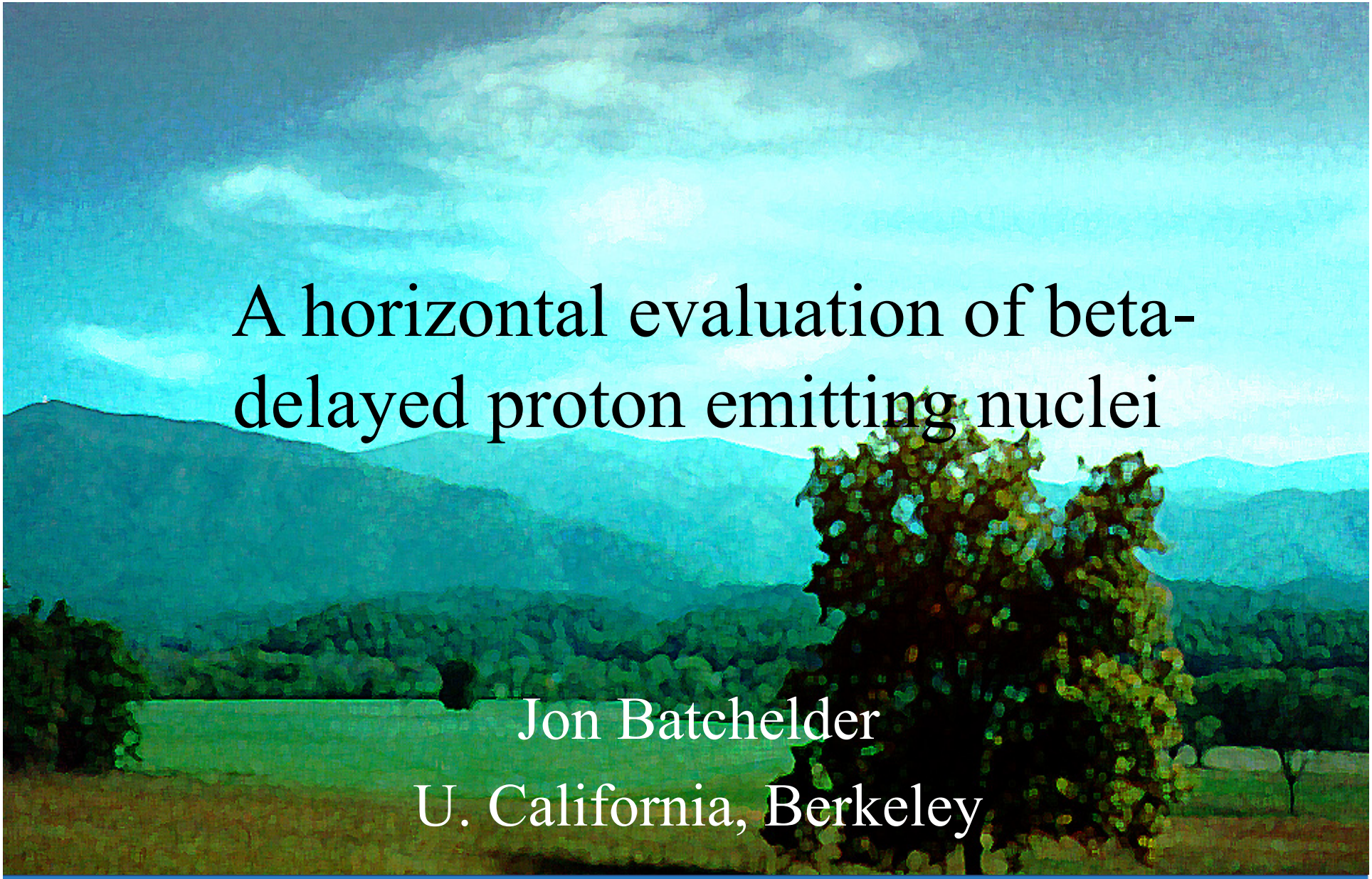


# A horizontal evaluation of beta-delayed proton emitting nuclei

Jon Batchelder
U. California, Berkeley

US National Nuclear Data Week 2015 (CSEWG-NDAC-USNDP-NDAG)

