New Experiments With Potential Applications for Ariel

Wolfgang Mittig

Dark decay of the neutron: the neutron lifetime puzzle

τ_{bottle} = 879.6 +- 0.6 s counting remaining neutrons

τ_{beam} = 888.0 +- 2.0 s counting emitted protons

Difference 4σ !!

Dark Matter Interpretation of the Neutron Decay Anomaly

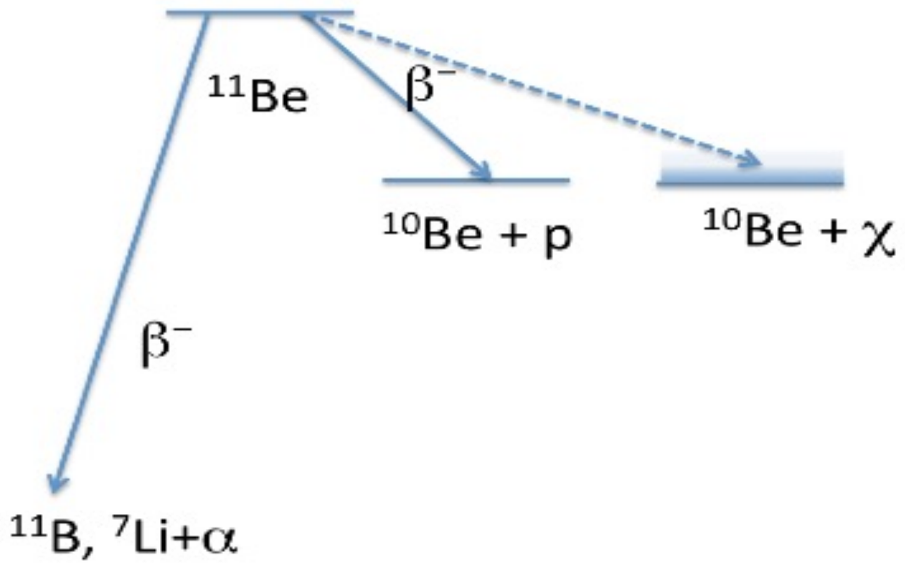
Bartosz Fornal and Benjamín Grinstein PRL120(2018)191801

1% branch n → ~~invisible + visible~~; n → invisible

see talk yesterday
by Susan Gardner

The quasi-free neutron dark decay: detectable reaction product

M. Pfützner and K. Riisager
PHYSICAL REVIEW C **97**, 042501(R) (2018)
Nuclear dark decays:
937.9 MeV< m_χ< $m_n - S_n$ Fulfilled in neutron halo nuclei



Rough estimation of dark decay of the quasi-free neutron of 11Be by
M. Pfützner and K. Riisager

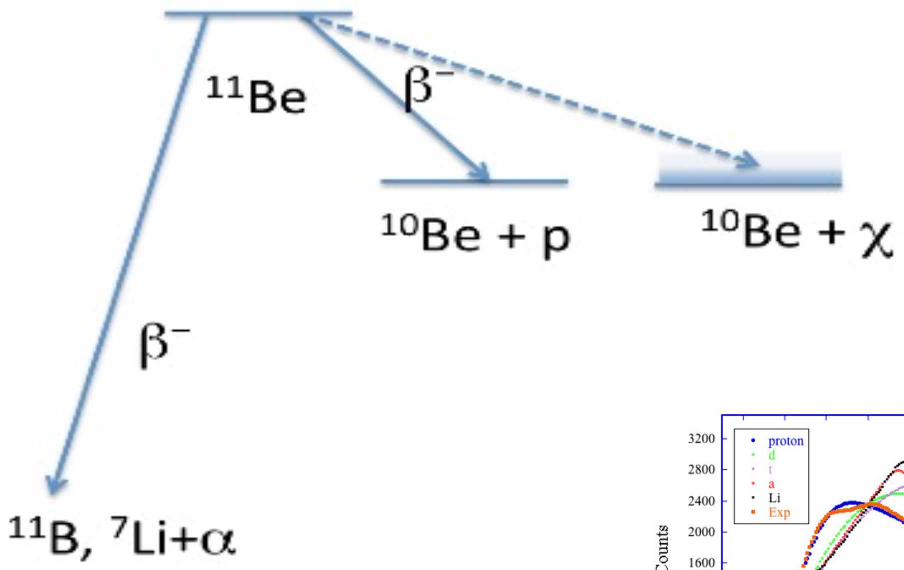
$T_{½\ neutron}$=880s

Life time anomaly ~8s~1%→
partial lifetime= 880s*100=88000s
Lifetime of ^{11}Be:13.8s → B_χ~13/88000~1.5*10^{-4}

Phase space corrections!!!

The quasi-free neutron dark decay

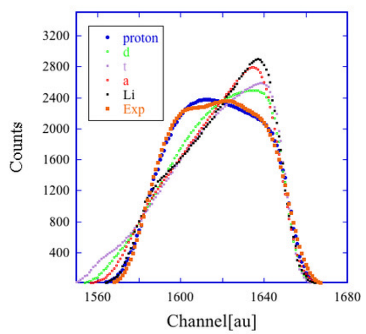
M. Pfützner and K. Riisager
PHYSICAL REVIEW C **97**, 042501(R) (2018)

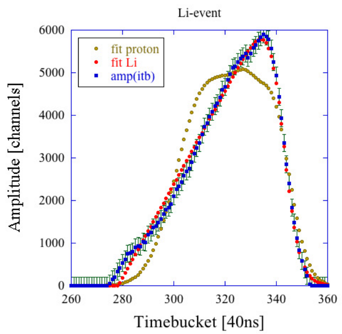


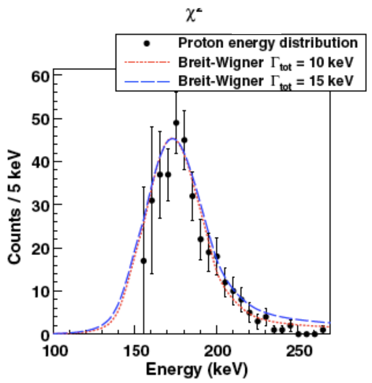
1) How much ^{10}Be is produced ?
Produced in the ^{11}Be decay
AMS at Cern Isolde: $B_{10Be} = 8.3(9)*10^{-6}$
K. Riisager *et al.*, Phys. Lett. B **732**, 305 (2014).
2) How much ^{10}Be is produced
by proton decay?:
Measure the proton decay branch:
C.Wrede@NSCL
Triumf pAT-TPC

Direct Observation of Proton Emission in ^{11}Be

Y. Ayyad *et al.*
Phys. Rev. Lett. **123**, 082501 – Published 22 August 2019







The quasi-free neutron (dark) decay

- First direct observation of $\beta^- p$ decay in a neutron-rich nuclei.
- Branching ratio is 1.2×10^{-5} , with 30% uncertainty… CERN-ISOLDE yield(ed) 8.0×10^{-6}, so no indication of dark decay
- A narrow resonance with Γ=12(5) keV, $J^{\pi} = (1/2^{+})$ in ^{11}B was inferred. E_x = 11425(20)keV (proton decay energy 178+-20keV) with Γ/Γ_{sp}~0.33
- Decay into the continuum would be characterized by a much smaller branching ratio (10^{-10})
- Heated discussion: resonance, no resonance, …
- See http://arxiv.org/abs/2205.04973.

Questions to answer

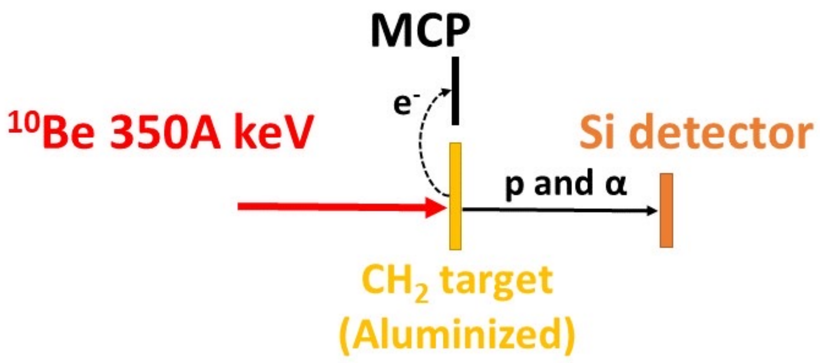
1) Can the existence of a ½+ state near threshold for proton emission in ^{11}B be confirmed or not? Can its characteristic features such as a significant spectroscopic factor be confirmed?

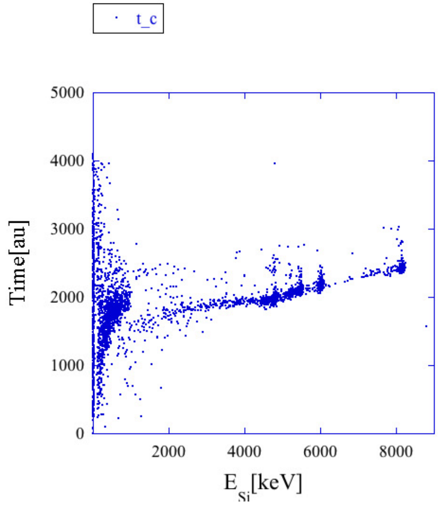
Evidence of near-threshold resonance in ^{11}B relevant to β-delayed proton emission of ^{11}Be.

