Locations of breakup in reactions near the fusion barrier

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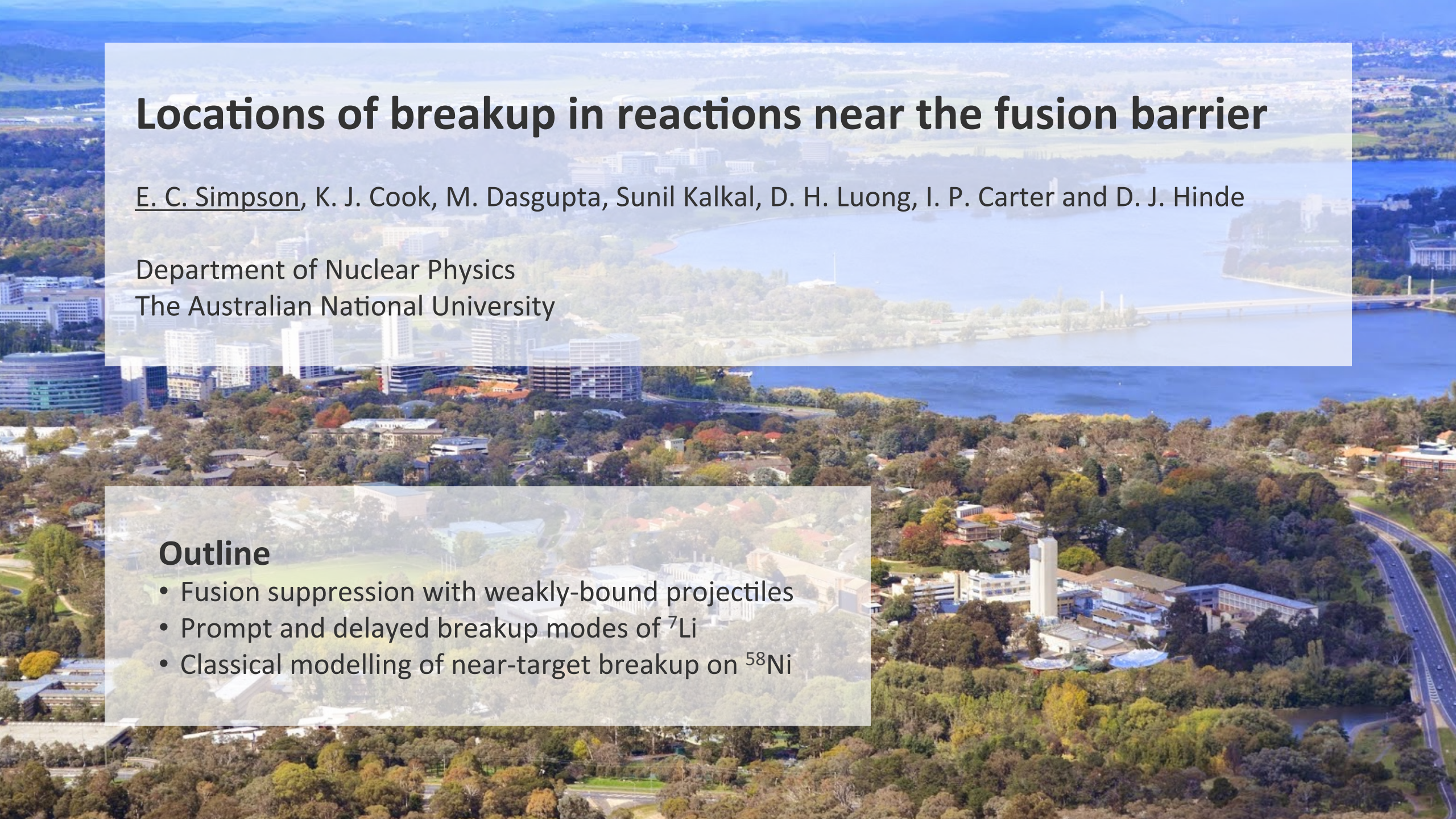


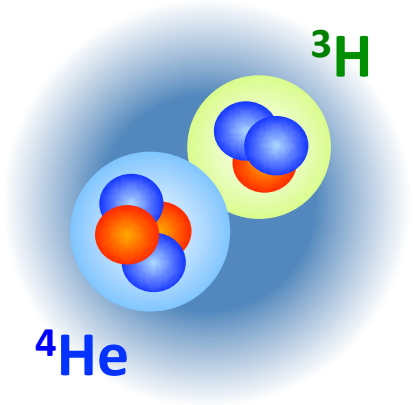
Outline

- Fusion suppression with weakly-bound projectiles
- Prompt and delayed breakup modes of ^{7}Li
- Classical modelling of near-target breakup on ^{58}Ni

