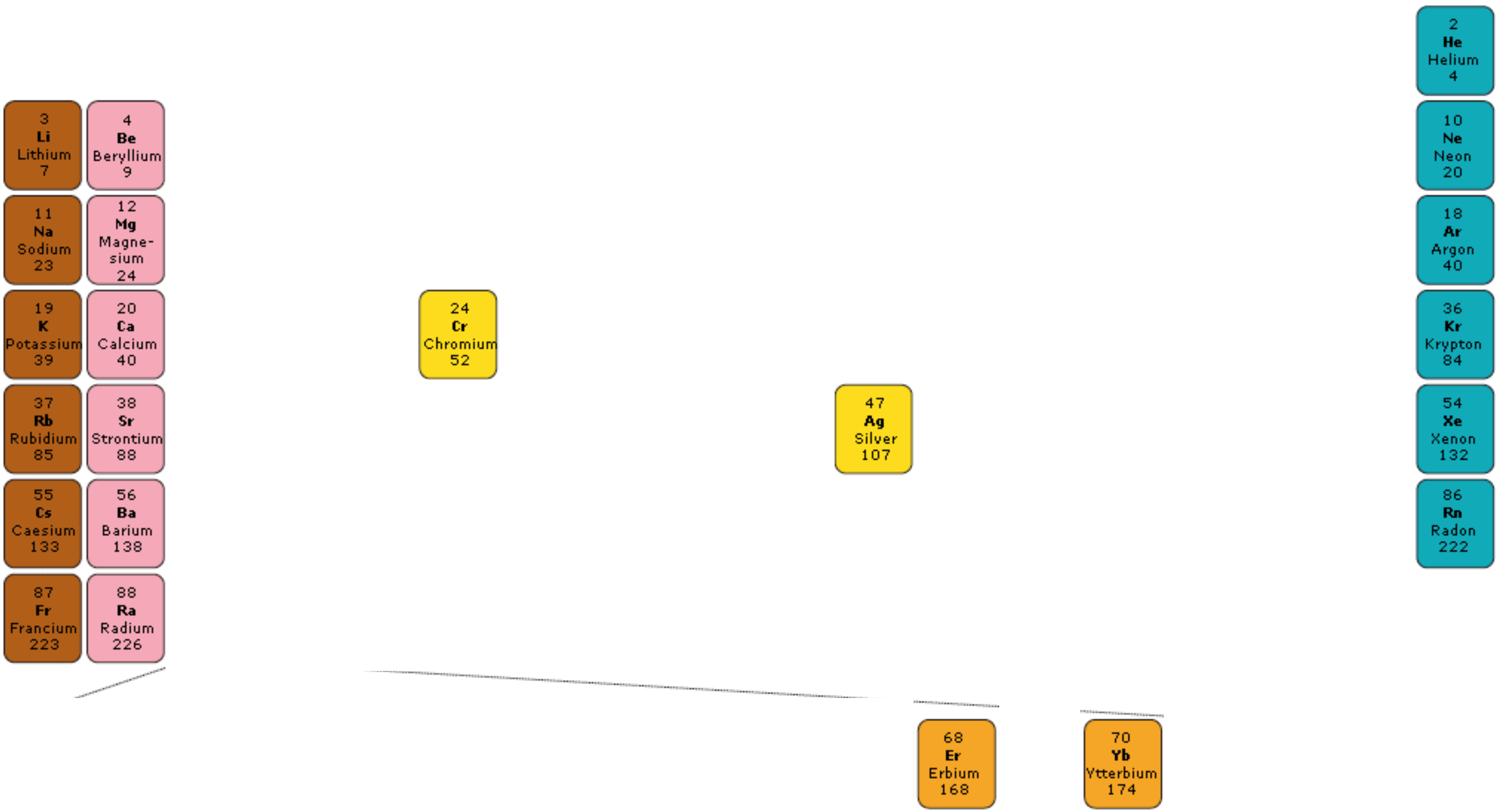
↓

Analyze and compare to SM

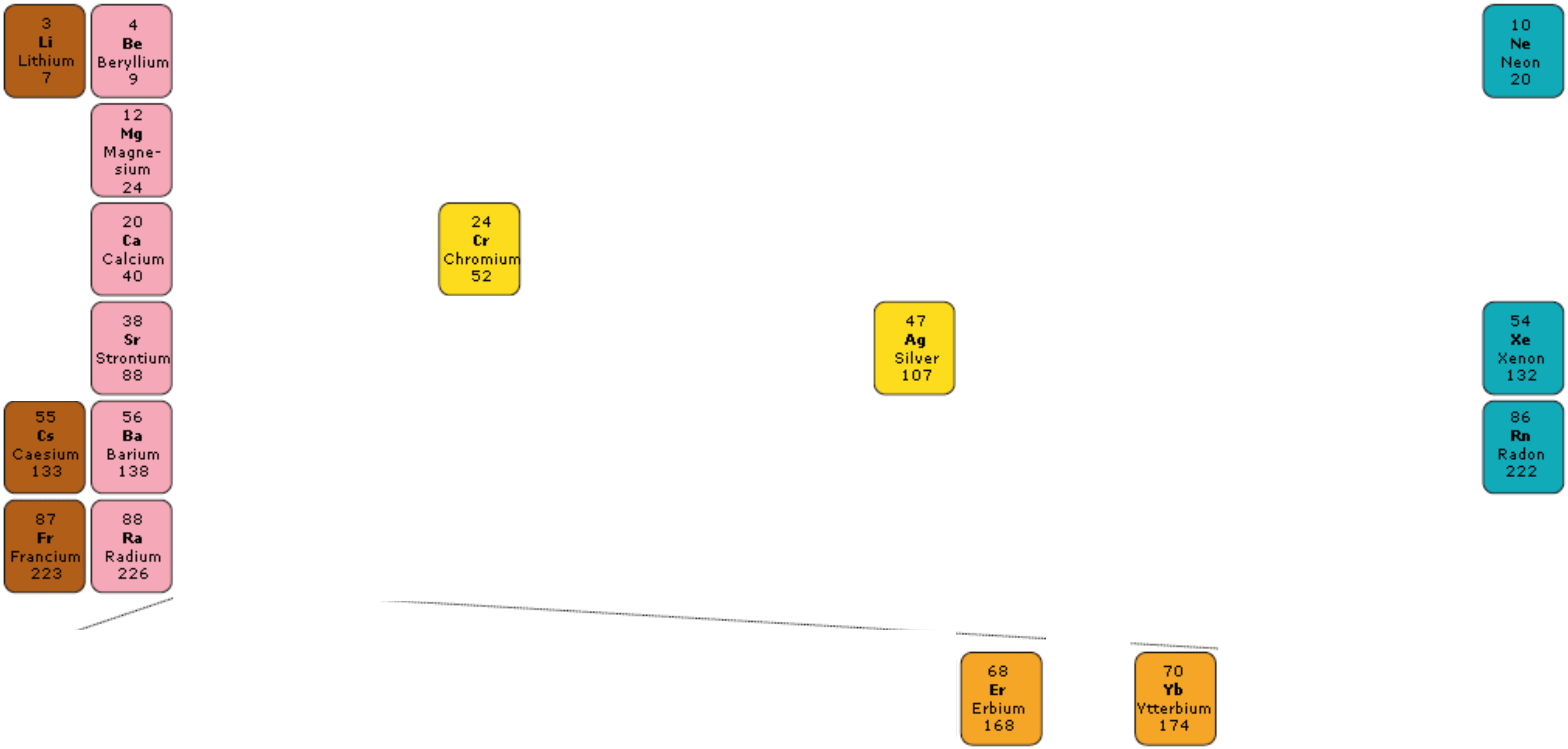
Why Neon? - (I) The Period Table

1 **H** Hydrogen 1																	2 **He** Helium 4
3 **Li** Lithium 7	4 **Be** Beryllium 9											5 **B** Boron 11	6 **C** Carbon 12	7 **N** Nitrogen 14	8 **O** Oxygen 16	9 **F** Fluorine 19	10 **Ne** Neon 20
11 **Na** Sodium 23	12 **Mg** Magne-sium 24											13 **Al** Aluminum 27	14 **Si** Silicon 28	15 **P** Phosp-horus 31	16 **S** Sulphur 32	17 **Cl** Chlorine 35	18 **Ar** Argon 40
19 **K** Potassium 39	20 **Ca** Calcium 40	21 **Sc** Scandium 45	22 **Ti** Titanium 48	23 **V** Vanadium 51	24 **Cr** Chromium 52	25 **Mn** Mang-anese 55	26 **Fe** Iron 56	27 **Co** Cobalt 59	28 **Ni** Nickel 58	29 **Cu** Copper 63	30 **Zn** Zinc 64	31 **Ga** Gallium 69	32 **Ge** Germ-anium 74	33 **As** Arsenic 75	34 **Se** Selenium 80	35 **Br** Bromine 79	36 **Kr** Krypton 84
37 **Rb** Rubidium 85	38 **Sr** Strontium 88	39 **Y** Yttrium 89	40 **Zr** Zirconium 90	41 **Nb** Niobium 93	42 **Mo** Molyb-denum 98	43 **Tc** Techn-etium 97	44 **Ru** Ruthenium 102	45 **Rh** Rhodium 103	46 **Pd** Palladium 106	47 **Ag** Silver 107	48 **Cd** Cadmium 114	49 **In** Indium 115	50 **Sn** Tin 120	51 **Sb** Antimony 121	52 **Te** Tellurium 130	53 **I** Iodine 127	54 **Xe** Xenon 132
55 **Cs** Caesium 133	56 **Ba** Barium 138	57-71	72 **Hf** Hafnium 180	73 **Ta** Tantalum 181	74 **W** Tungsten 184	75 **Re** Rhenium 187	76 **Os** Osmium 192	77 **Ir** Iridium 193	78 **Pt** Platinum 195	79 **Au** Gold 197	80 **Hg** Mercury 202	81 **Tl** Thallium 205	82 **Pb** Lead 208	83 **Bi** Bismuth 209	84 **Po** Polonium 209	85 **At** Astatine 210	86 **Rn** Radon 222
87 **Fr** Francium 223	88 **Ra** Radium 226	89-103	104 **Unq** Unnilq-uadium 260	105 **Unp** Unnilp-entium 262	106 **Unh** Unnilh-exium 263	107 **Uns** Unnils-eptium 262	108 Uno Unnilo-ctium 265	109 **Une** Unnile-nnium 266									
57 **La** Lanth-anum 139	58 **Ce** Cerium 140	59 **Pr** Praseo-dymium 141	60 **Nd** Neody-mium 142	61 **Pm** Prome-thium 145	62 **Sm** Samarium 152	63 **Eu** Europium 153	64 **Gd** Gado-linium 158	65 **Tb** Terbium 159	66 **Dy** Dysp-rosium 164	67 **Ho** Holmium 165	68 **Er** Erbium 168	69 **Tm** Thulium 169	70 **Yb** Ytterbium 174	71 **Lu** Lutetium 175			
89 **Ac** Actinium 227	90 **Th** Thorium 232	91 **Pa** Protac-tinium 231	92 **U** Uranium 238	93 **Np** Neptunium 237	94 **Pu** Plutonium 244	95 **Am** Americium 243	96 **Cm** Curium 247	97 **Bk** Berkelium 247	98 **Cf** Califor-nium 251	99 **Es** Einste-inium 254	100 **Fm** Fermium 257	101 Md Mende-levium 258	102 **No** Nobelium 255	103 Lr Lawre-ncium 256			

Why Neon? - (I) The Period Table of Trappable Elements



Why Neon? - (I) The Period Table of Trappable Elements Not already used for MOT β Decay



Why Neon? - (I) The Period Table of Trappable Elements Not already used for MOT β Decay & Decent to Calculate/Implement

3
Li
Lithium
7

10
Ne
Neon
20

Why Neon? - (I) The Period Table of Trappable Elements Not already used for MOT β Decay & Decent to Calculate/Implement

3

3
Li
Lithium
7

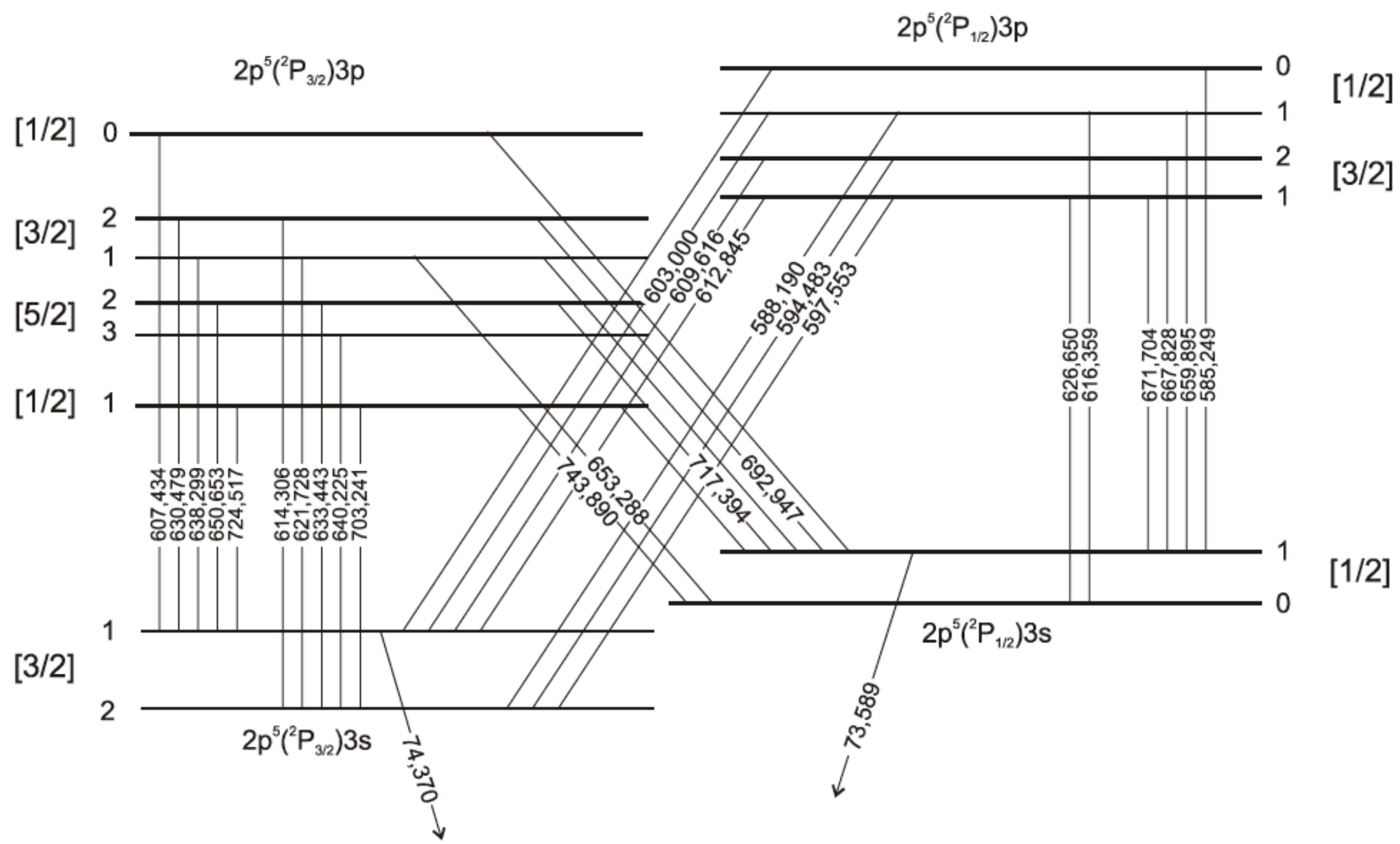
Easier to produce
Trap setup exists in Israel (as does design for production of ^{8}Li)
Easy wavelengths
Harder to trap (messy level scheme)

10

10
Ne
Neon
20

Easy to trap
Interesting physics other the beta decay
Needs to be in metastable state
Problematic WL for lasers
Harder to produce

Why Neon? - (I) The Period Table of Trappable Elements Not already used for MOT β Decay & Decent to Calculate/Implement



