A Neutron Source Facility for Energy Dependent Detector Characterization

julius.scherzinger@nuclear.lu.se

PhD student at
Lund University, Sweden
European Spallation Source

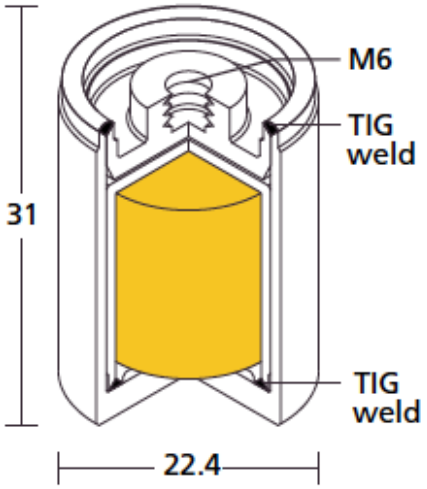
Overview

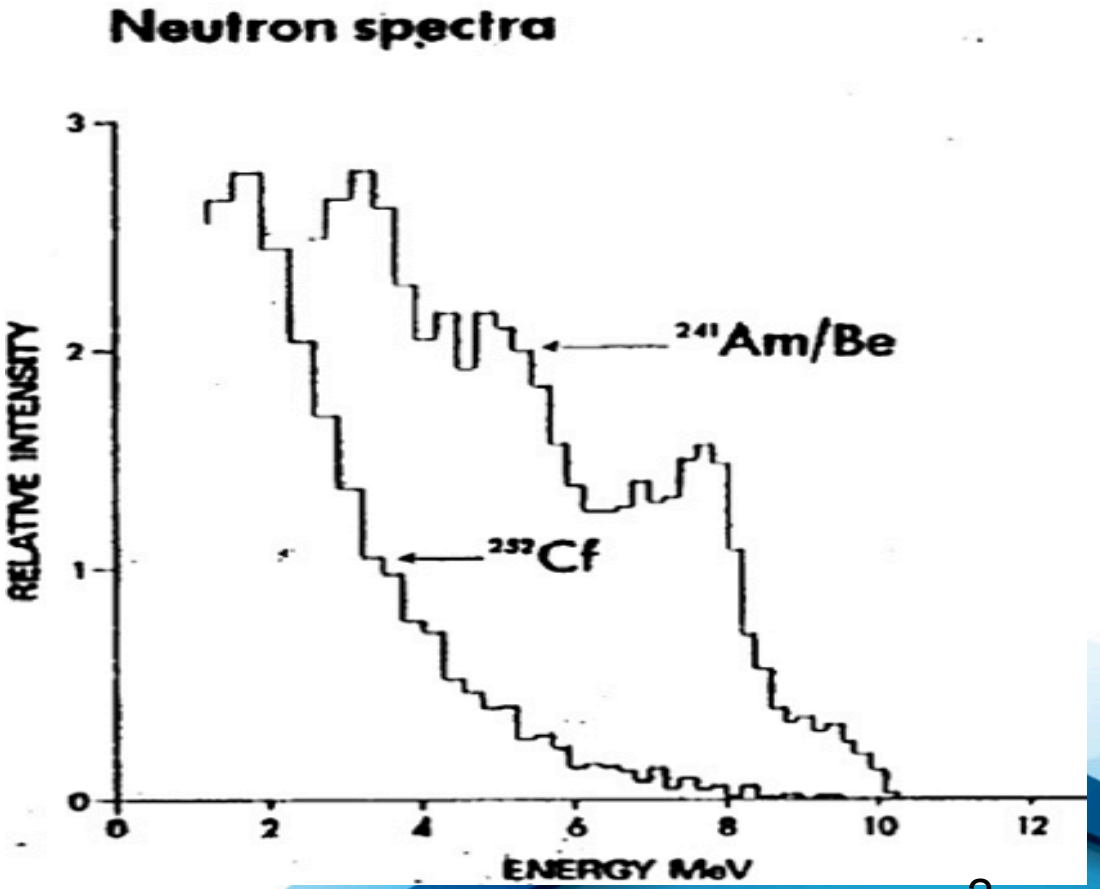
- Low cost neutron irradiation facility for detector characterization
- First results establishing viability of method:
  - blind irradiation using a mixed field
  - neutron “tagging”

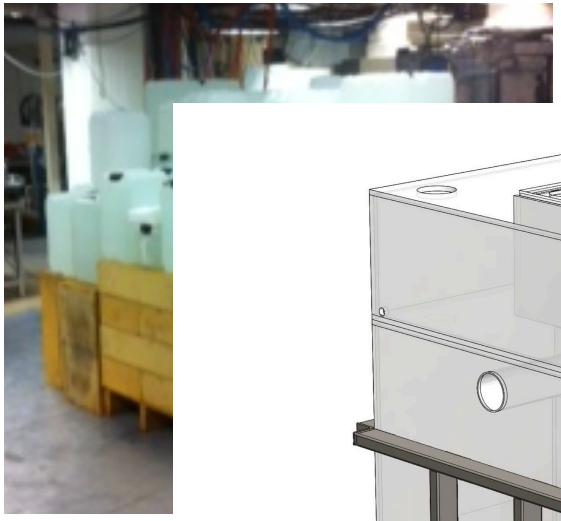
AmBe source

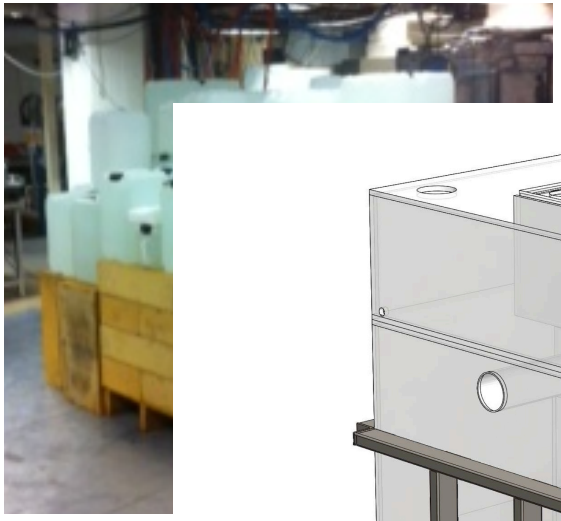
$$^{241}Am \rightarrow {}^{237}Np + \alpha \left(Q \sim 5.5MeV\right)$$

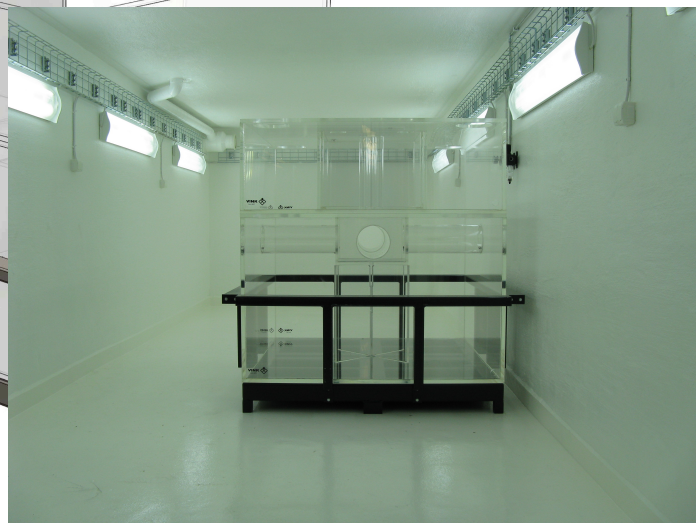
$$\hookrightarrow \; {}^{9}Be(\alpha,n)^{12}C$$

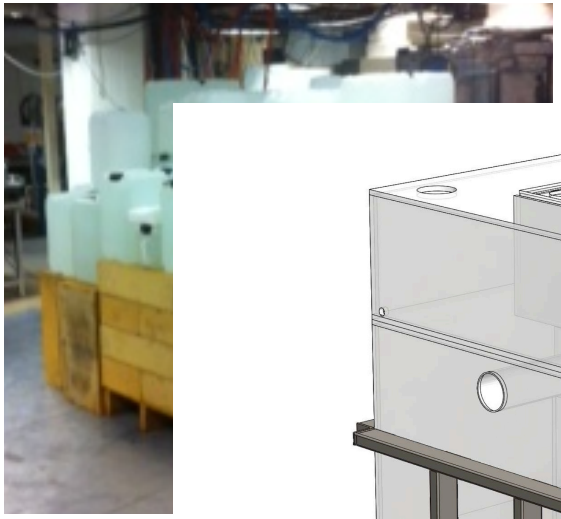


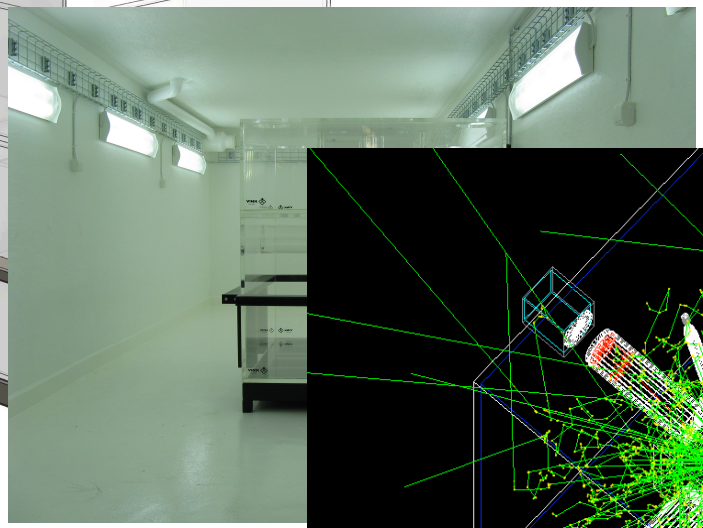


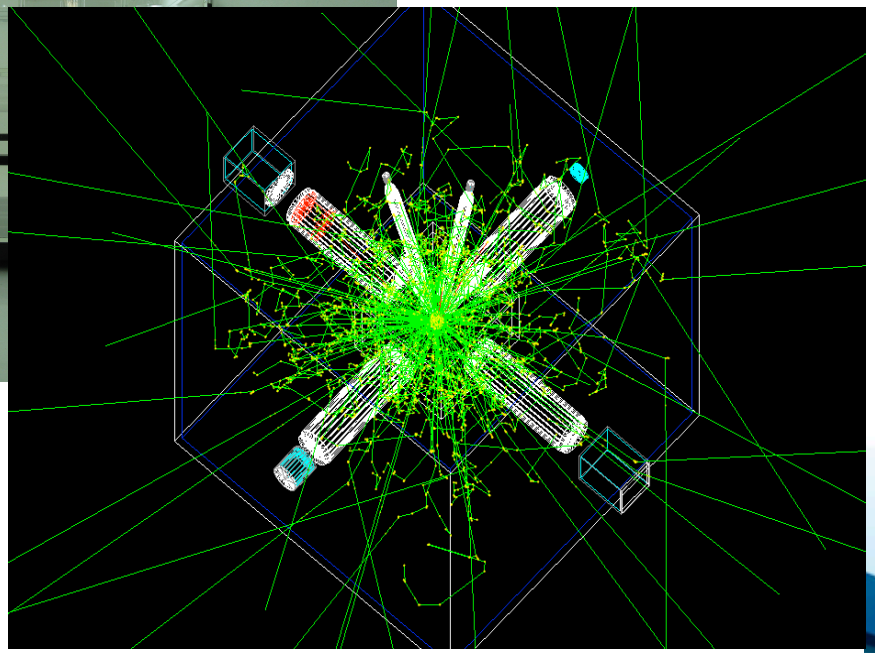












GEANT4 simulation, courtesy of J. Annand, University of Glasgow

Scintillator Properties

- Mapping
  - Pulse Shape Discrimination (PSD)
    - Pulse Shape (PS)
    - Figure-of-Merit (FOM)
  - Proton Light Yield
    - Quenching (MeV_{ee}/MeV<1)
    - Non linearity