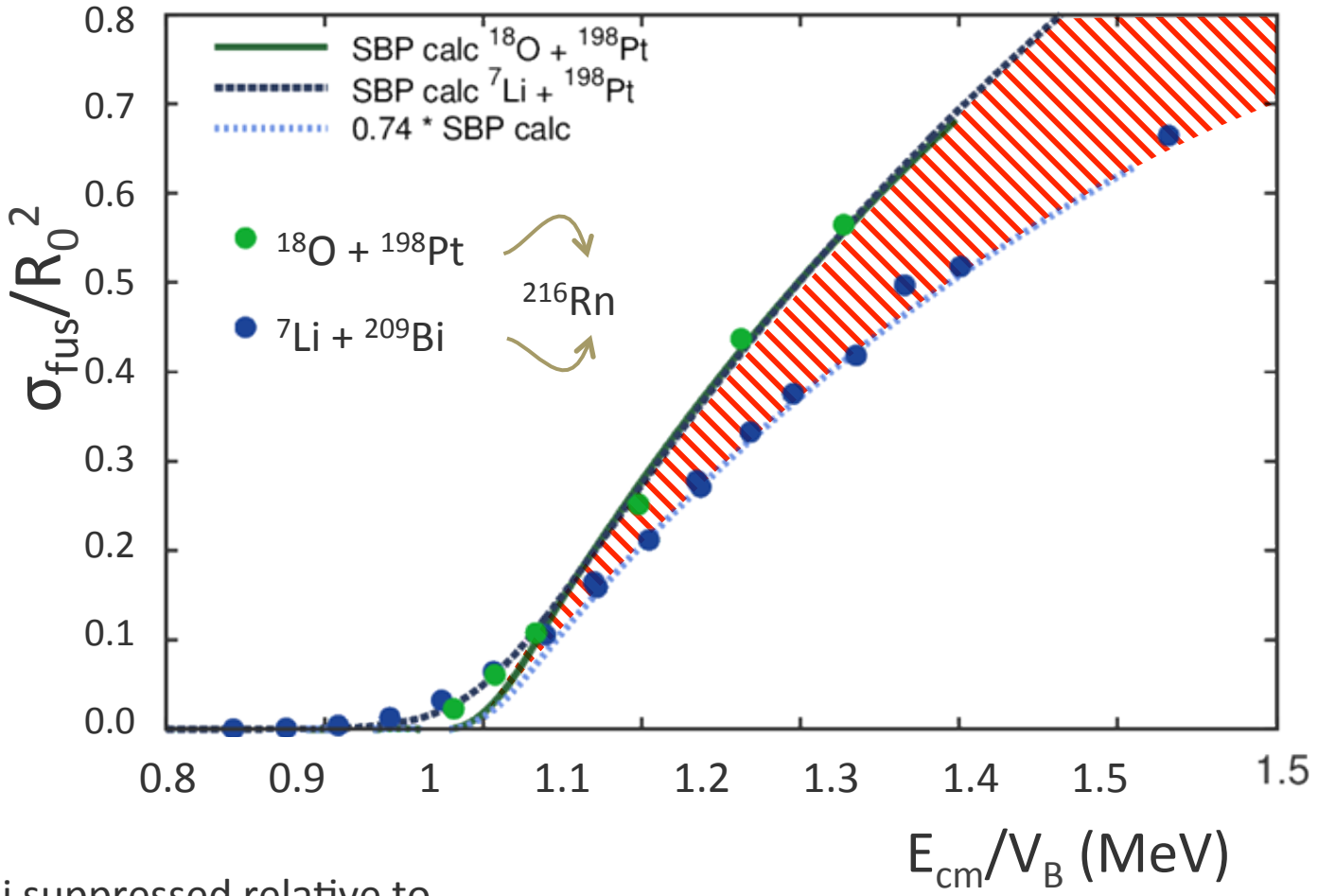
Above barrier fusion suppression

^{7}Li

Weakly-bound, elastic breakup likely



S_{BU} = 2.467 MeV



Fusion of weakly bound ^{7}Li+^{209}Bi suppressed relative to single-barrier calculation in contrast to ^{18}O+^{198}Pt

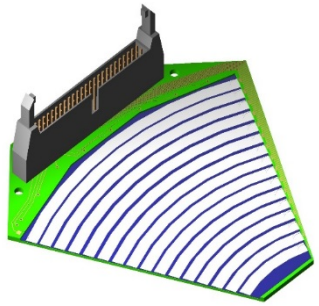
Also ^{6}Li, ^{9}Be, many heavy targets

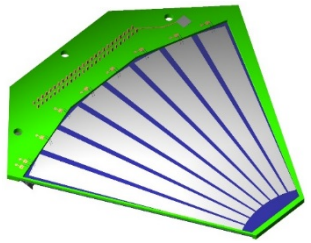
Dasgupta *et al.*, PRC 66, 041602(R) (2002); PRC 70, 024606 (2004); Wu *et al.*, PRC 68 044605 (2004)