# β – delayed proton emission

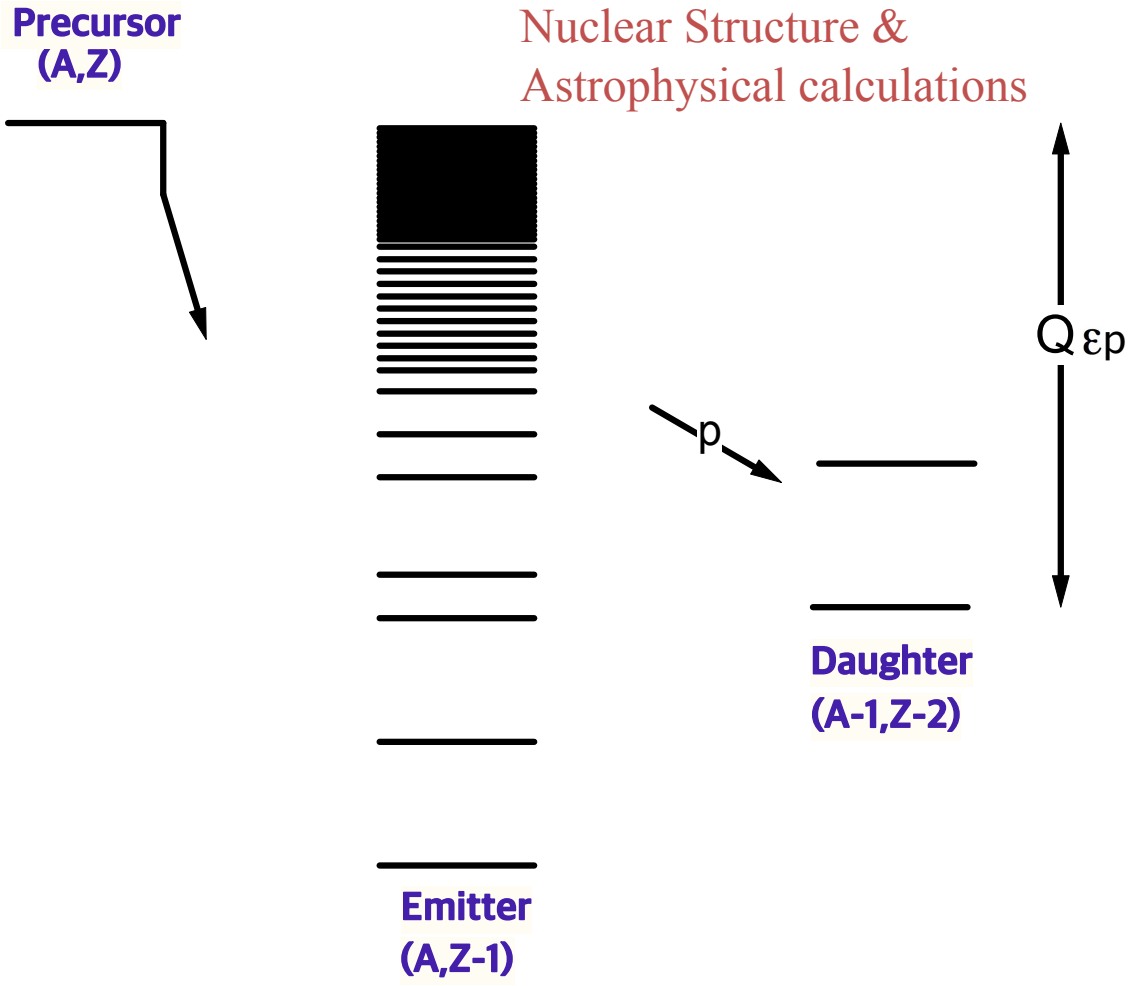
- What is it?
- Why is it important?
- plans/progress
- Last evaluation of β-p was:

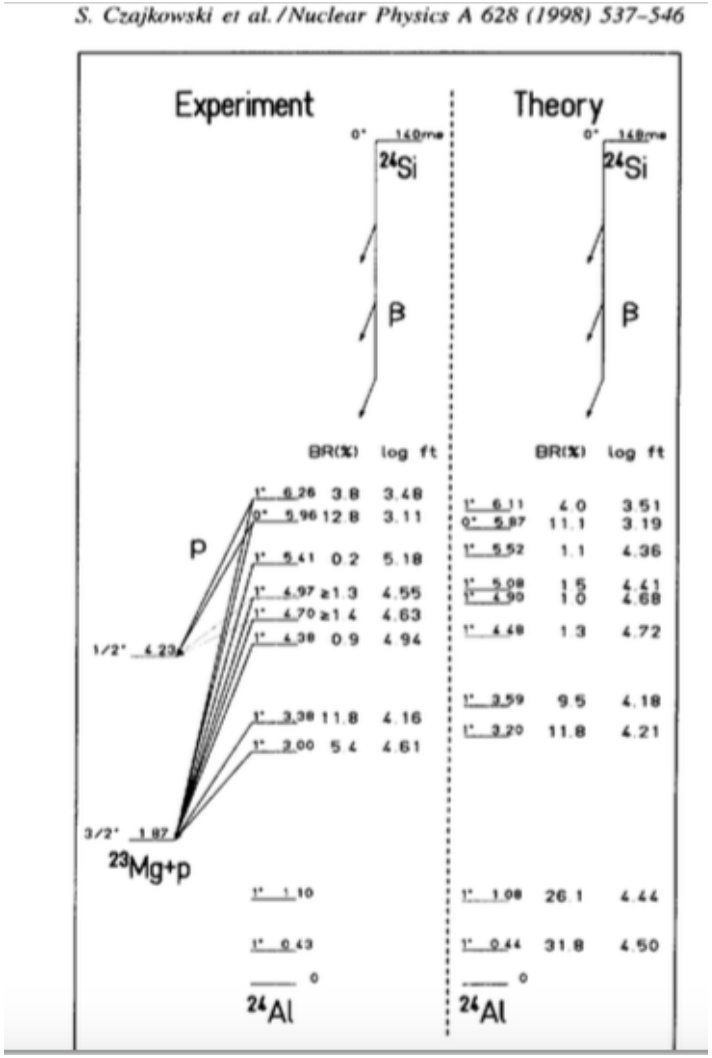
"Delayed Proton Radioactivities" J. Cerny and J. C. Hardy, Ann.Rev.Nucl.Part.Sci. 27, 333 (1977).