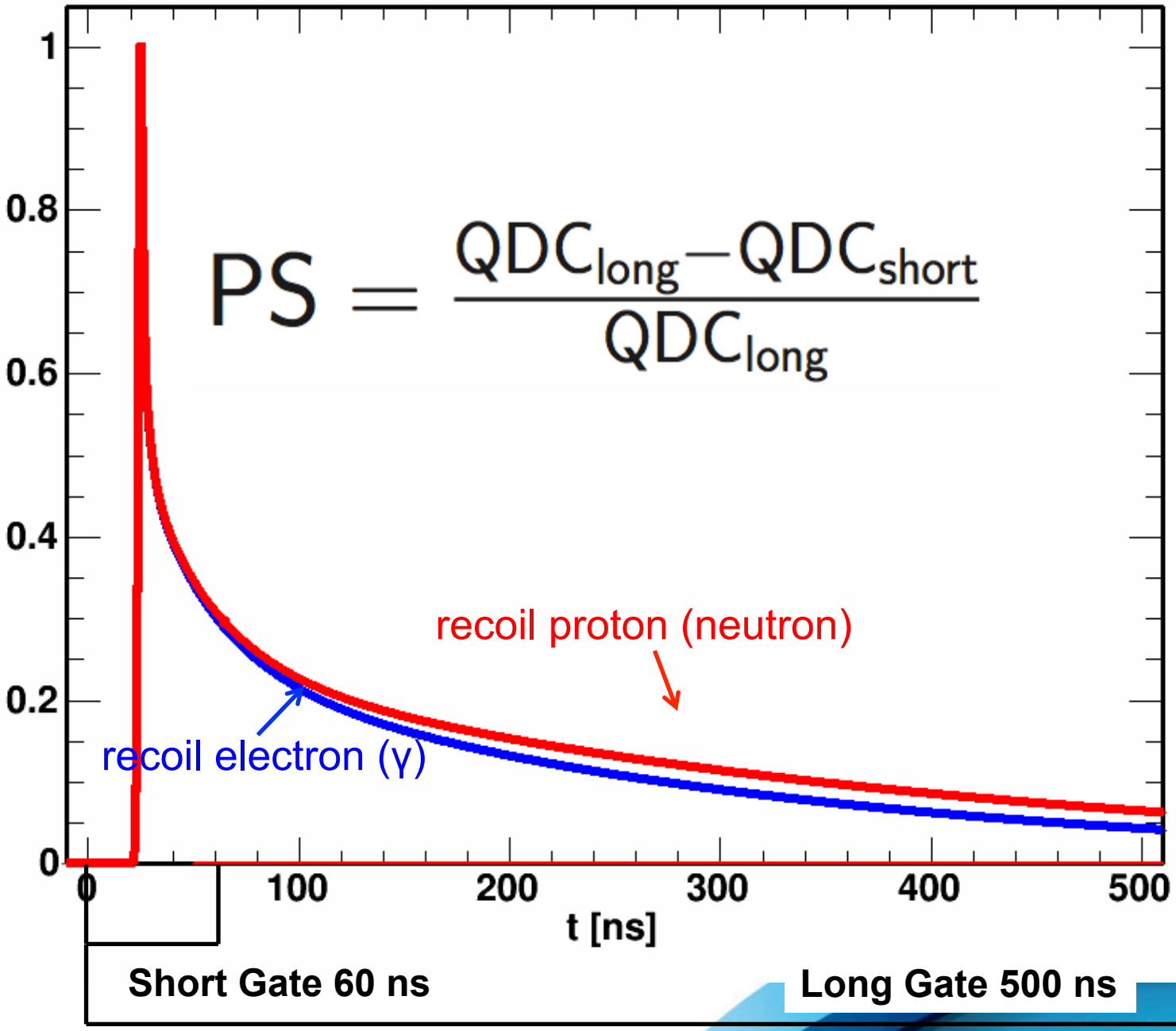
Scintillator

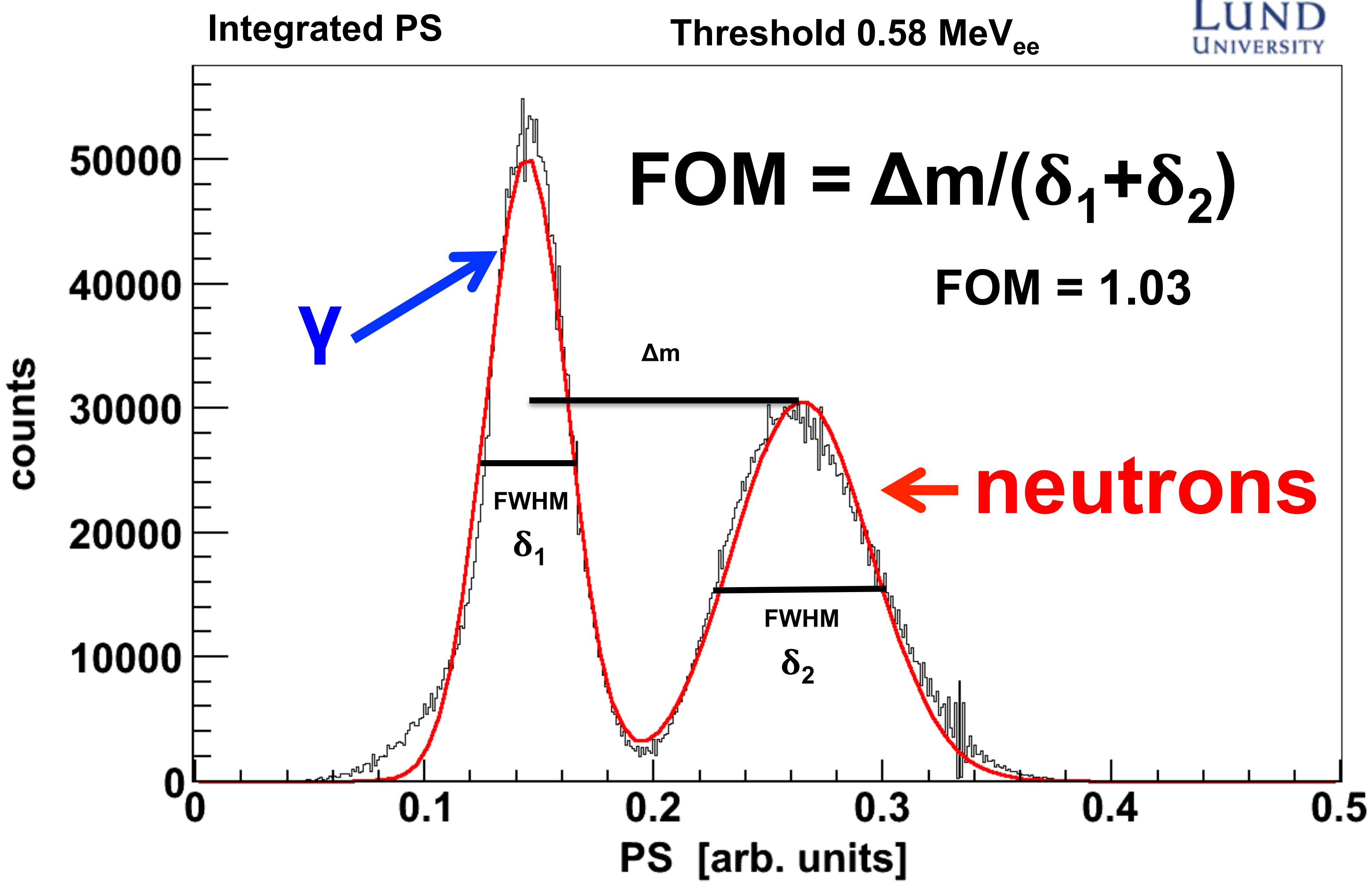
- ET 9821 KB
  - 3 inch
  - borosilicate glass
- NE-213
- Optical coupled
  - dry fitted
  - light guide
- Aluminum Cell
  - 10 cm X 7.5 cm
  - sandblasted and painted

Scintillator

- Hamamatsu R580
  - 2 inch
  - borosilicate glass
- ^{4}He
  - 179 bar
- Optical coupled
  - dry fitted
- Active Volume
  - 1.05 l

R. Jebali et al., "Response comparison between a 4He-based fast neutron detector and a NE-213 liquid scintillator reference cell ", to be submitted to Nucl. Inst. and Meth. A

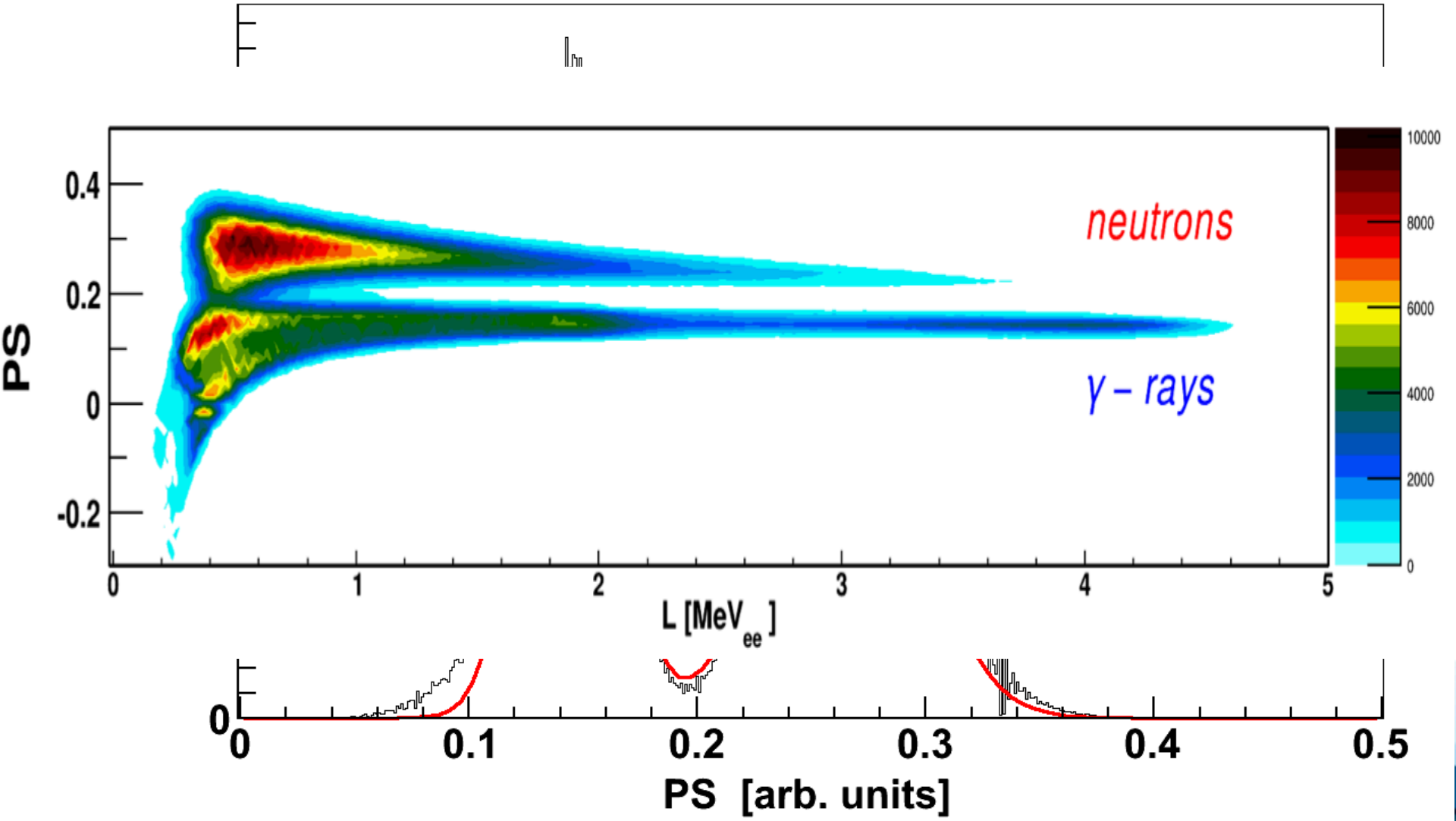

$PS = \frac{QDC_{long} - QDC_{short}}{QDC_{long}}$
recoil proton (neutron)
recoil electron (γ)
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
t [ns]
Short Gate 60 ns
Long Gate 500 ns



Integrated PS
Threshold 0.58 MeV$_{ee}$
FOM = Δm/(δ$_1$+δ$_2$)
FOM = 1.03
γ
Δm
FWHM
δ$_1$
FWHM
δ$_2$
neutrons
counts
50000
40000
30000
20000
10000
0
0.1
0.2
0.3
0.4
0.5
PS [arb. units]