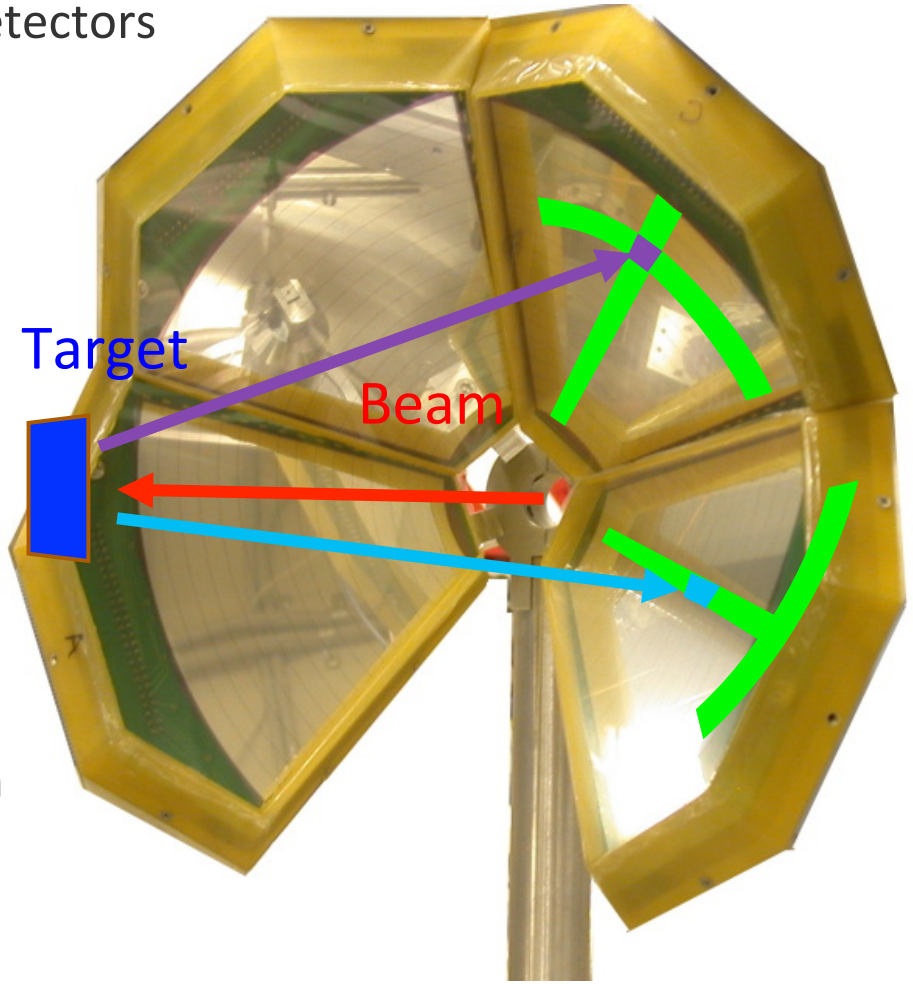
Experiment: Fragment detection

BALiN array

Double-Sided Silicon Strip Detectors





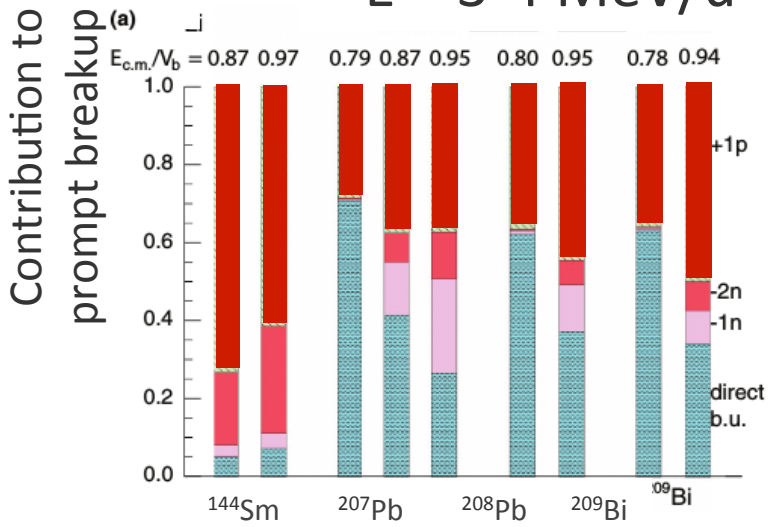


In this “lampshade” configuration sensitive only to backward angles

$115° < \theta < 170°$

$30° < \phi < 330°$

E = 3-4 MeV/u



α+α

α+p

α+d

Transfer

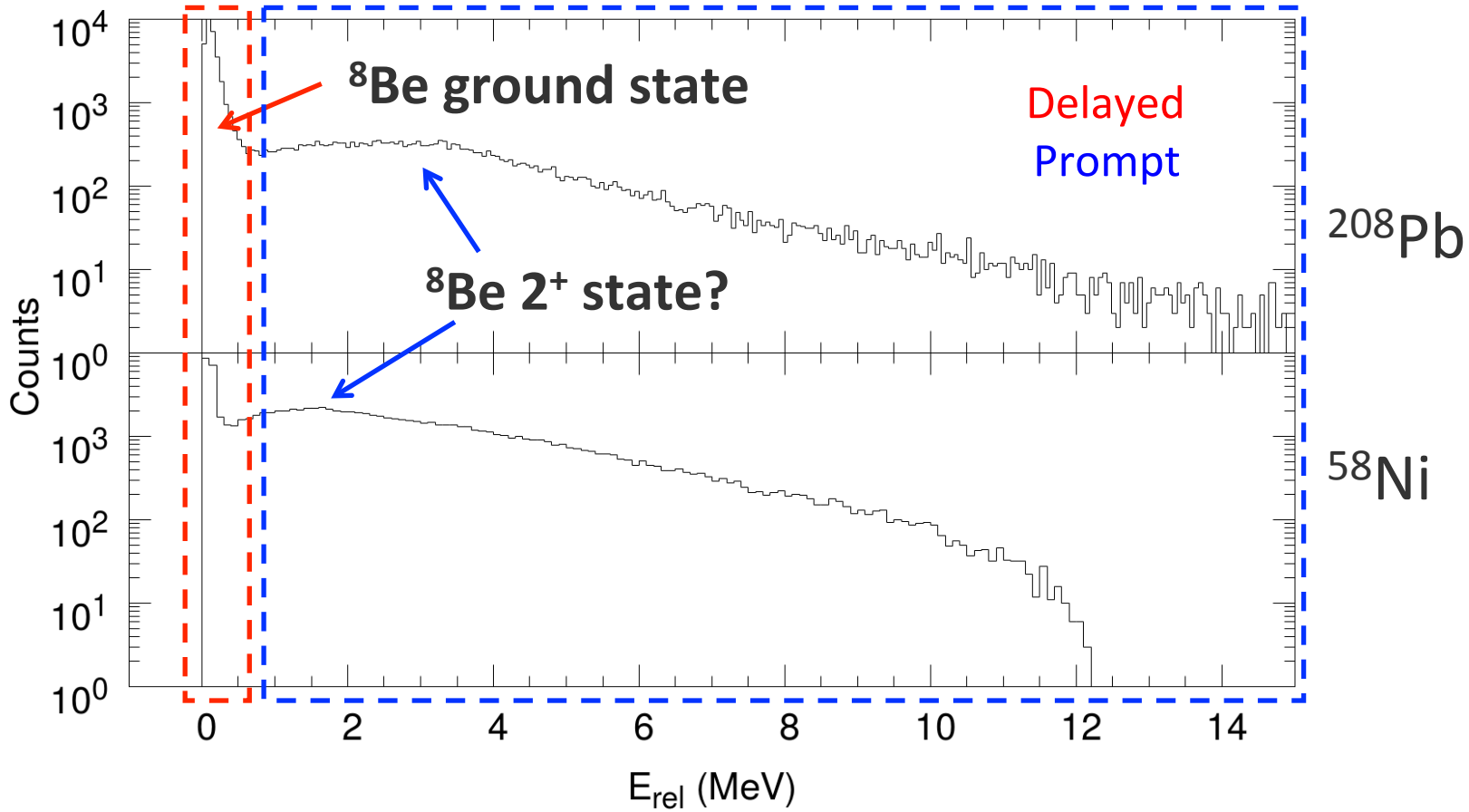
α+t

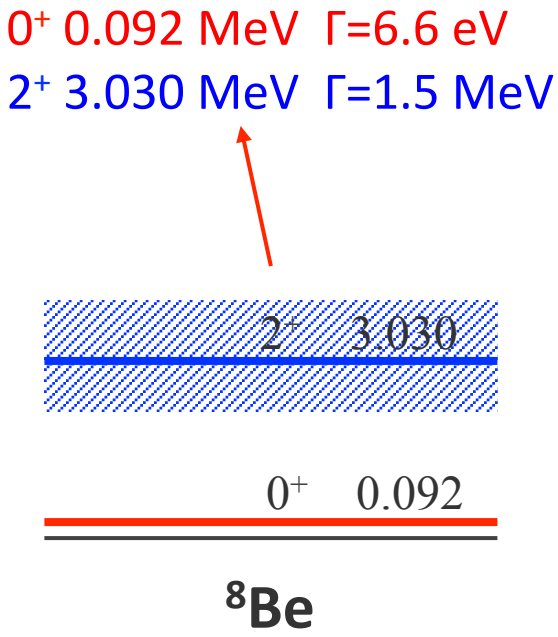
Direct

[D. H. Luong, ANU PhD Thesis (2012)]