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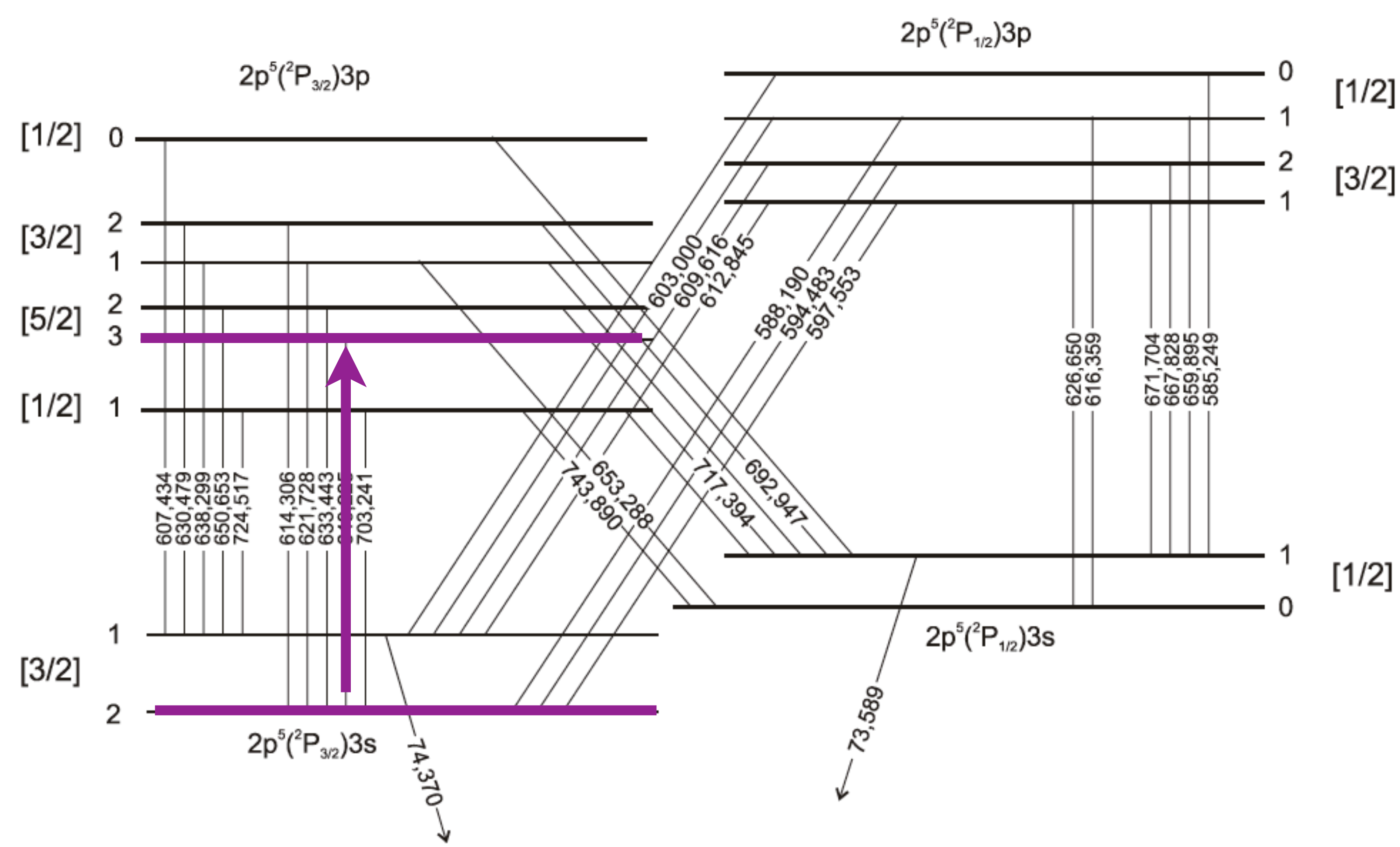
10

10
Ne
Neon
20



Fully closed transition for even neon isotopes (single frequency for trapping).

- Easy to trap
- Interesting physics other the beta decay
- Needs to be in metastable state
- Problematic WL for lasers
- Harder to produce

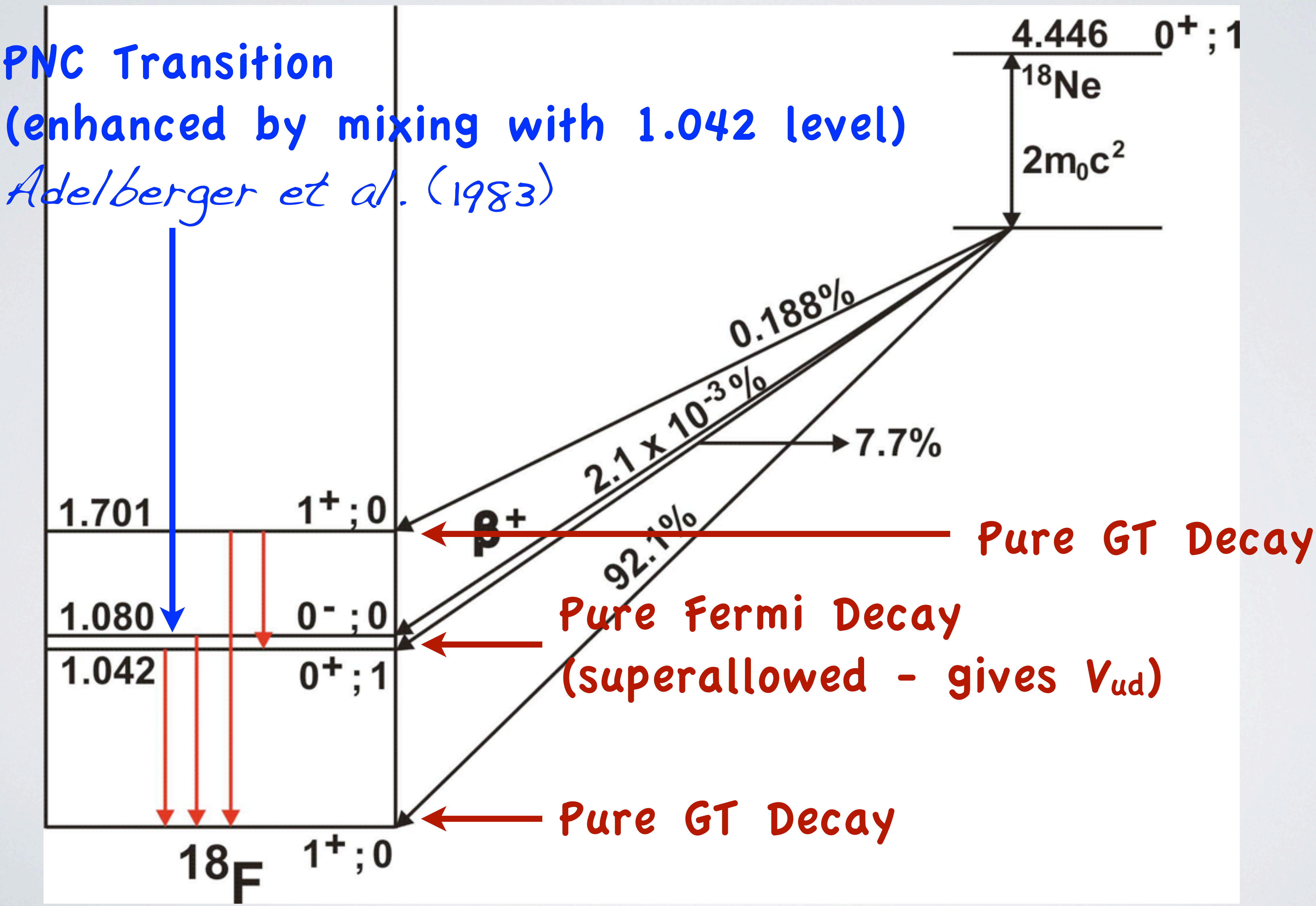
Why Neon? - (I) The Period Table of Trappable Elements Not already used for MOT β Decay & Decent to Calculate/Implement

Ne	Ne16	Ne17	Ne18	Ne19	Ne20	Ne21	Ne22	Ne23	Ne24	Ne25	Ne26	Ne27	Ne28	Ne29	Ne30	Ne31	Ne32
-248.59° -246.08° -228.7°	122 keV	109.2 ms	1672 ms	17.22 s				37.24 s	3.38 m	602 ms	197 ms	32 ms	17 ms	0.2 s			
0	0+	1/2-	0+	1/2+	0+	3/2+	0+	5/2+	0+	(1/2,3/2)+	0+		0+		0+		0+
20.1797 0.0112%	2p	ECp,ECα,...	EC	EC	90.48	0.27	9.25	β^-	β^-	β^-	β^-n	β^-n	β^-n	β^-			

Why Neon? - (I) The Period Table of Trappable Elements Not already used for MOT β Decay & Decent to Calculate/Implement

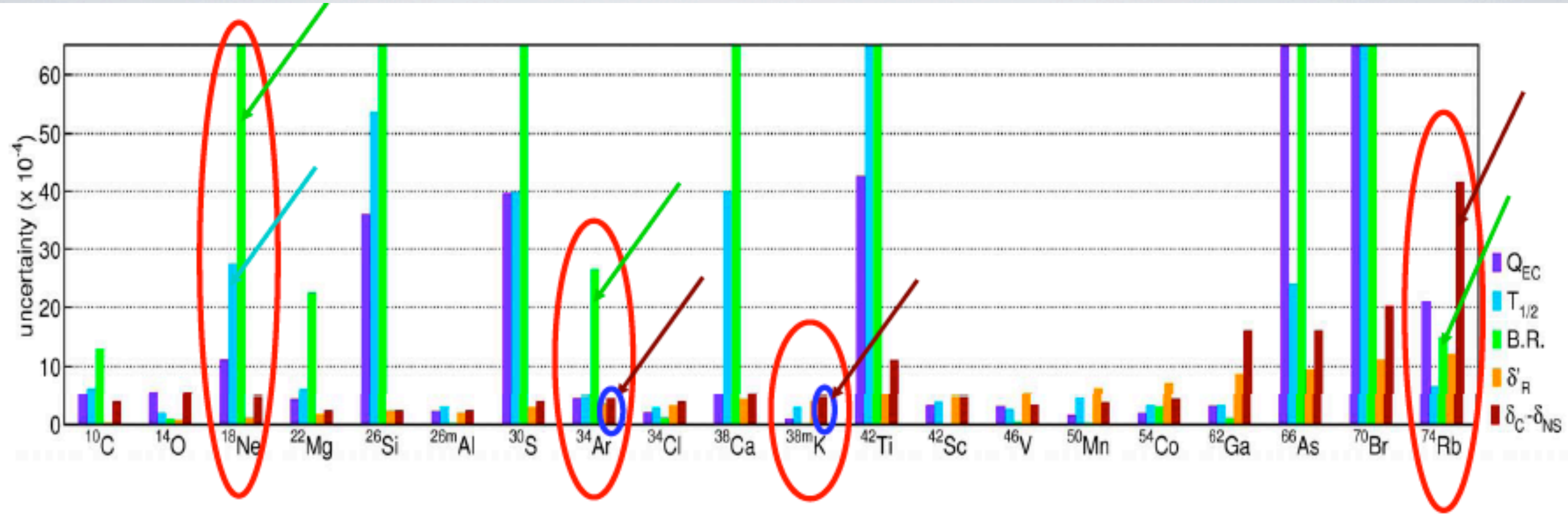
Ne	Ne16	Ne17	Ne18	Ne19	Ne20	Ne21	Ne22	Ne23	Ne24	Ne25	Ne26	Ne27	Ne28	Ne29	Ne30	Ne31	Ne32
-248.59° -246.08° -228.7°	122 keV	109.2 ms	1672 ms	17.22 s				37.24 s	3.38 m	602 ms	197 ms	32 ms	17 ms	0.2 s			
0	0+	1/2-	0+	1/2+	0+	3/2+	0+	5/2+	0+	(1/2,3/2)+	0+		0+		0+		0+
20.1797 0.0112%	2p	ECp,ECα,...	EC	EC	90.48	0.27	9.25	β^-	β^-	β^-	β^-n	β^-n	β^-n	β^-			

Why ^{18}Ne?



4.446 0+ ; 1
18Ne
2m0c2
0.188%
2.1 x 10-3 %
7.7%
92.1%
β+
1.701 1+ ; 0
1.080 0- ; 0
1.042 0+ ; 1
18F 1+ ; 0
PNC Transition
(enhanced by mixing with 1.042 level)
Adelberger et al. (1983)
Pure GT Decay
Pure Fermi Decay
(superallowed - gives Vud)
Pure GT Decay

V_{ud} Uncertainties for superallowed decays

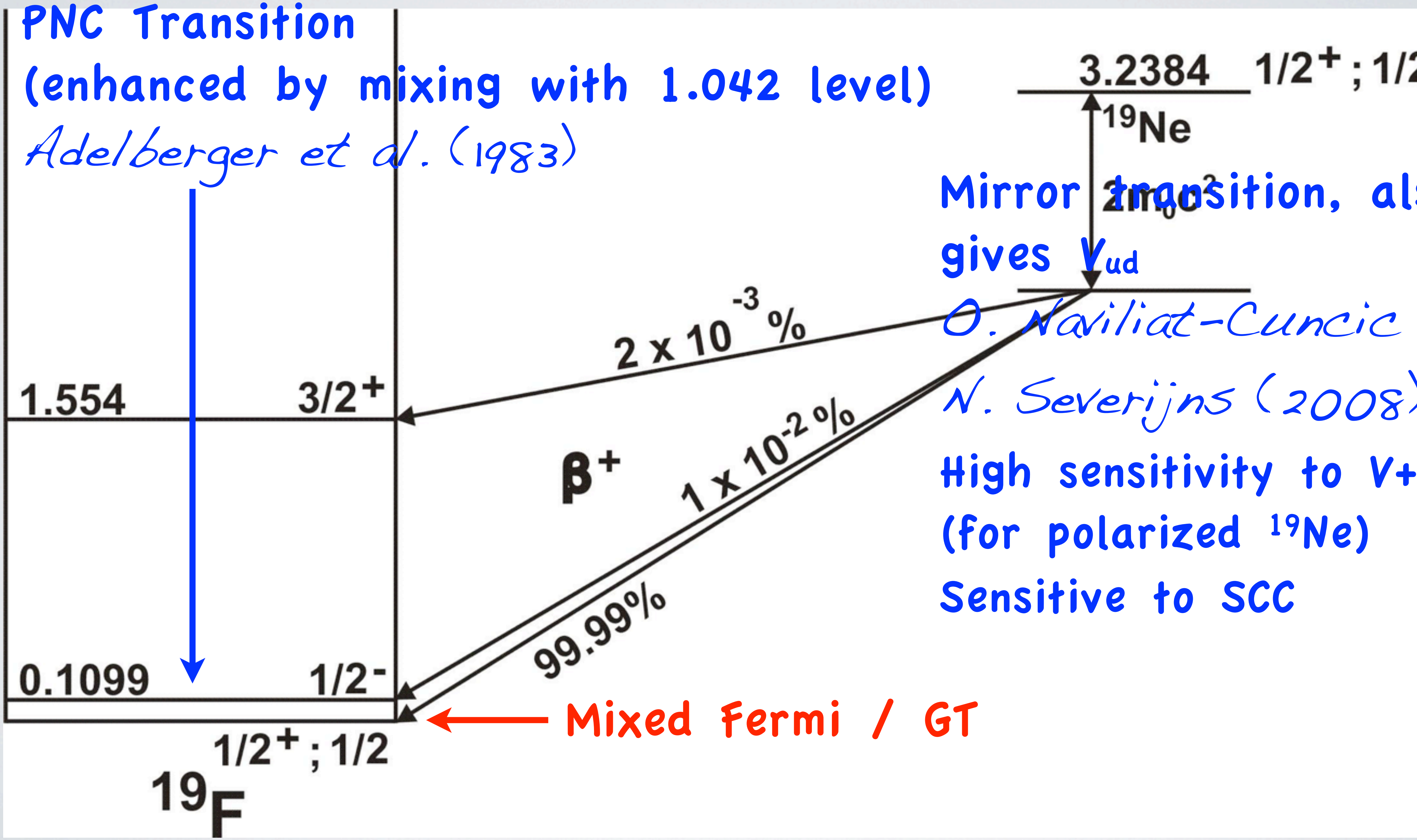


Options:

- improve quantities indicated by green & blue arrows
- if CVC accepted → Ft-measurements test δ_c - δ_{NS} from theoretical models
- go for factor ~10 higher precision in Ft than available now for the 4 isotopes indicated

N. Severijns, presentation BriX workshop 2008, SCK-CEN, Mol, Belgium, 2008.

Why ^{19}Ne?