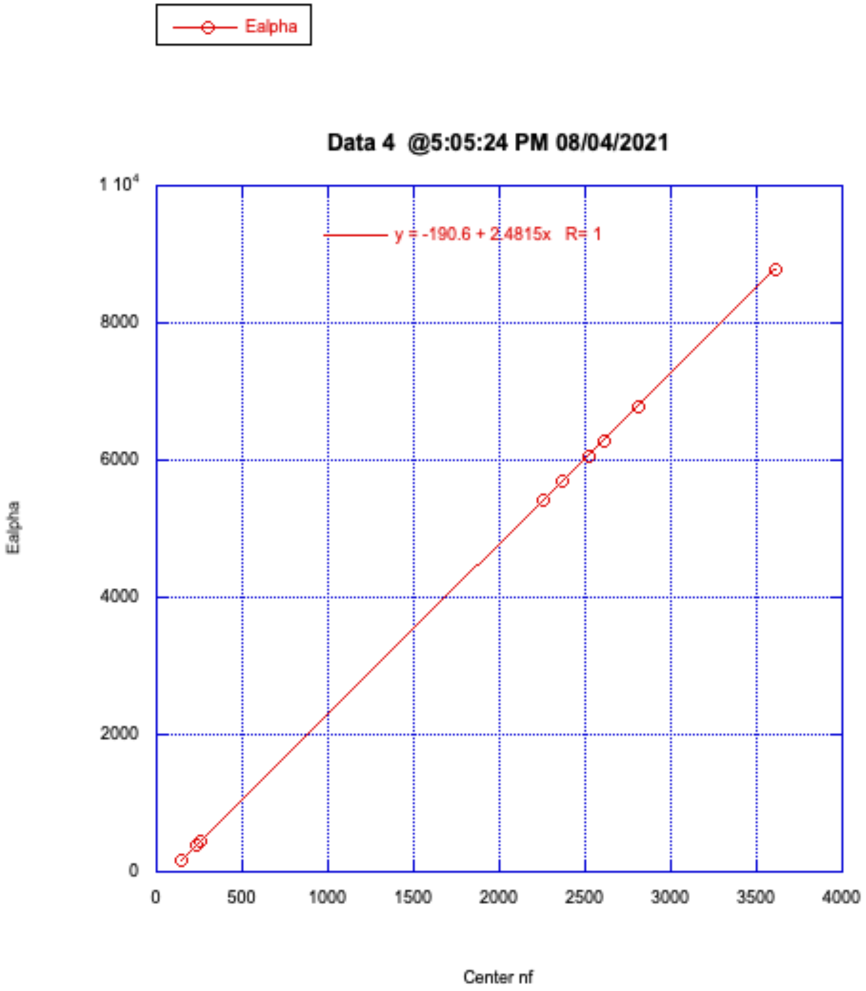
Y. Ayyad,[1,2,*] W. Mittig,[2,3] T. Tang,[2] B. Olaizola,[4] G. Potel,[5] N. Rijal,[2] N. Watwood,[2] H. Alvarez-Pol,[1] D. Bazin,[2,3] M. Caamaño,[1] J. Chen,[6] M. Cortesi,[2] B. Fernández-Domínguez,[1] S. Giraud,[2] P. Gueye,[2,3] R. Jain,[2,3] B. Kay,[6] E. A. Maugeri,[7] B. Monteagudo,[2] F. Ndayisabye,[2,3] S. N. Paneru,[2] J. Pereira,[2] E. Rubino,[2] C. Santamaria,[2] D. Schumann,[7] J. Surbrook,[2,3] L. Wagner,[2] J. C. Zamora,[2] and V. Zelevinsky[2,3]

2) Can the branching ratio for proton decay of this state be confirmed or not? (C. Wrede et al., ongoing)

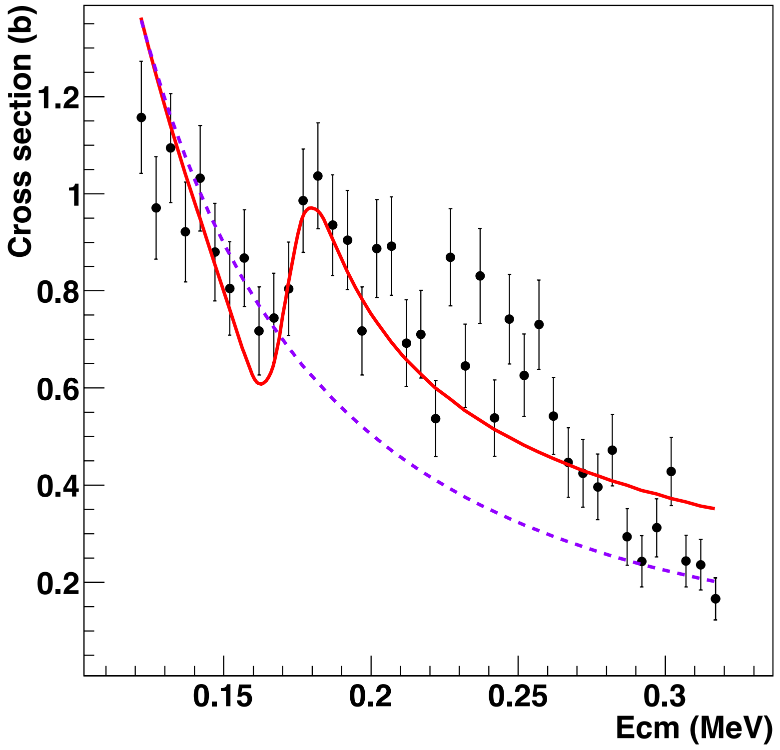
^{10}Be beam from ReA3
thick target method to scan the resonance







Result: excitation function of elastic scattering 10Be+p



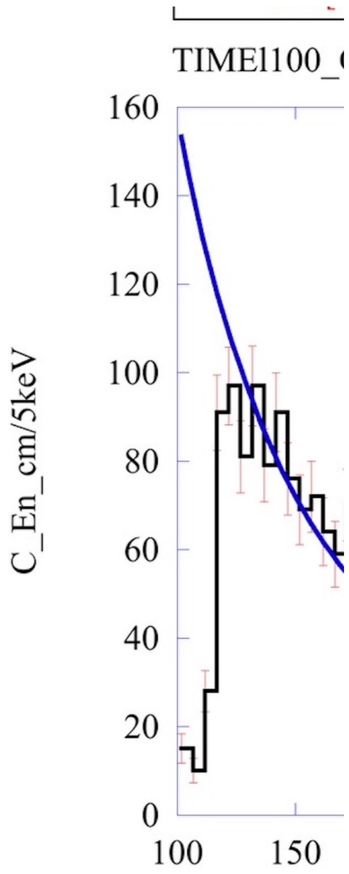
Fit with code Azur2

Er=(171 +-20)keV

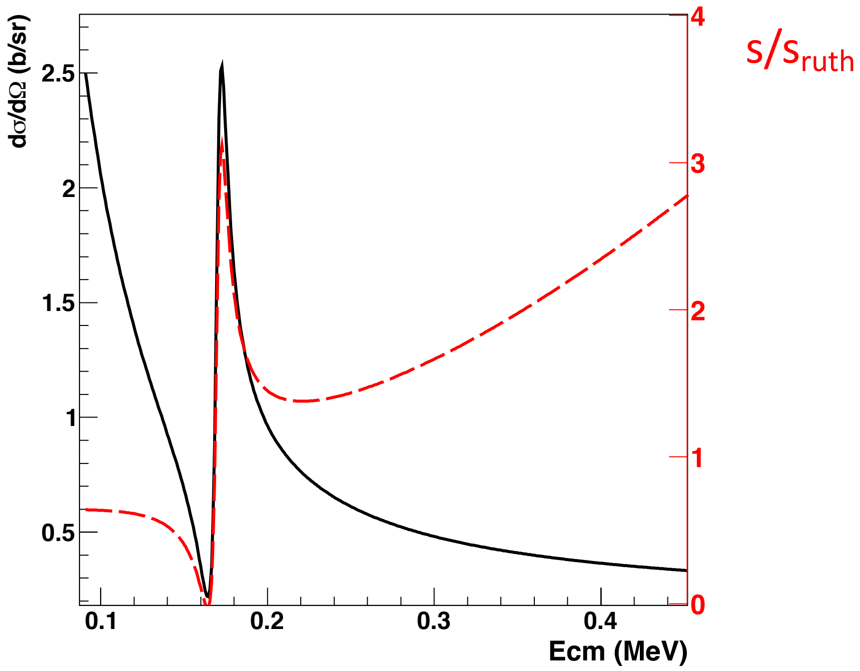
Γ=16keV

Γ_p=4.5 keV

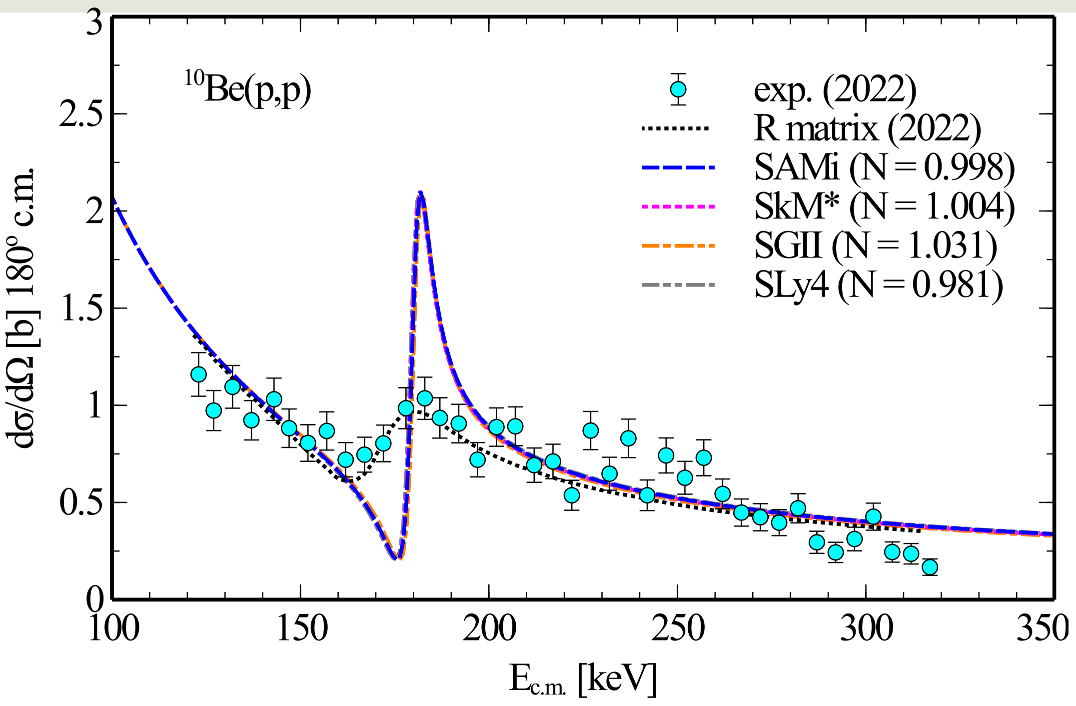
Γ_α=11keV



Excitation function of elastic scattering $^{10}Be+p$



SPOMC*1.78



MinhLoc BUI
N. Auerbach
V. Zelevinsky
Private comm May 2022

Compare with other results: FSU

Observation of a Near-Threshold Proton Resonance in ^{11}B

E. Lopez-Saavedra,[1,*] S. Almaraz-Calderon,[1,†] B. W. Asher,[1] L. T. Baby,[1] N. Gerken,[1] K. Hanselman,[1] K. W. Kemper,[1] A. N. Kuchera,[2] A. B. Morelock,[1] J. F. Perello,[1] E. S. Temanson,[1] A. Volya,[1] and I. Wiedenhöever[1]