Relative energy distribution

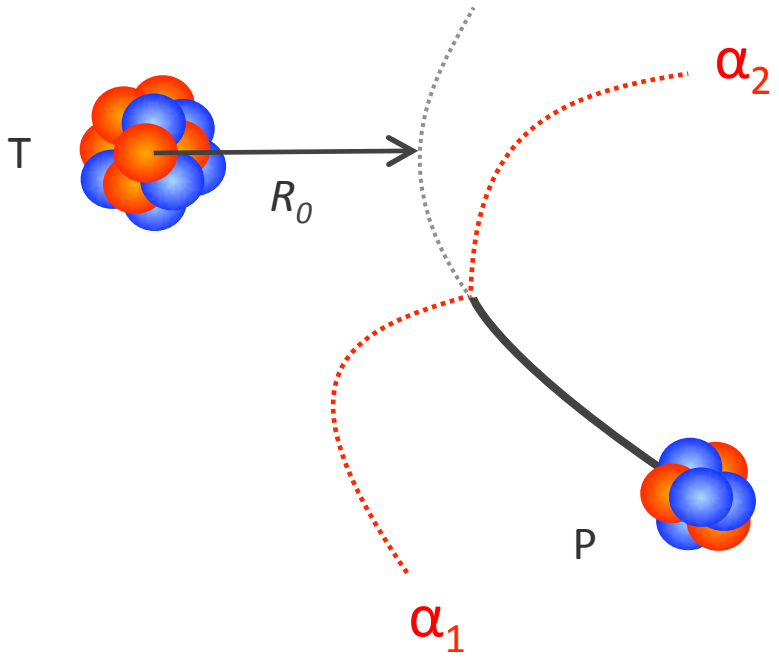
$^{7}Li \rightarrow {}^{8}Be \rightarrow \alpha + \alpha$





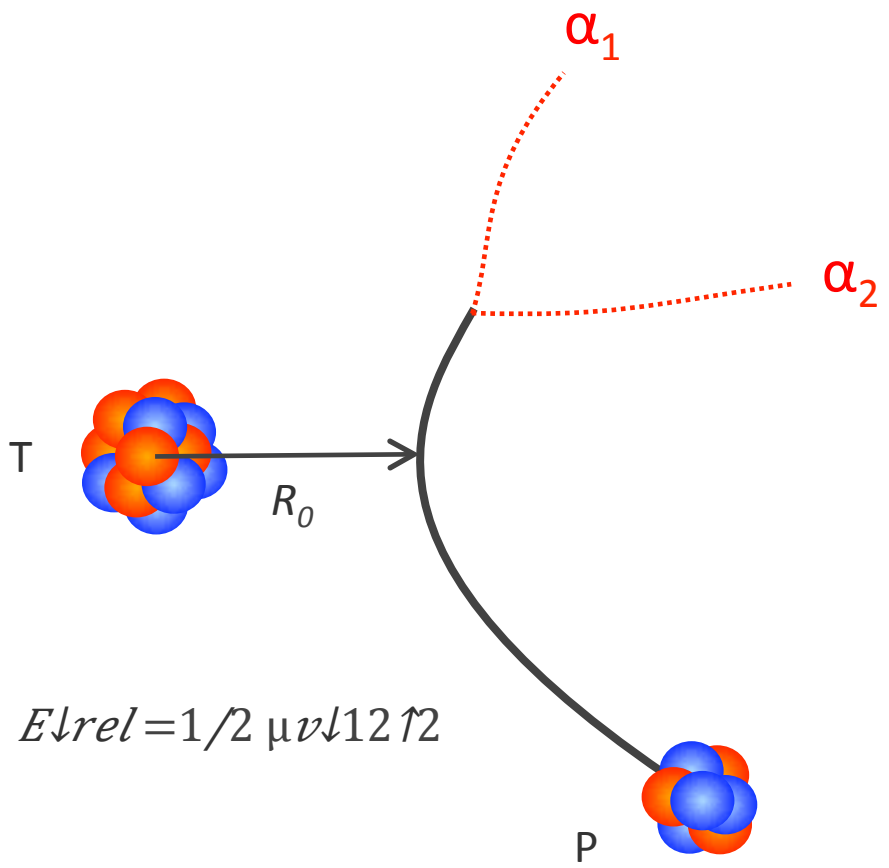
Prompt breakup

Incoming trajectory



Expect differences in opening angle θ_{12} and relative energy E_{rel}? Large E_{rel} correspond to earlier disintegration?

Outgoing trajectory



$E\downarrow rel = 1/2\ \mu v\downarrow 12\uparrow 2$

Plus, asymptotic ≡ very long-lived states

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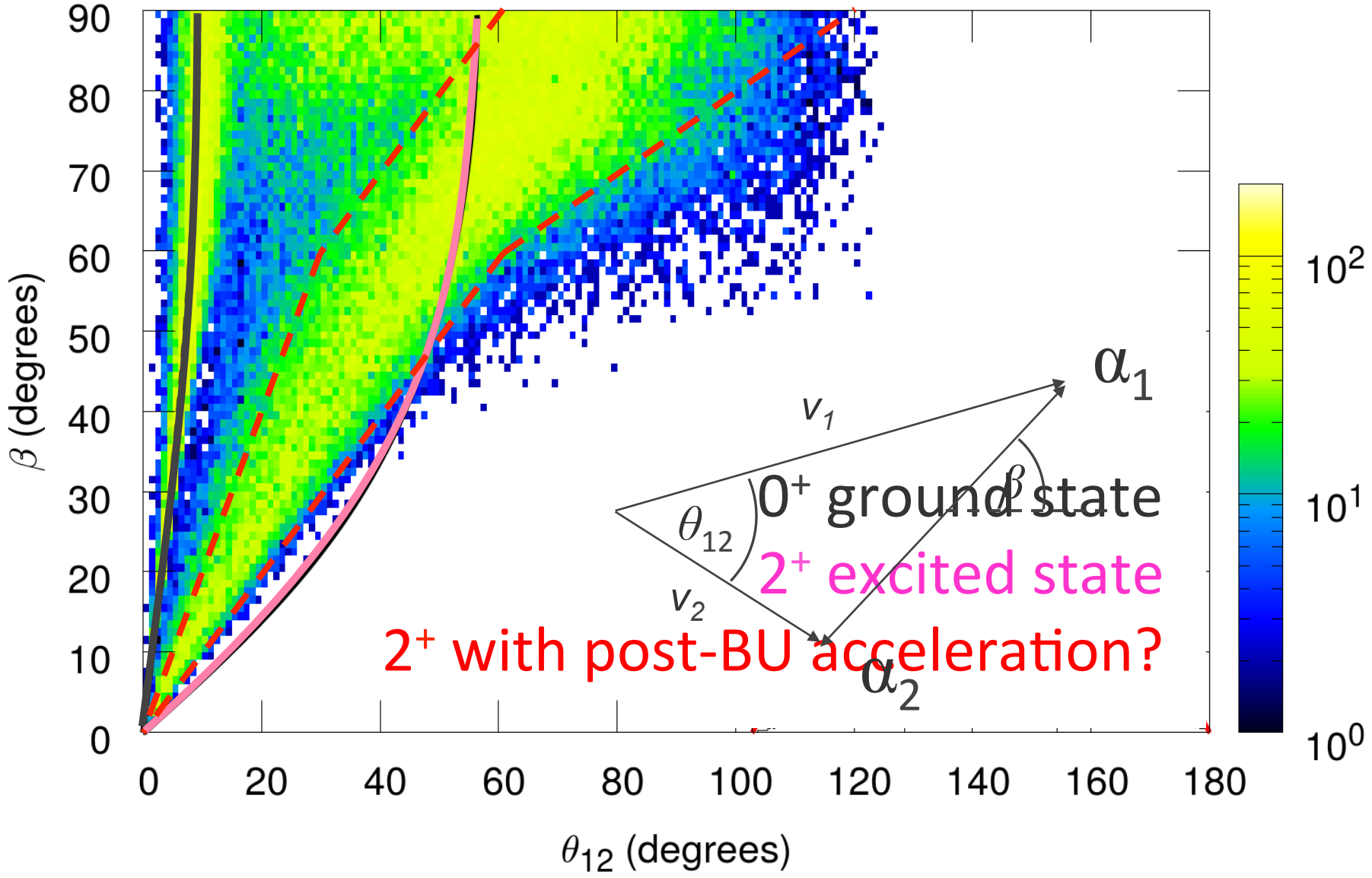
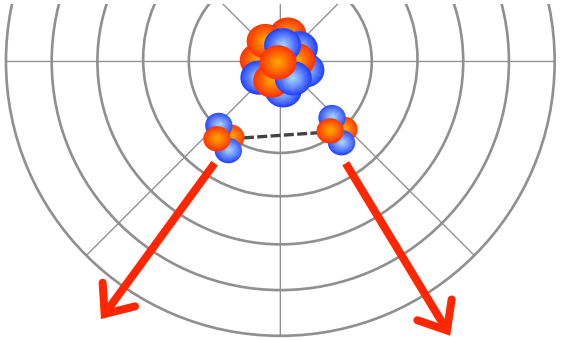
Experiment and asymptotic limits