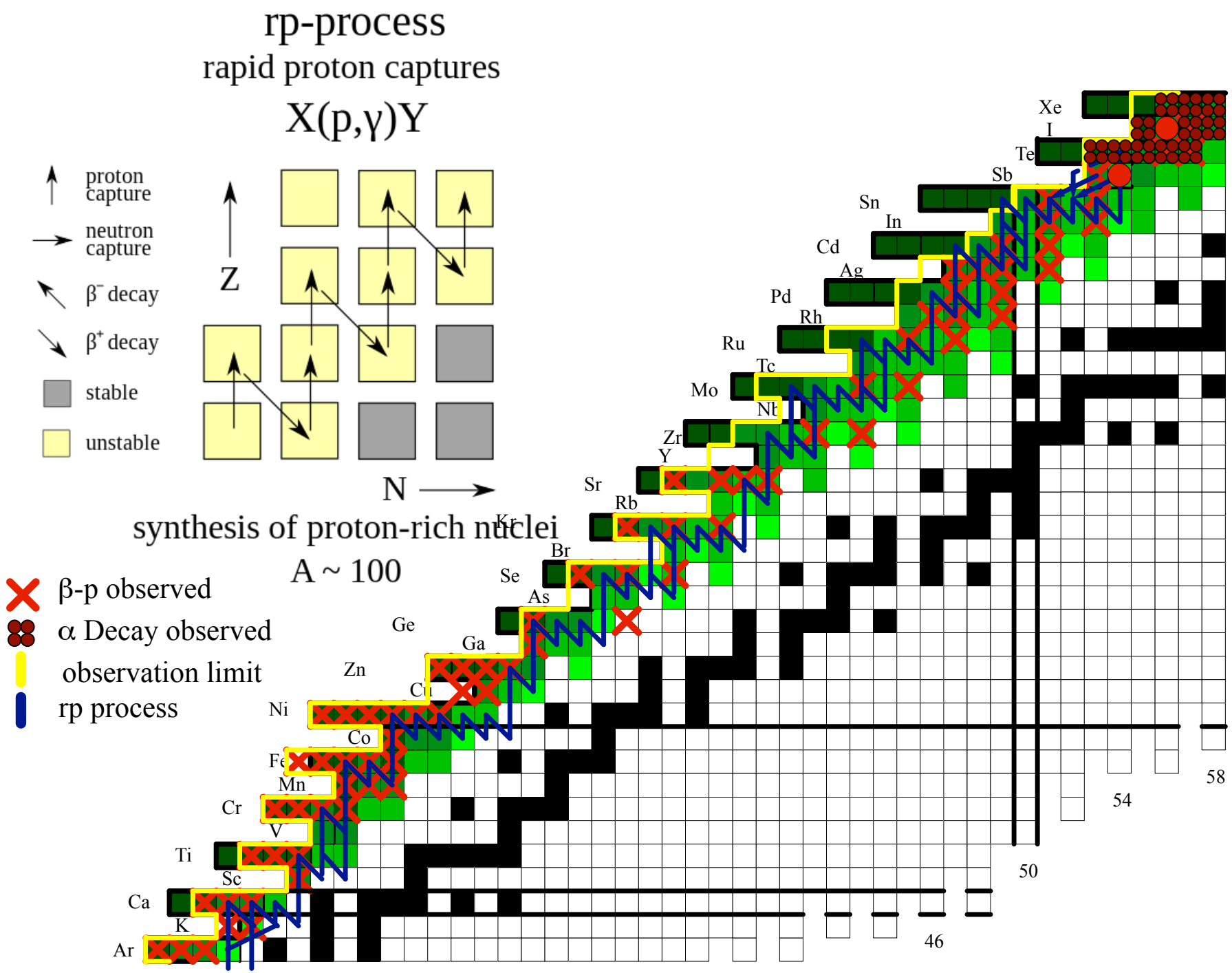
# β-p emission

β-delayed proton emission is a two step process where a nucleus (A, Z) $\beta^-$ decays (or electron capture) to a state in an intermediate precursor nucleus (A, Z-1), then emits a proton from that state to the ground or excited state of the daughter (A-1, Z-2).