[1] *Department of Physics Florida State University Tallahassee Florida 32306 ,USA*
[2] *Department of Physics Davidson College Davidson North Carolina 28035,USA*

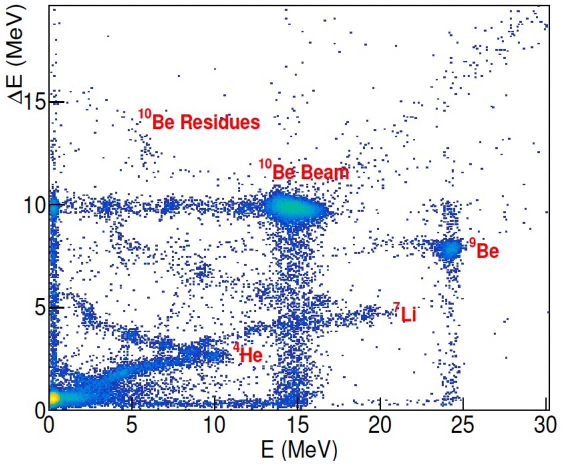


FIG. 1: Spectrum in the Ionization Chamber (IC) obtained using the E - ΔE sections during the present $^{10}Be(d,n)^{11}B^* \rightarrow {}^{10}Be + p$ measurement. The location of the ^{10}Be recoils is well separated from the direct ^{10}Be beam. Other components present in the spectrum are the primary ^{9}Be beam as well as He and Li breakup channels.

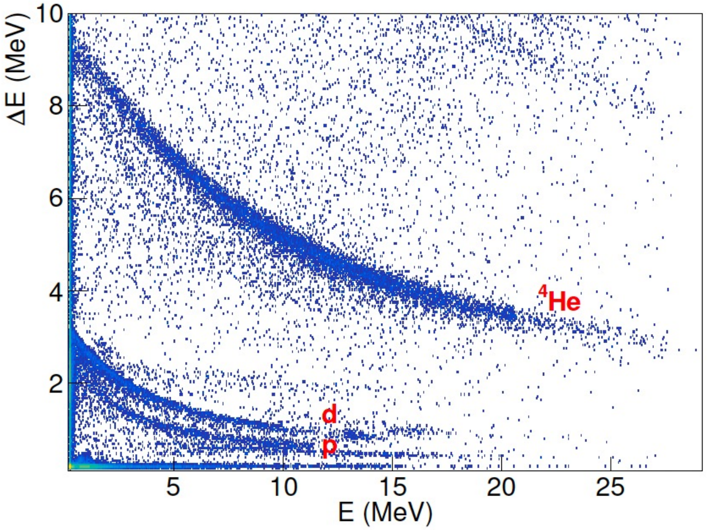


FIG. 2: E - ΔE spectrum obtained in the silicon-detector telescope. Bands of α particles (^4He), deuterons (d), and protons (p) are visible and well separated from each other.

If the ½+ state in ^{11}B has a significant spectroscopic factor it should be populated in a $^{10}Be(d,n)^{11}B^*$ -→^{10}Be+p

Compare with other results: FSU

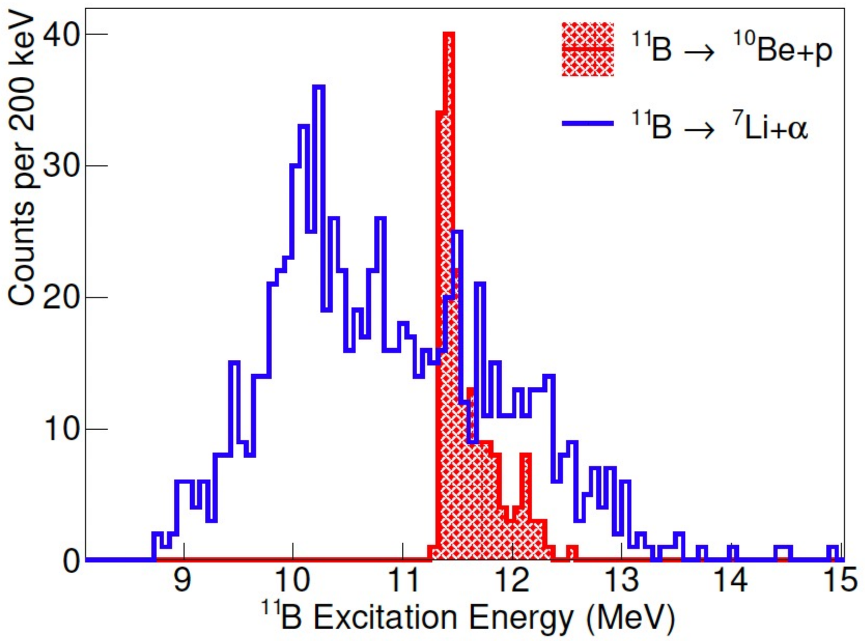


FIG. 3: Excitation energy spectrum in ^{11}B reconstructed from the $^{11}B^* \rightarrow {}^{10}Be + p$ (red) and $^{11}B^* \rightarrow {}^{7}Li + \alpha$ (blue). A prominent near-threshold peak at $E_{ex} = 11.44 \pm 0.04$ MeV is visible in the proton spectrum.

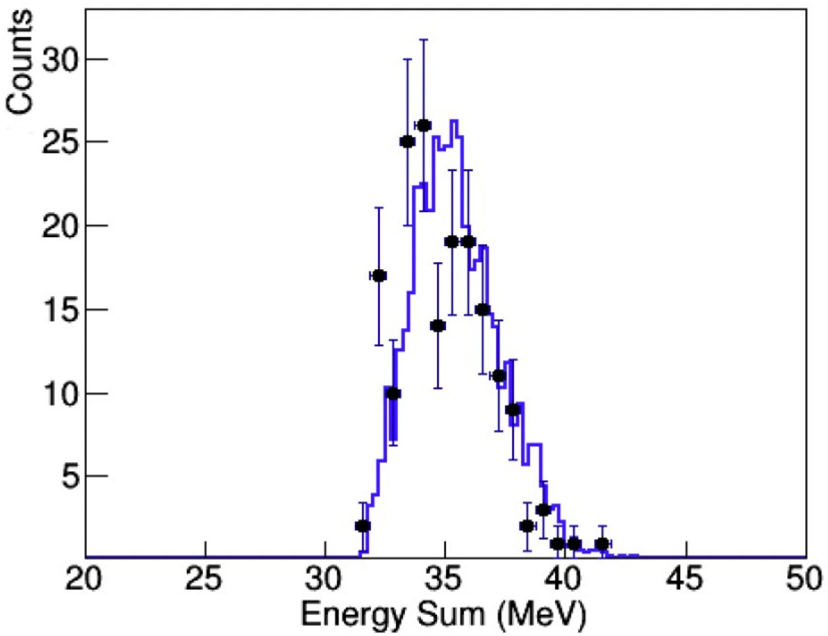


FIG. 4: Energy-sum signals of ^{10}Be + p events for the 11.44 MeV state, compared with a Monte Carlo simulation (in blue) that takes into account the DWBA-calculated angular distribution of the $^{10}Be(d,n)^{11}B^*$ reaction. A value of $\ell = 0$ fits well the experimental data.