PNC Transition
(enhanced by mixing with 1.042 level)
Adelberger et al. (1983)

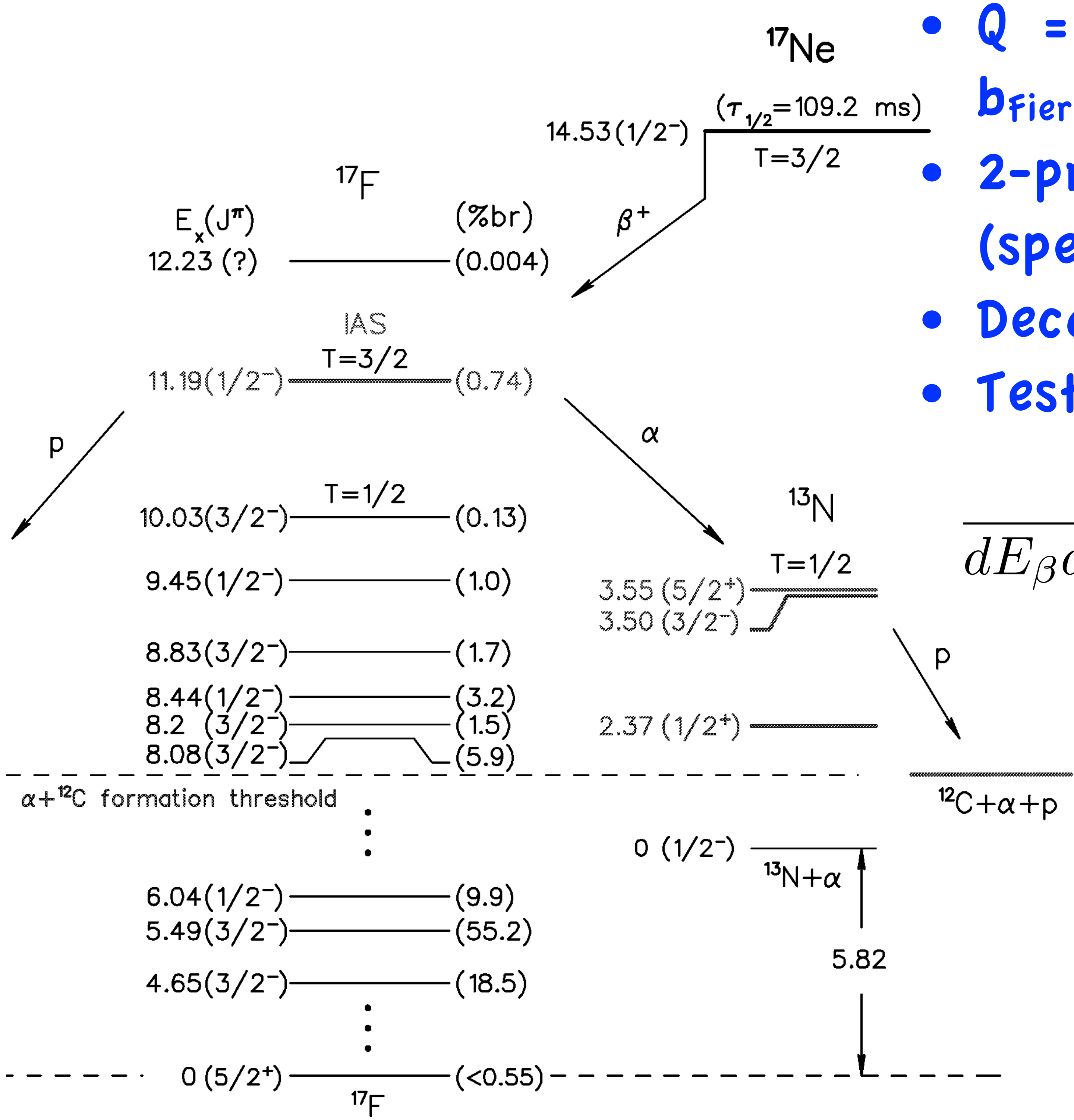
Mirror transition, also gives V_{ud}
O. Naviliat-Cuncic and N. Severijns (2008)

High sensitivity to V+A
(for polarized ^{19}Ne)

Sensitive to SCC

Mixed Fermi / GT

Why ^{17}Ne?

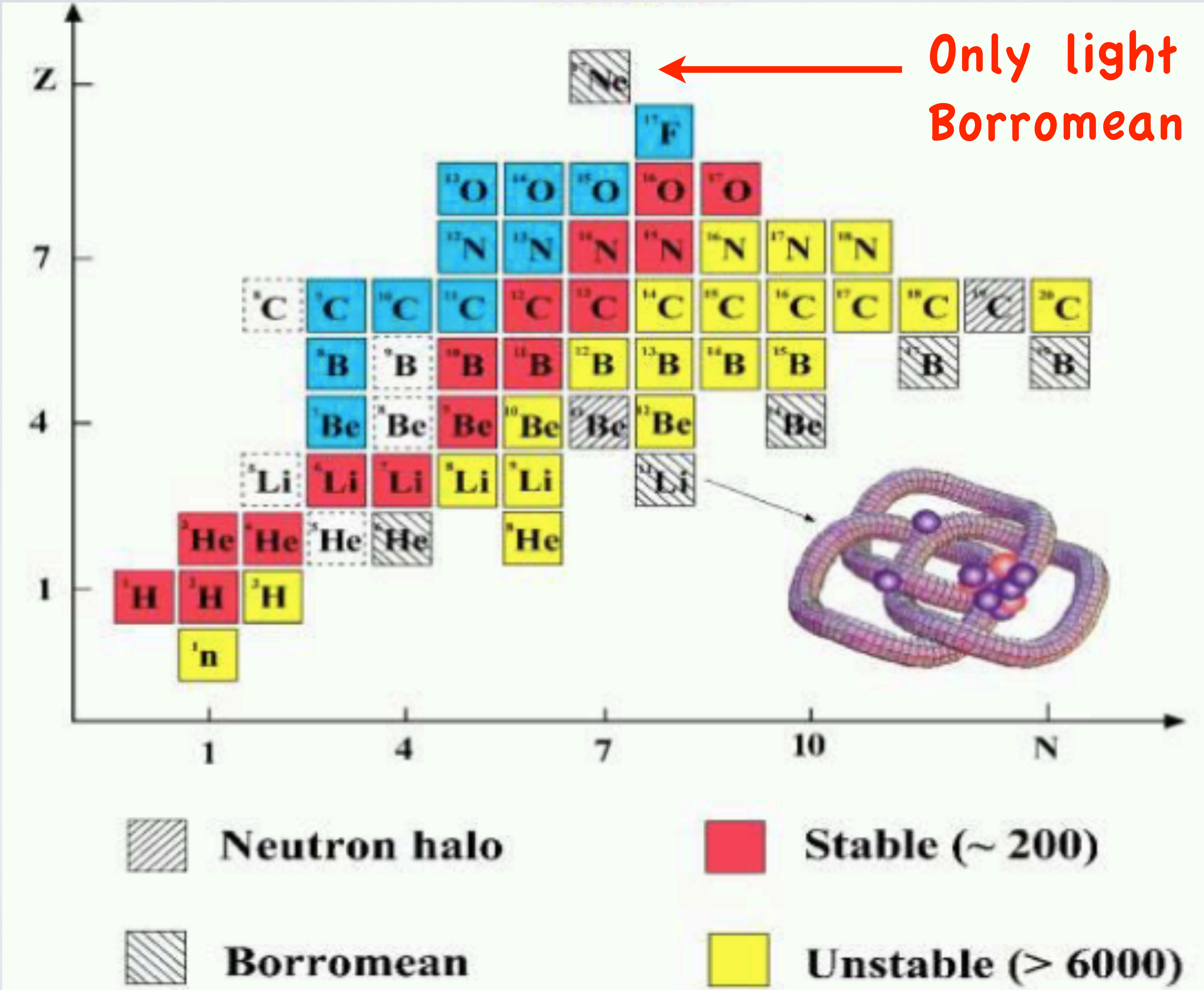


- Q = 14MeV - allows extraction of b_{Fierz} (maybe)
- 2-proton Borromean halo nucleus (spectroscopy)
- Decay to halo nucleus ^{17}F
- Test of forbidden β-decays

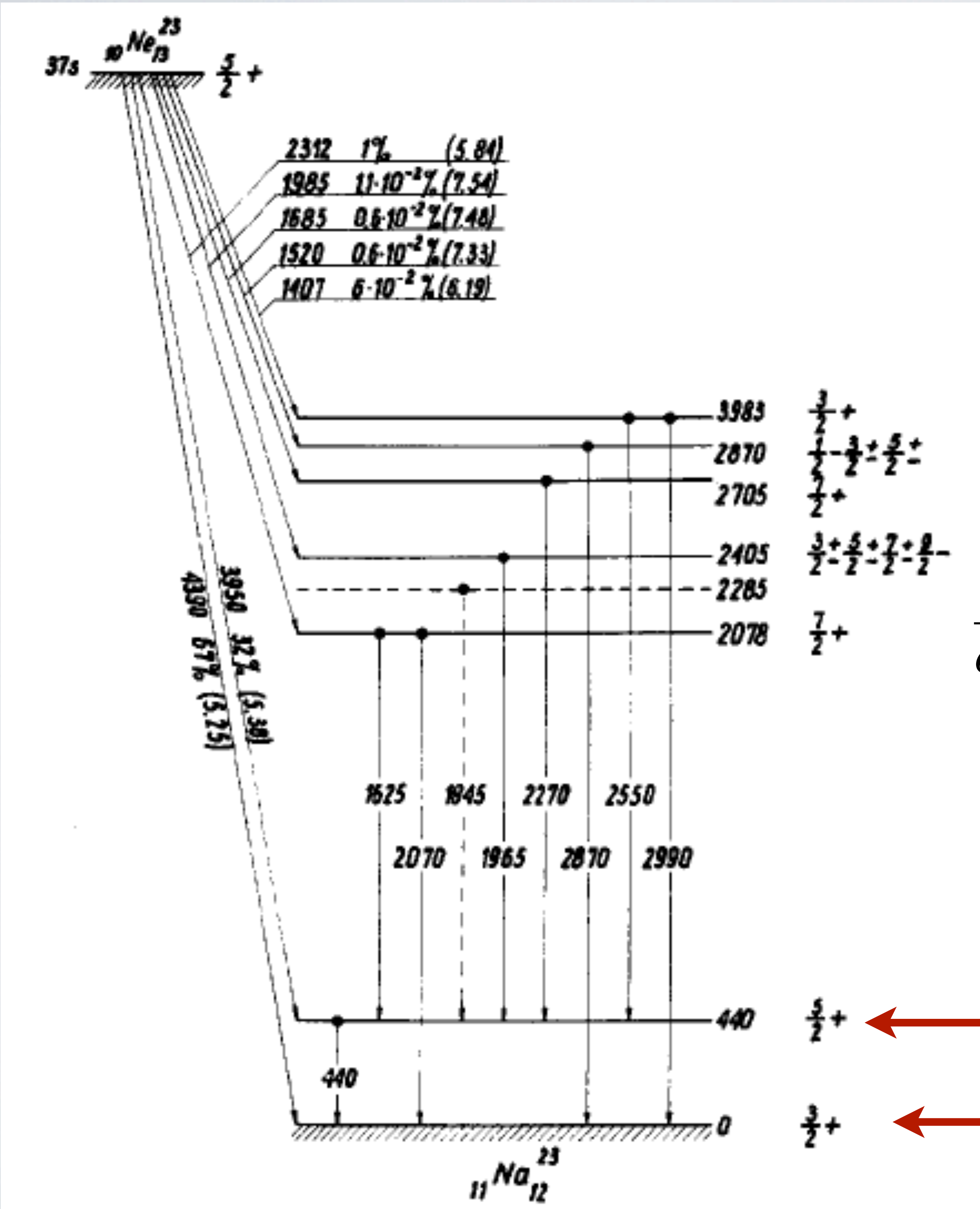
$$\frac{d\Gamma}{dE_\beta d\Omega_\beta d\Omega_\nu} \propto \xi \left\{ 1 + a\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + b\frac{m}{E_e} \right\}$$

Borromean

Only light proton Borromean nucleus



Why ^{23}Ne?



$$\frac{d\Gamma}{dE_\beta d\Omega_\beta d\Omega_\nu} \propto \xi \left\{ 1 + a\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + b\frac{m}{E_e} \right\}$$

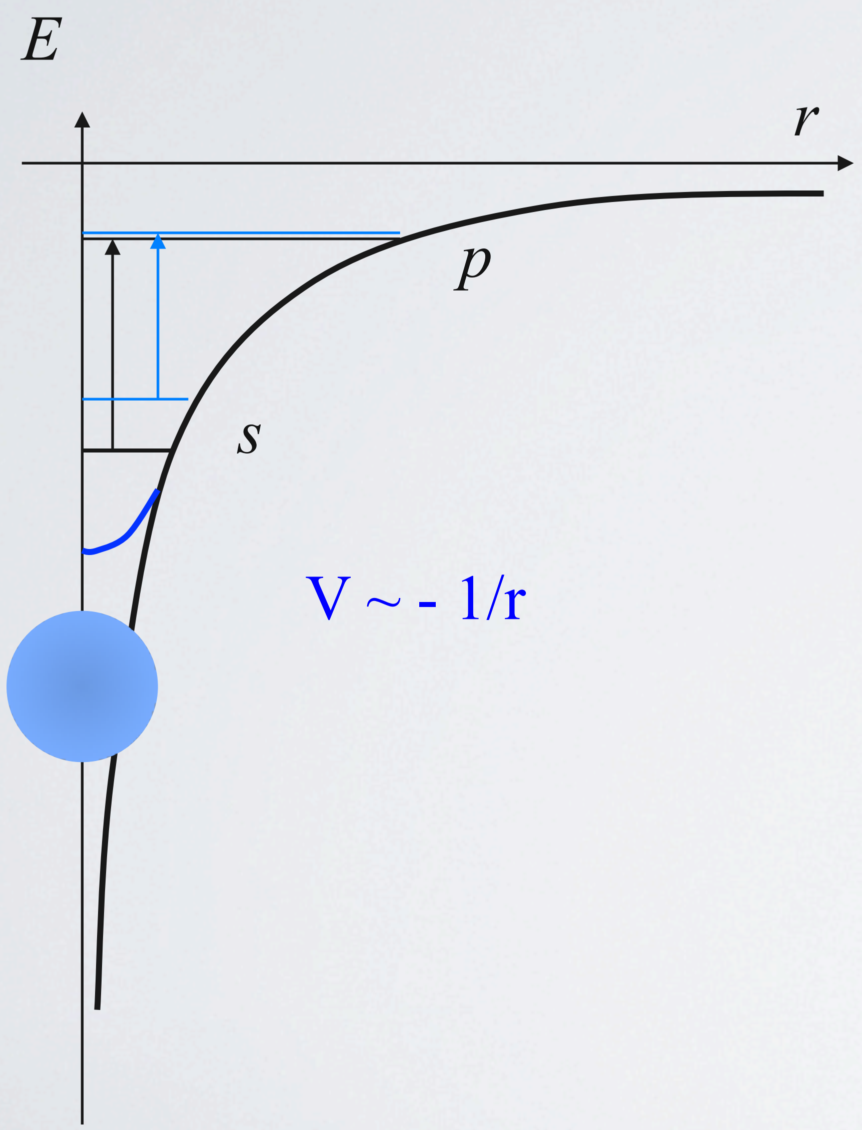
Almost Pure GT Decay

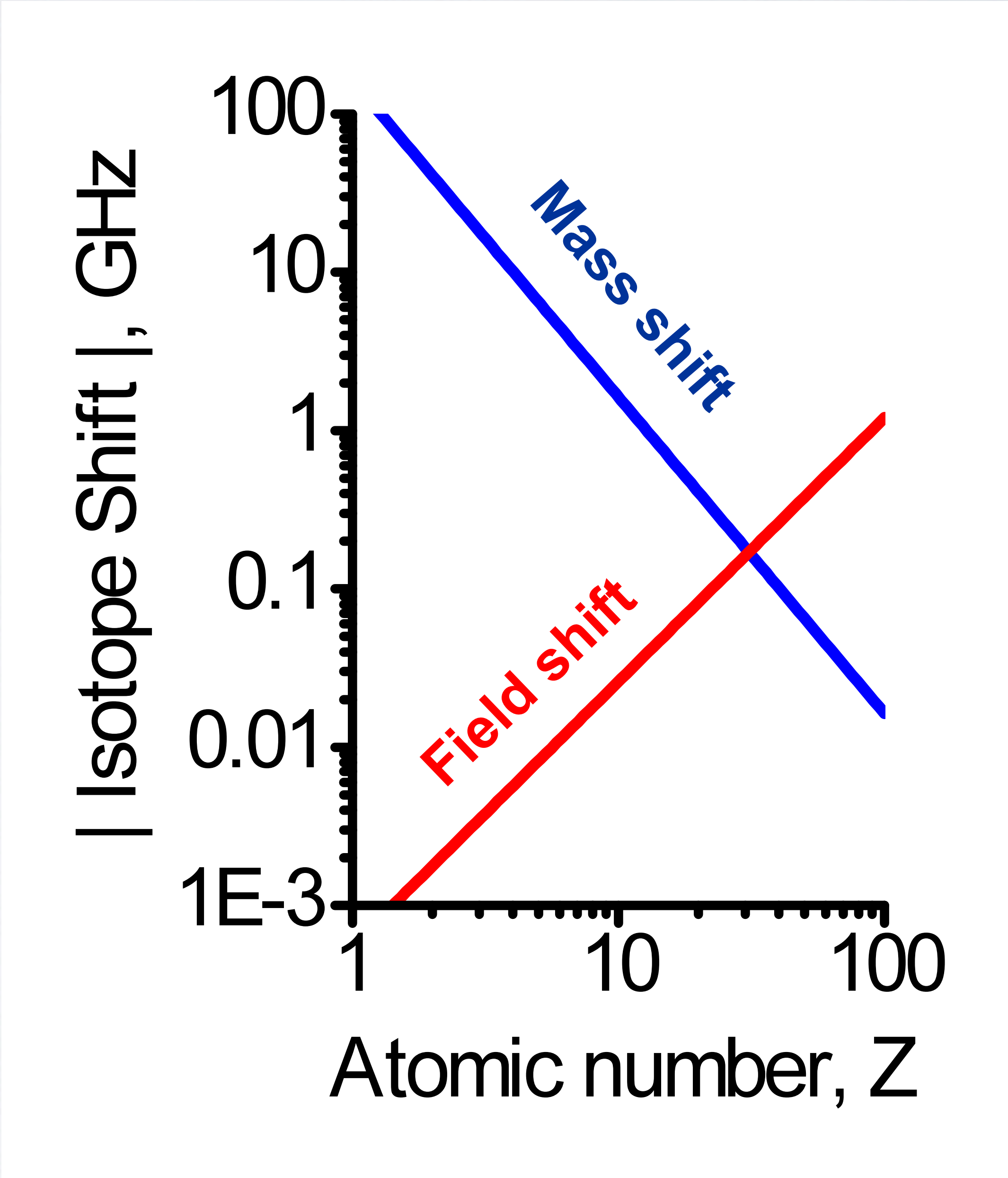
Pure GT Decay

Nuclear Structure Tests with Trapped Neon Isotopes

Isotope Shifts

$$\delta\nu_{FS} = -\frac{2\pi}{3} Ze^2 \cdot \Delta\left|\psi(0)\right|^2 \cdot \delta\left\langle r^2\right\rangle^{AA'}$$