Data is important for Nuclear Structure & Astrophysical calculations

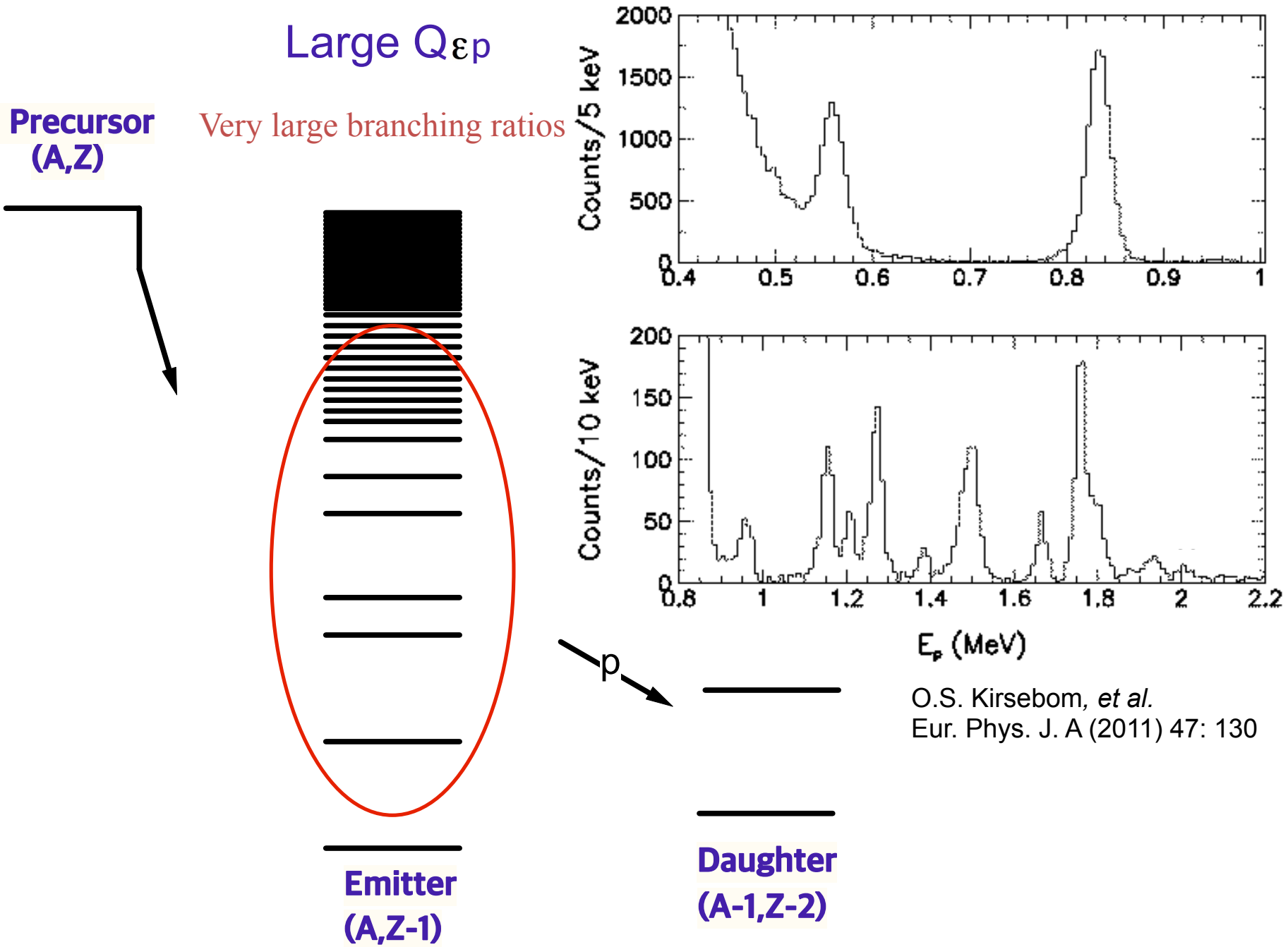



rp-process
rapid proton captures
X(p,γ)Y
proton capture
neutron capture
β⁻ decay
β⁺ decay
stable
unstable
Z
N
synthesis of proton-rich nuclei
A ~ 100
β-p observed
α Decay observed
observation limit
rp process
Xe
I
Te
Sb
Sn
In
Cd
Ag
Pd
Rh
Ru
Tc
Mo
Nb
Zr
Y
Sr
Rb
Kr
Br
Se
As
Ge
Ga
Zn
Cu
Ni
Co
Fe
Mn
Cr
V
Ti
Sc
Ca
K
Ar
58
54
50
46