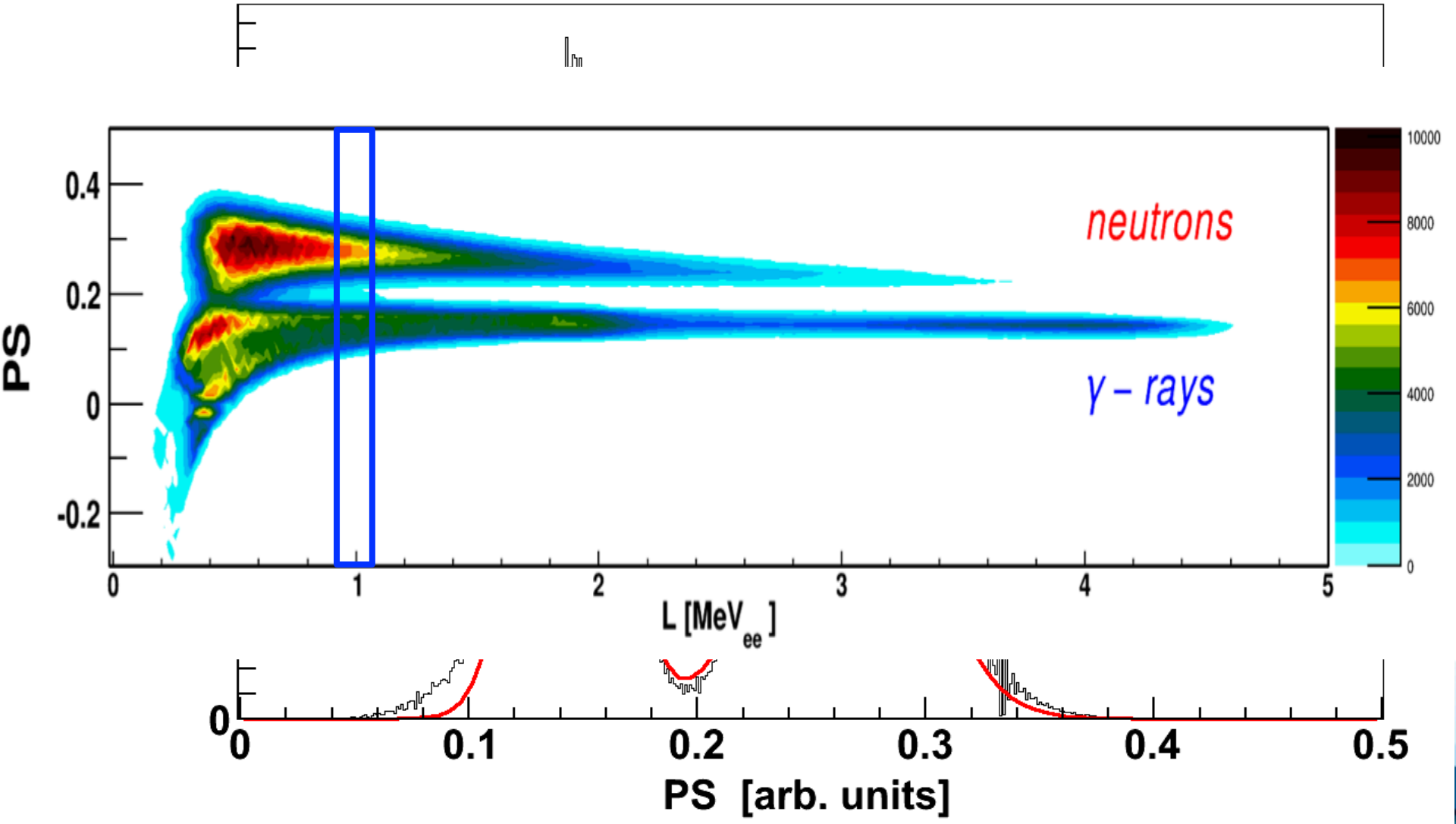
Integrated PS

Threshold 0.58 MeV_{ee}



Integrated PS

Threshold 0.58 MeV_{ee}

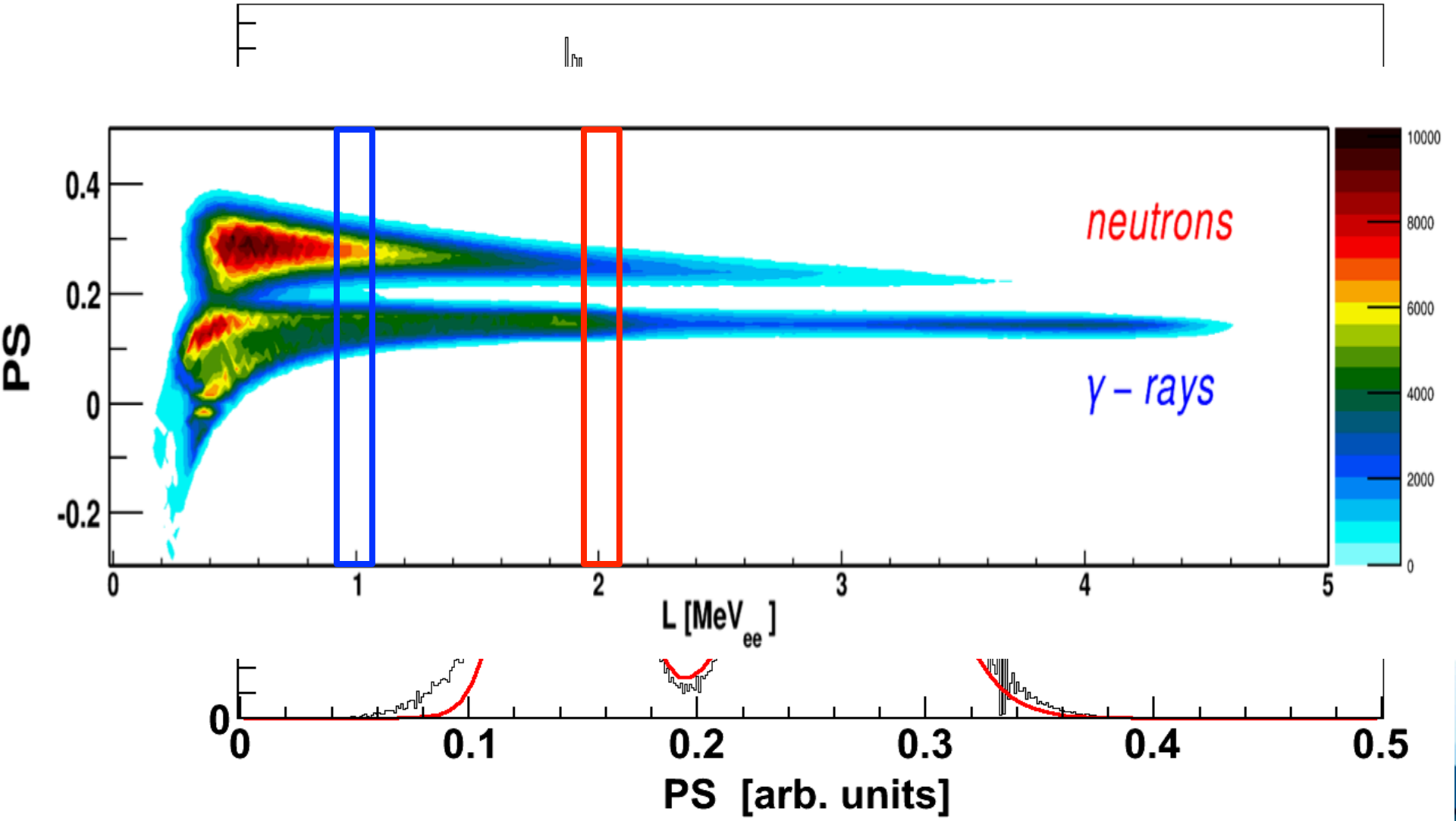


EUROPEAN SPALLATION SOURCE

LUND UNIVERSITY

Integrated PS

Threshold 0.58 MeV_{ee}



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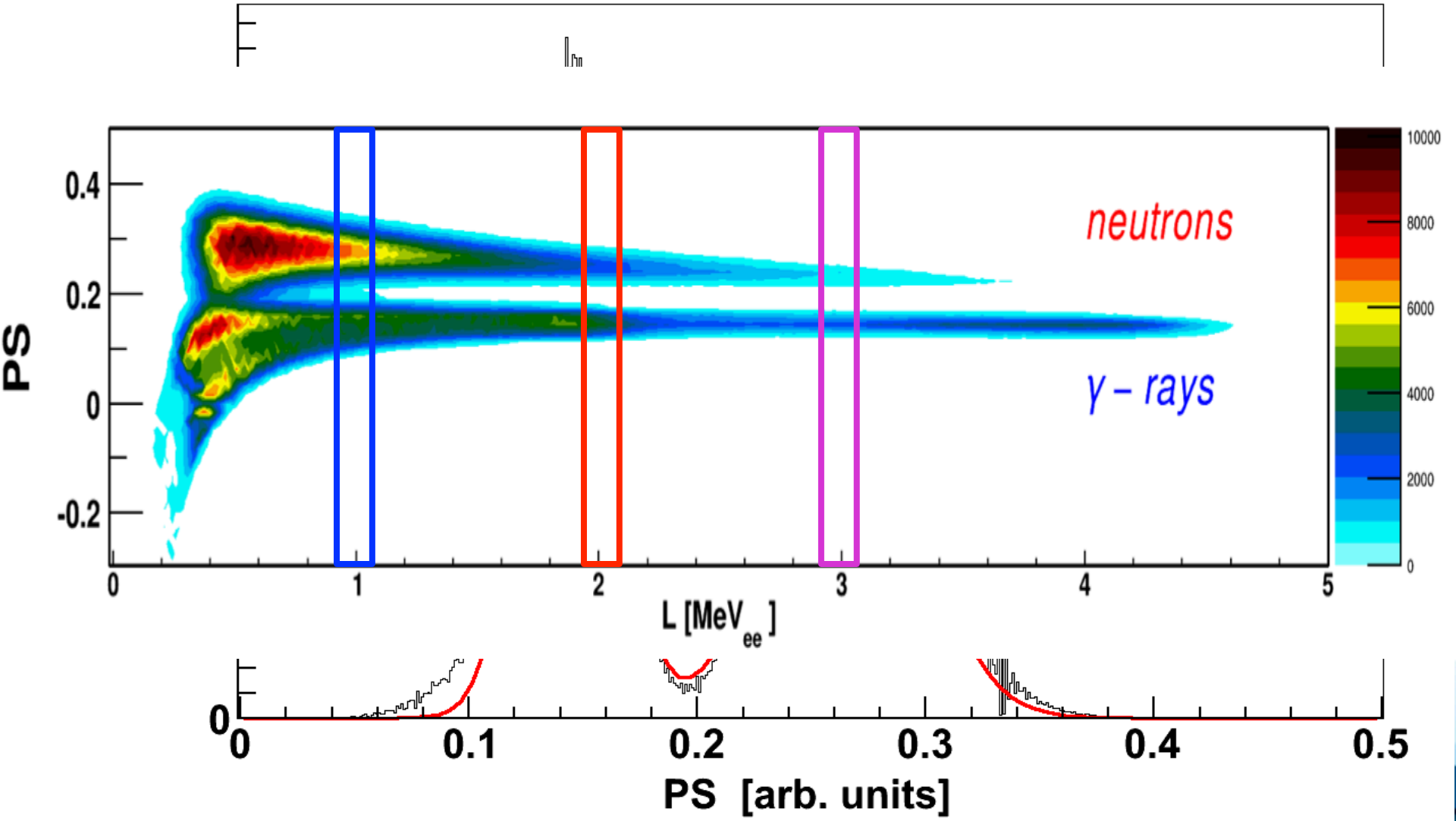

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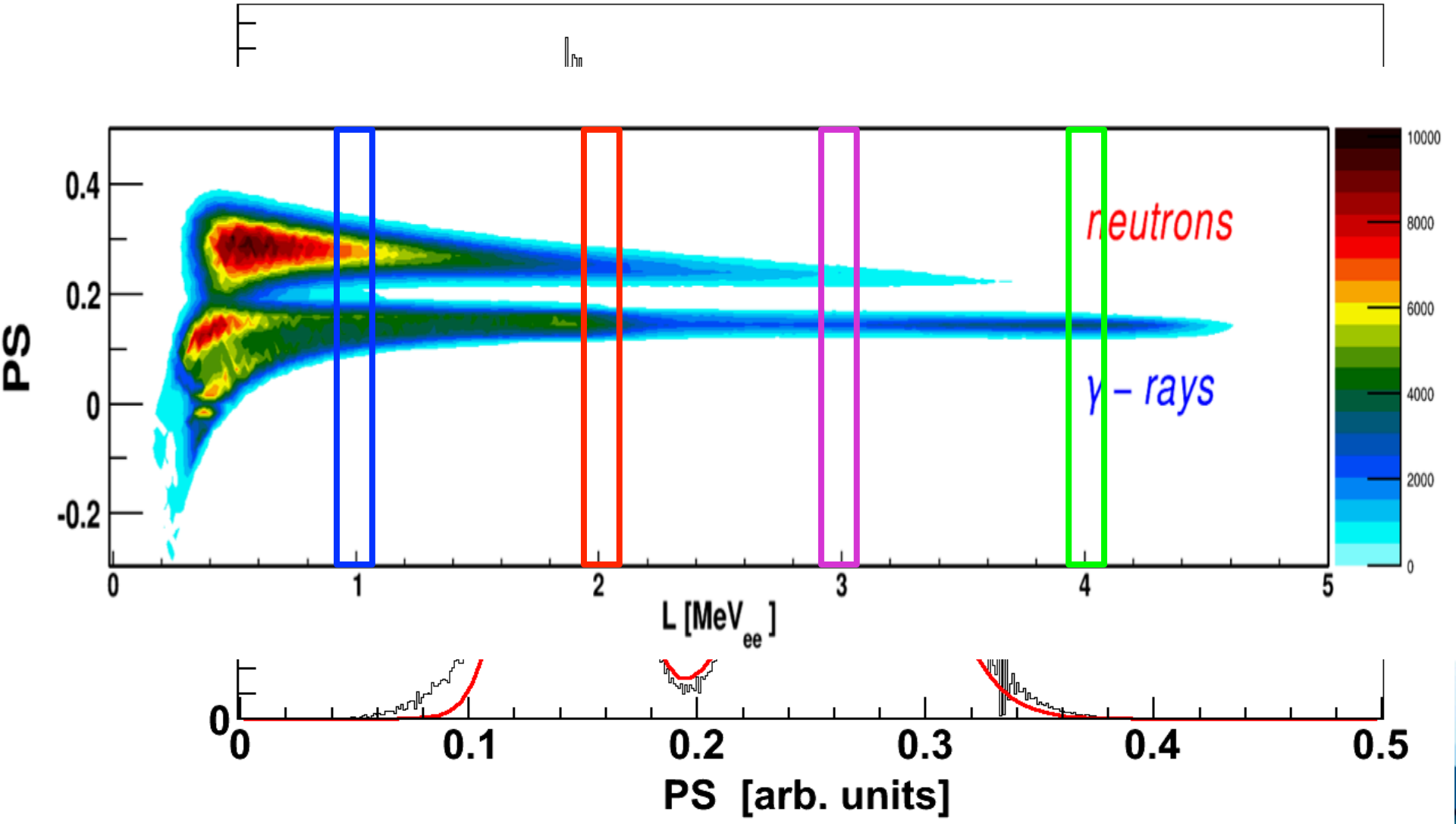
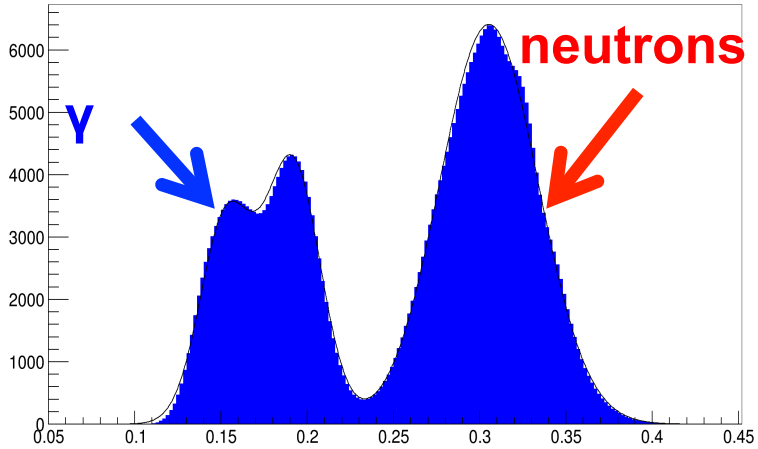
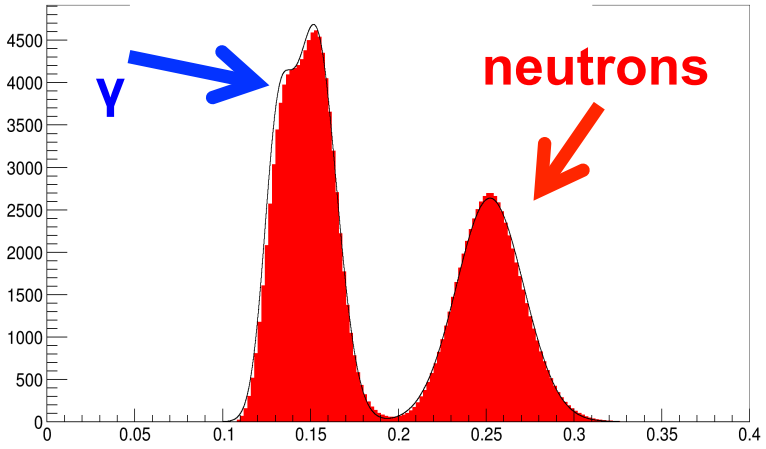