C2S = 0.27(6)

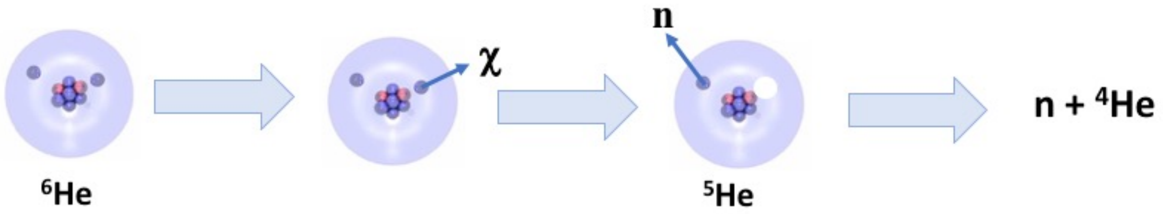
E_x=11.44MeV→
E_{res}=11.44-11.228=
(212+-40)keV

Dark Decay of ^{6}He

- Reminder: for estimation 1% decay branch for free neutron, so partial decay time 880*100s=88000s
- Branching ratio of a quasi-free neutron expected in a nucleus with a lifetime of T_{life} B ~ T_{life}/88000s=0.806s/88000s~1*10^{-5}-->10^{-7}

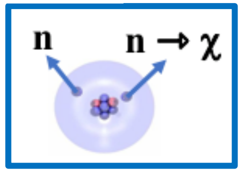
E819S_20 – June 11th to 17th 2021

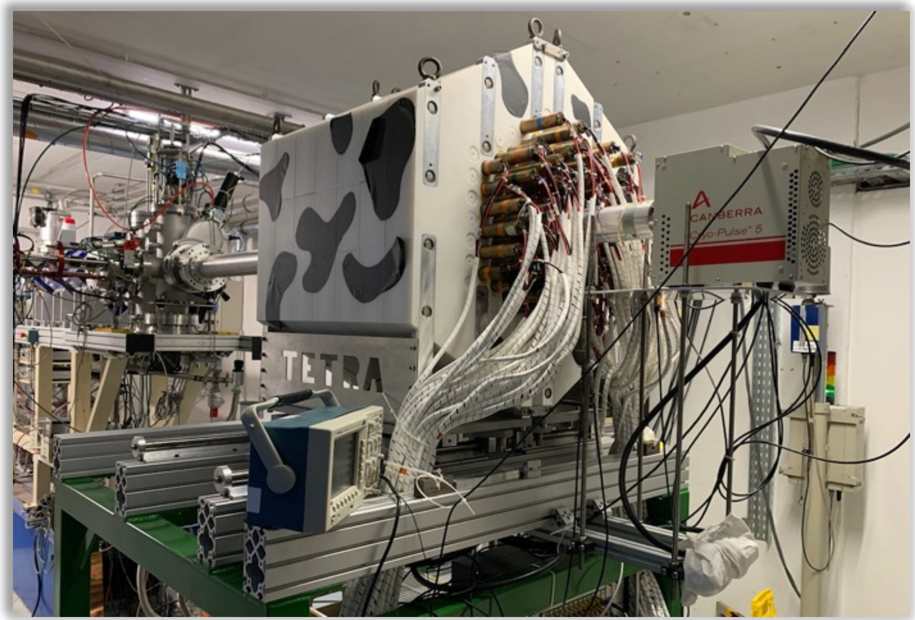
Is there a dark decay of neutrons in ^{6}He ?



Branching ratio estimates of **$B\chi = 1.2 \times 10^{-5}$**

Allowed energy window : **$M\chi$ < Mn - 975.45 keV**

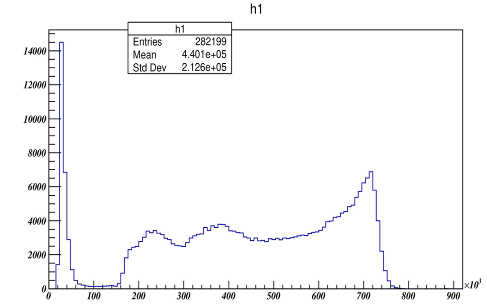




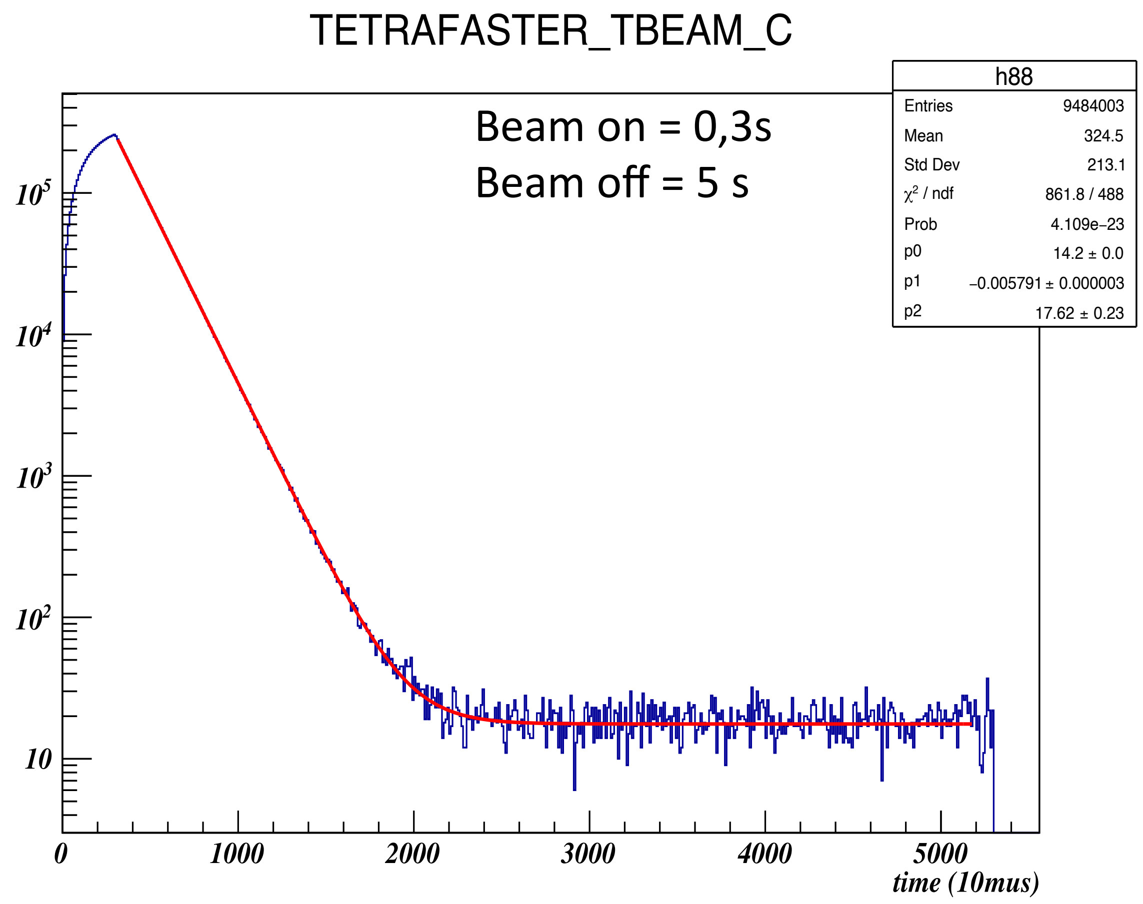
Hervé Savajols, Jean-Charles Thomas, Xavier Ledoux, Pierre Delahaye, Nathalie Lecesne, Dieter Ackermann, Marek Lewitowicz, Lucia. Caceres, Julien Piot, Christelle Stodel… (GANIL)
Sergey Lukianov, Vladimir Smirnov, Dimitry Testov, Sergey Stukalov (JINR Dubna)
Xavier Fléchard, Etienne Liénard …(LPC)
Vladimir Manéa, David Verney … (IJCLab)
W. Mittig, Y. Ayyad …. (NSCL/FRIB)
Philippe Dessagne,… (IPHC)

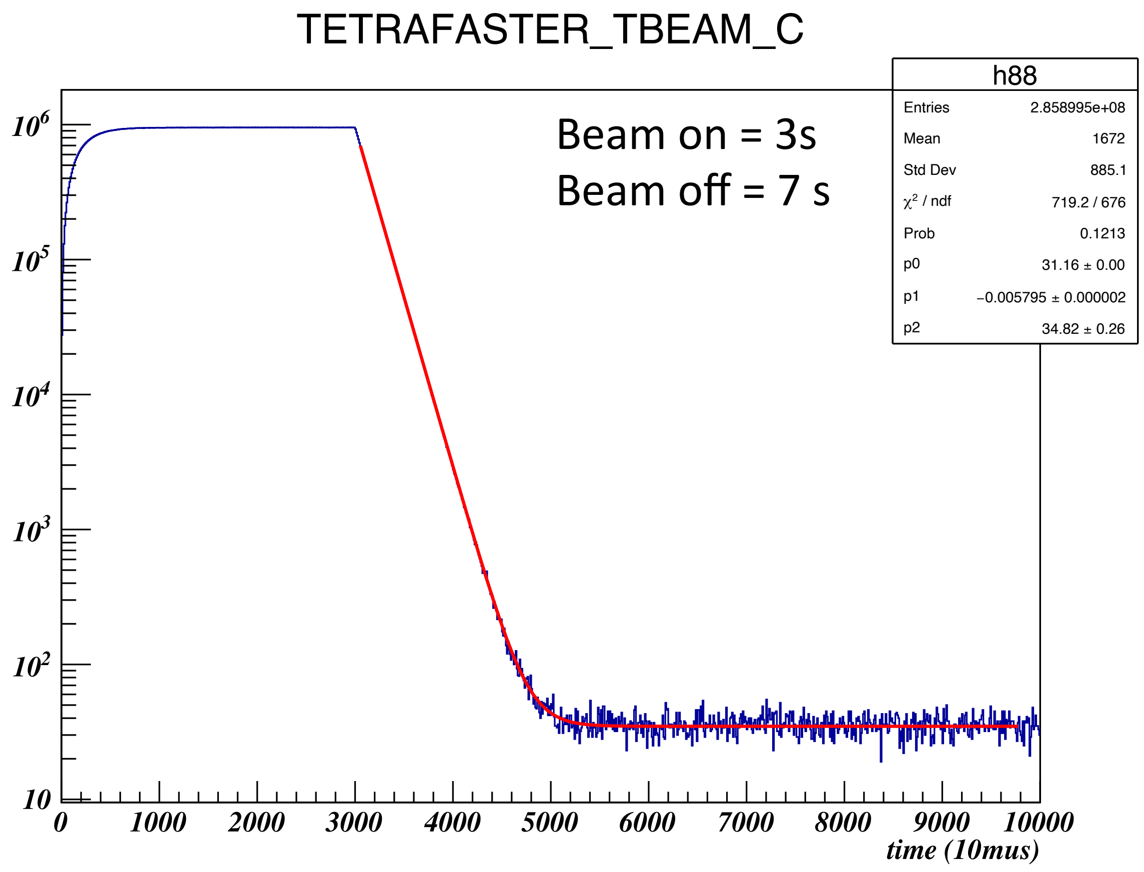
$^6He^{1+}$ SPIRAL1 world record beam intensity ($2{\times}10^8$ pps)