Isotope Shift (Energy Level Change)

$$\delta\nu = \delta\nu_{FS} + \delta\nu_{MS}$$

Nuclear Size

$$\propto Z \cdot \delta \langle r^2 \rangle$$

CM Motion

$$\propto \frac{A - A'}{AA'}$$

Neon vs. Helium *(Mueller et al.)* Mass Shift

Isotope	$(A'-A_{20})/(A_{20}A')$
^{17}Ne	-0.0088
^{18}Ne	-0.0055
^{19}Ne	-0.0026
^{21}Ne	0.0023
^{22}Ne	0.0045
^{23}Ne	0.0065

Isotope	$(A'-A_{20})/(A_{20}A')$
^{6}He	0.0833
^{8}He	0.125

- Sign change in Mass Shift.
- Effect ~10 times smaller, better control on change in r^2.
- Harder to calculate for A>12.
- But more cases (and 3 stable).

It’s not all fun and games

It's not all fun and games

- Neon trapping only in the excited metastable Ne^* state.
- RF discharge/electron beam excitation typically gives 10^{-5} - 10^{-6} efficiency.
- Neon trapping uses difficult wavelength (640nm).

It's not all fun and games

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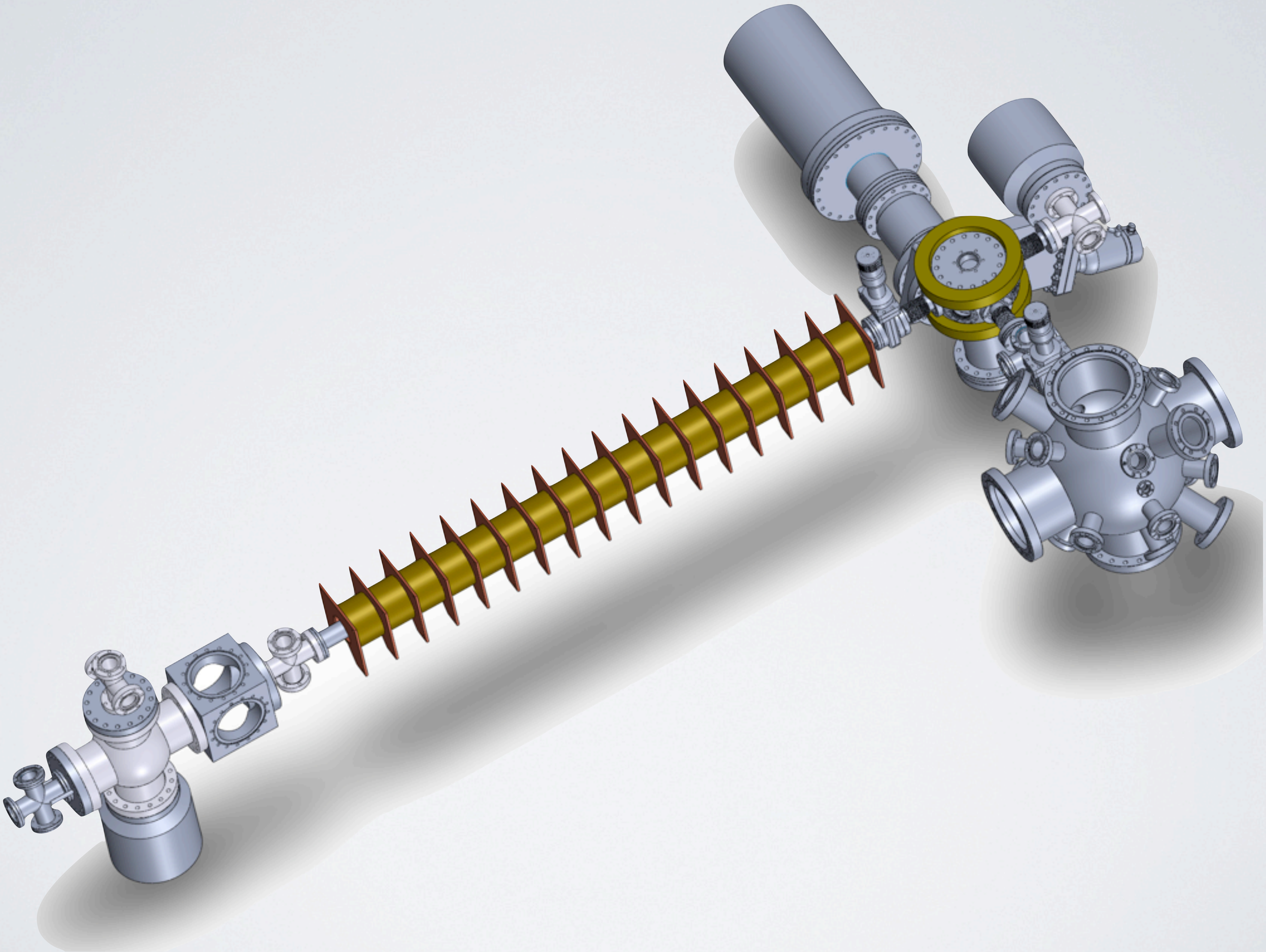
But....

- Even numbers isotopes have no hyperfine splitting (single laser trapping) + Simple polarizing scheme for most odd isotopes (I=1/2).
- Destructive probing of metastable beam is easy.
- Transport of noble gas from production target relatively simple (diffusion).
- Many isotopes to probe.
- Many combinations of coefficients -> many constraints on phase space.
- TOF calibration using Penning/Associative ionization

$$Ne^* + Ne^* \rightarrow Ne + Ne^+ + e^-$$
$$Ne^* + Ne^* \rightarrow Ne_2^+ + e^-$$

Some Technical Aspects



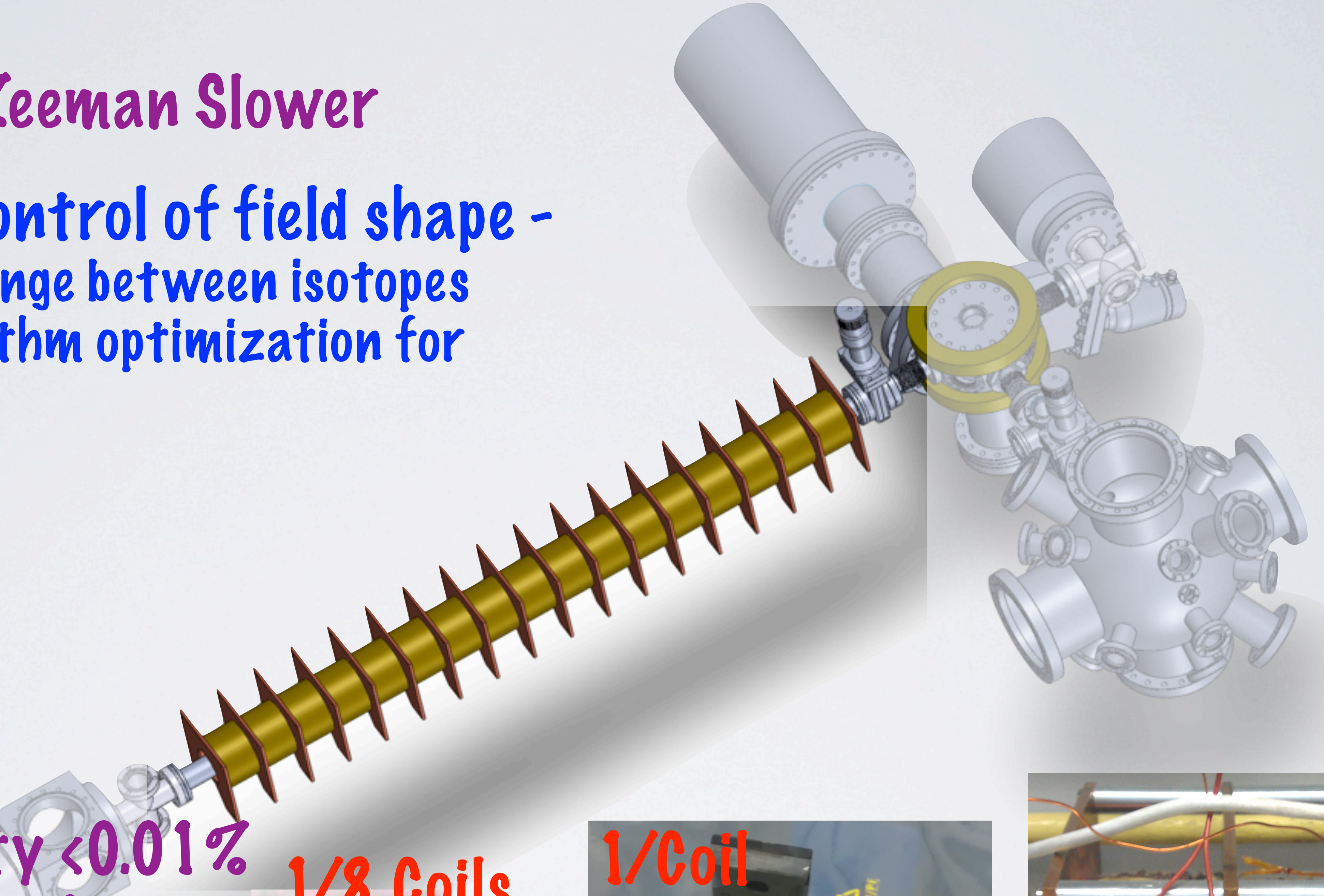
Some Technical Aspects - I

Multi-Coil Zeeman Slower

Computer control of field shape -

On the fly change between isotopes

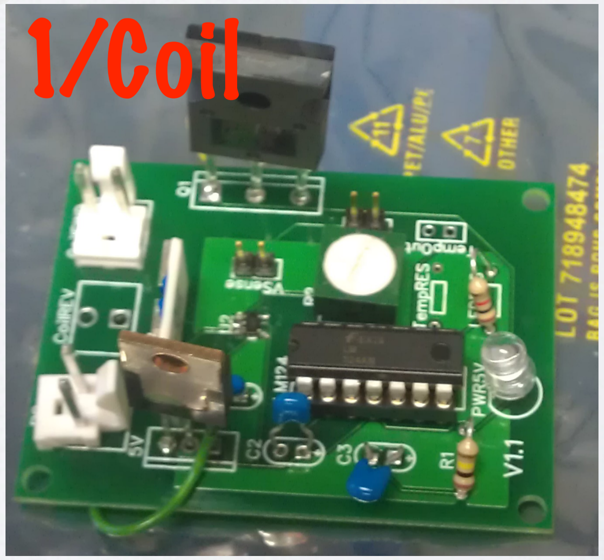
Genetic algorithm optimization for velocity/flux