$$\Delta L = \pm 0.1 MeV_{ee}$$

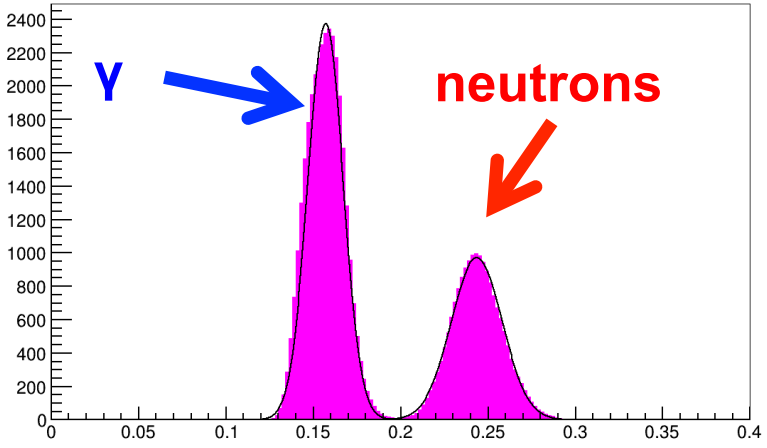
PS @ 1 MeV_{ee}



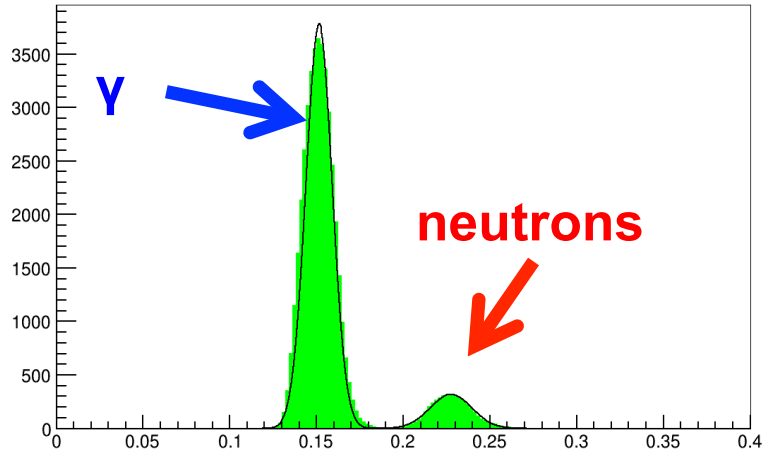
PS @ 2 MeV_{ee}

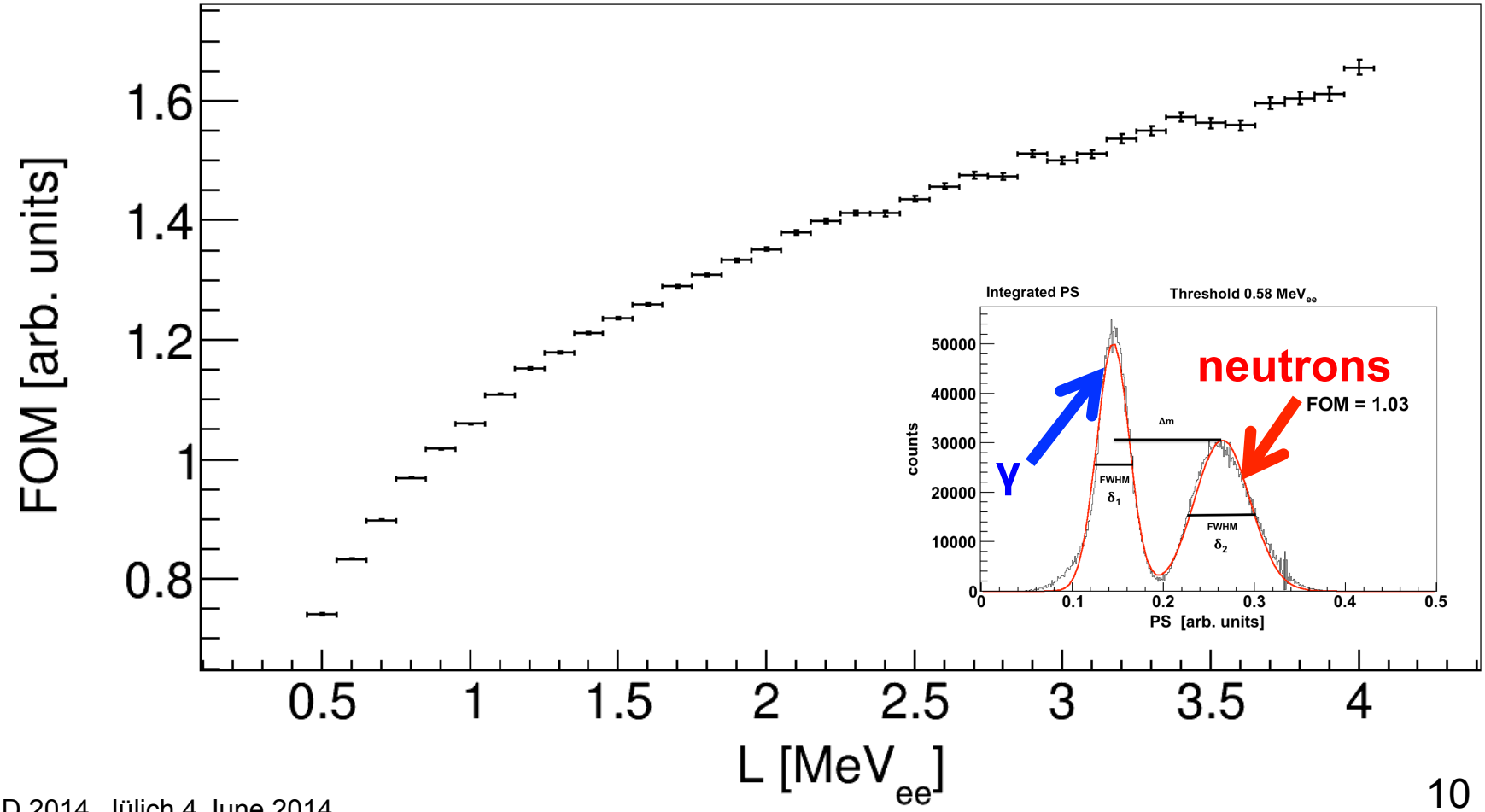


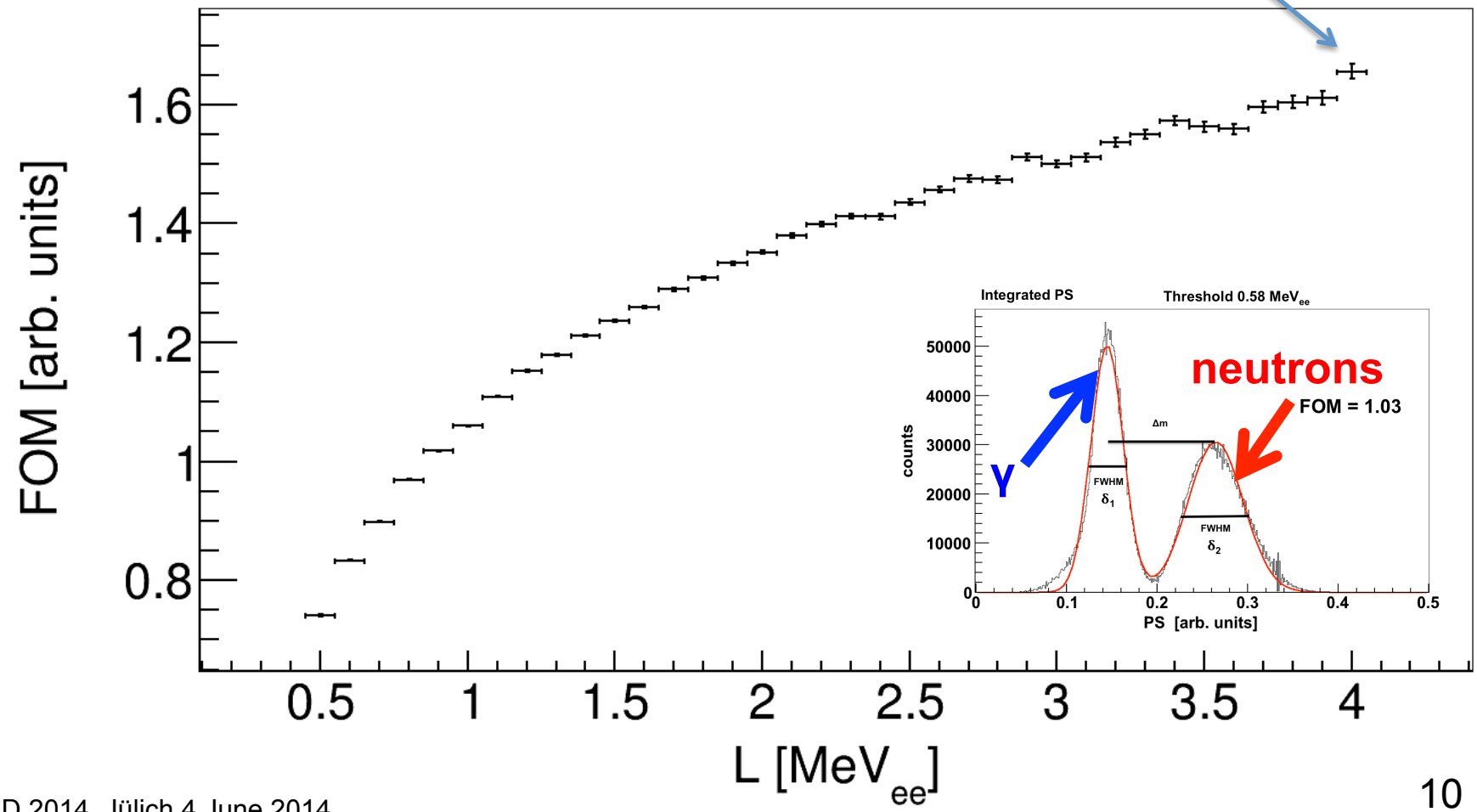
PS @ 3 MeV_{ee}

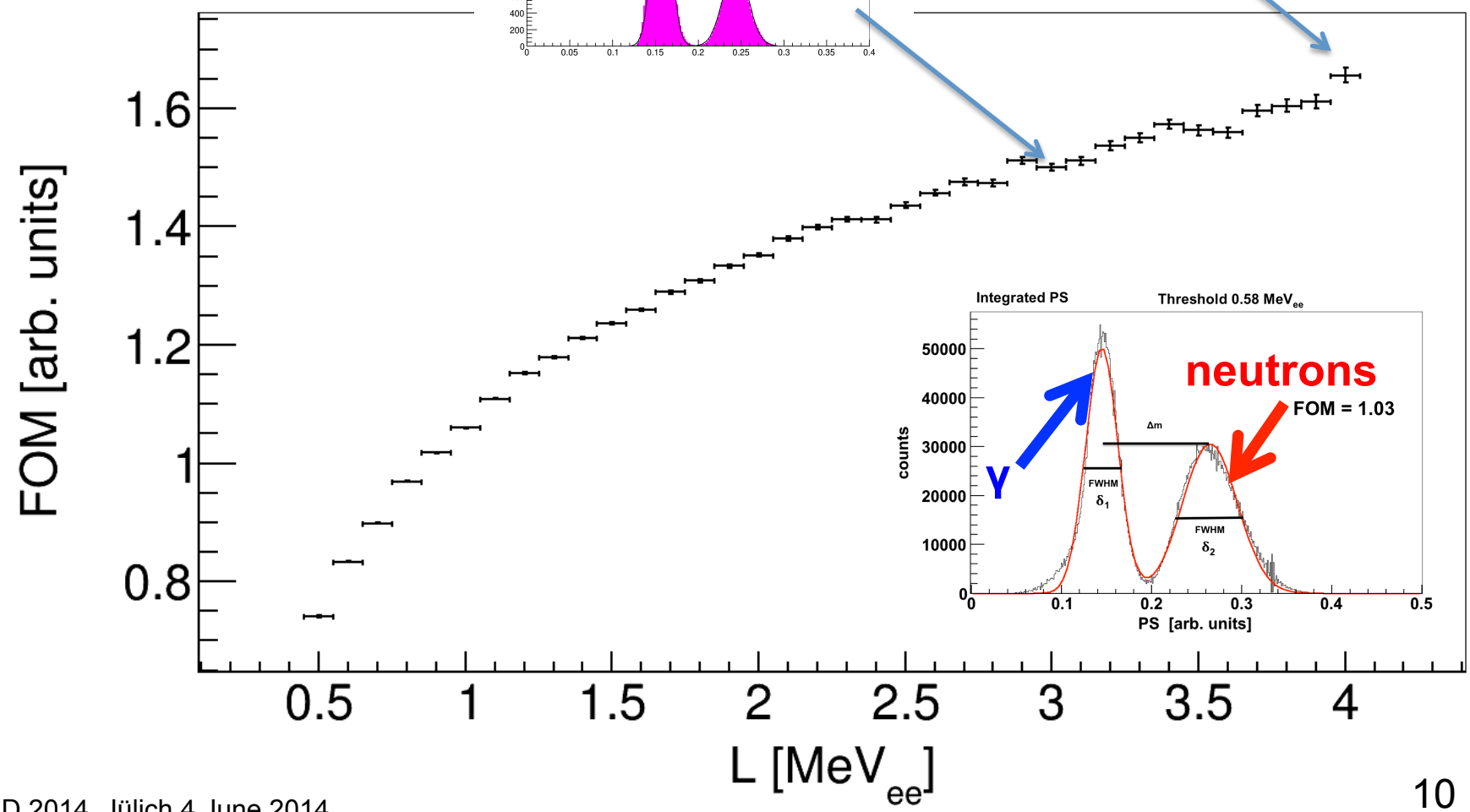


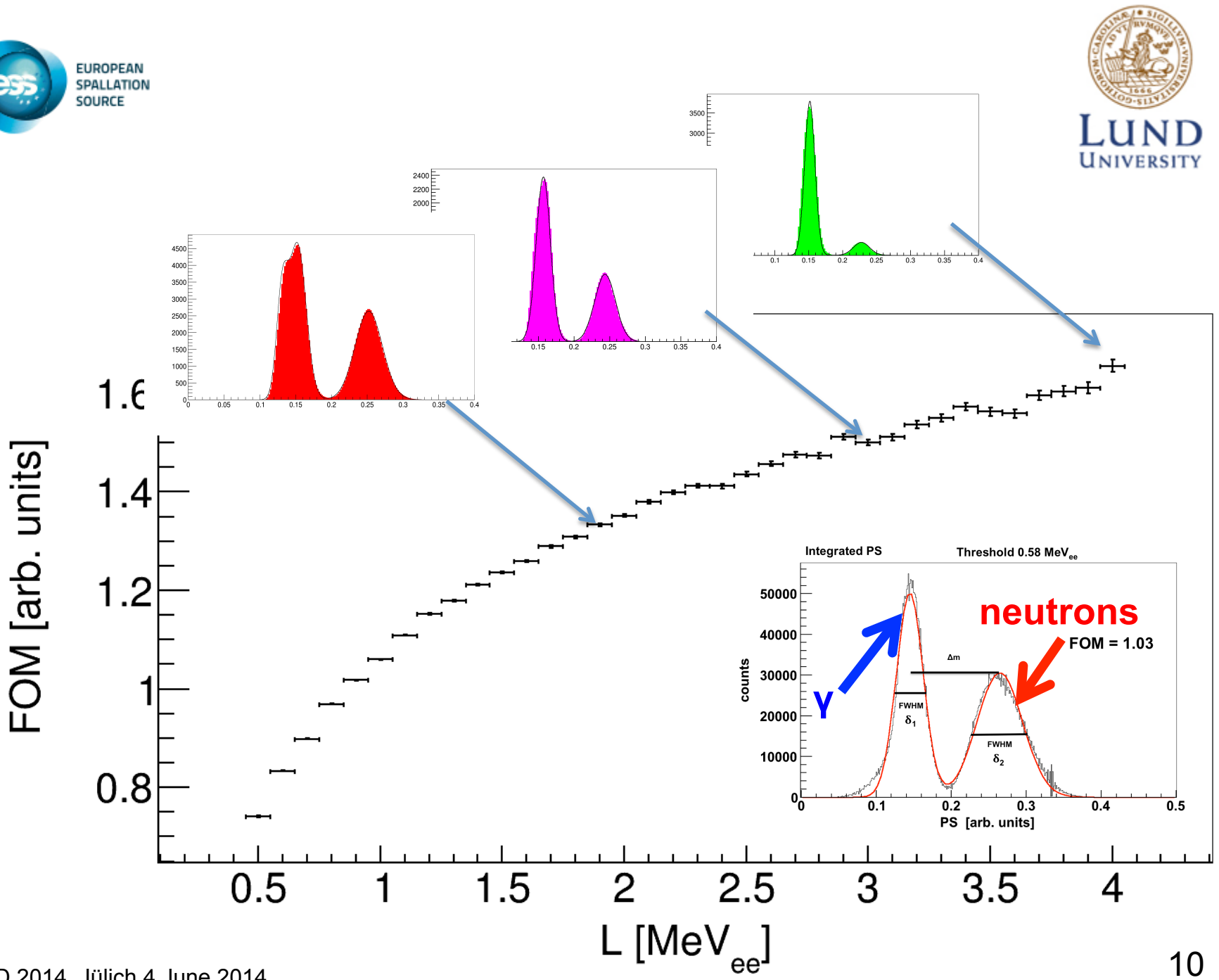
PS @ 4 MeV_{ee}

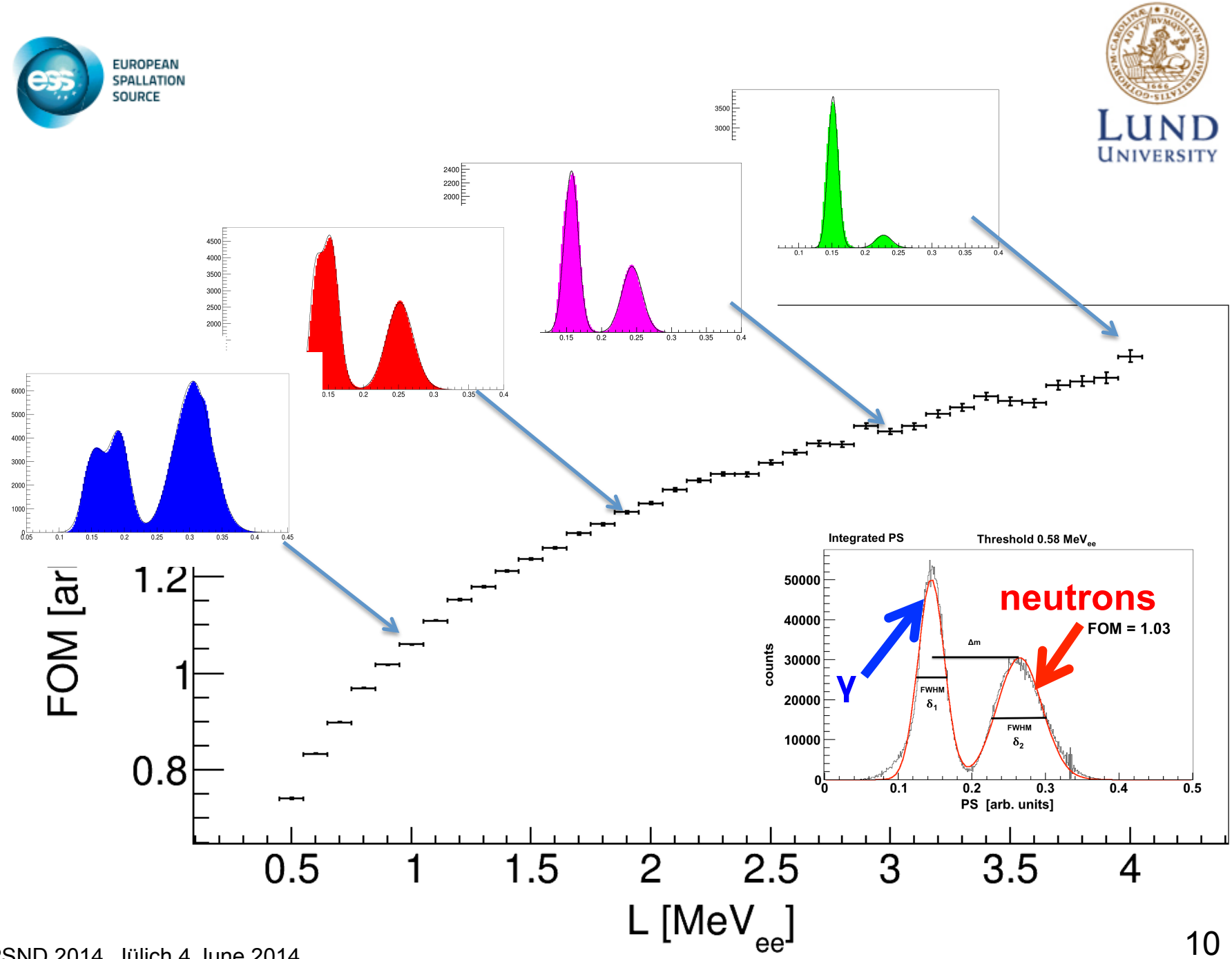



FOM [arb. units]
1.6
1.4
1.2
1
0.8
0.5
1
1.5
2
2.5
3
3.5
4
L [MeV$_{ee}$]
Integrated PS
Threshold 0.58 MeV$_{ee}$
counts
50000
40000
30000
20000
10000
0
0
0.1
0.2
0.3
0.4
0.5
PS [arb. units]
γ
neutrons
FOM = 1.03
Δm
FWHM
δ$_1$
FWHM
δ$_2$


FOM [arb. units]
L [MeV$_{ee}$]
Integrated PS
Threshold 0.58 MeV$_{ee}$
counts
PS [arb. units]
neutrons
FOM = 1.03
γ
Δm
FWHM
δ$_1$
FWHM
δ$_2$


FOM [arb. units]
L [MeV$_{ee}$]
Integrated PS
Threshold 0.58 MeV$_{ee}$