Simpson *et al.*, PRC 93, 024605 (2016)

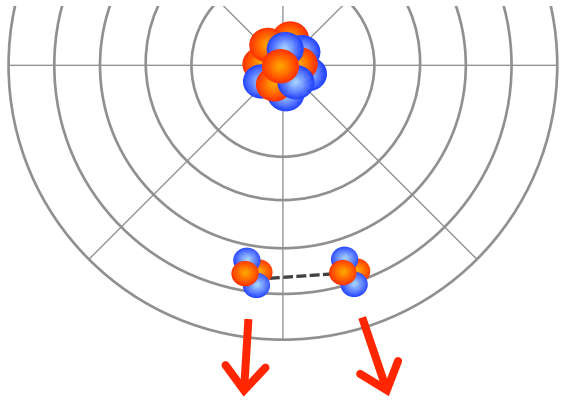
Post breakup acceleration

Suppose prompt breakup originates in the 2^+ resonance, with well defined initial E_x:



Sensitivity to target proximity

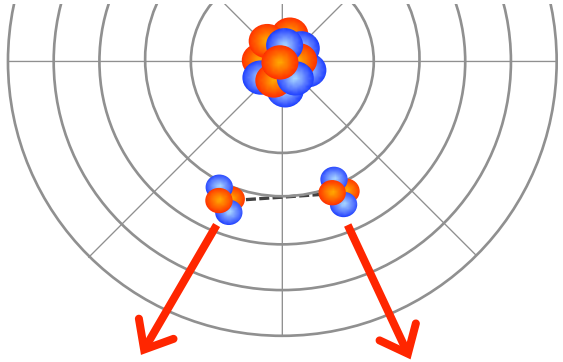
- Near target gives greater acceleration
- Larger changes in final E_{rel} w.r.t E_x



- Further from target, weaker acceleration
- Final E_{rel} closer to of E_x

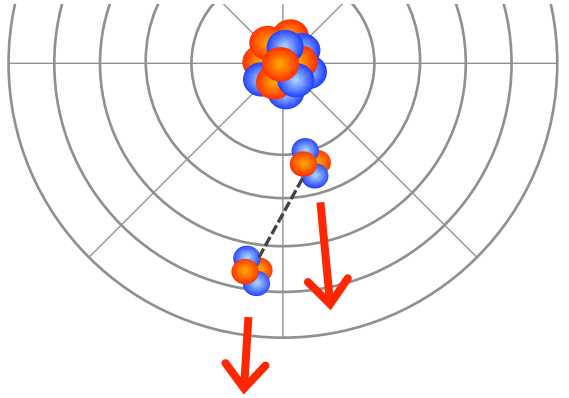
Post breakup acceleration

Suppose prompt breakup originates in the 2^+ resonance, with well defined initial E_x:



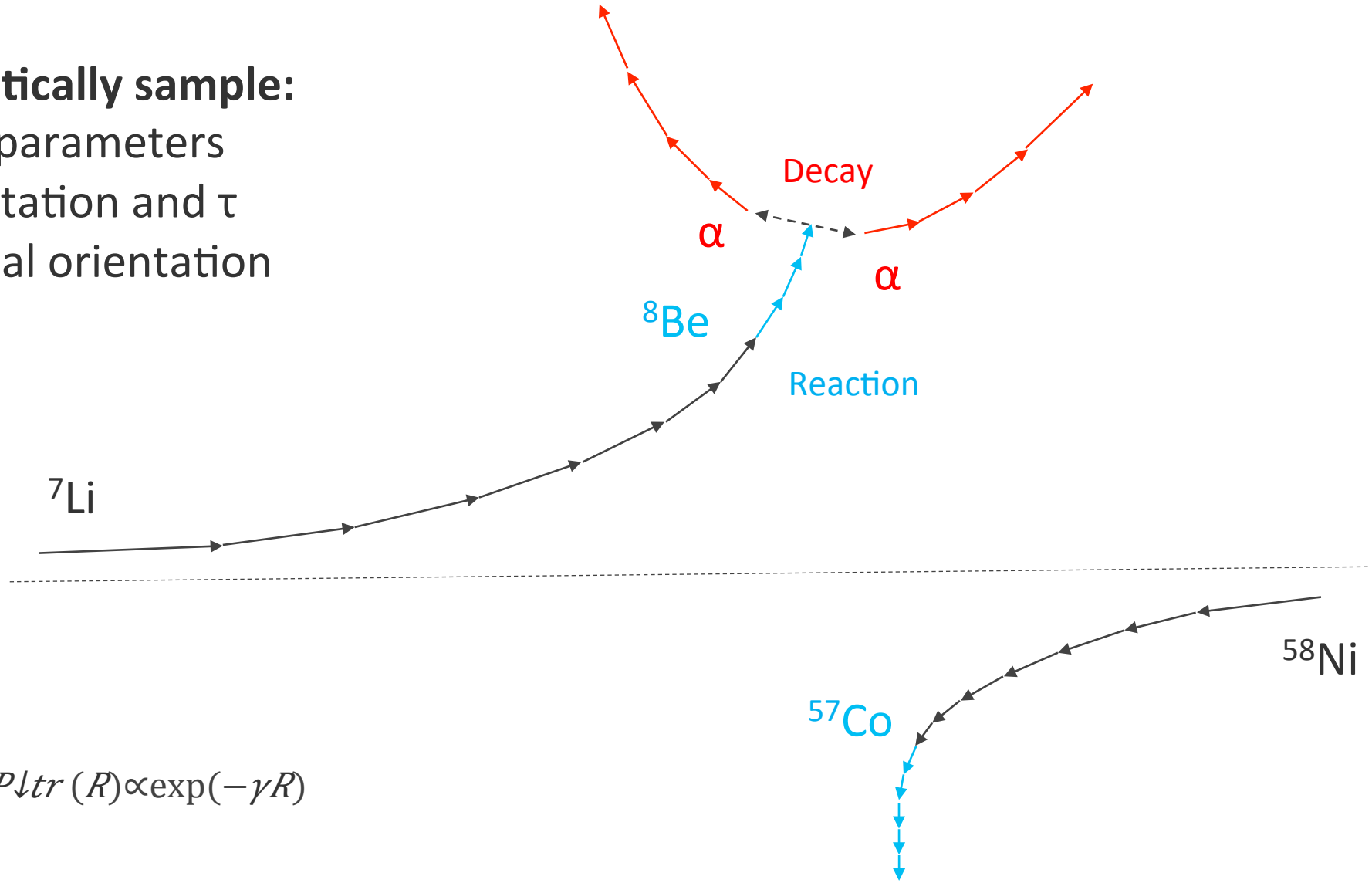
Sensitivity to orientation

- Aligned perpendicular to the target field, leads to larger E_{rel}
- Aligned parallel to the target field, acceleration tells to reduce the final relative energy E_{rel}