Neutron multidetector TETRA with 50% efficiency



^{8}He neutron decay in TETRA



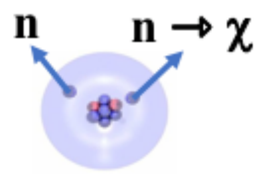


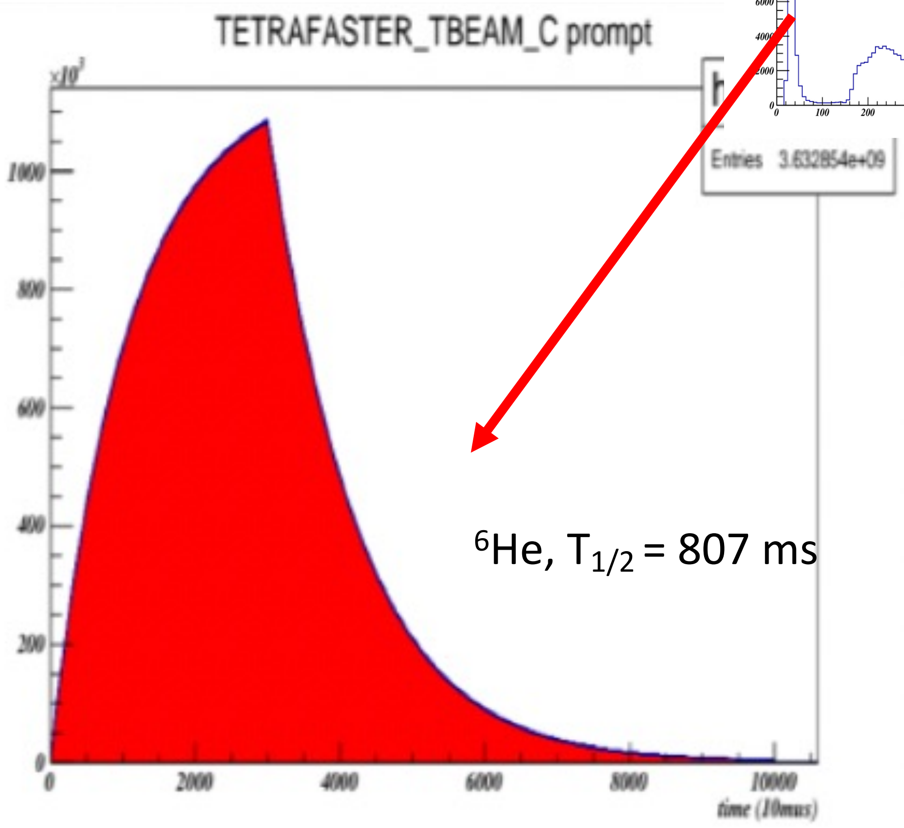
$T_{1/2} = 119.50 \pm 0.08\ s$

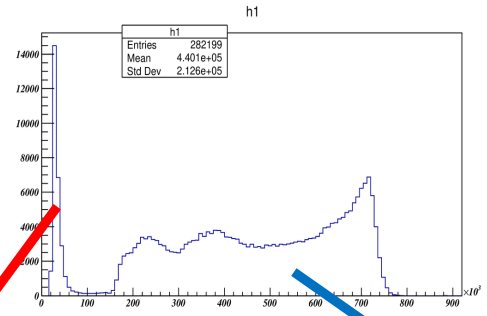
$T1/2 = 119.61 \pm 0.04\ s$

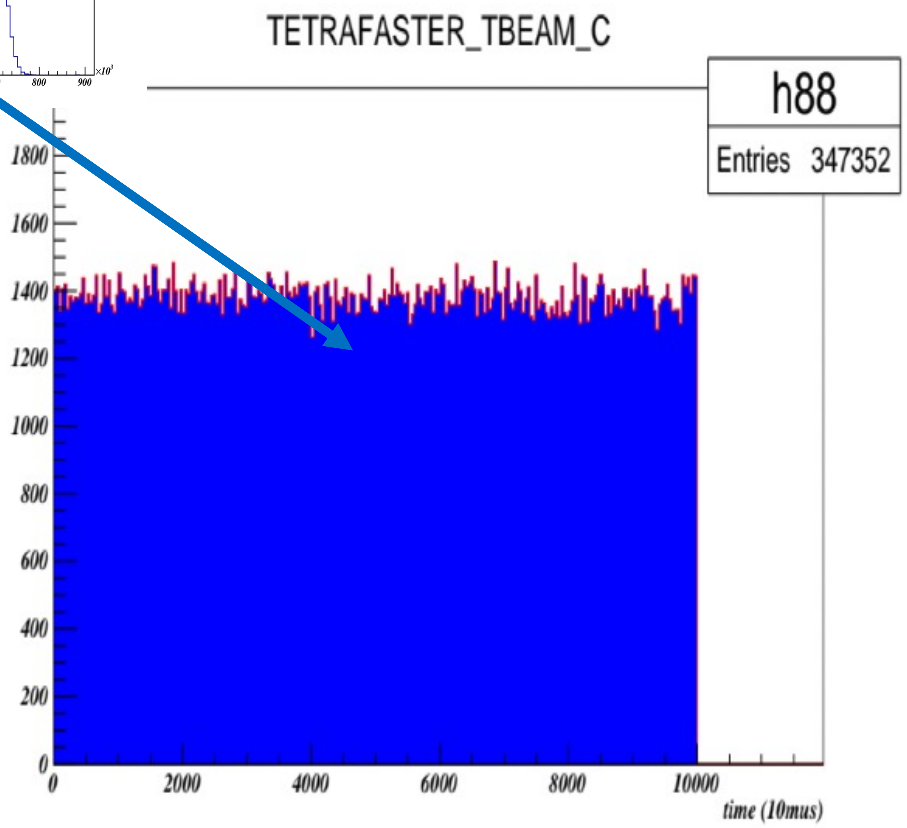
^{6}He dark decay

Le Joubioux Marius et al.
Converging to an upper limit of 10**-9









^{6}He, $T_{1/2}$ = 807 ms

Possible Dark Matter Candidates Mass

M.Battaglieri

~50 orders of magnitude

Our domain <1eV~1GeV

S. Gardner, G.M. Fuller / Progress in Particle and Nuclear Physics 71 (2013) 167–184

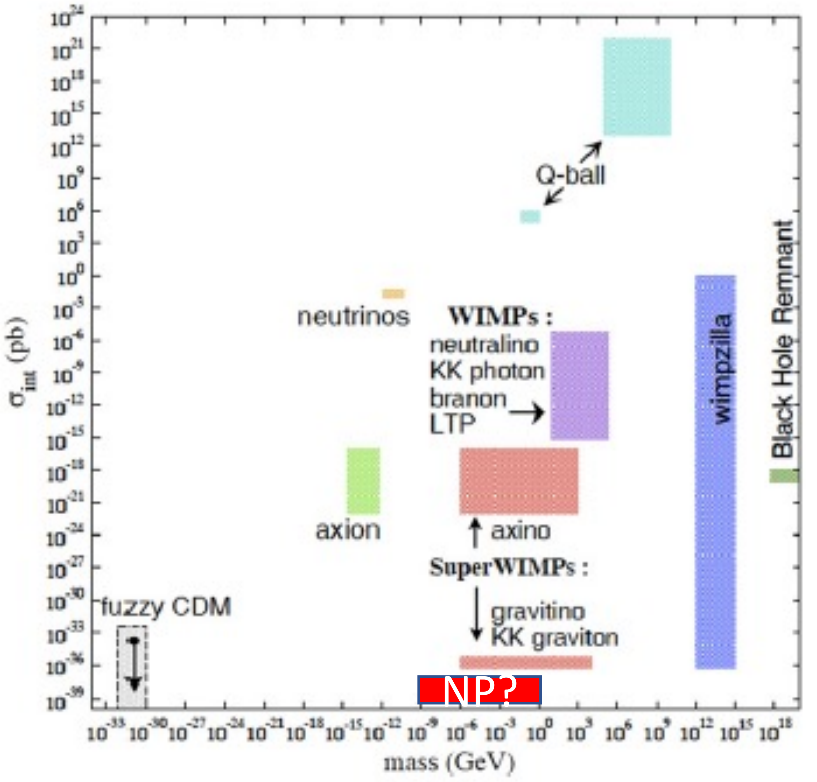
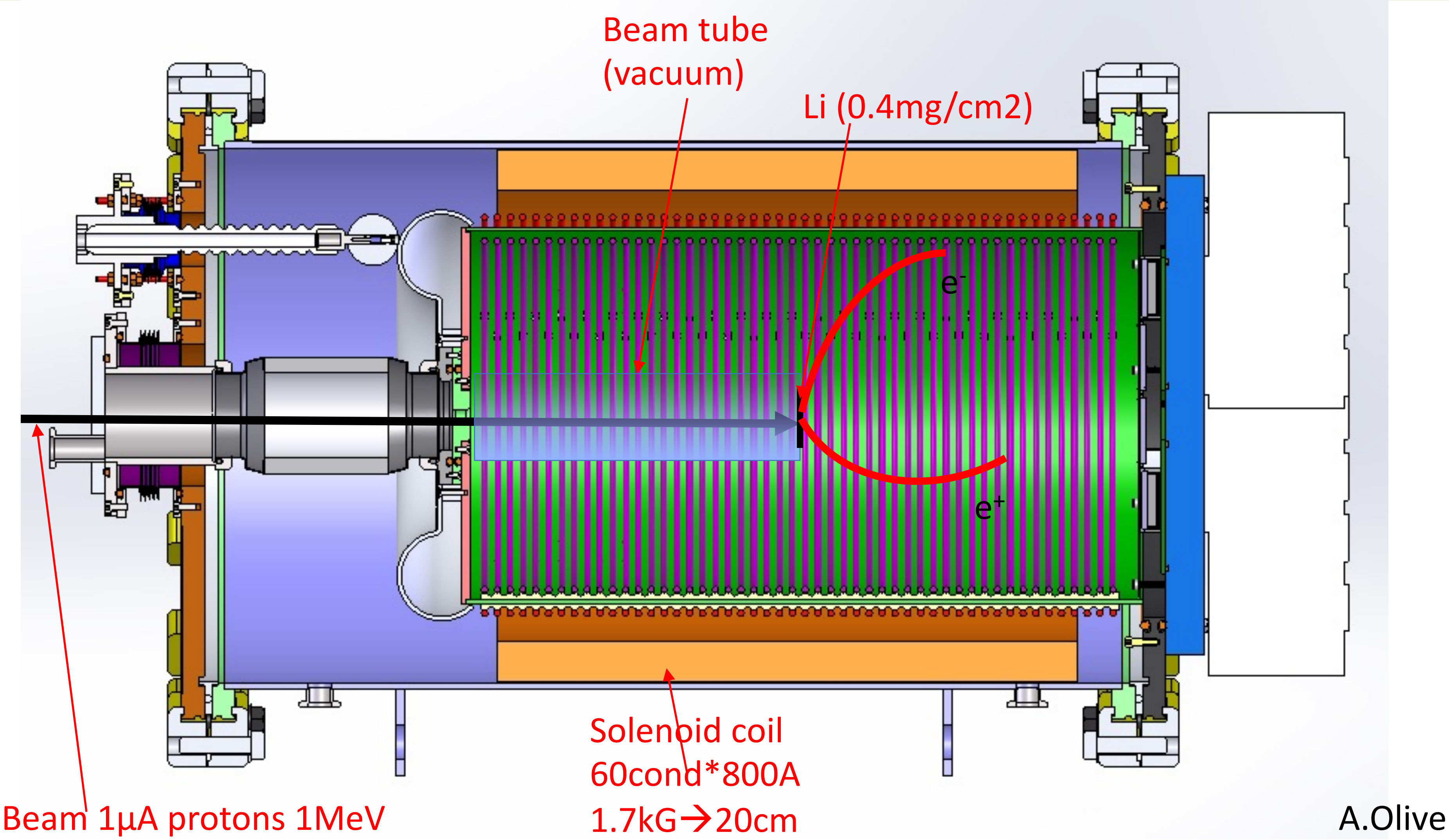
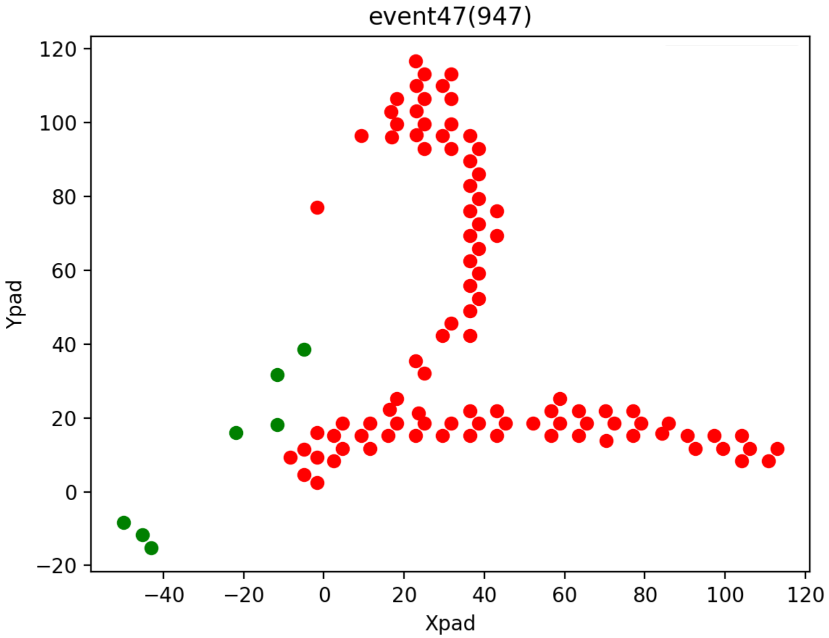


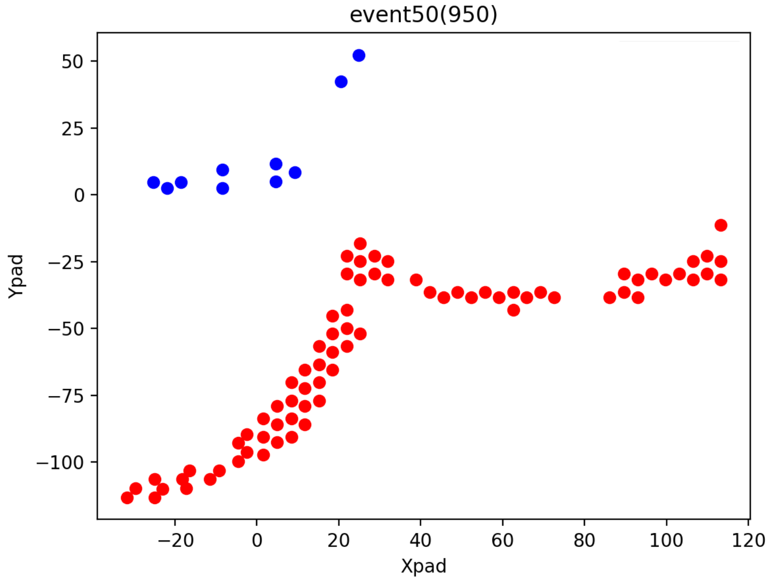
Fig. 1. Estimated loci of select dark-matter models in the space of candidate mass in GeV versus dark-matter–candidate-nucleon interaction cross section in pb.