# Large $Q_{\varepsilon p}$

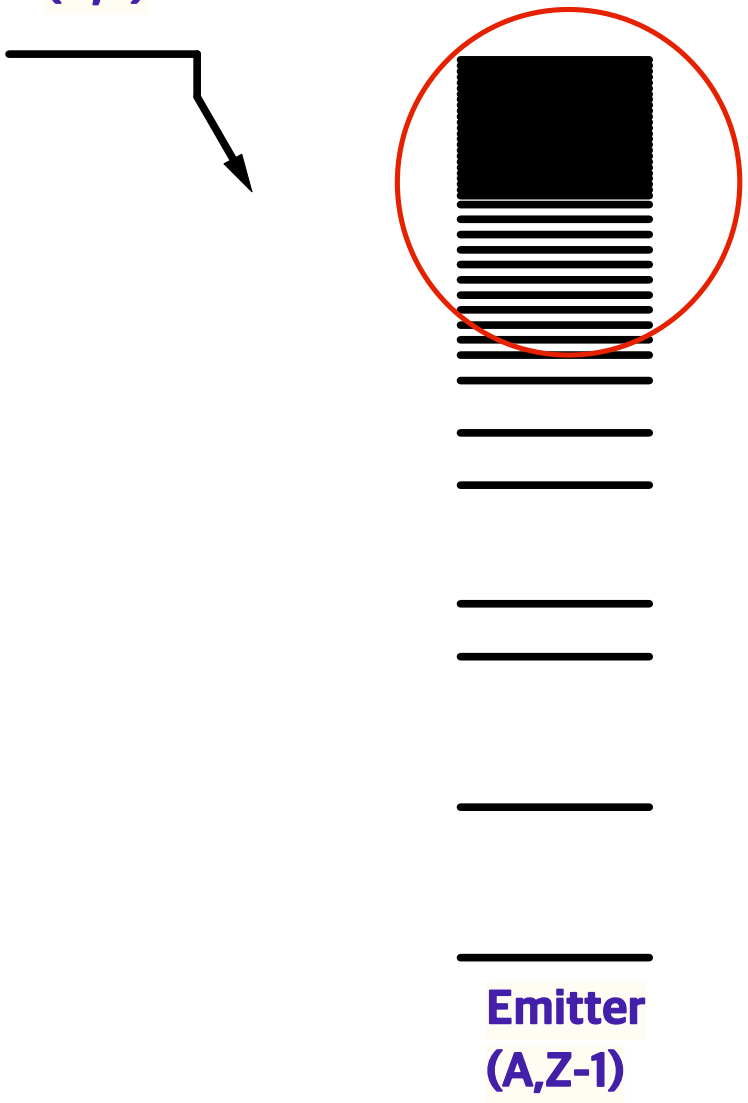
Very large branching ratios




O.S. Kirsebom, *et al.*
Eur. Phys. J. A (2011) 47: 130

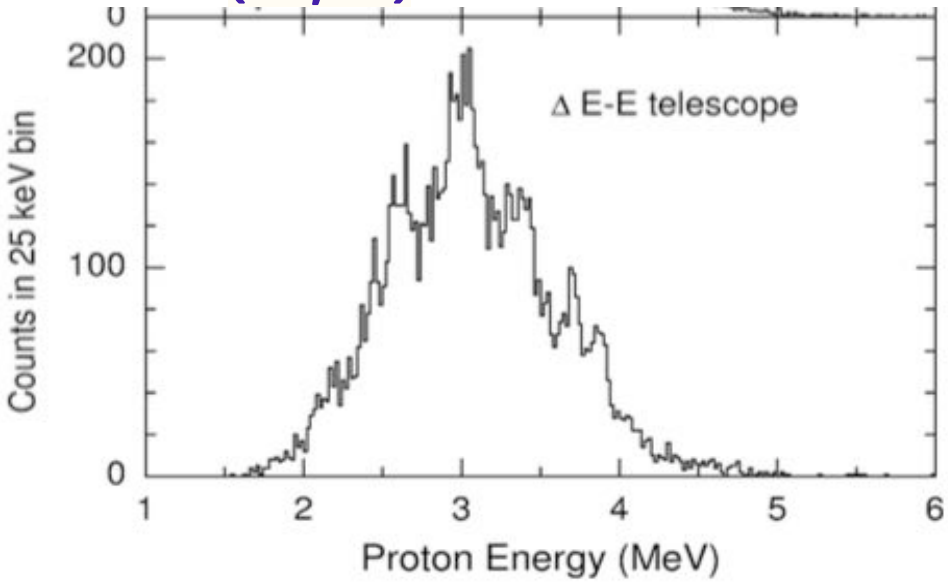
# Small $Q_{\varepsilon p}$

**Precursor (A,Z)**



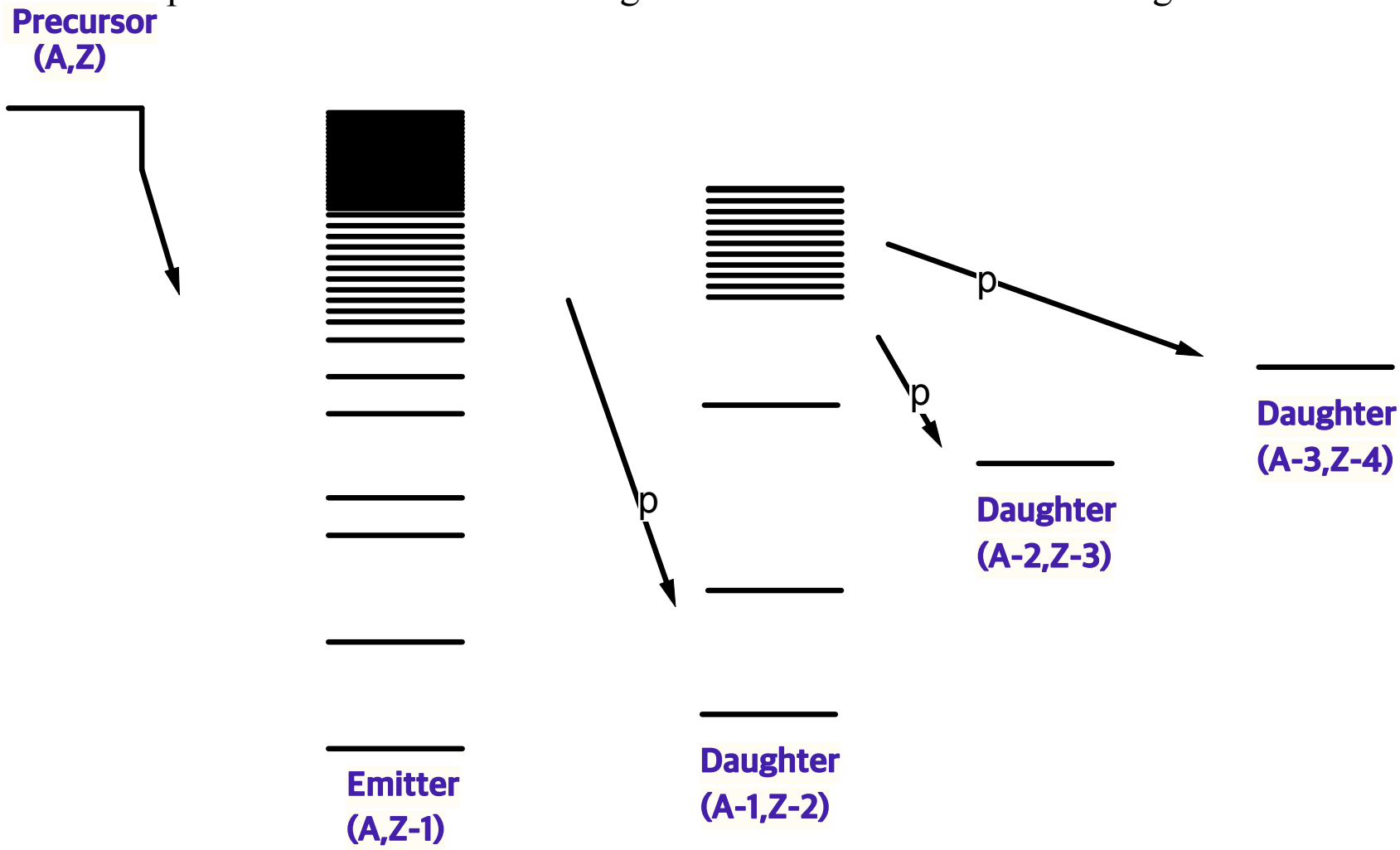

Small branching ratios

**Daughter (A-1,Z-2)**



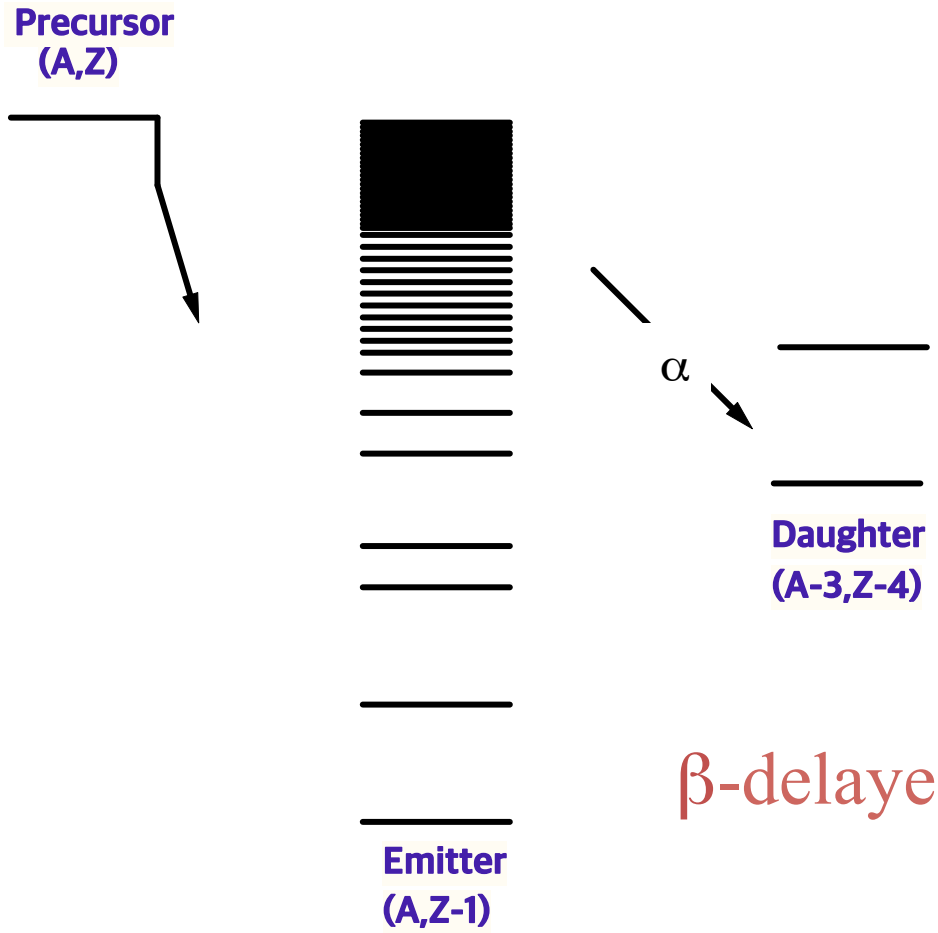
# β – delayed 2 & 3proton emission

β-delayed proton emission is a two step process where a