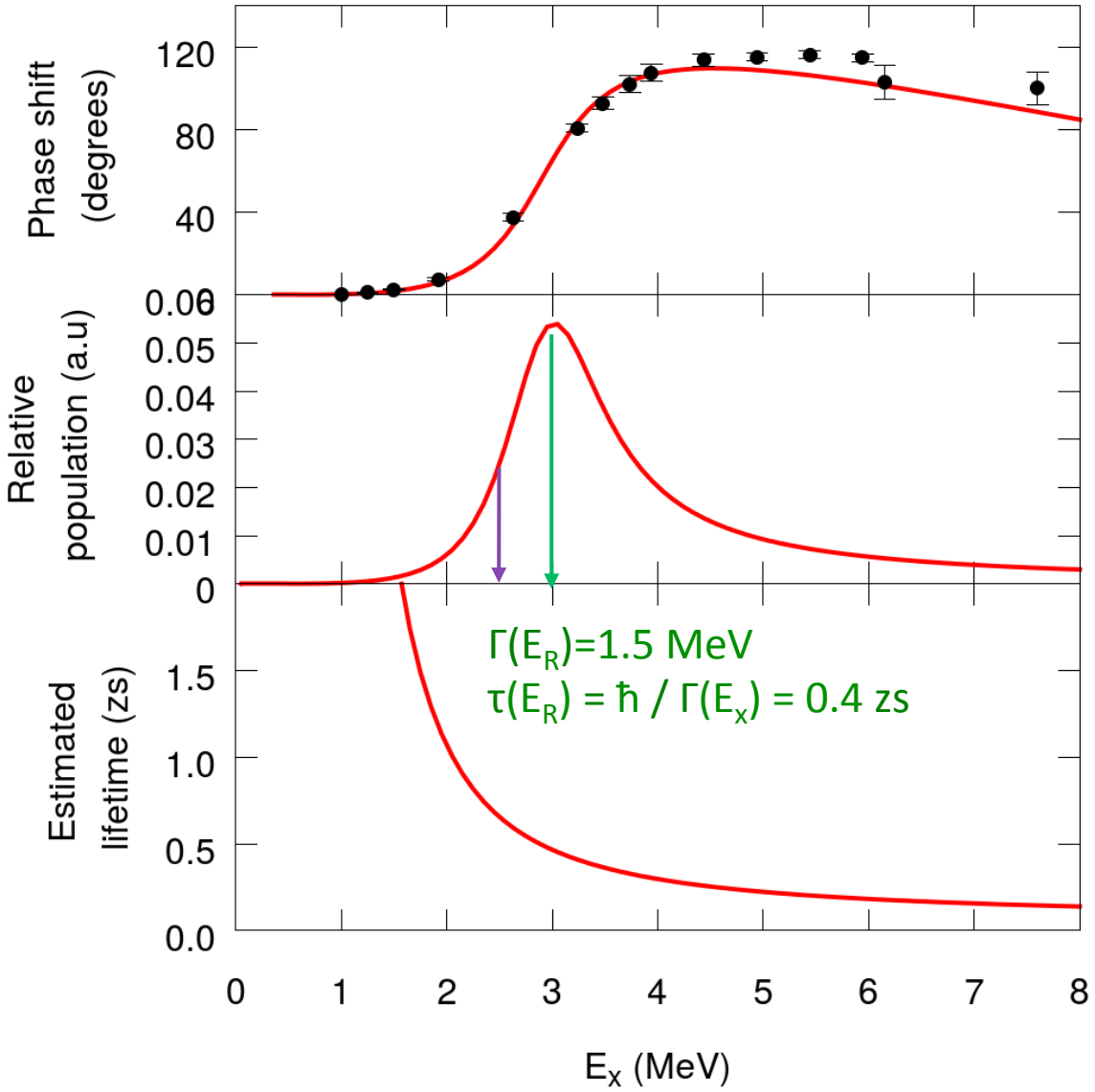
Monte Carlo trajectory simulations

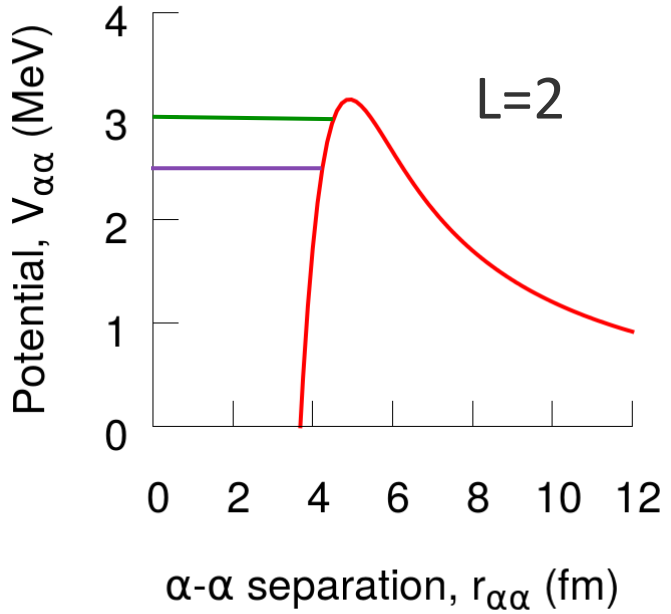
Stochastically sample:
Impact parameters
^{8}Be excitation and τ
α-α initial orientation