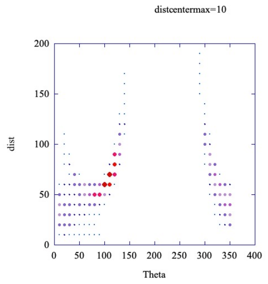
X17 boson: pAT-TPC for e+e- detection

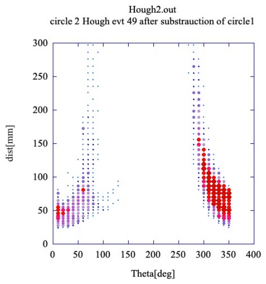


e+-e- pairs: seagulls





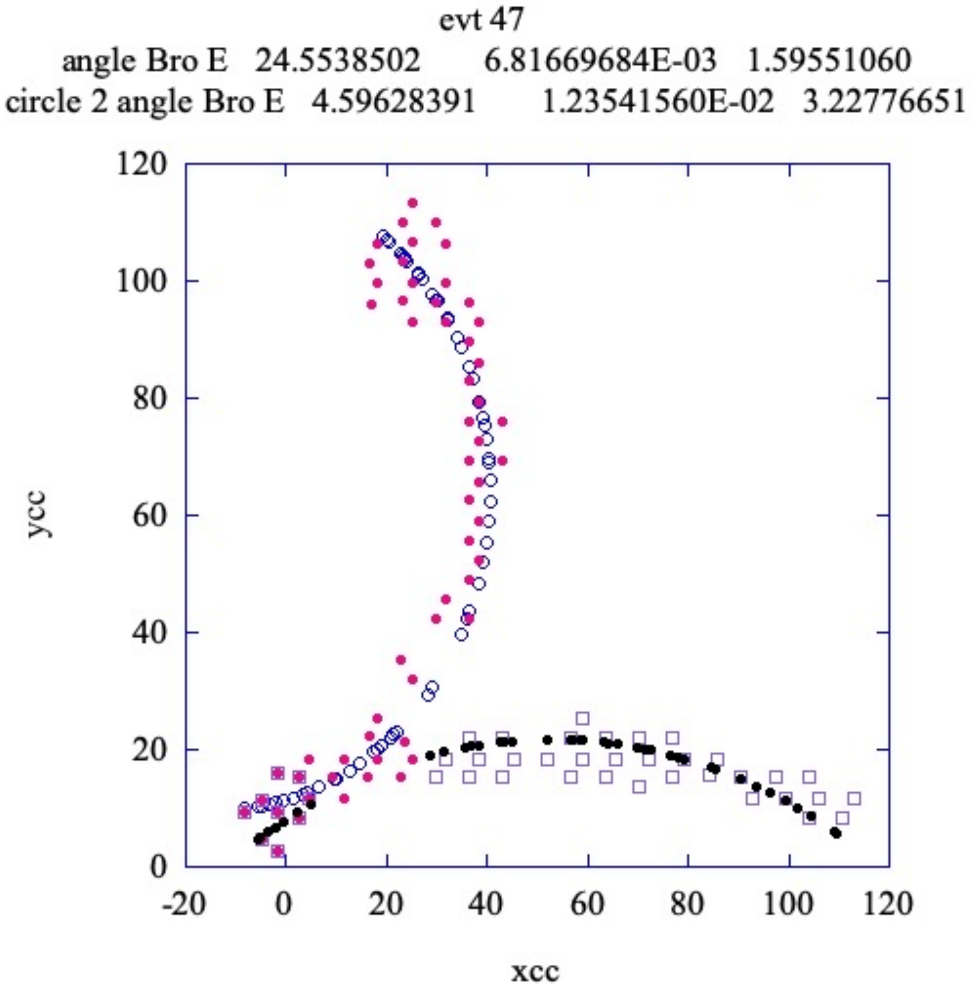


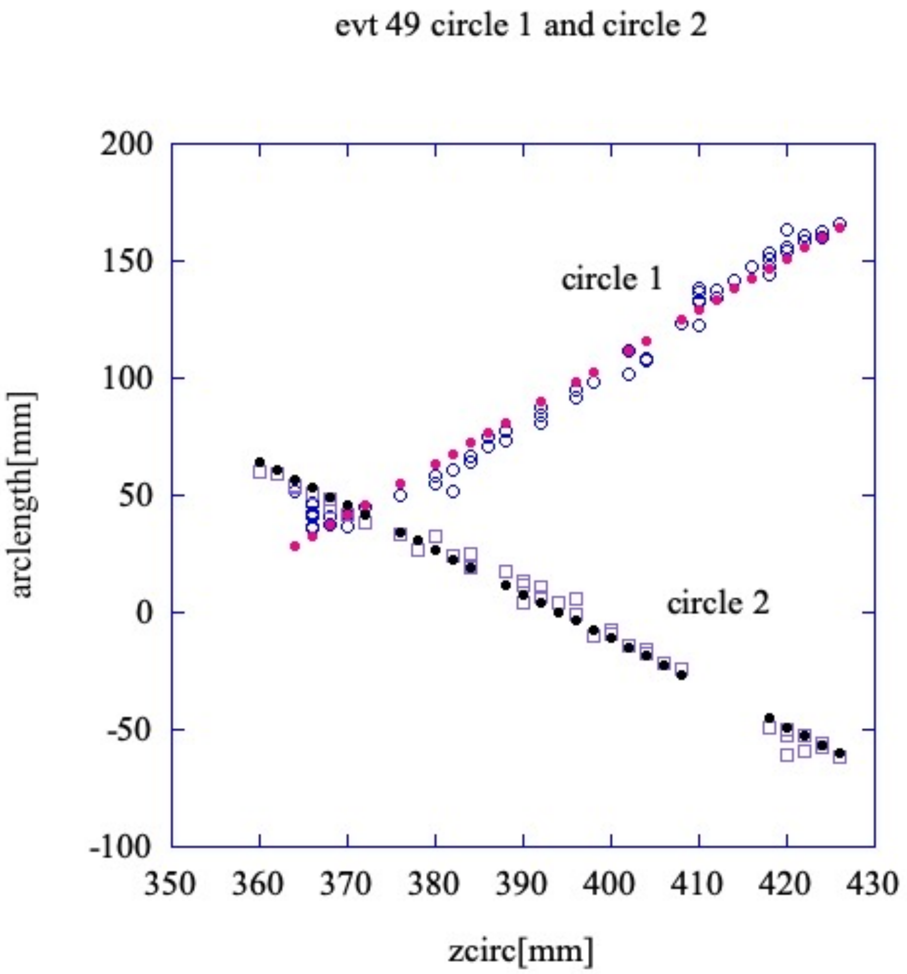


1) Use output of clustering
2) Take the maximum in the Hough plot
3) Calculate center and radius
4) Make circle fit of the hits near this circle→circle 1
5) Take out all points near this circle except near zero
6) Make Hough analysis for second circle
7) Make circle fit of the hits near this circle→circle 2

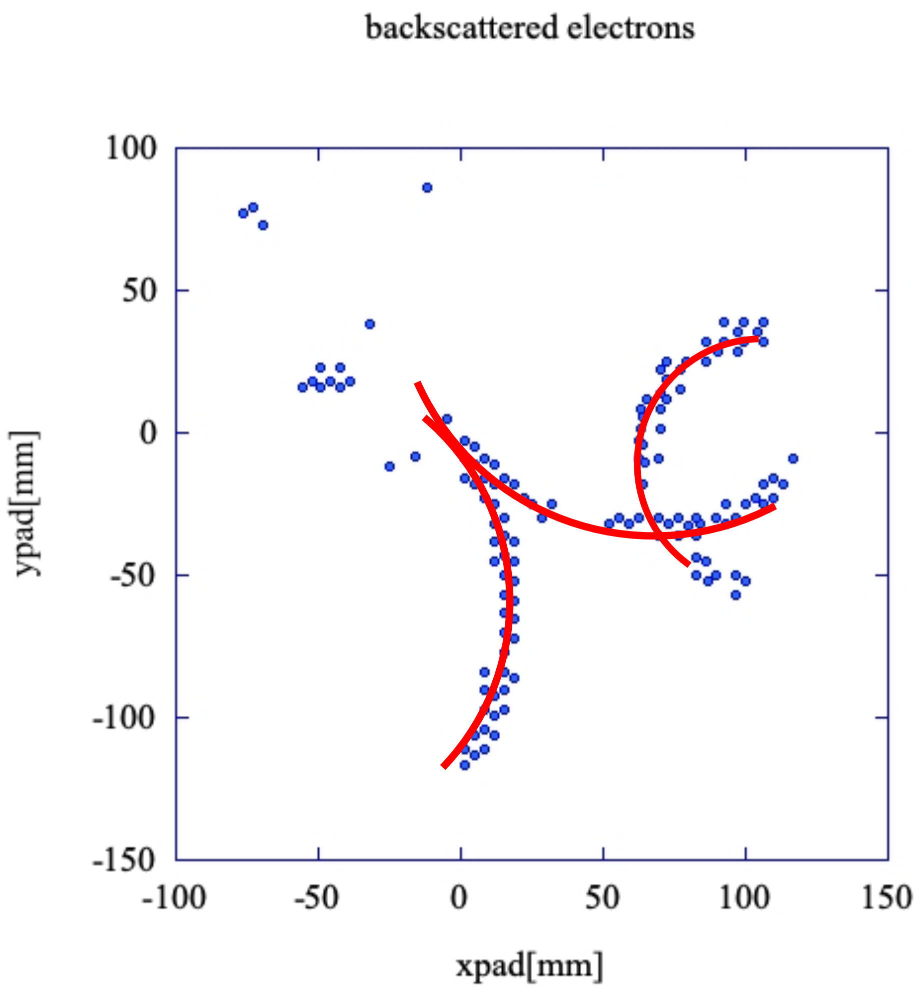
18

e+-e- pairs: seagulls