neutrons
FOM = 1.03
γ
Δm
FWHM
δ$_1$
FWHM
δ$_2$
counts
PS [arb. units]


FOM [arb. units]
L [MeV$_{ee}$]
Integrated PS
Threshold 0.58 MeV$_{ee}$
neutrons
FOM = 1.03
γ
Δm
FWHM δ$_1$
FWHM δ$_2$
counts
PS [arb. units]


FOM [ar
1.2
1
0.8
0.5
1
1.5
2
2.5
3
3.5
4
L [MeV$_{ee}$]
Integrated PS
Threshold 0.58 MeV$_{ee}$
counts
PS [arb. units]
neutrons
FOM = 1.03
γ
Δm
FWHM
δ$_1$
FWHM
δ$_2$

“Tagged” Neutrons

J. Scherzinger et al.,"A source-based fast-neutron facility for precision irradiations”, arXiv:1405.2686[physics.ins-det] (2014), submitted to Nucl. Inst. and Meth. A

$$^{241}Am \rightarrow {}^{237}Np + \alpha\left(Q \sim 5.5MeV\right)$$

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$$\hookrightarrow {}^{9}Be(\alpha,n)^{12}C^{*}$$

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$$\hookrightarrow \gamma \quad \text{(4.43 MeV)}$$