nucleus (A, Z) $\beta^-$-decays to a state in an intermediate precursor nucleus (A, Z-1), then emits a proton from that state to the ground or excited state of the daughter.



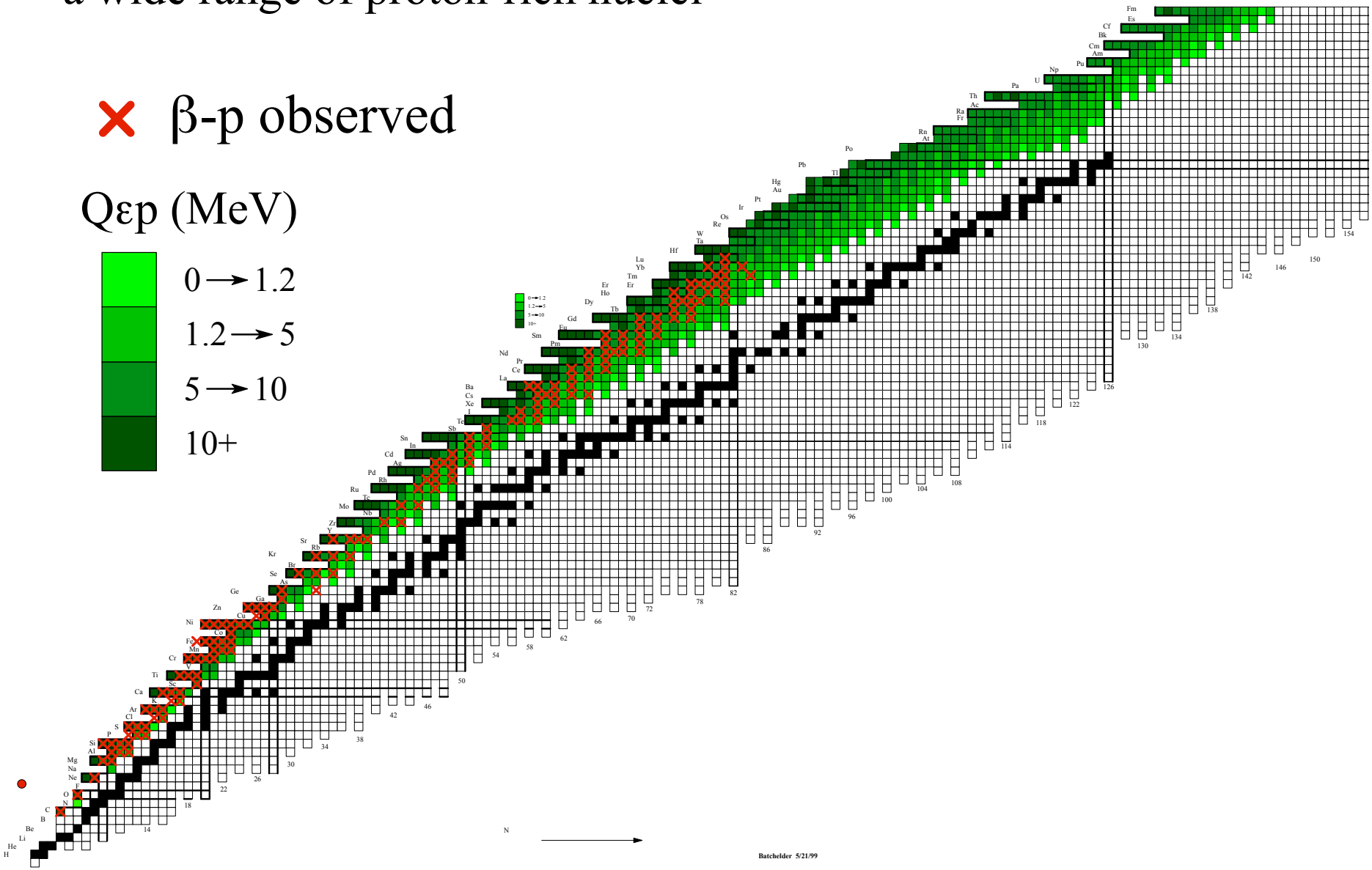
# β – delayed alpha emission

β-delayed proton emission is a two step process where a nucleus (A, Z) $\beta^-$-decays to a state in an intermediate precursor nucleus (A, Z-1), then emits a proton from that state to the ground or excited state of the daughter.