e+-e- pairs: backscattered electrons



We must train the NI before the AI

Ronsac: Random Object Sample Consensus
(Random Sample Consensus (Ransac) for linear objects
is two dimensional, here it has 9 dimensions)

I

Multiparticle decay

C. M. Campbell, R. M. Clark, H. L. Crawford, M. Cromaz, P. Fallon,
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Y. Ayyad, D. Bazin, S. Beceiro-Novo, J. Chen, M. Cortesi, M. DeNudt, S. Giraud,
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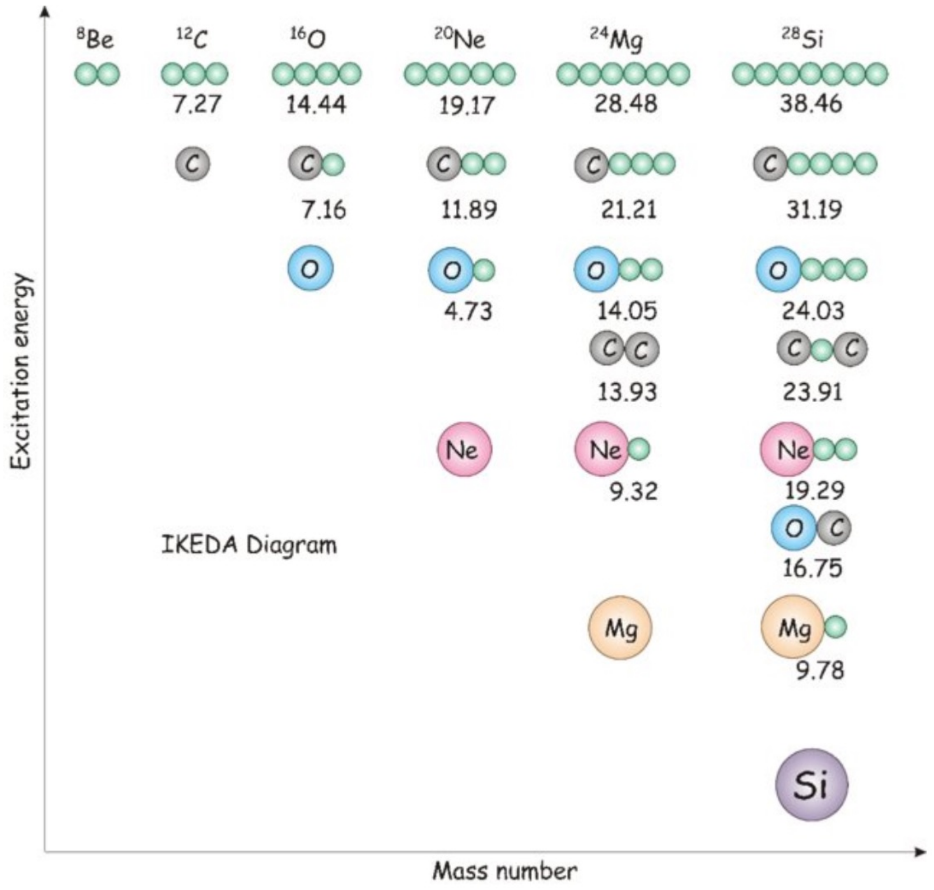
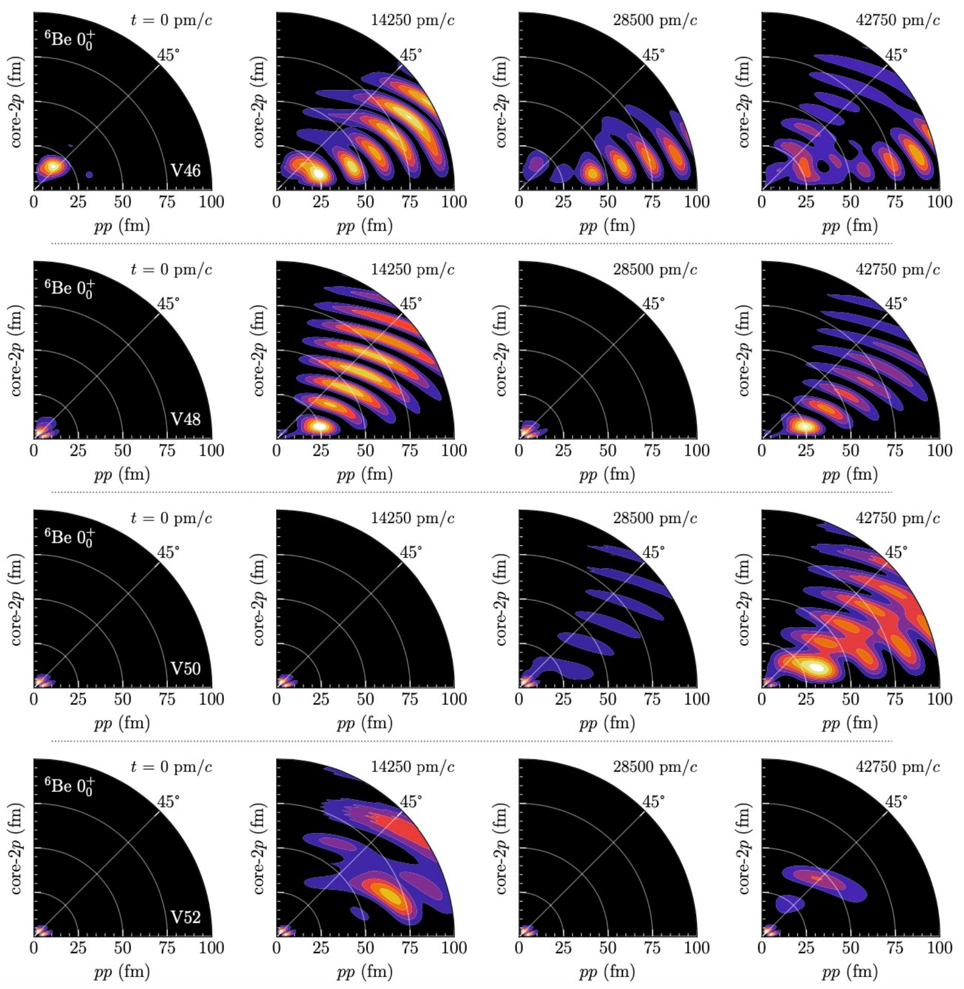
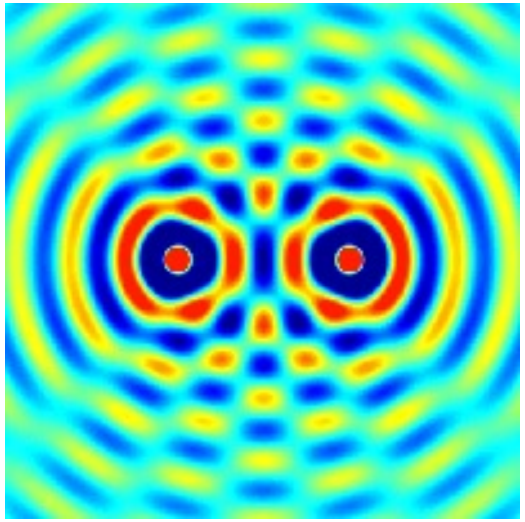