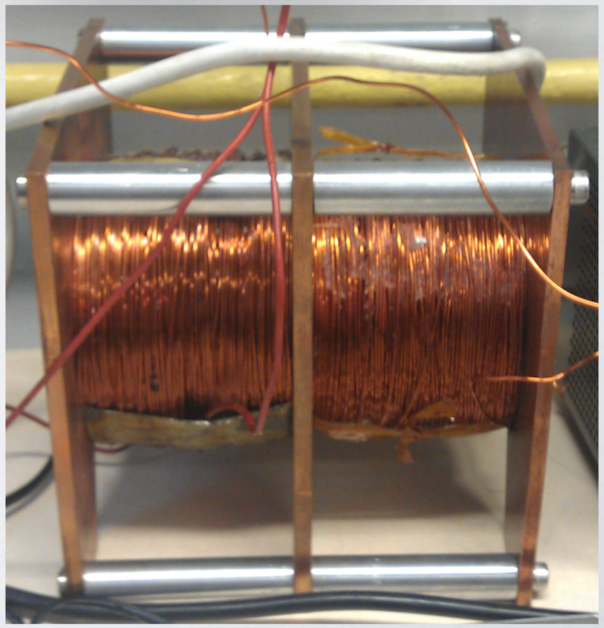
Field stability <0.01% easily achieved

1-2 System

1/8 Coils



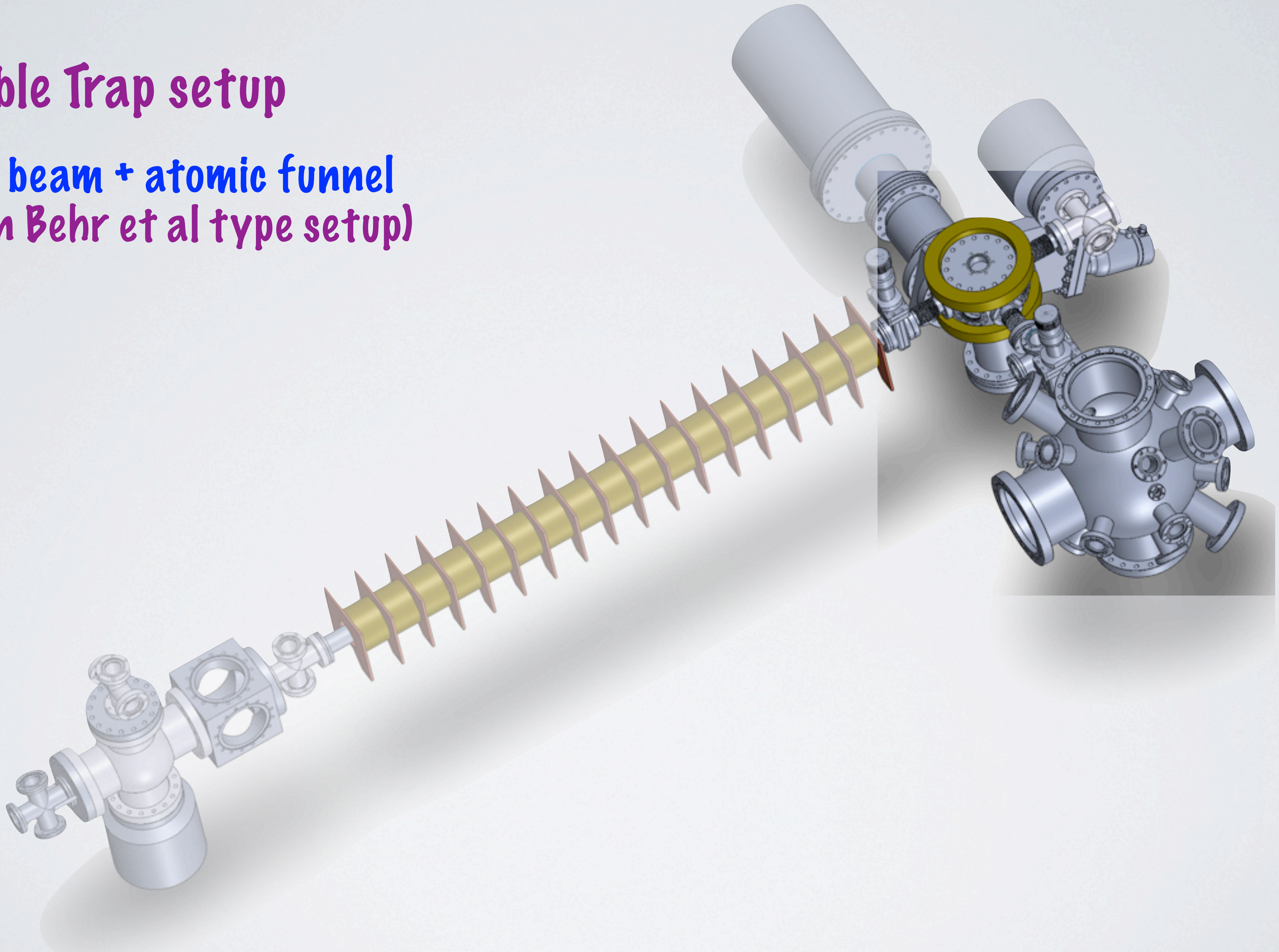
1/Coil



Some Technical Aspects - II

Double Trap setup

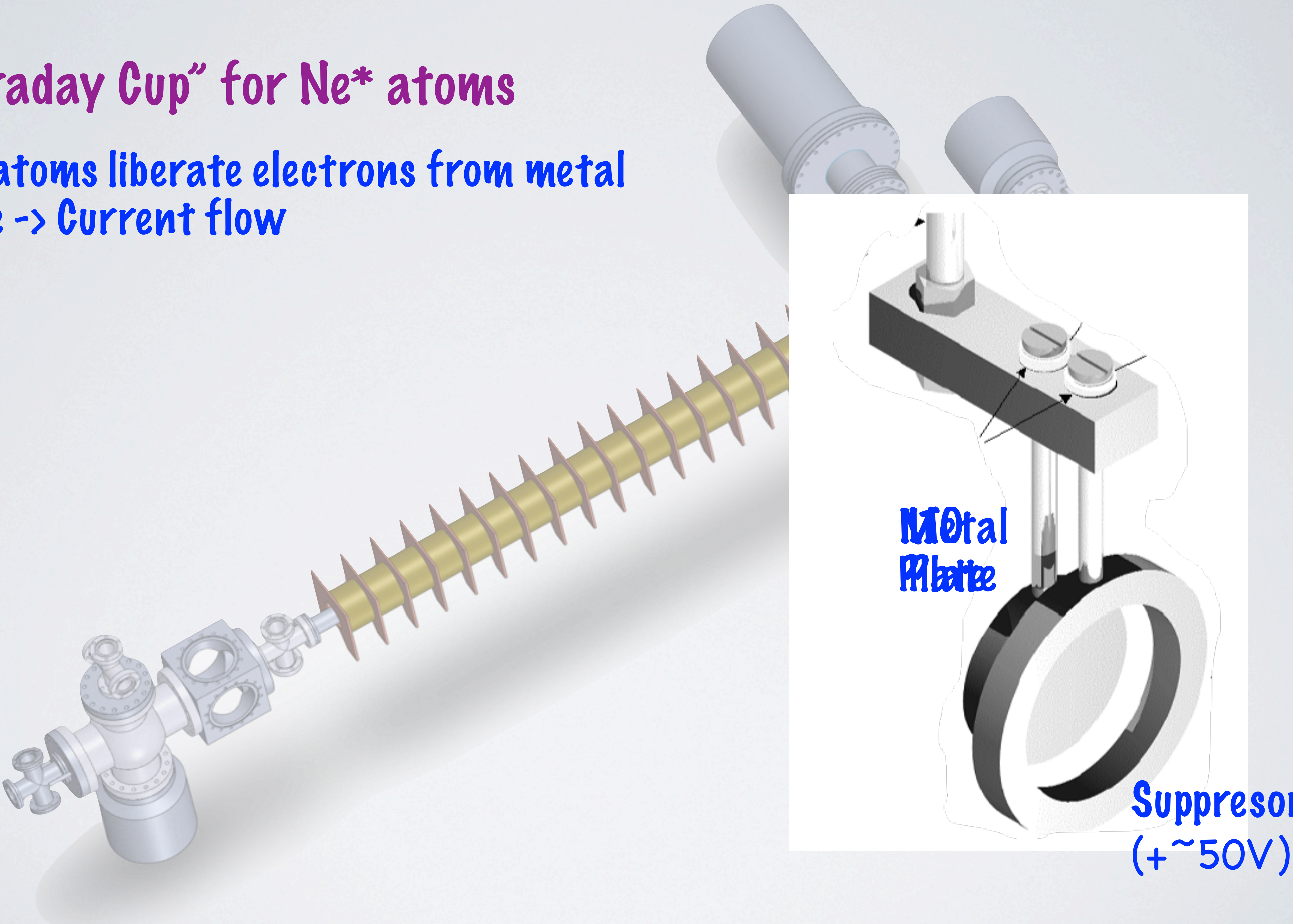
Push beam + atomic funnel
(John Behr et al type setup)



Some Technical Aspects - III

"Faraday Cup" for Ne* atoms

Ne* atoms liberate electrons from metal plate -> Current flow

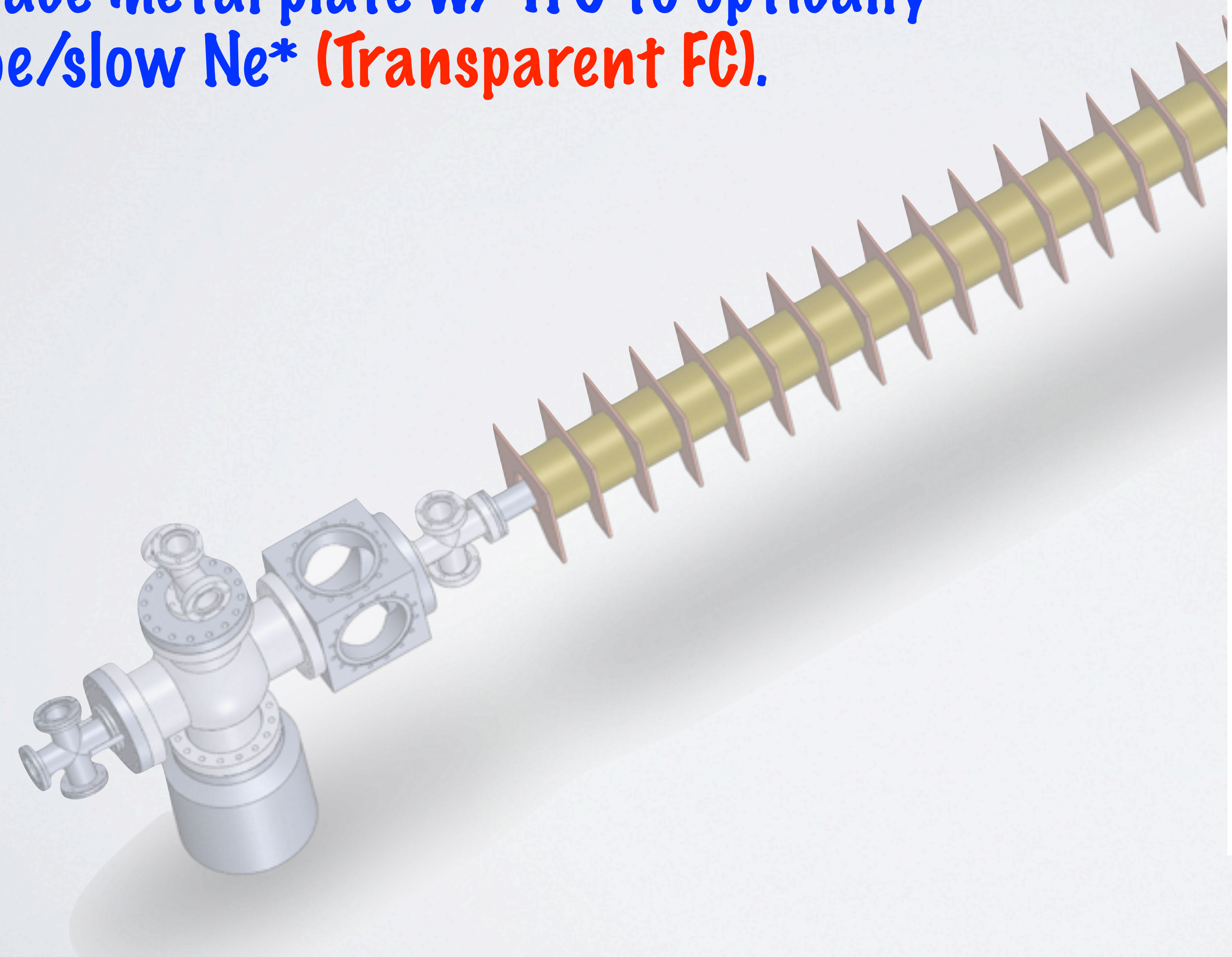


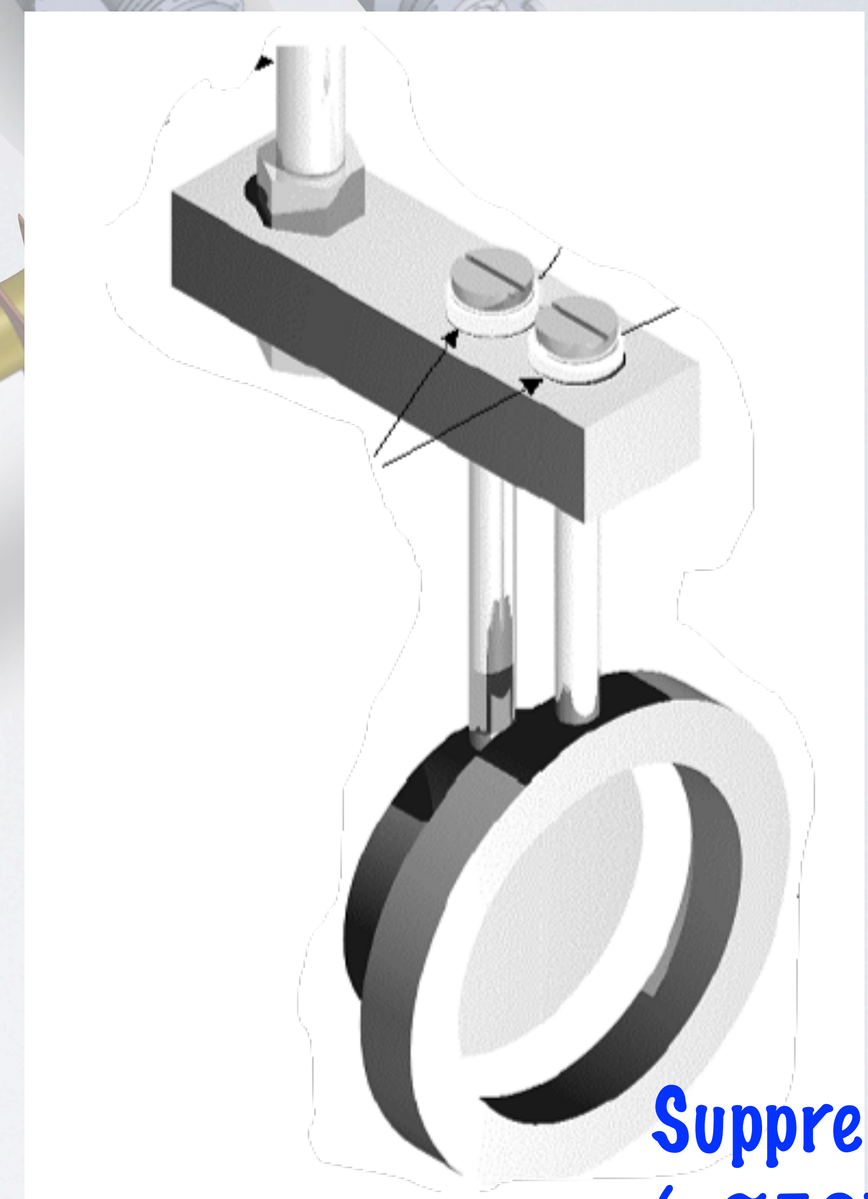
Some Technical Aspects - III

"Faraday Cup" for Ne* atoms

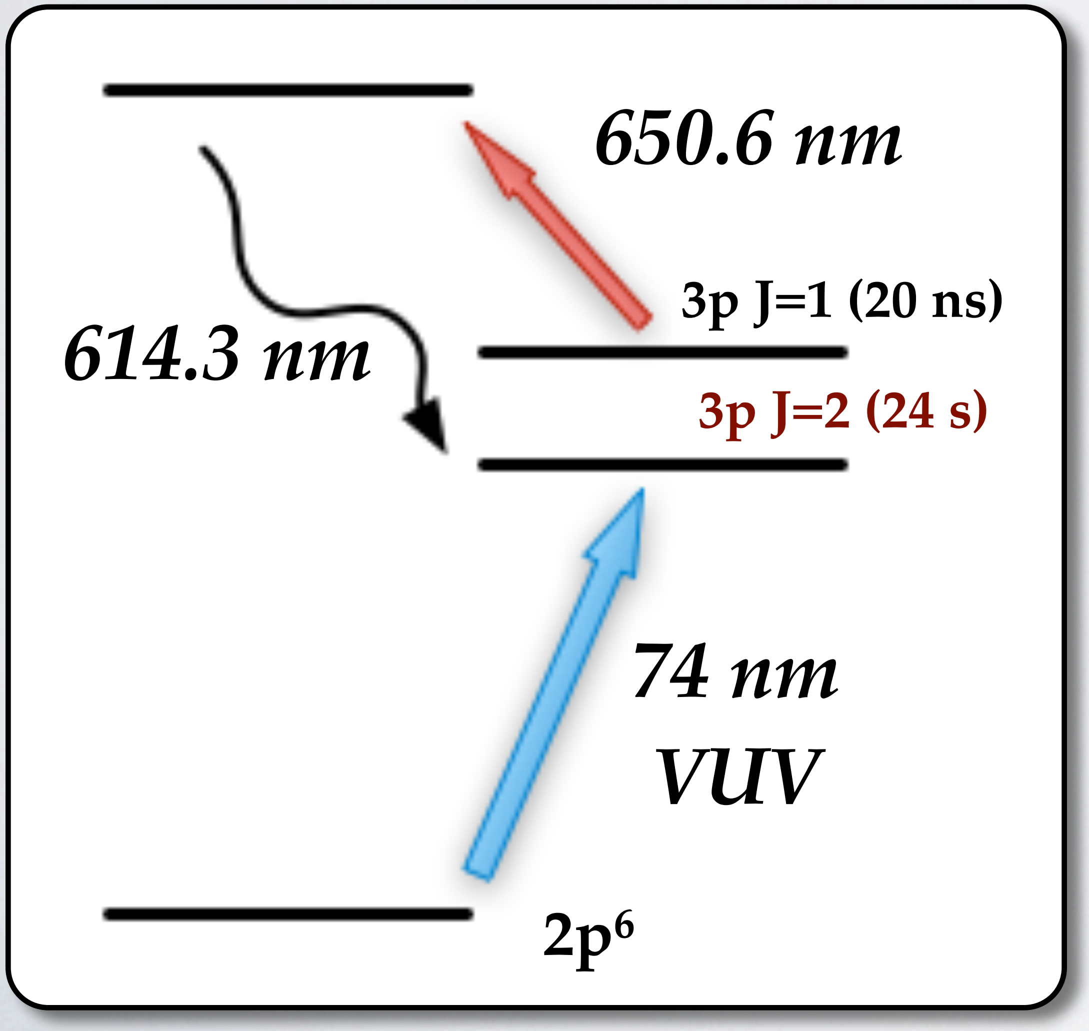
Ne* atoms liberate electrons from metal plate -> Current flow

Replace metal plate w/ ITO to optically probe/slow Ne* (Transparent FC).