~60%

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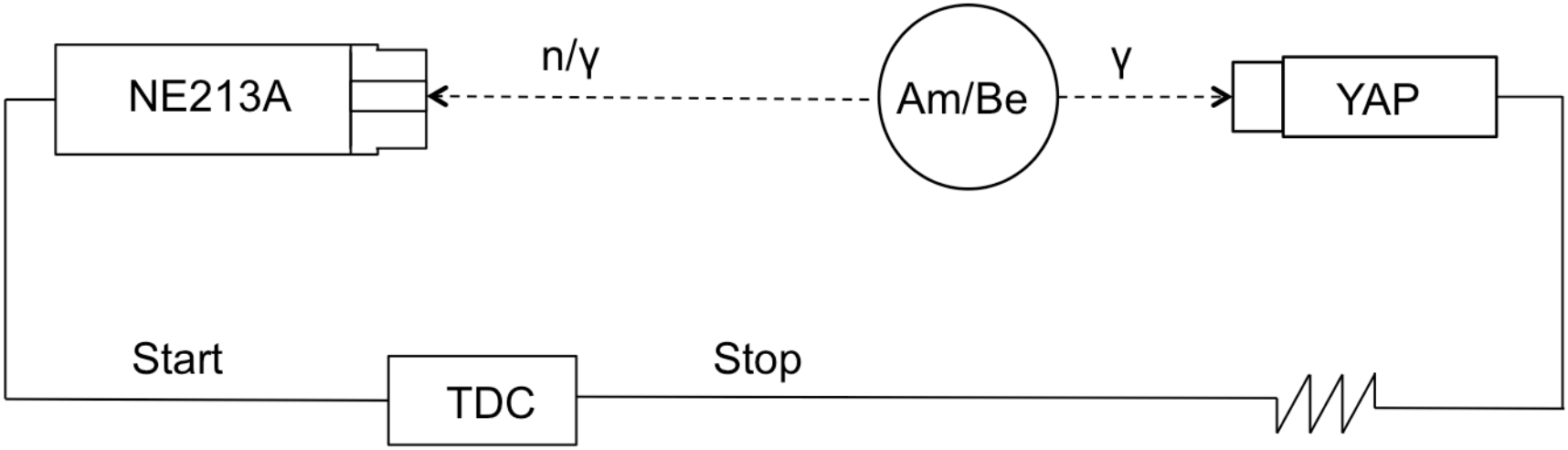
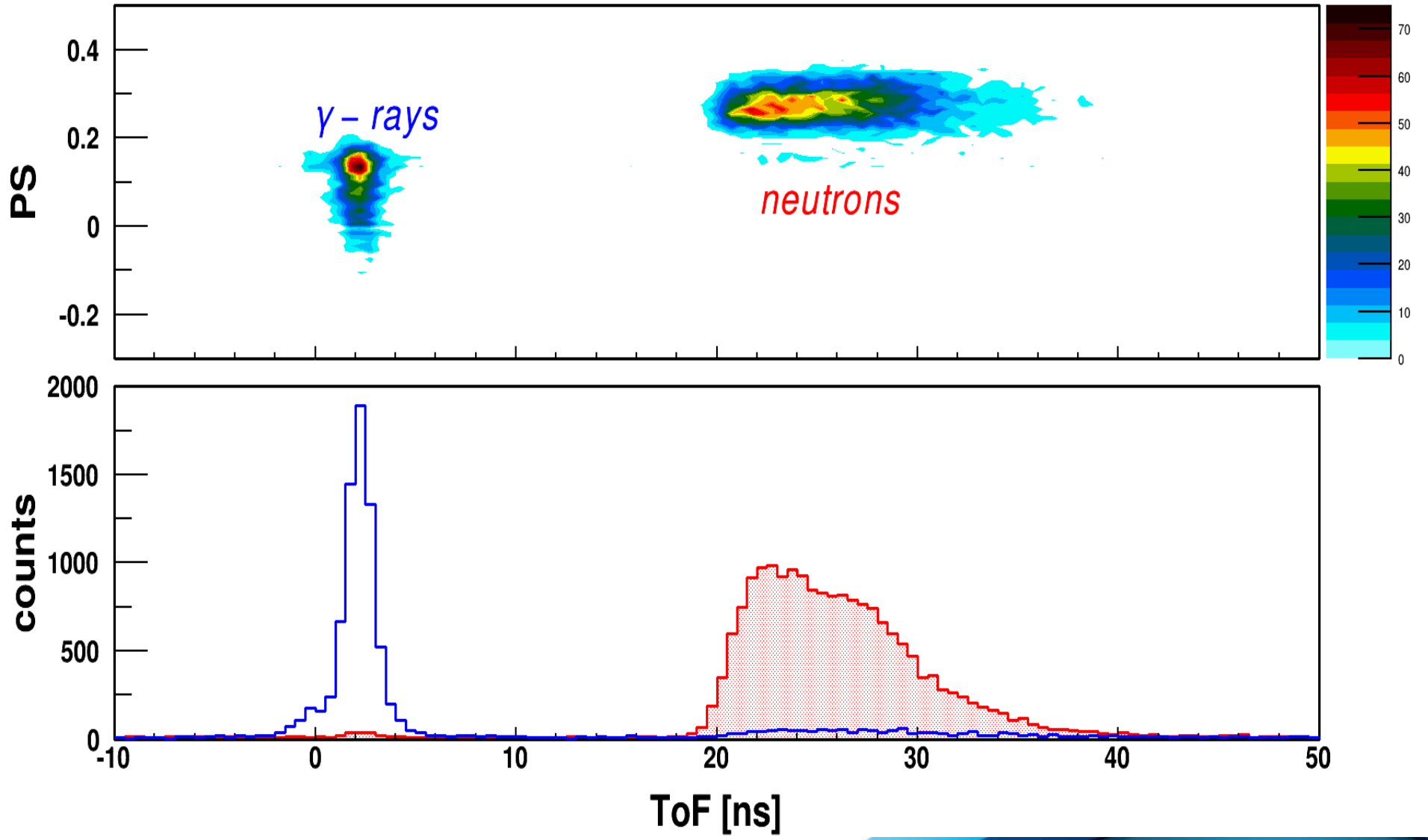
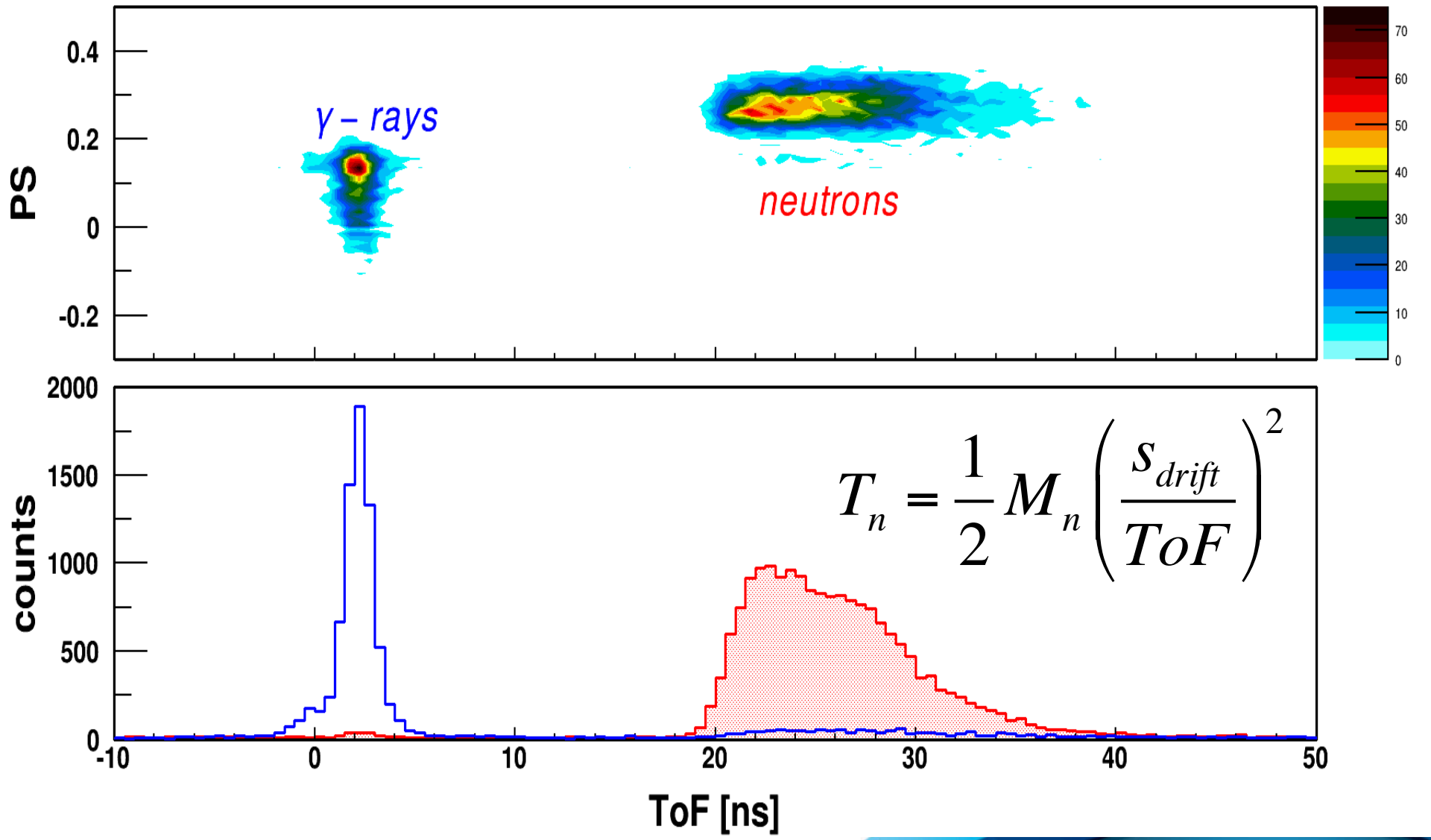
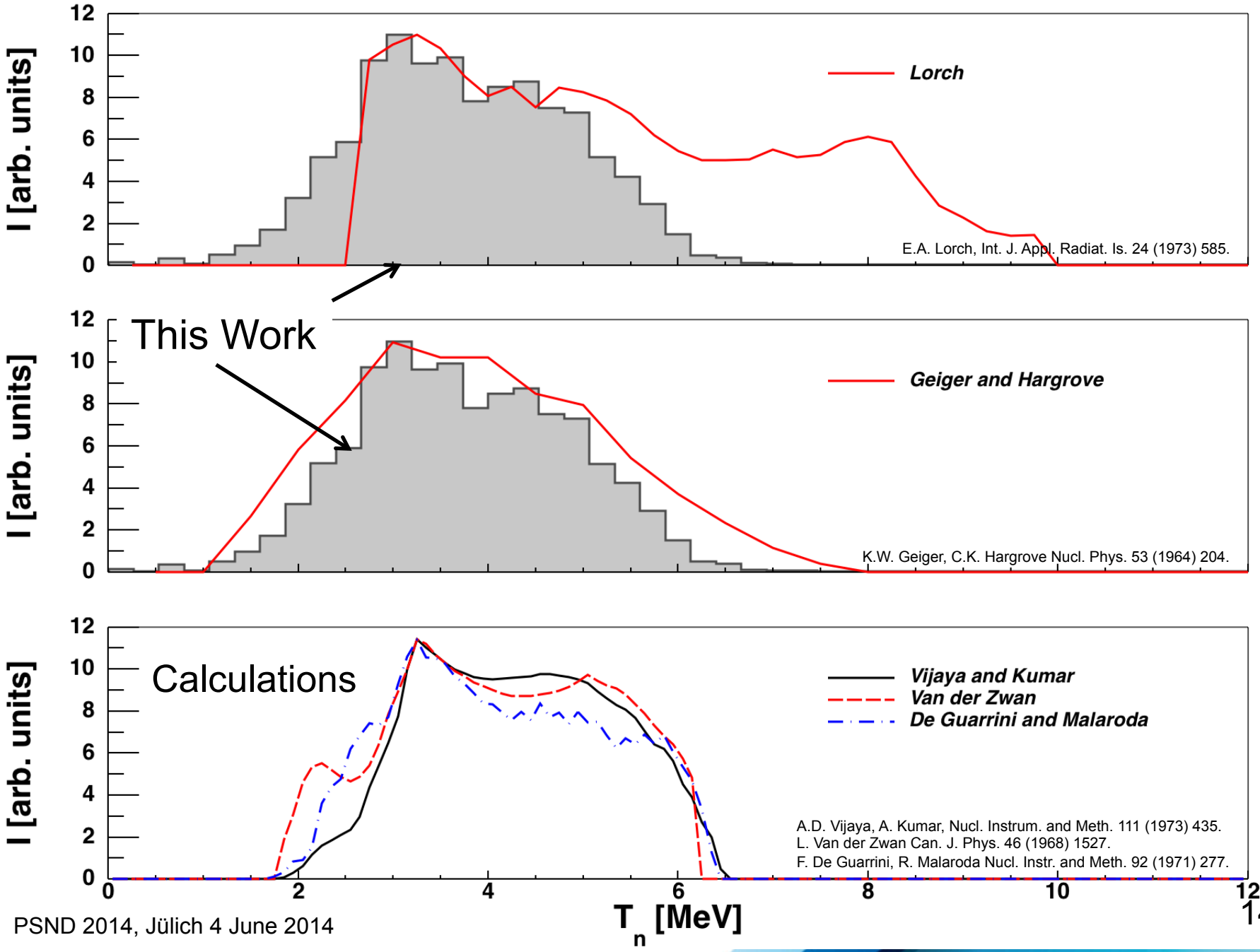
$$\hookrightarrow \gamma \quad (4.43\ \text{MeV})$$

~60%

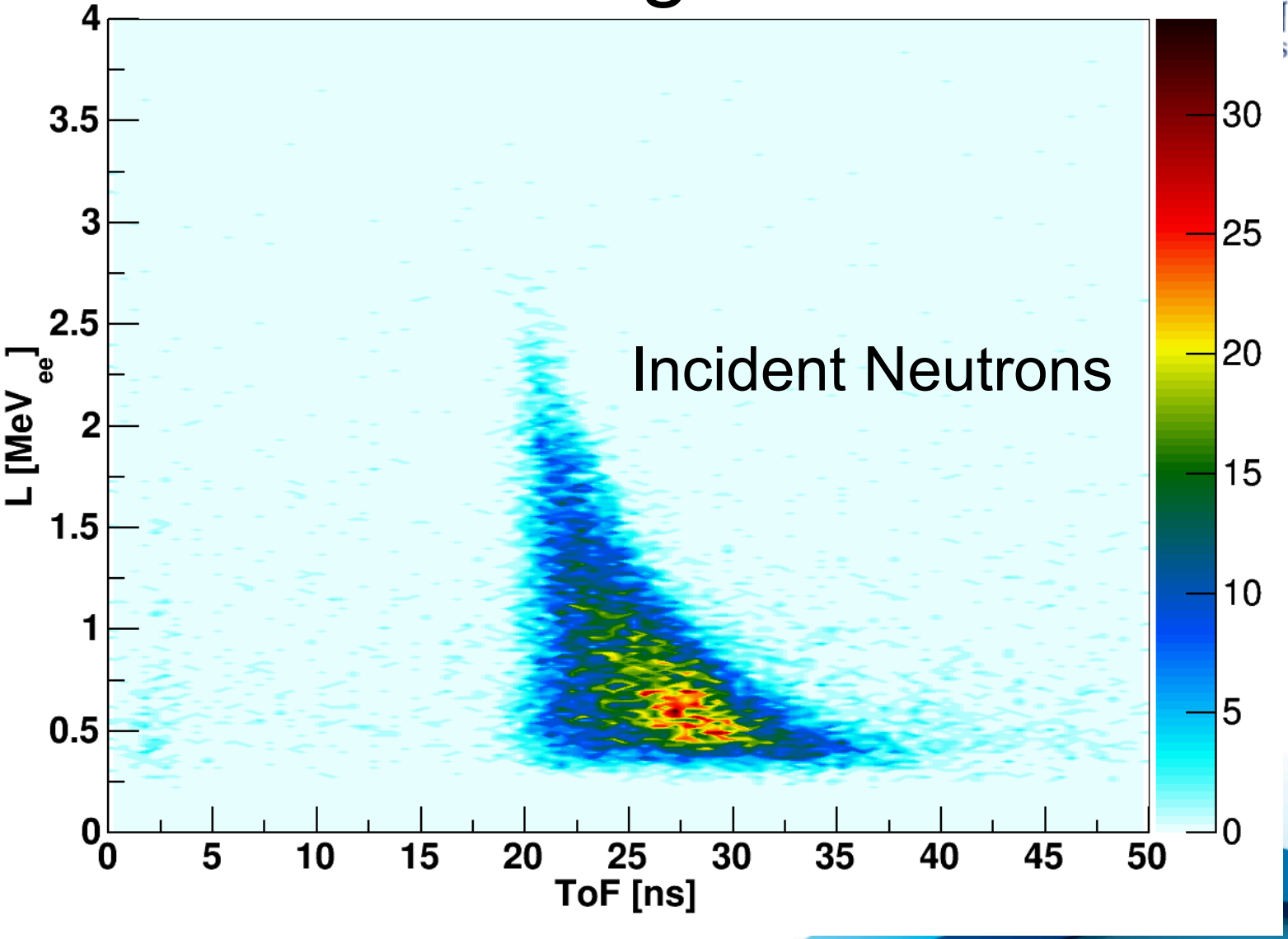



γ – rays
neutrons
PS
0.4
0.2
0
-0.2
70
60
50
40
30
20
10
0
counts
2000
1500
1000
500
0
-10
0
10
20
30
40
50
ToF [ns]