Multiparticle decay: example $^6Be \rightarrow ^4He+p+p$





S. M. Wang, N. Michel, W. Nazarewicz, and F. R. Xu, "Structure and decays of nuclear three-body systems: The Gamow coupled-channel method in Jacobi coordi- nates," Phys. Rev. C 96, 044307 (2017).

Simin Wang private Communication

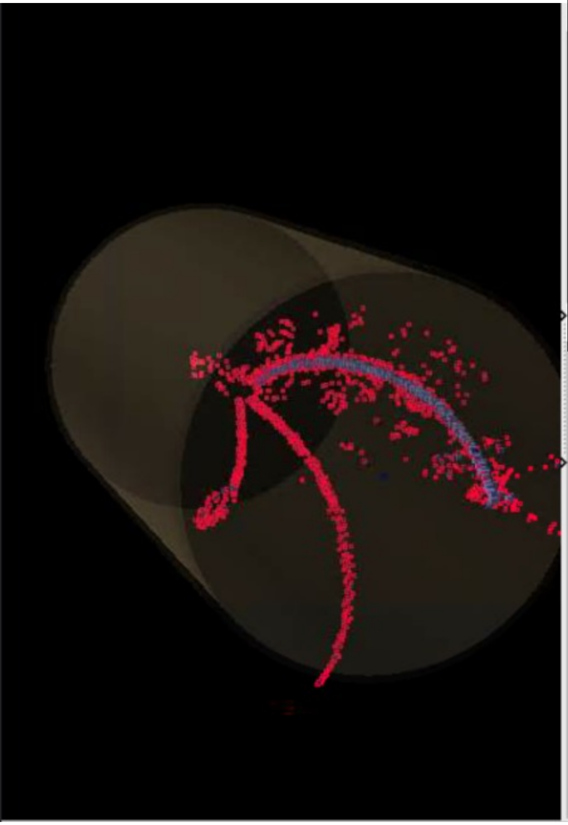
Fermion Pair Dynamics in Open Quantum Systems

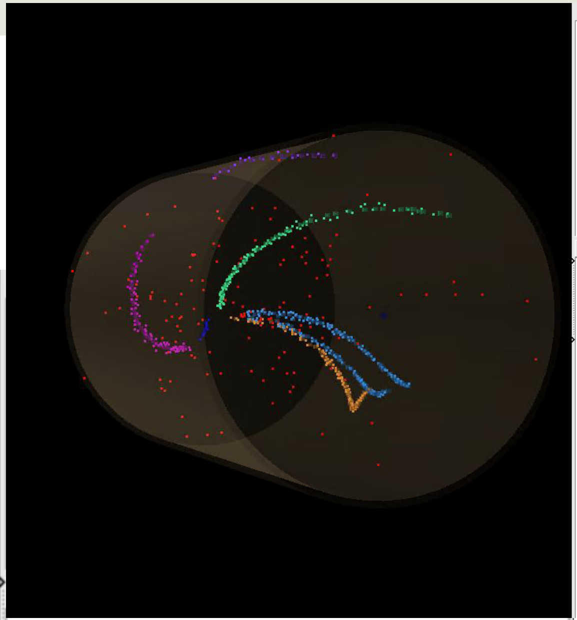
S. M. Wang (王思敏) and W. Nazarewicz

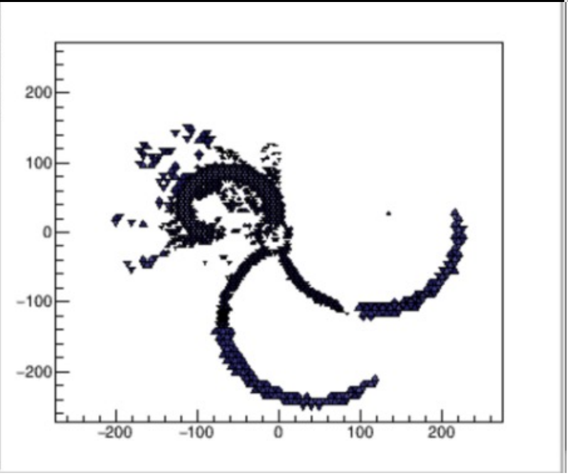
Phys. Rev. Lett. **126**, 142501 – Published 7 April 2021

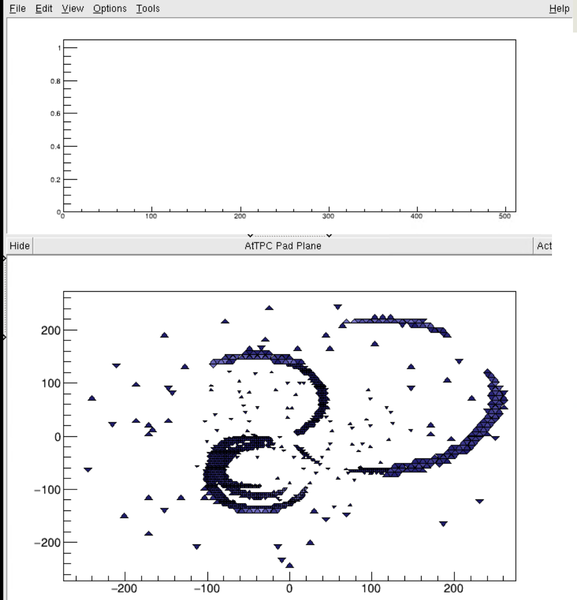
K. Hagino and H. Sagawa. Decay dynamics of the unbound ^{25}O and ^{26}O nuclei. Phys. Rev. C, 93:034330, Mar 2016

Multiparticle Decay Near Threshold $^{16}O(\alpha,\alpha')xy$: Squids









Y.Ayyad et al

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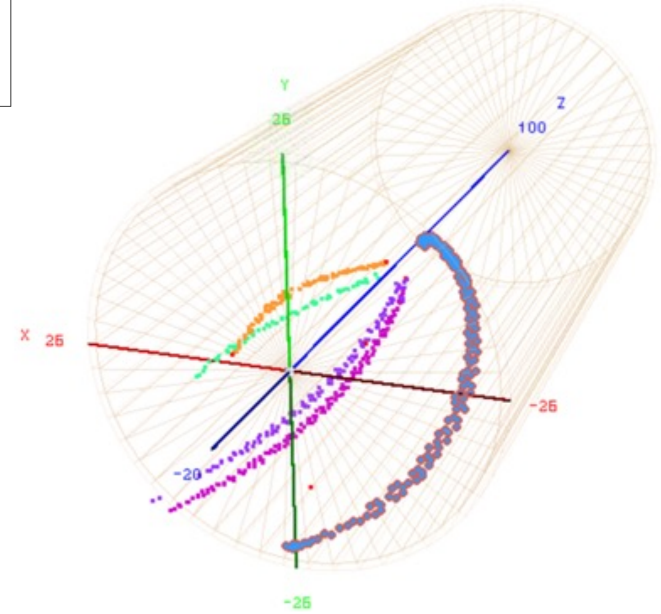
C. Hoffman, B. Kay
Argonne National Laboratory

Not finalized



Summary