Neon is Nice But....
(Technical Aspect - IV)



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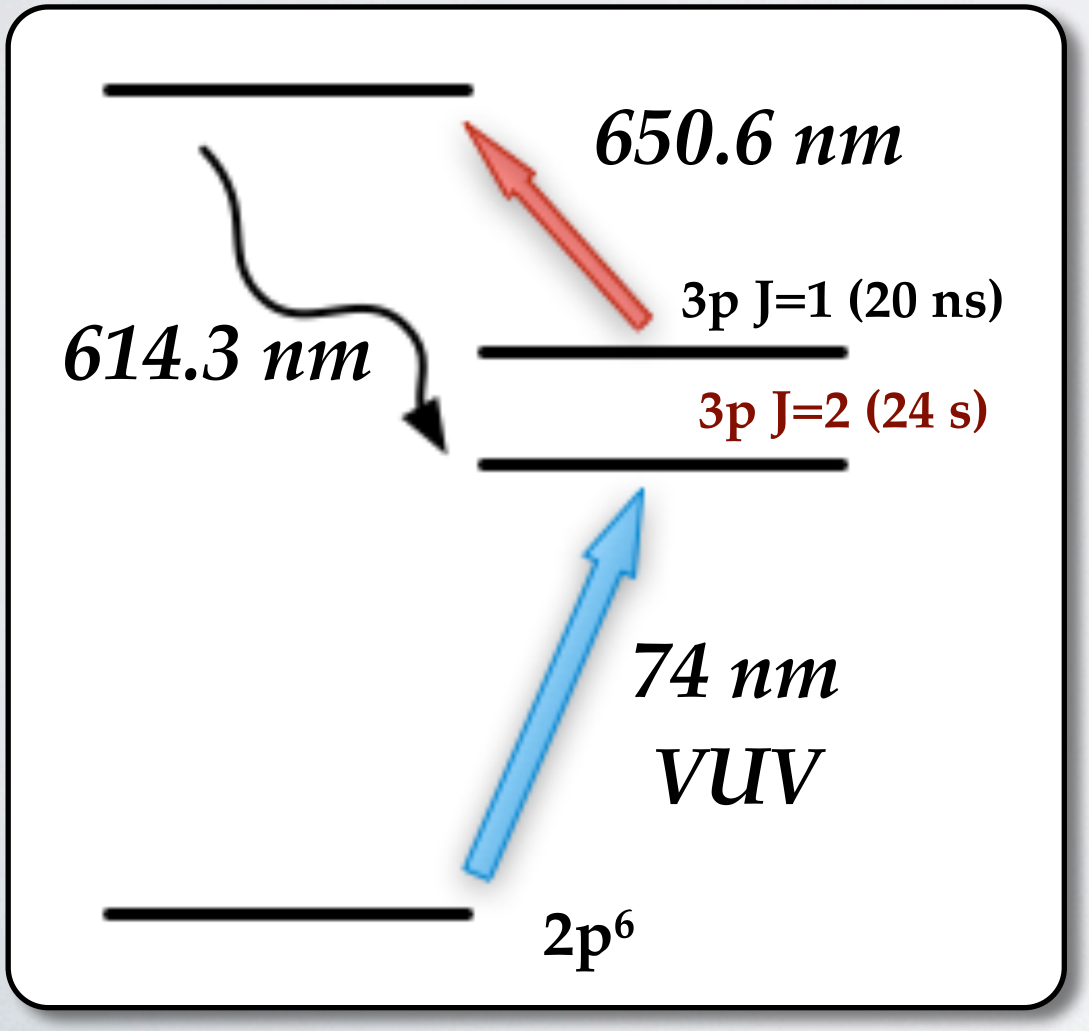

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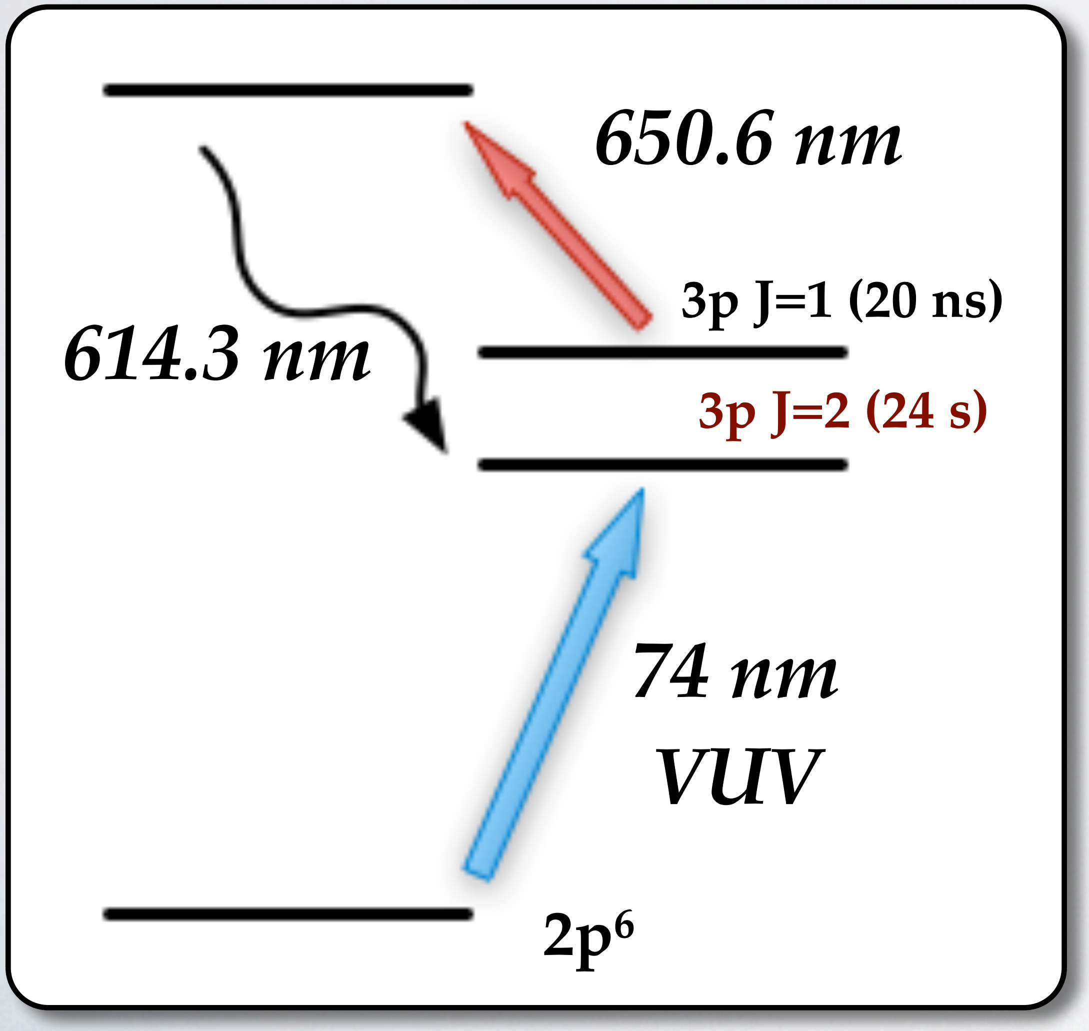
Possible solution (based in work at ANL for Kr/Ar)

All optical excitation



- 2 photon excitation and spontaneous decay into metastable (long lived) state.
- ^{18}Ne has same level structure as stable ^{20}Ne, some complications with ^{19}Ne.
- Trapping on J=2 → J'=3 transition at 640nm.

Neon is Nice But....
(Technical Aspect - IV)

Predicted improved of 2-3 orders of magnitude in efficiency.

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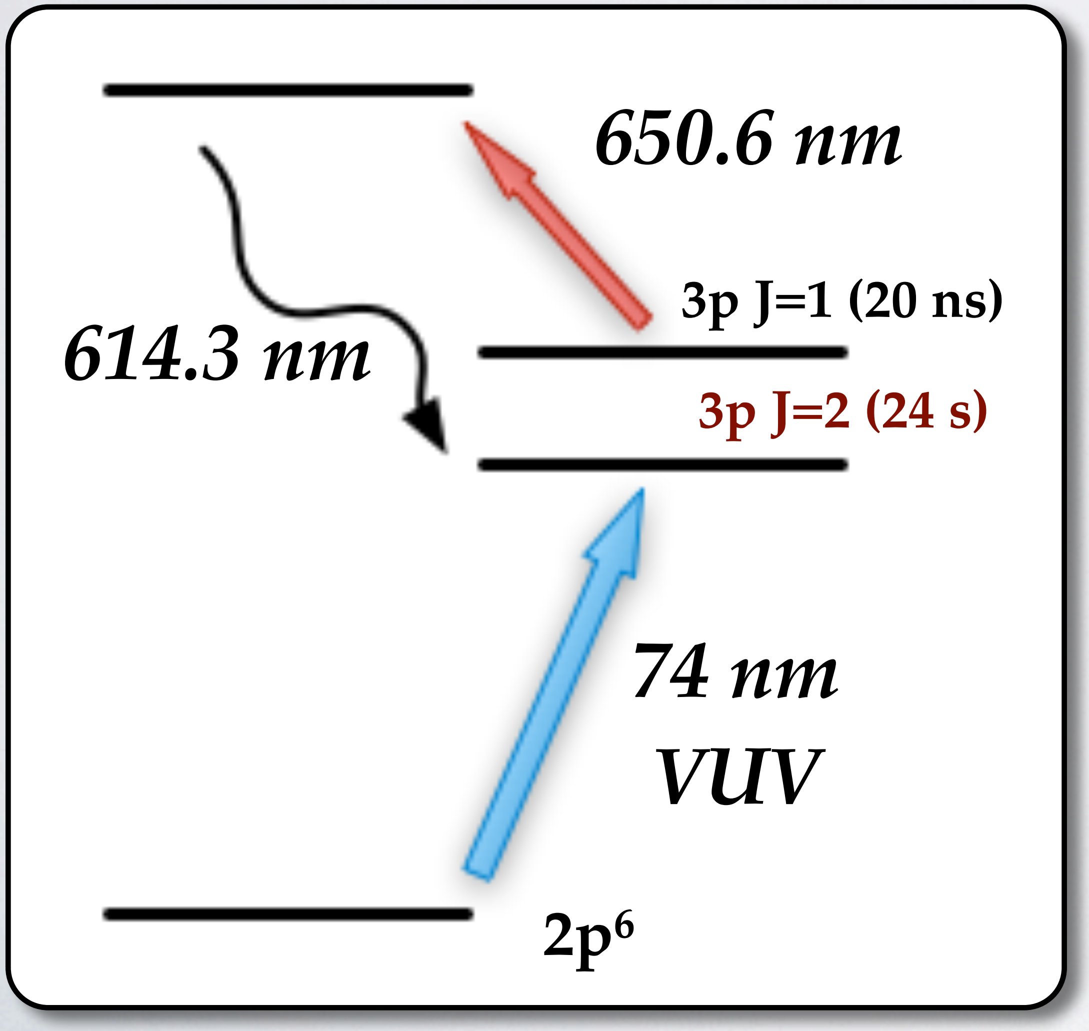

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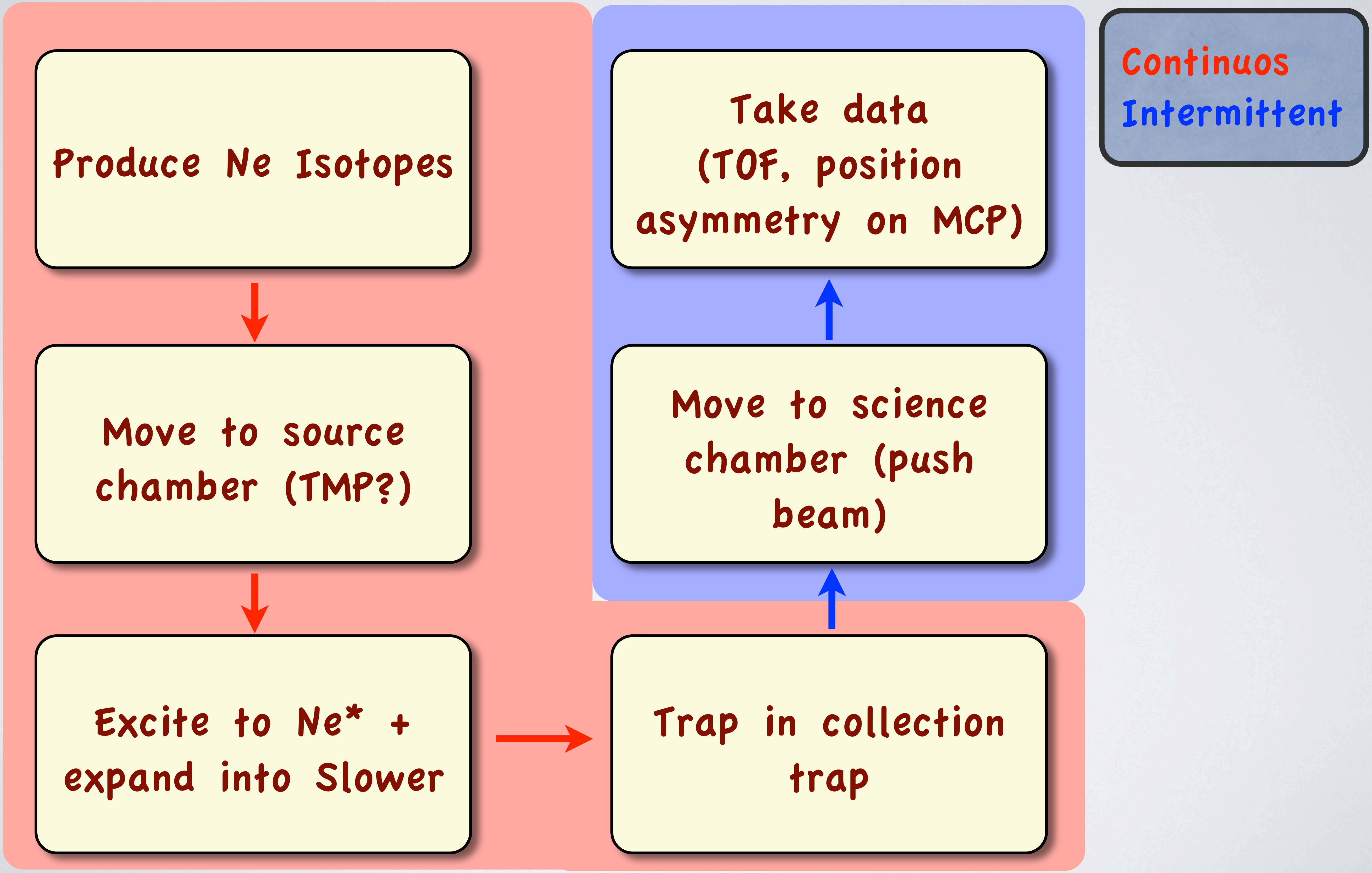
Measurement Scheme

General Scheme



A Brief Aside

Optical traps

- Once cooled and trapped by the MOT, atoms can be trapped by the purely dipole force.

Interaction of laser E field and induced dipole moment:

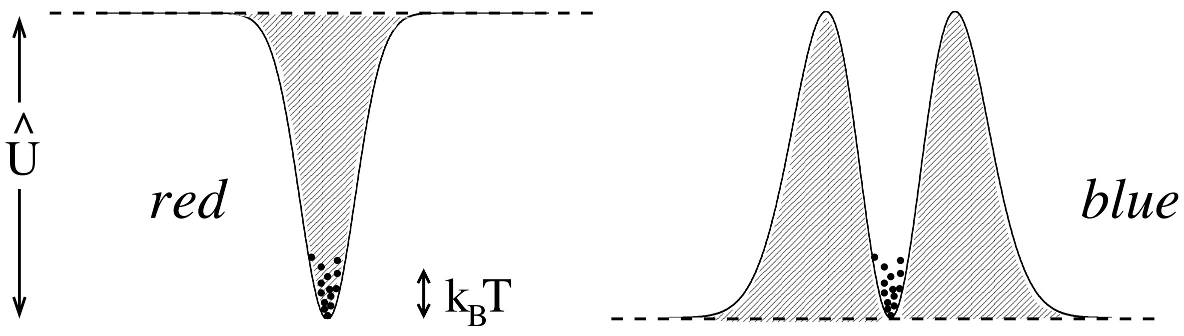
$$\tilde{p} = \alpha \tilde{E}$$

$$U_{dip} = -\frac{1}{2}\langle \mathbf{pE} \rangle$$

$$U_{dip}(\vec{r}) = \frac{3\pi c^2}{2w_0^3}\frac{\Gamma}{\Delta}I(\vec{r})$$

$$\gamma_{sc}(\vec{r}) = \frac{3\pi c^2}{2\hbar w_0^3}\left(\frac{\Gamma}{\Delta}\right)^2 I(\vec{r})$$

$$\Delta = w_{laser} - w_0$$



Red detuned traps are attractive

Blue detuned traps are repulsive

Looking Ahead (Tech V)

Dark Blue Traps

- Currently testing two optical traps (dark cavities surrounded by blue detuned light). Based on designs by Davidson *et al.* (slightly modified).

Friedman, N., Kaplan, A., and Davidson, N. Adv. At. Mol. Opt. Phys., 48:99 (2002).