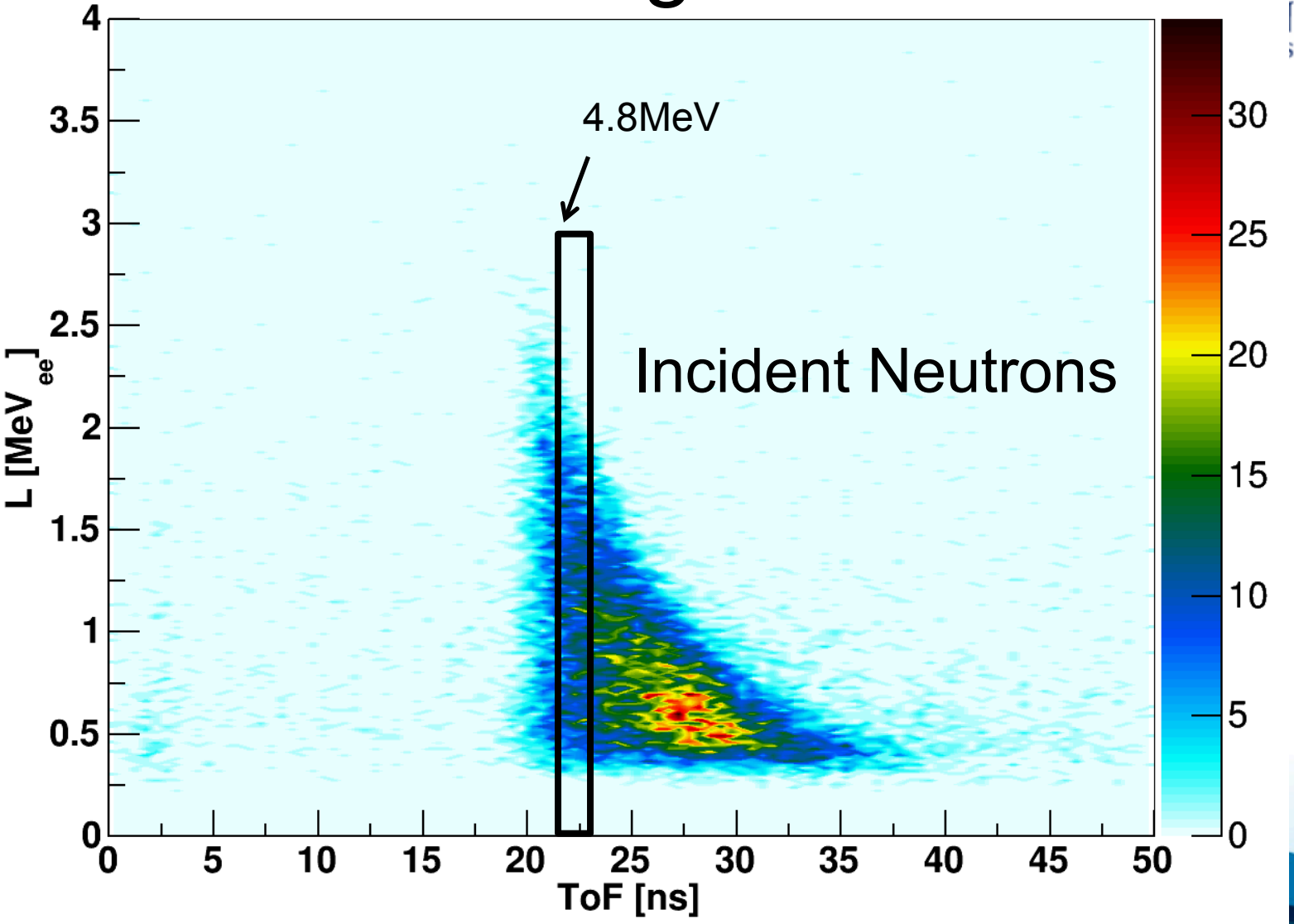

γ – rays
neutrons
PS
0.4
0.2
0
-0.2
70
60
50
40
30
20
10
0
counts
2000
1500
1000
500
0
-10
0
10
20
30
40
50
ToF [ns]
$T_n = \frac{1}{2} M_n \left(\frac{s_{drift}}{ToF} \right)^2$

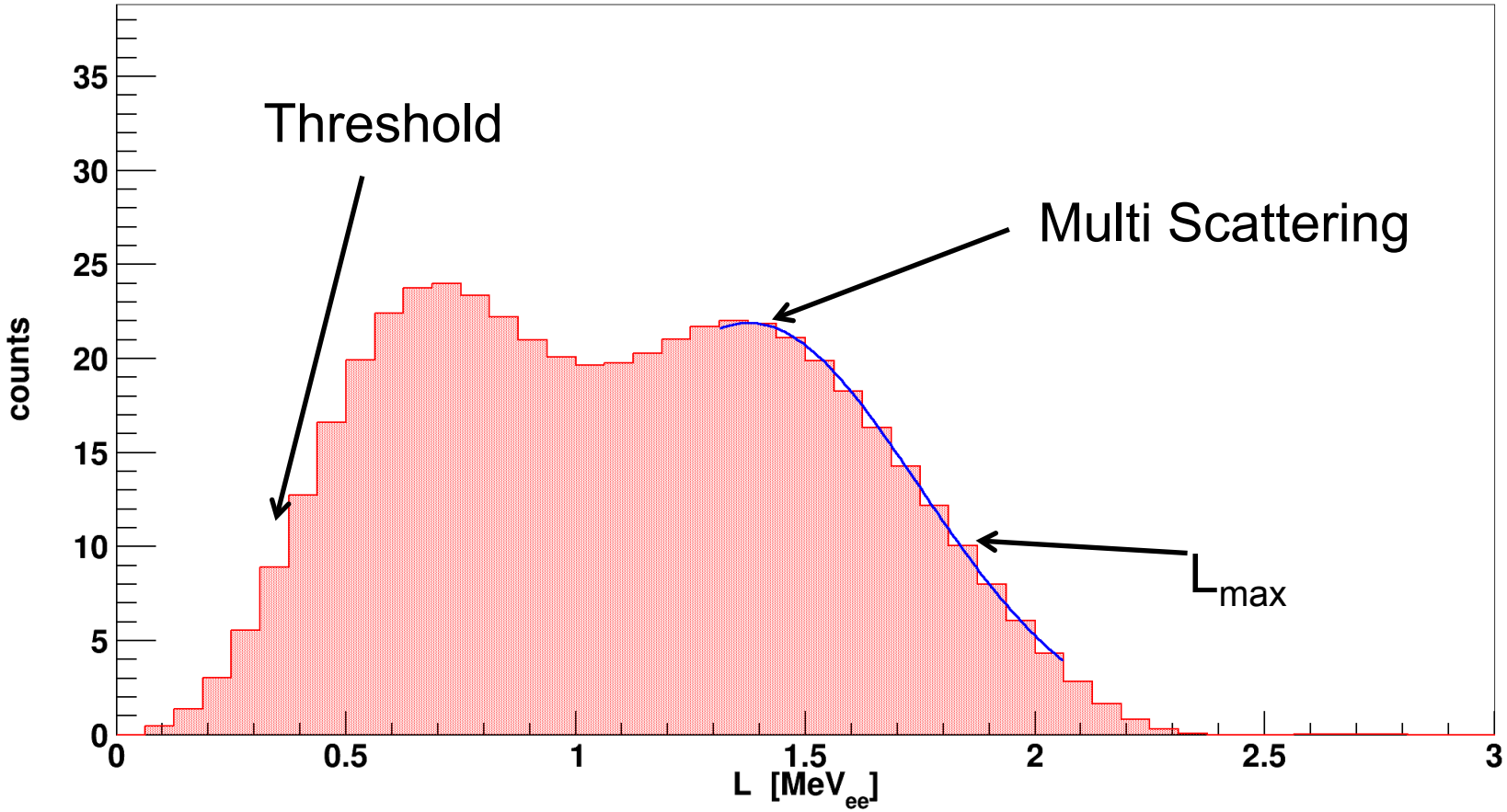

I [arb. units]
Lorch
E.A. Lorch, Int. J. Appl. Radiat. Is. 24 (1973) 585.
This Work
Geiger and Hargrove
K.W. Geiger, C.K. Hargrove Nucl. Phys. 53 (1964) 204.
Calculations
Vijaya and Kumar
Van der Zwan
De Guarrini and Malaroda
A.D. Vijaya, A. Kumar, Nucl. Instrum. and Meth. 111 (1973) 435.
L. Van der Zwan Can. J. Phys. 46 (1968) 1527.
F. De Guarrini, R. Malaroda Nucl. Instr. and Meth. 92 (1971) 277.
T n [MeV]

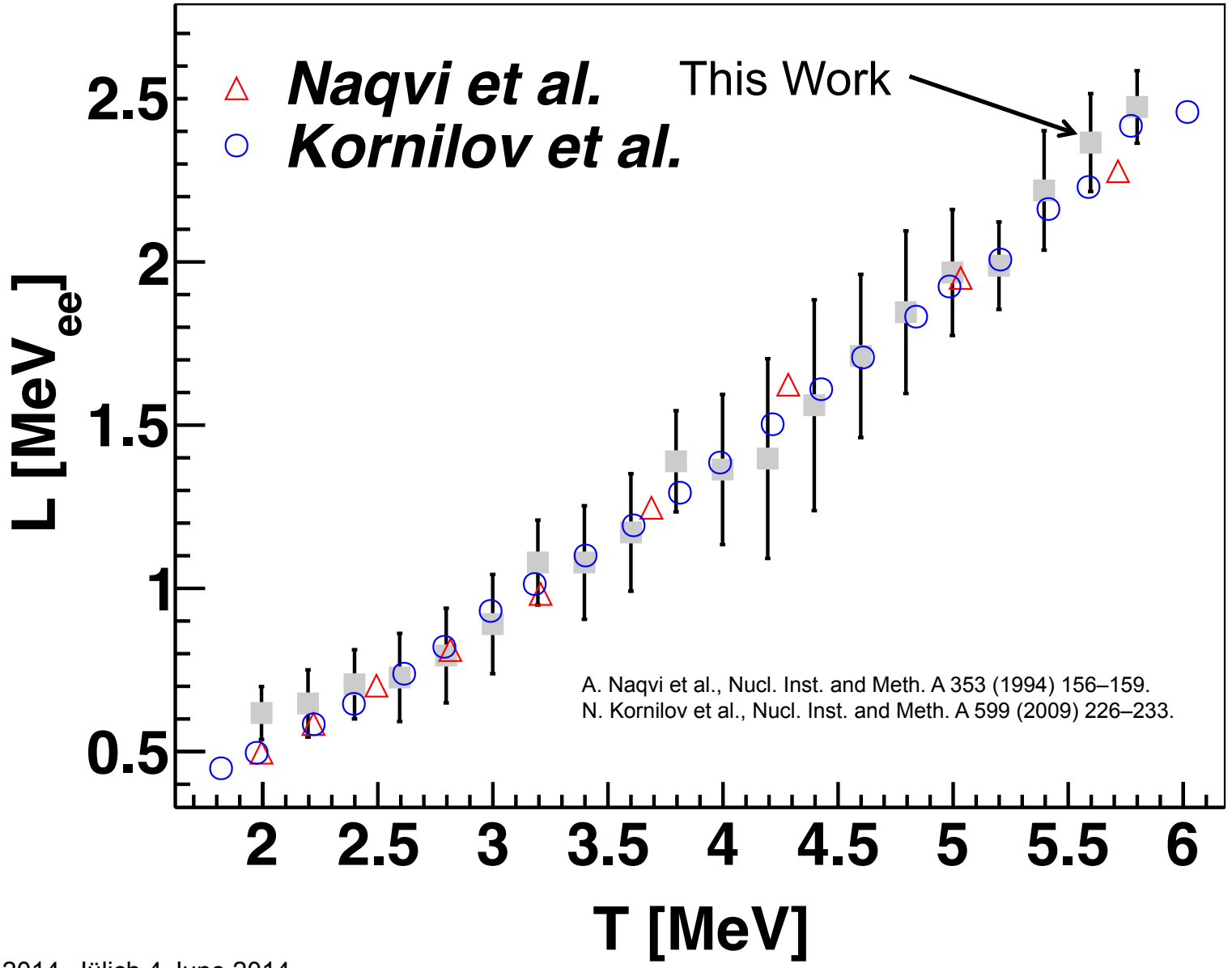
Proton Light Yield



Proton Light Yield




Threshold
Multi Scattering
L_{max}
counts
L [MeV$_{ee}$]
0
5
10
15
20
25
30
35
0
0.5
1
1.5
2
2.5
3