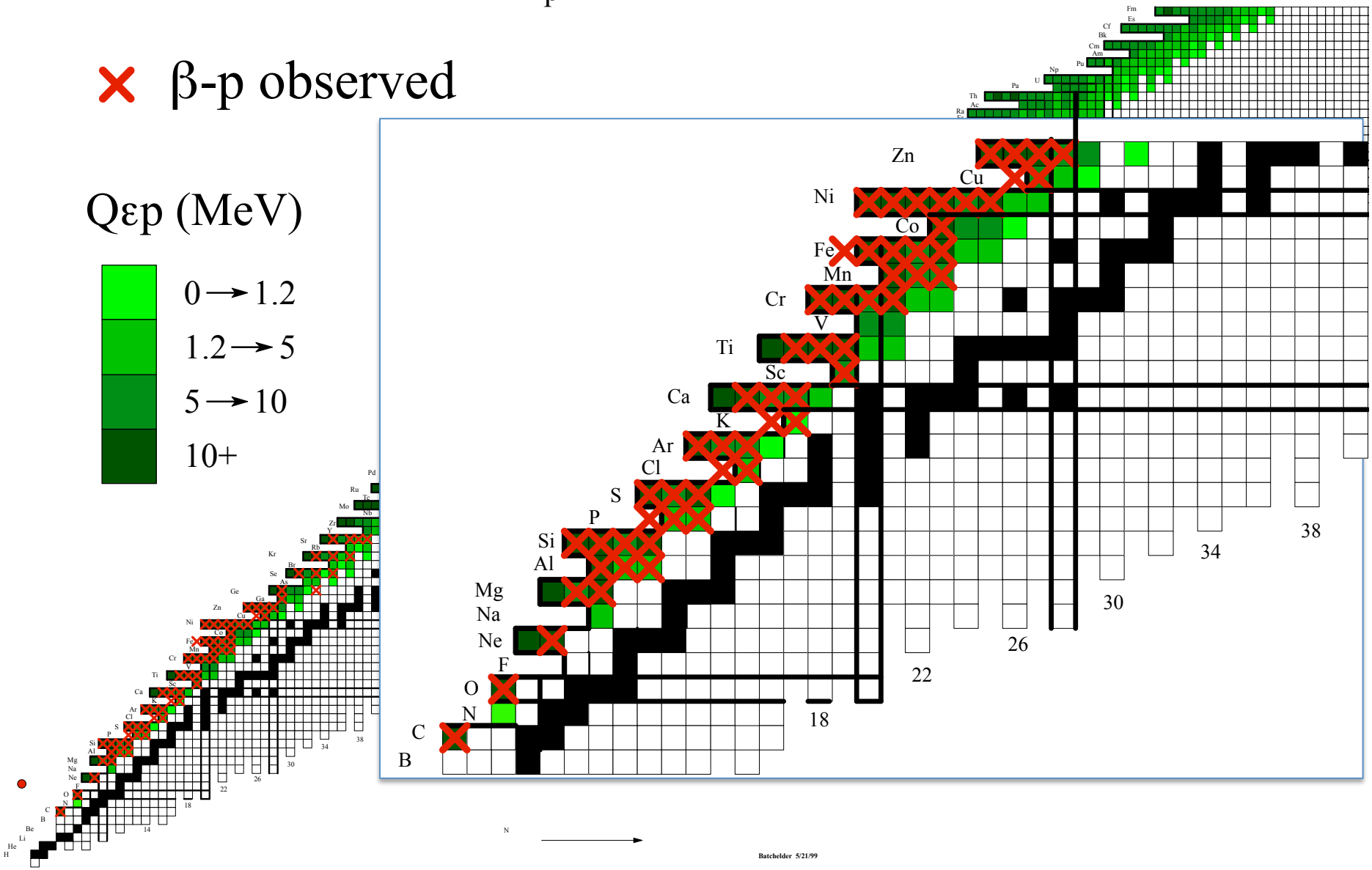

β-delayed α emission

β-p is energetically possible and has been observed over a wide range of proton-rich nuclei



Many studies both older and recent have been done on the lighter nuclei with high $Q_{\varepsilon p}$

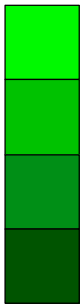
× β-p observed



Far fewer studies on heavier β-p nuclei
often only the existance of decay mode was observed,
with BR not measured.

× β-p observed

Qεp (MeV)