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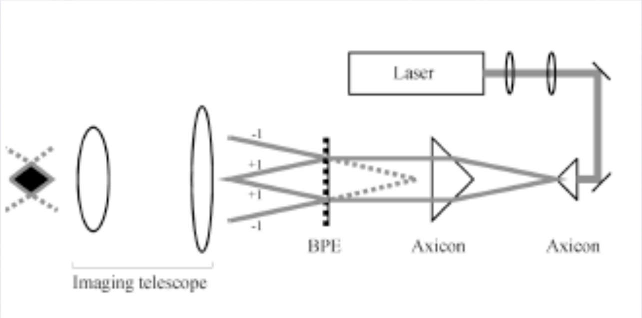
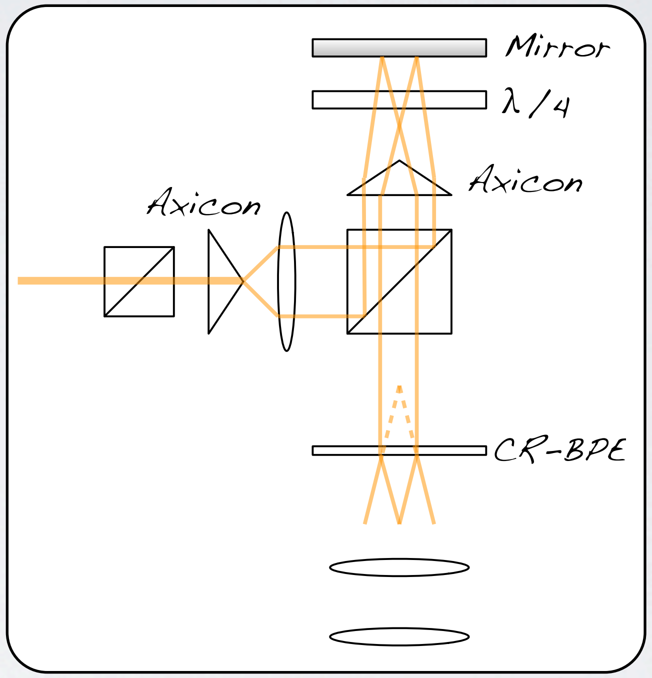
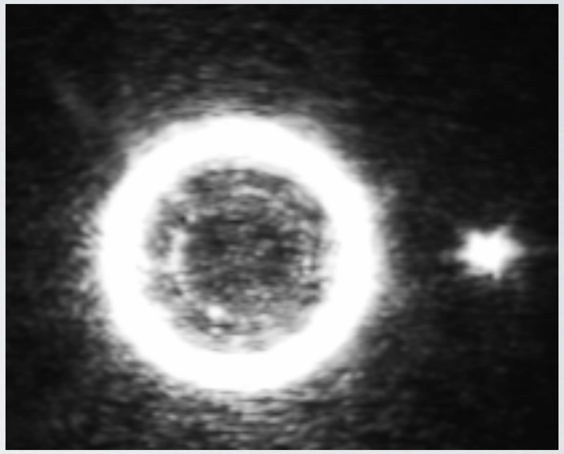
Single beam "axicon" trap







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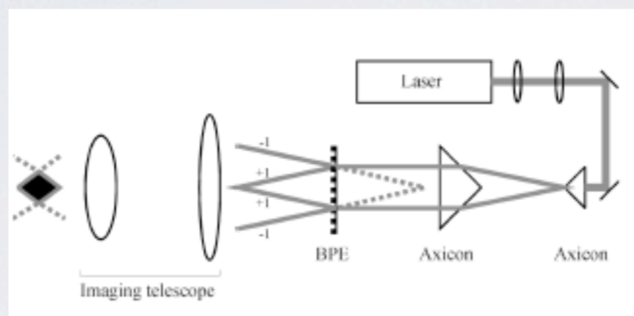
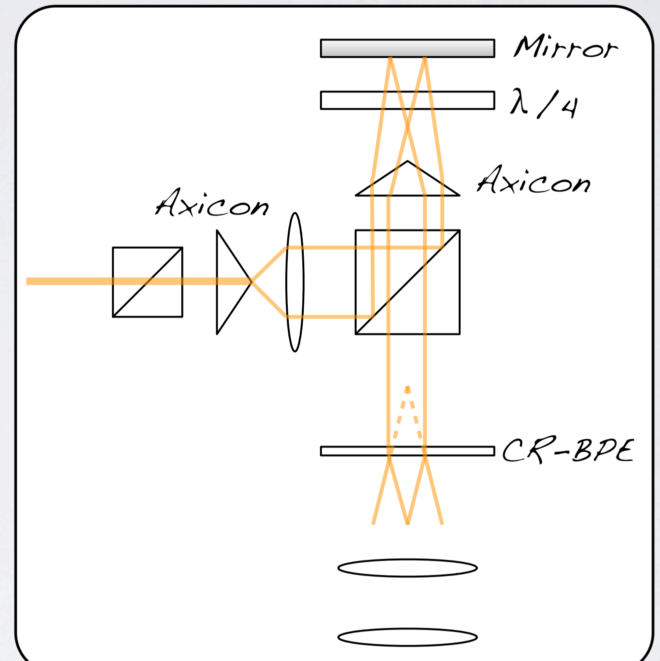
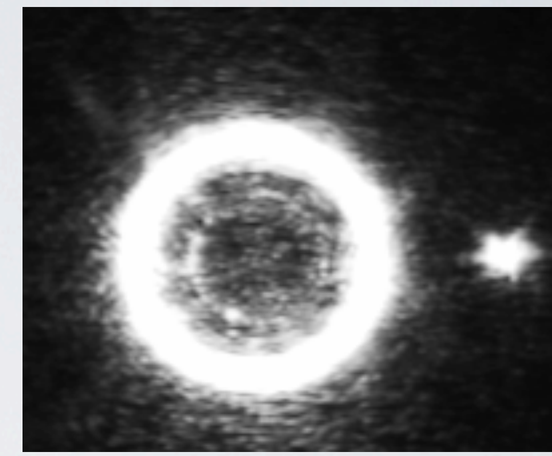
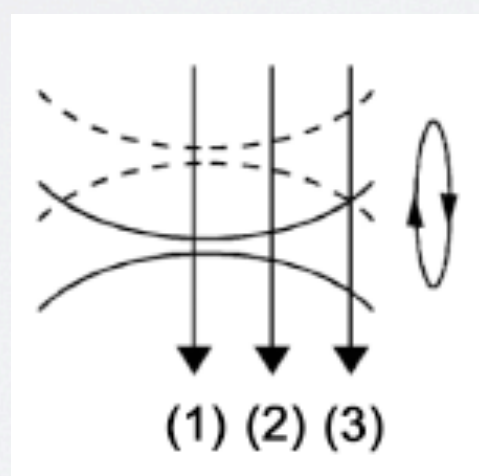
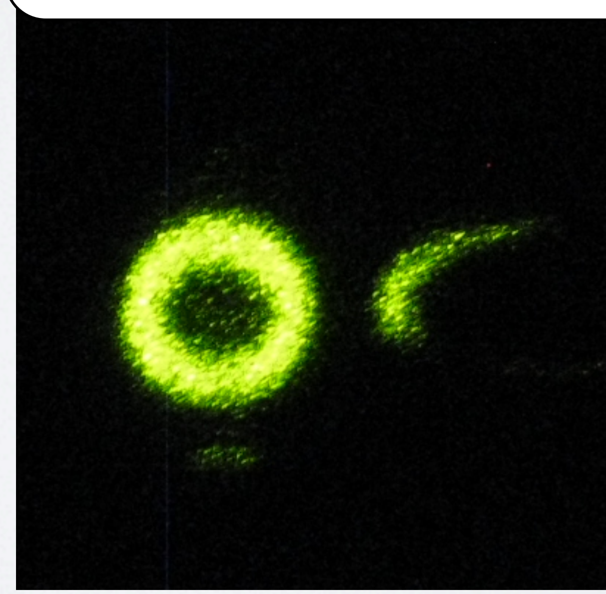


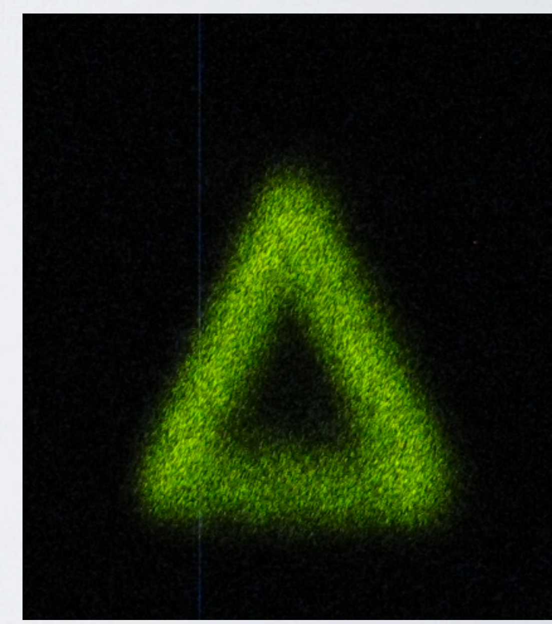




ROtating Beam Optical Trap (but in 2 orthogonal directions)







Digitally controlled

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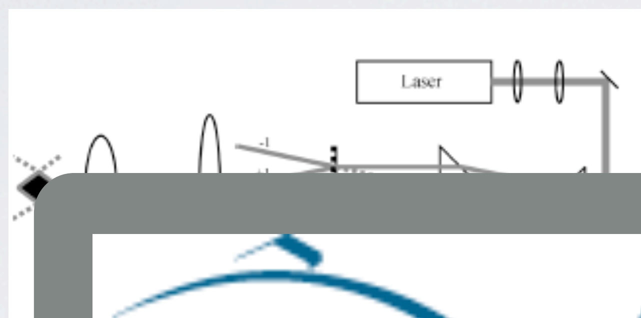

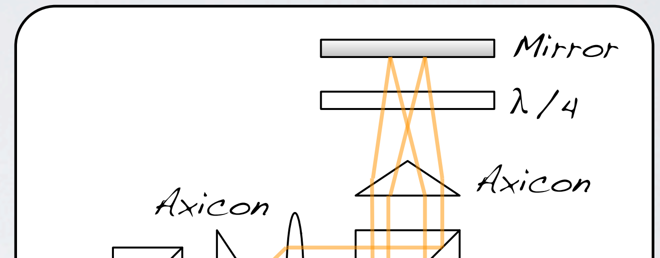

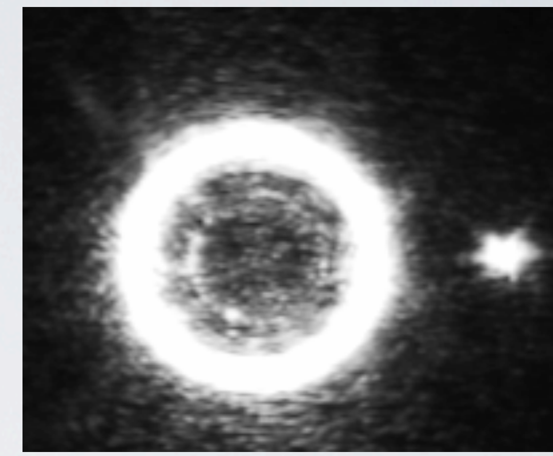

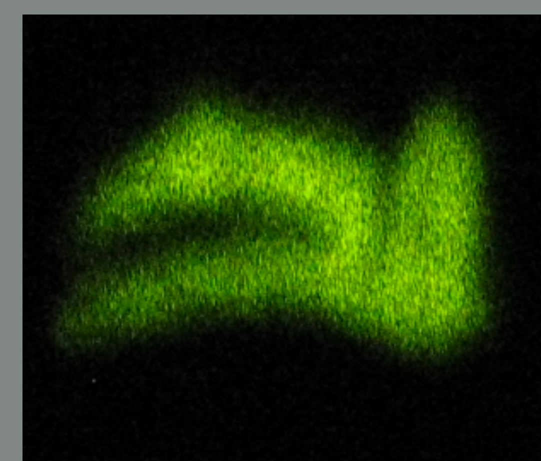

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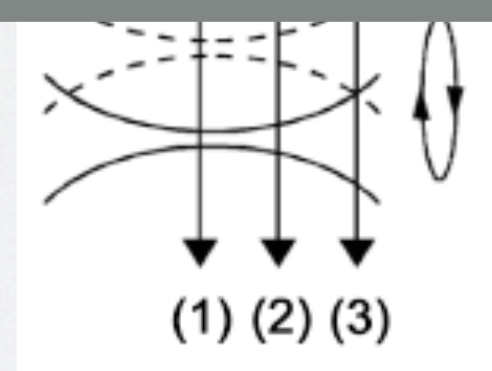

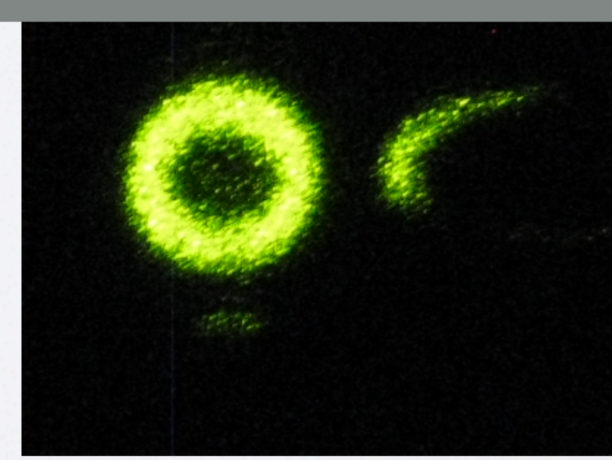

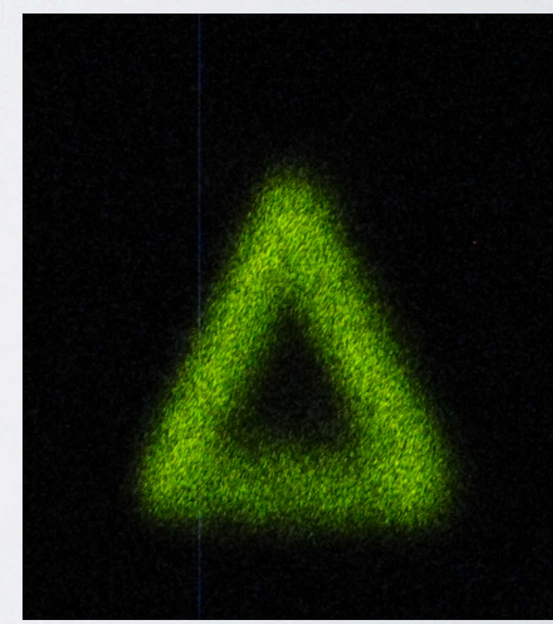

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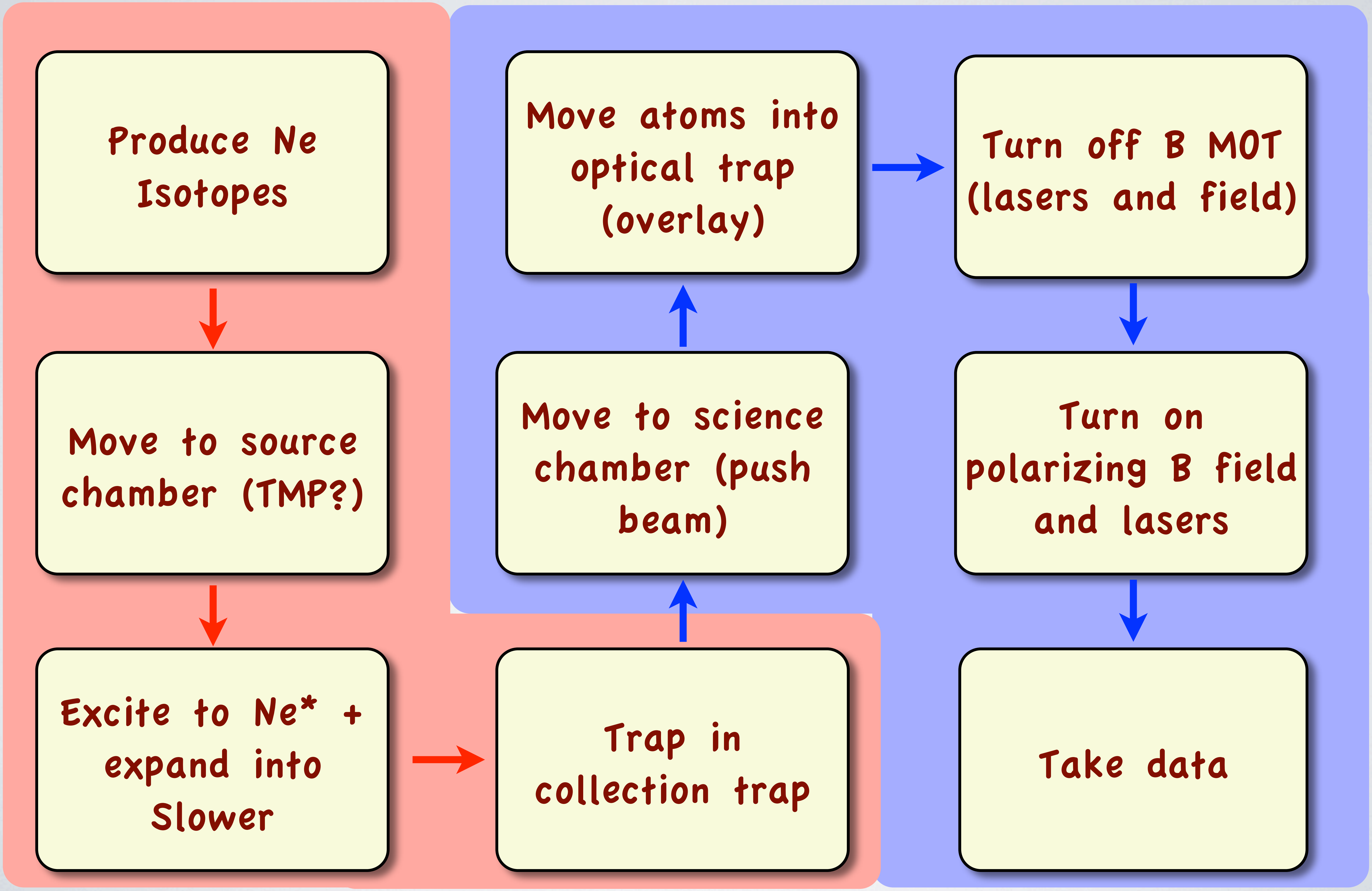
Polarization Measurement