Naqvi et al.
Kornilov et al.
This Work
A. Naqvi et al., Nucl. Inst. and Meth. A 353 (1994) 156–159.
N. Kornilov et al., Nucl. Inst. and Meth. A 599 (2009) 226–233.
L [MeV$_{ee}$]
T [MeV]
0.5
1
1.5
2
2.5
2
2.5
3
3.5
4
4.5
5
5.5
6

Conclusion

- Fast neutron detection
  - Blind irradiation behaves as expected
  - Neutron “tagging” technique promising
  - NE-213 characterization in good agreement with other groups

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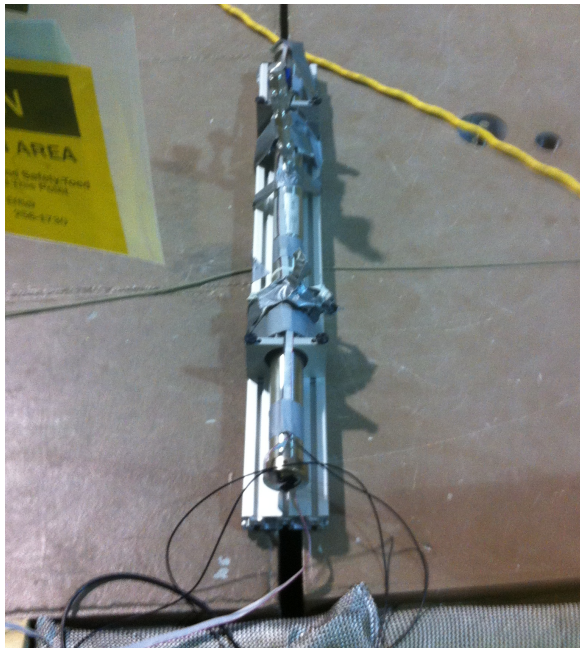
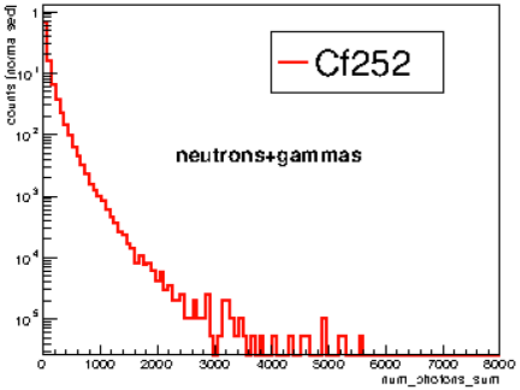
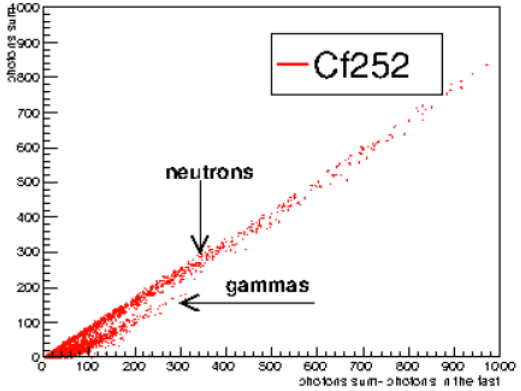
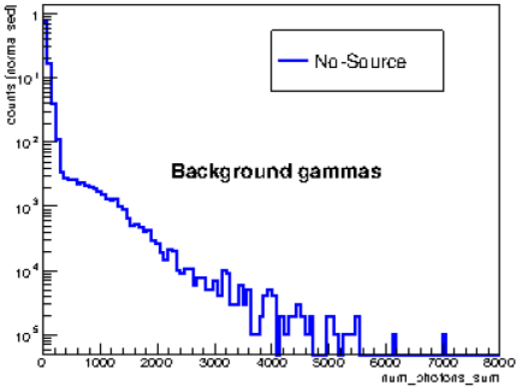
“High” energy background studies

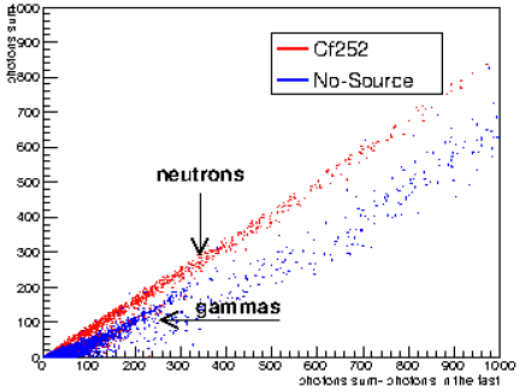
SNS
“High” Energy Background



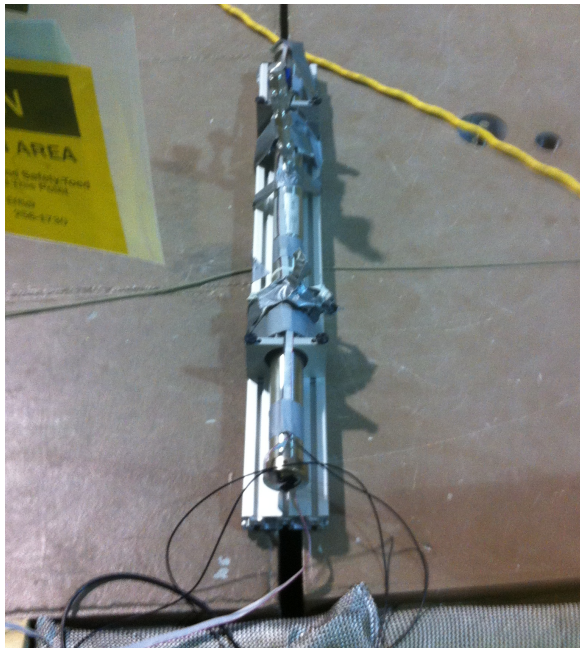


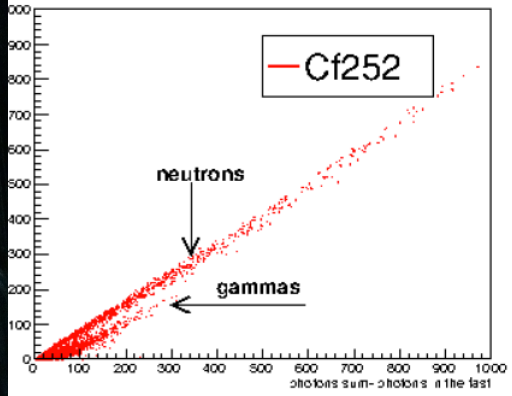


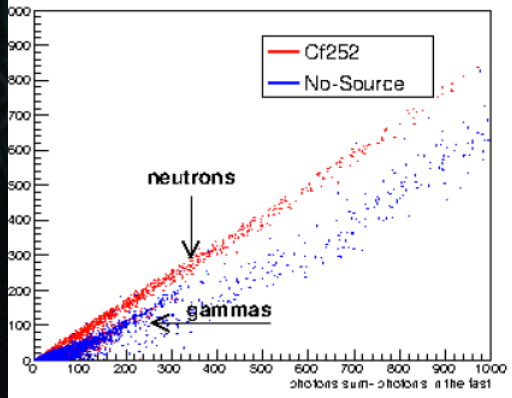




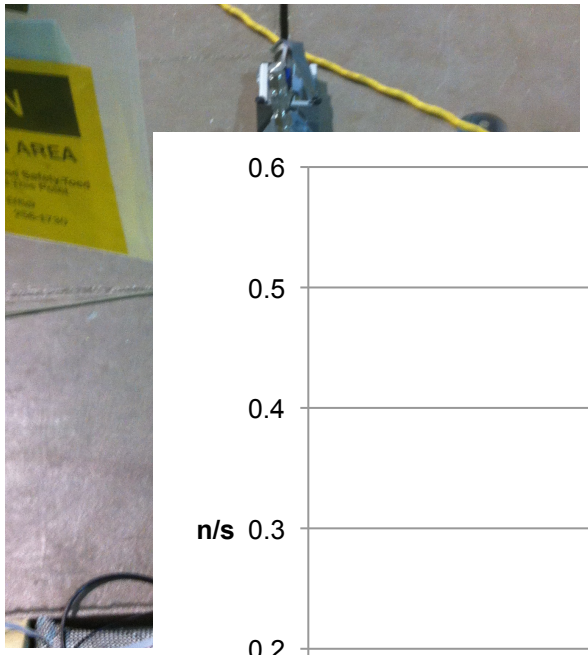
SNS
“High” Energy Background

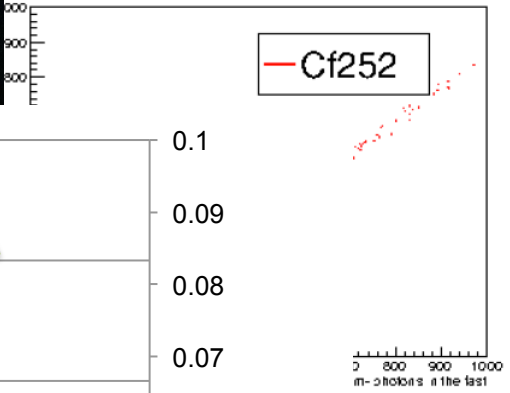


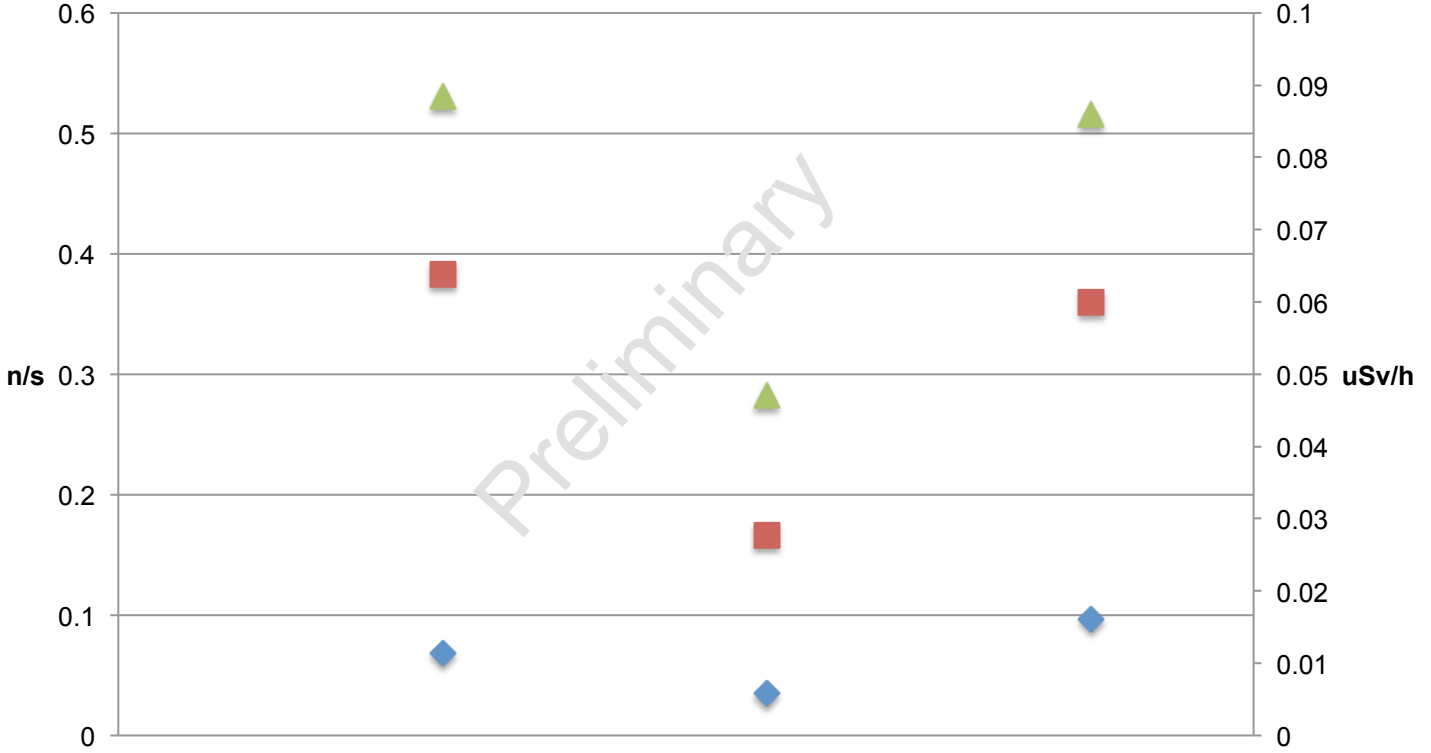


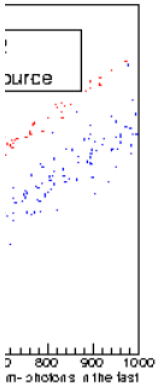


SNS
“High” Energy Background









Outlook

- Upgrading existing equipment
  - Flash ADC; to complement QDCs
  - Wide-Range TDC; 10 ms drift times
  - ^{3}He tube
  - Moderator/Shielding
    - Cd
    - PE

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    - Cd
    - PE

“Tagged” thermal neutrons

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