0 → 1.2

1.2 → 5

5 → 10

10+

# At higher Z, α-decay dominates

Proton Decay observed

Alpha Decay observed

β-p observed

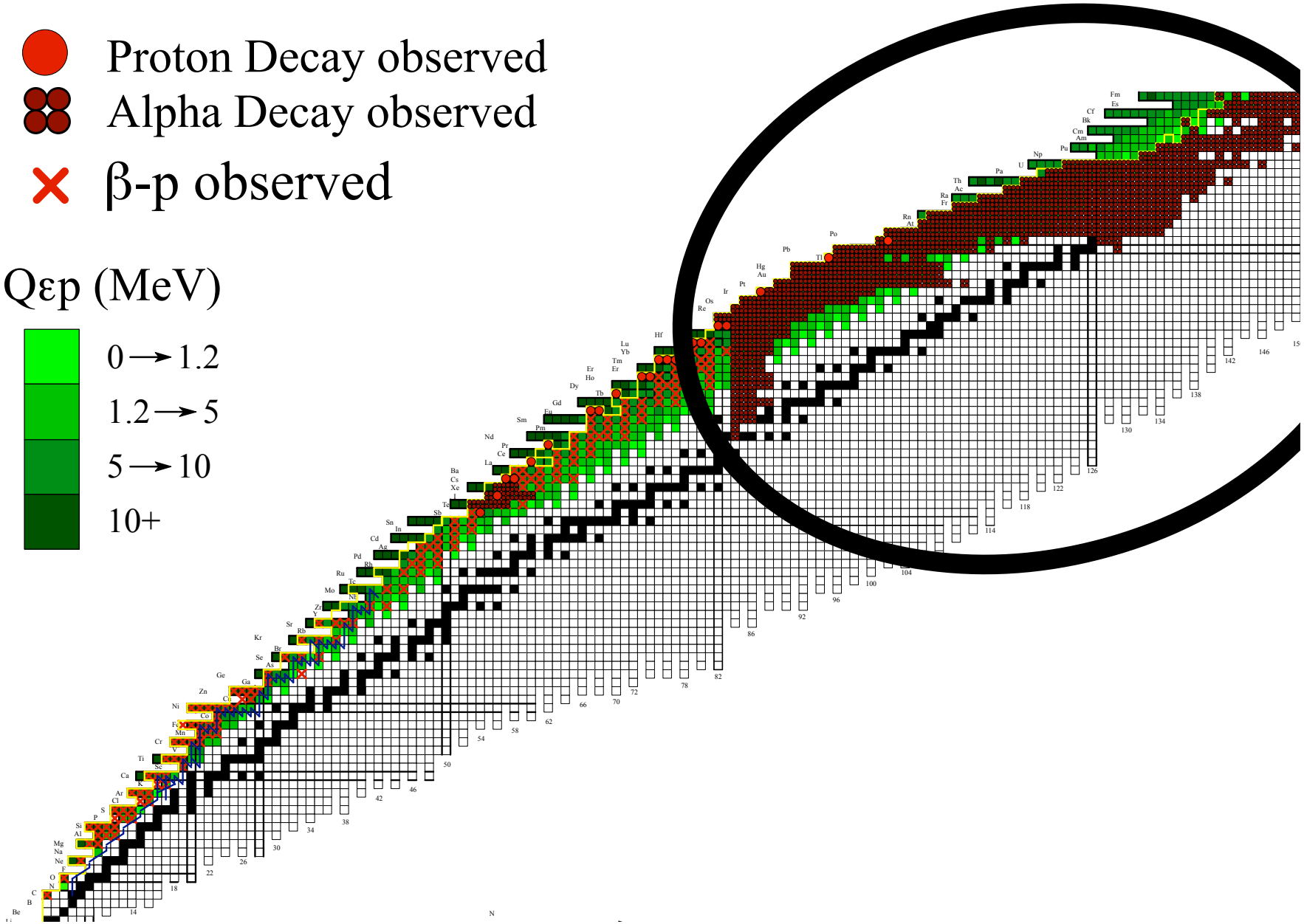
Qεp (MeV)

0 → 1.2

1.2 → 5

5 → 10

10+



# table with A, Z, $T_{1/2}$, $J^{\pi}$, $Q_{\varepsilon p}$, BR(%), refs

171 β-p emitters
11 β-2p emitters
3 β-3p emitters
7 β-α emitters

plots of known and predicted emiters
plot of $Q_{\varepsilon p}$ vs BR

| B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|
| A | Z | Jp | t1/2 | Qep (MeV) | BR (%) beta-p | BR (%) beta-2p | BR (%) beta-3p | Qea (MeV) | BR (&%) beta-a | Refs |
| 9 | C | | 126.5(9) ms | 16.6680(2) | 61.60% | | | 14.81(5) | 38(6)% | 2004Ti06, 1988Mi03,2000Ge09,2001Be51 |
| 13 | O | 3/2- | 8.58(5) ms | 15.83(1) | 10.9 (20) | | | | | 2005Kn02 |
| 17 | Ne | 1/2- | 109.2(6) ms | 13.9485(4) | ≈100 | | | | | 1988Bo39 |
| 20 | Mg | | 90.8(24) ms | 28.52(3) | 30.3(14)% | | | | | 1995Pi03, 2012Wa15 |
| 20 | Na | | 447.9(23) ms | 1.049(1) | | | | 9.163(1) | 20.1(93)% | 2013La22 |
| 21 | Mg | 5/2+ | 122(3) ms | 10.67(2) | 32.6(10)% | | | 6.537(17) | <0.5% | 1973Se08 |
| 22 | Al | 4+ | 91.1(5) ms | 13.1(4)# | 44(3)% | 1.10(11)% | | | | 2006Ac04, 1997Bl03,1982Ca16 |
| 22 | Si | 0+ | 29(2) ms | 15.14(50)# | 32(4)% | | | | | 1996Bl11, 1997Cz02 |
| 23 | Si | | 42.3(4) ms | 16.8(5)# | 71(3)% | 3.6(3)% | | | | 1997Cz02, 1997Bl04 |
| 23 | Al | 5/2+ | 446(6) ms | 4.6406(4) | 1.22(5)% | | | | | 1995Ti08, 2011Ki26 |
| 24 | Al | 4+ | 2.053(4) s | 2.193(1) | 0.0016(3)% | | | 4.569(1) | 0.035(6)% | 1979Ho08, 1994Ba54 |
| 24 | Si | 0+ | 140(8) ms | 8.93(3) | 38(4)% | | | | | 1998Cz01,2001Ba07 |
| 25 | Si | 5/2+ | 220(3) ms | 10.47(1) | 35.0(20)% | | | | | 2004Th09 |
| 26 | P | 3+ | 43.7(6) ms | 12.6(2)# | 36.8(22)% | 2.16(24)% | | | | 2004Th09,1983Ca06 |
| 27 | S | (5/2)+ | 15.5(15) ms | 16.88(40)# | 2.3(9)% | 2.0(11)% | | | | 1991Bo32, 2001Ca60 |

To do:

Evaluation is mostly done (~80%) ish...

Make seperate table for β-2p (and β-3p)

& Seperate table for βα

create 2d plot of $Q_{\varepsilon p}$ vs. BR. vs. Z