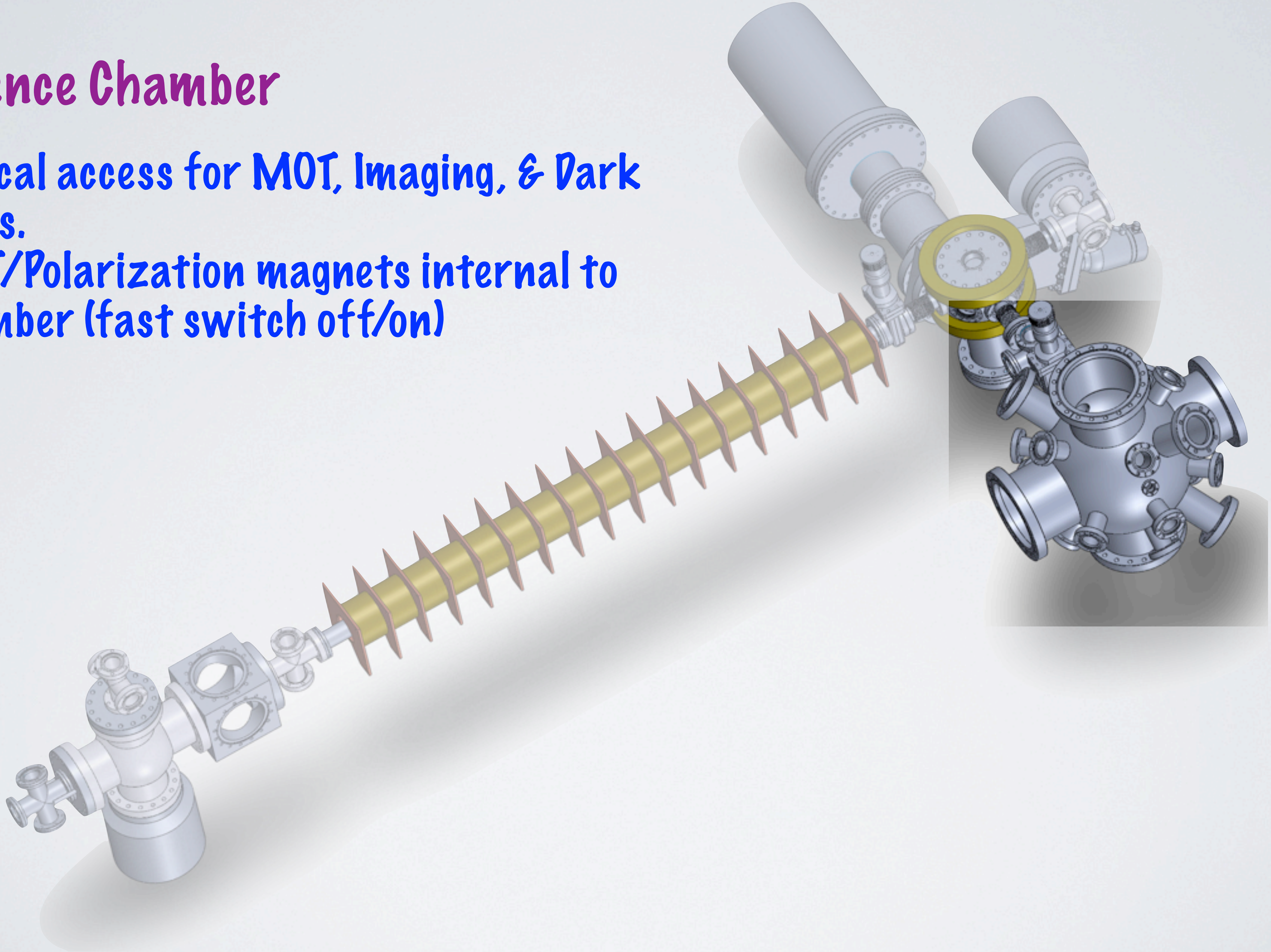
General Scheme



Some Technical Aspects - VI

Science Chamber

Optical access for MOT, Imaging, & Dark traps.
MOT/Polarization magnets internal to chamber (fast switch off/on)



Prospects for Production in Israel

^{17}Ne:

$^{16}O + ^{3}He \rightarrow ^{17}Ne + 2n$ - 26.7 MeV Thershold

$^{19}F + p \rightarrow ^{17}Ne + 3n$ - 36.6 MeV Threshold (LiF Target)

$^{20}Ne + ^{3}He \rightarrow ^{17}Ne + ^{6}He$ - 27 MeV Threshold

^{18}Ne: Explored as a possible source for β beams

$^{19}F + p \rightarrow ^{18}Ne + 2n$

- 13 MeV Protons of LiF target, $3x10^{-5}/p$ (*Takayama (2009)*)

$^{16}O + ^{3}He \rightarrow ^{18}Ne + n$ - 3.2 MeV threshold

$^{20}Ne + p \rightarrow ^{18}Ne + t$ - 20 MeV threshold

^{19}Ne:

$^{20}Ne + n \rightarrow ^{19}Ne + 2n$ - 16.8 MeV threshold

$^{20}Ne + p \rightarrow ^{19}Ne + d$ - 15 MeV Threshold

$^{19}F + p \rightarrow ^{19}Ne + n$

- 4 MeV Threshold
- ($10^{-3}/p$ for thick LiF, *Kitwanga et. al (1990)*).

$^{19}F + ^{3}He \rightarrow ^{19}Ne + t$ - 3.2 MeV Threshold

^{23}Ne:

$^{23}Na + n \rightarrow ^{23}Ne + p$ - 3.7 MeV threshold (neutron production target).

Can this be done in Israel?

SARAF

* New, (very) high current p/d accelerator (5mA/up to 40MeV) under construction at SOREQ.
* Neutron production also possible with Liquid-Li (for eg., but under construction). Talk by M. Hass.

Weizmann Institue

* Neutron generator being purchased.
* Some production schemes may also be possible with the VDG accelerator.

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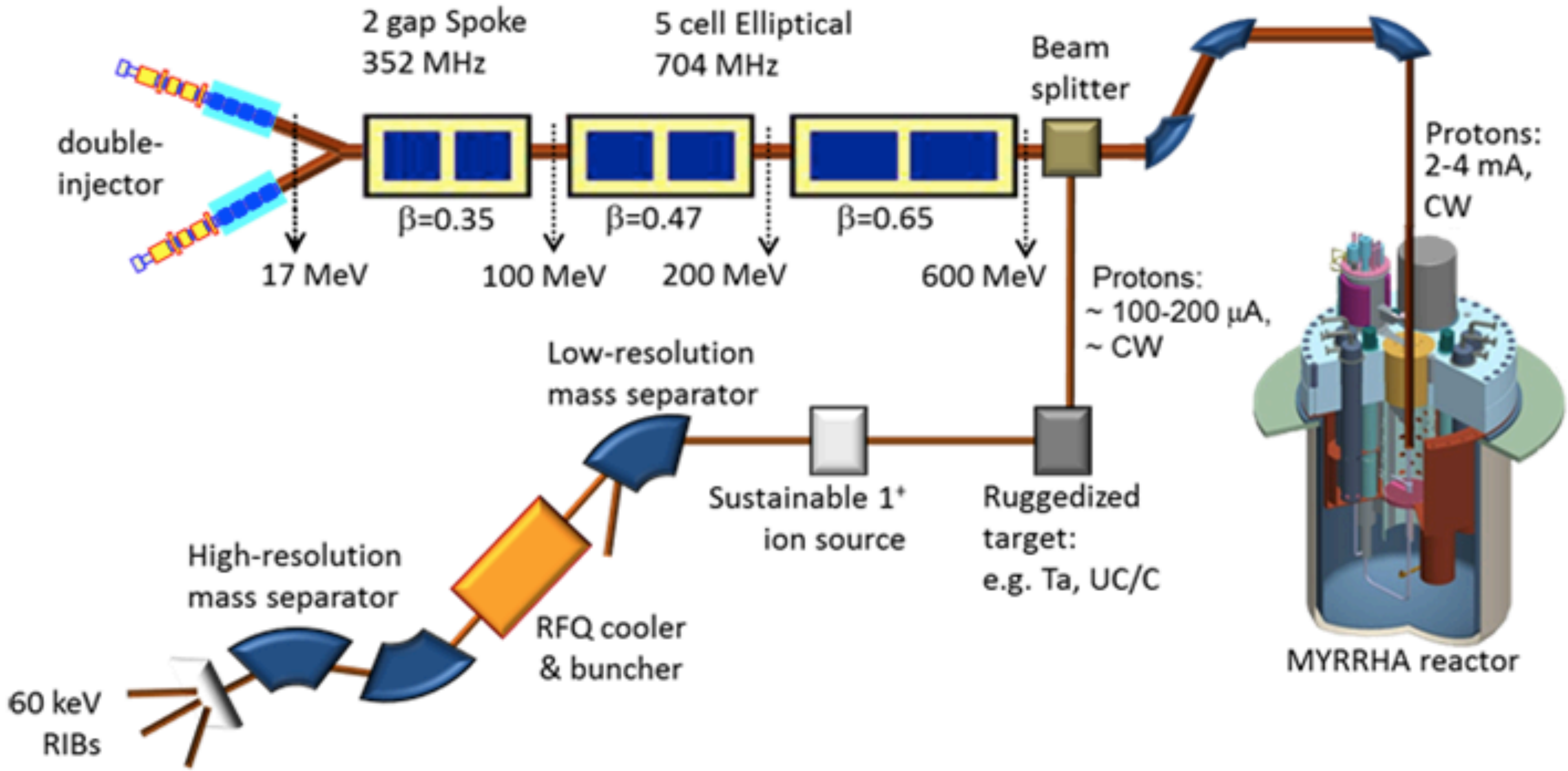
SARAF

VDG

NG

SARAF (Maybe)


2 gap Spoke
352 MHz
5 cell Elliptical
704 MHz
Beam
splitter
double-
injector
β=0.35
β=0.47
β=0.65
17 MeV
100 MeV
200 MeV
600 MeV
Protons:
2-4 mA,
CW
Protons:
~ 100-200 μA,
~ CW
Low-resolution
mass separator
Sustainable 1+
ion source
Ruggedized
target:
e.g. Ta, UC/C
High-resolution
mass separator
RFQ cooler
& buncher
60 keV
RIBs
MYRRHA reactor

Possible Production Schemes @ MYRRHA w/ protons (non-spallation)

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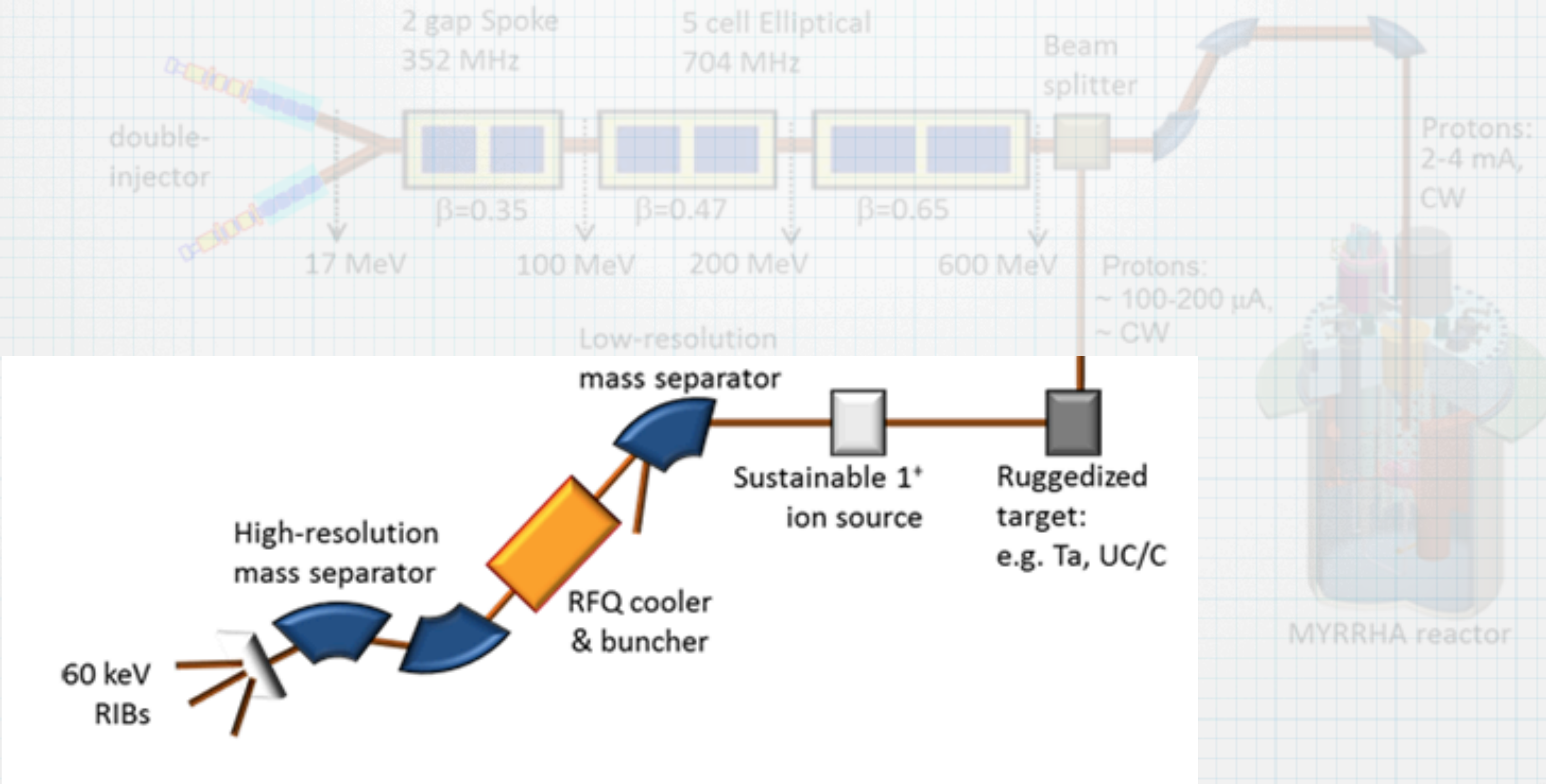
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100 MeV
200 MeV
600 MeV
Protons:
~ 100-200 μA,
~ CW
Low-resolution
mass separator
Sustainable 1+
ion source
Ruggedized
target:
e.g. Ta, UC/C
High-resolution
mass separator
RFQ cooler
& buncher
60 keV
RIBs
MYRRHA reactor

MYRRHA w/ Carbide Target

On-line data							Extrapolation to 100 μA target
Facility	**Target and ion source**	**Ion**	**Mass no. (A)**	**Half-life**	**Beam intensity (μA)**	**Measured yield (ions/s)**	**Estimated yield (ions/s)**
TRIUMF	SiC/C FEBIAD	Ne	17	109 ms	75	1.7E+05	2.3E+05
			18	1.672 s		7.9E+06	1.1E+07
			19	17.34 s		6.9E+07	9.2E+07
			23	37.24 s		4.2E+07	5.6E+07
			24	3.38 min		1.5E+06	2.0E+06
			25	602 ms		3.9E+02	5.2E+02

Other things to do with neon

- Neon EIT (Already have grant for developing this).
- Atomic beam lithography.
- Autoresonance in Ne* MOT.

Summary

- Neon is a interesting candidate for beyond SM search (but this of course was known long ago).
- HUJI has an active program which in aimed at achieving accurate measurements for Ne isotope.
- Productions schemes are possible in Israel (at least some of them are) and are also certainly possible @ MYRRHA.
- We would welcome the opportunity to run @ MYRRHA in a few years.