$$P\downarrow tr\,(R) \propto \exp(-\gamma R)$$

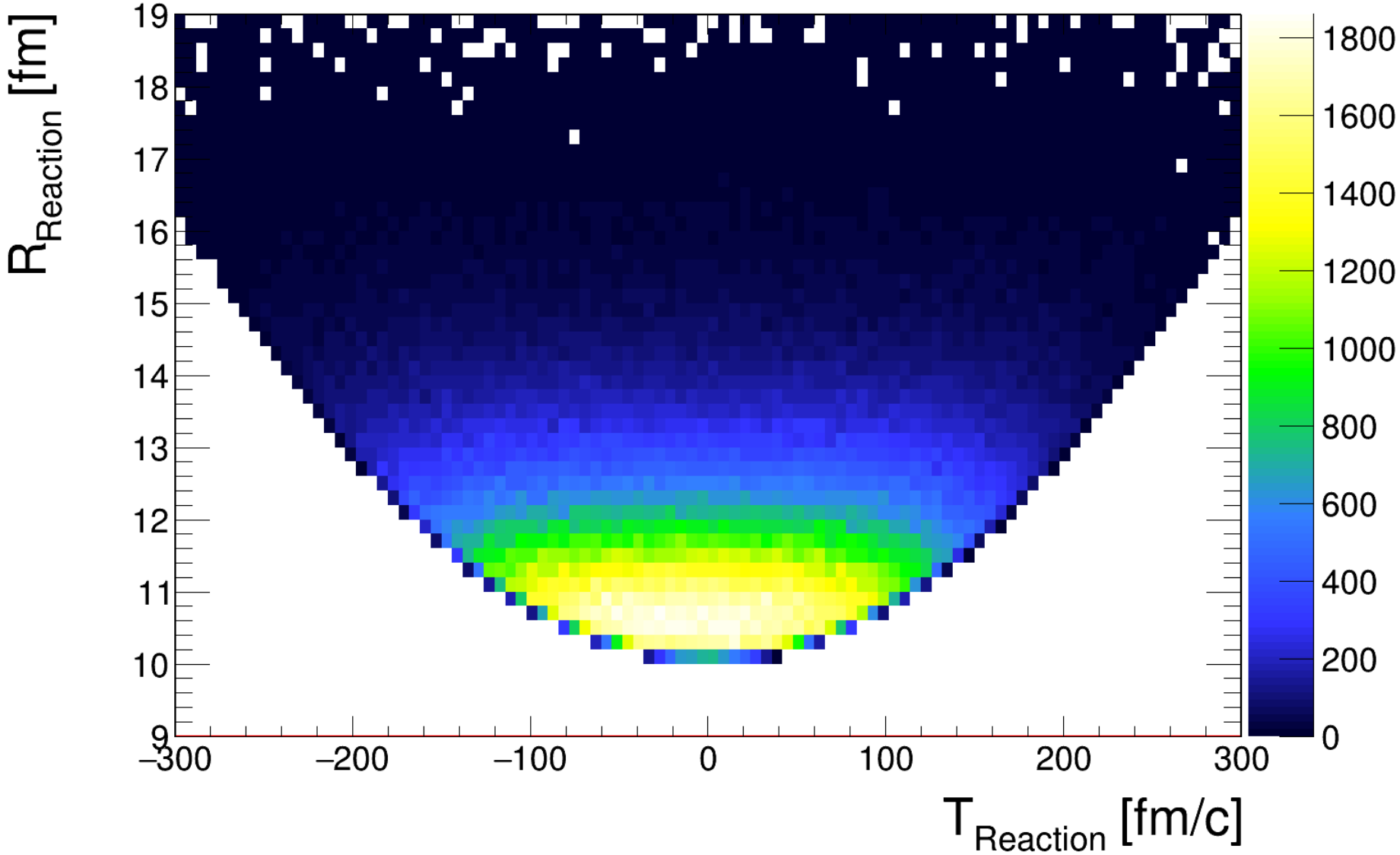
$^{8}Be\ 2^{+}$ resonance



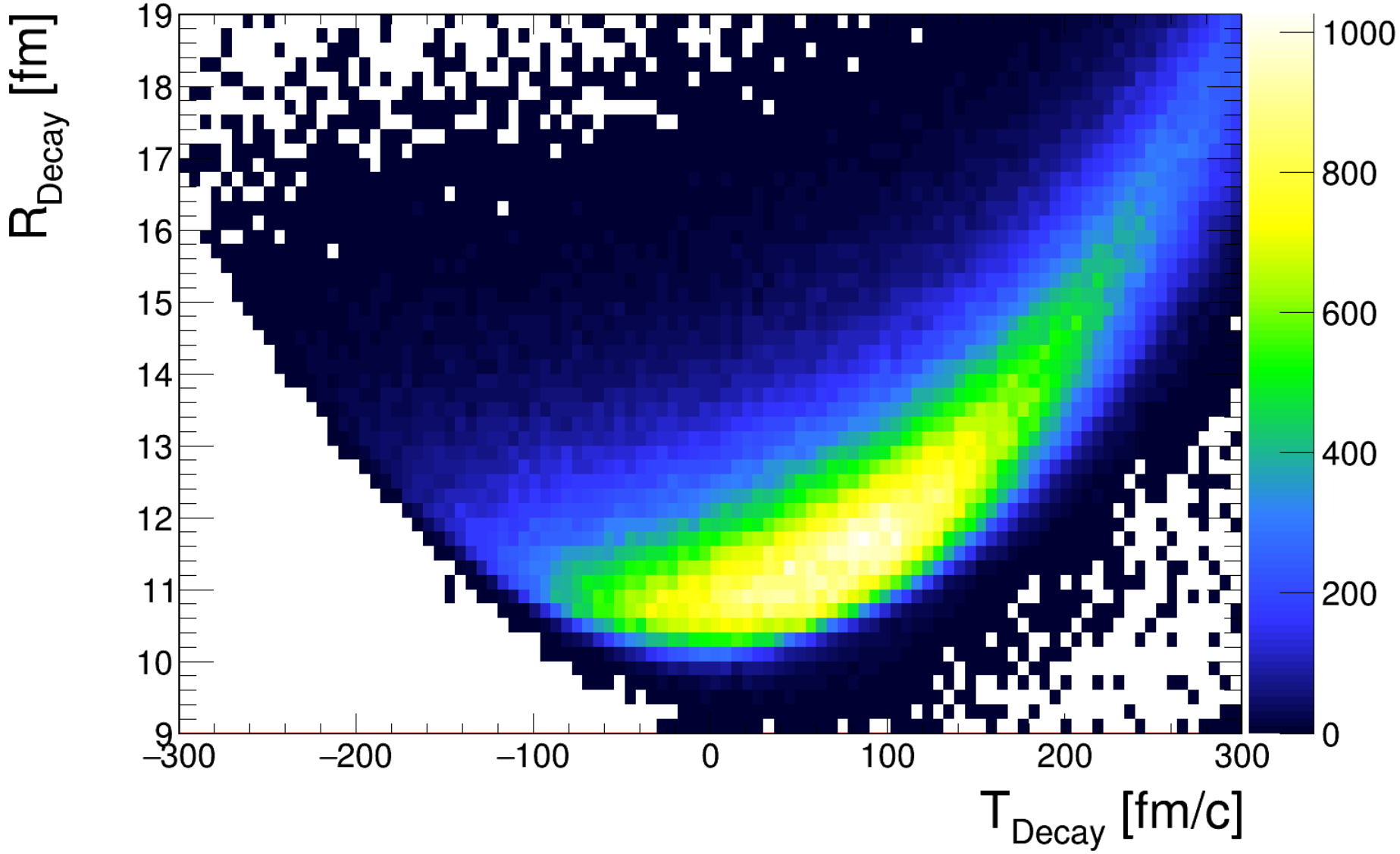


F. C. Barker, Aust. J. Phys 41, 743 (1988)
A. M. Lane and R. G. Thomas, Rev. Mod. Phys. 30, 257 (1958)

Reaction point



^{8}Be decay point



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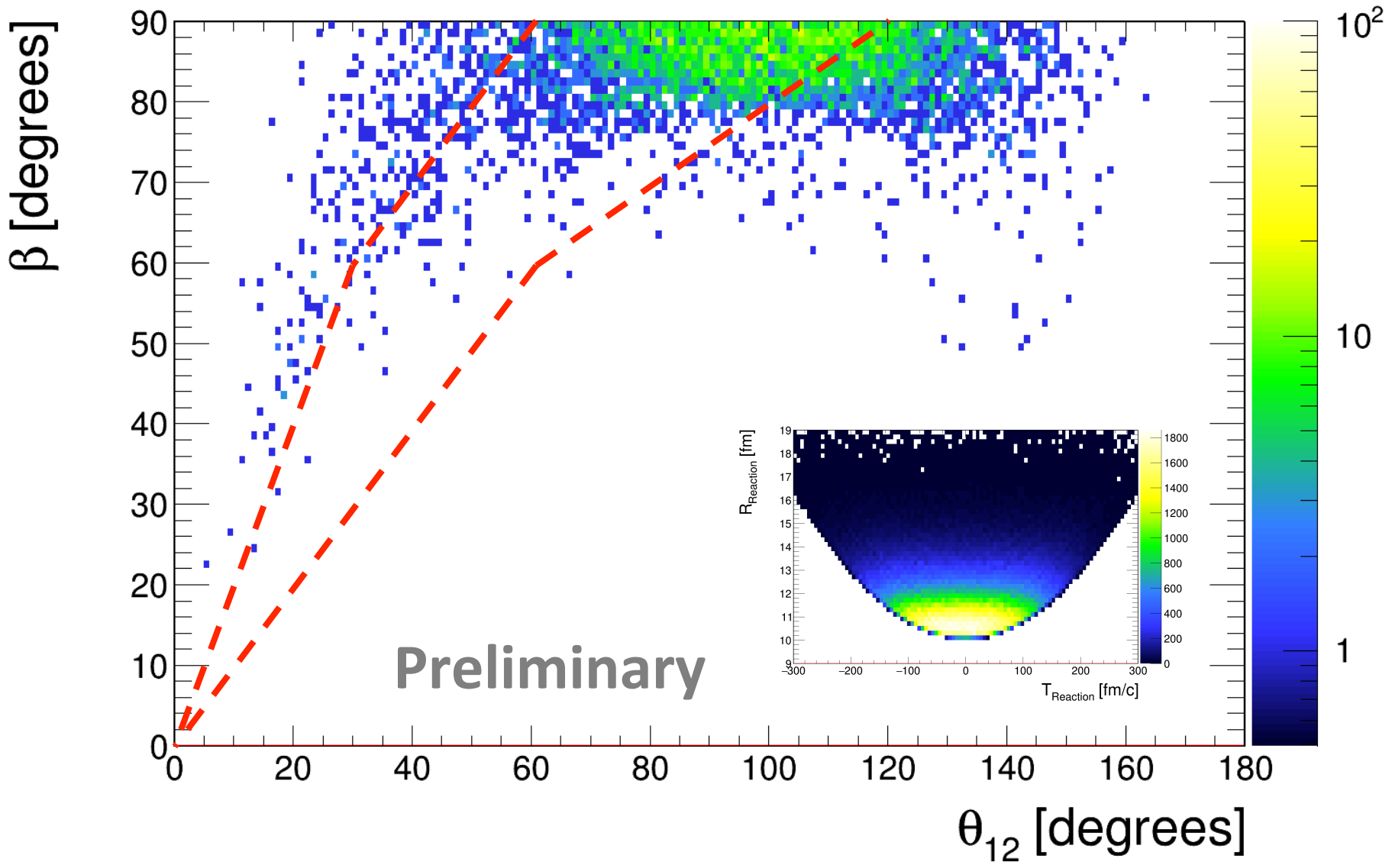
Simulation assuming instant decay



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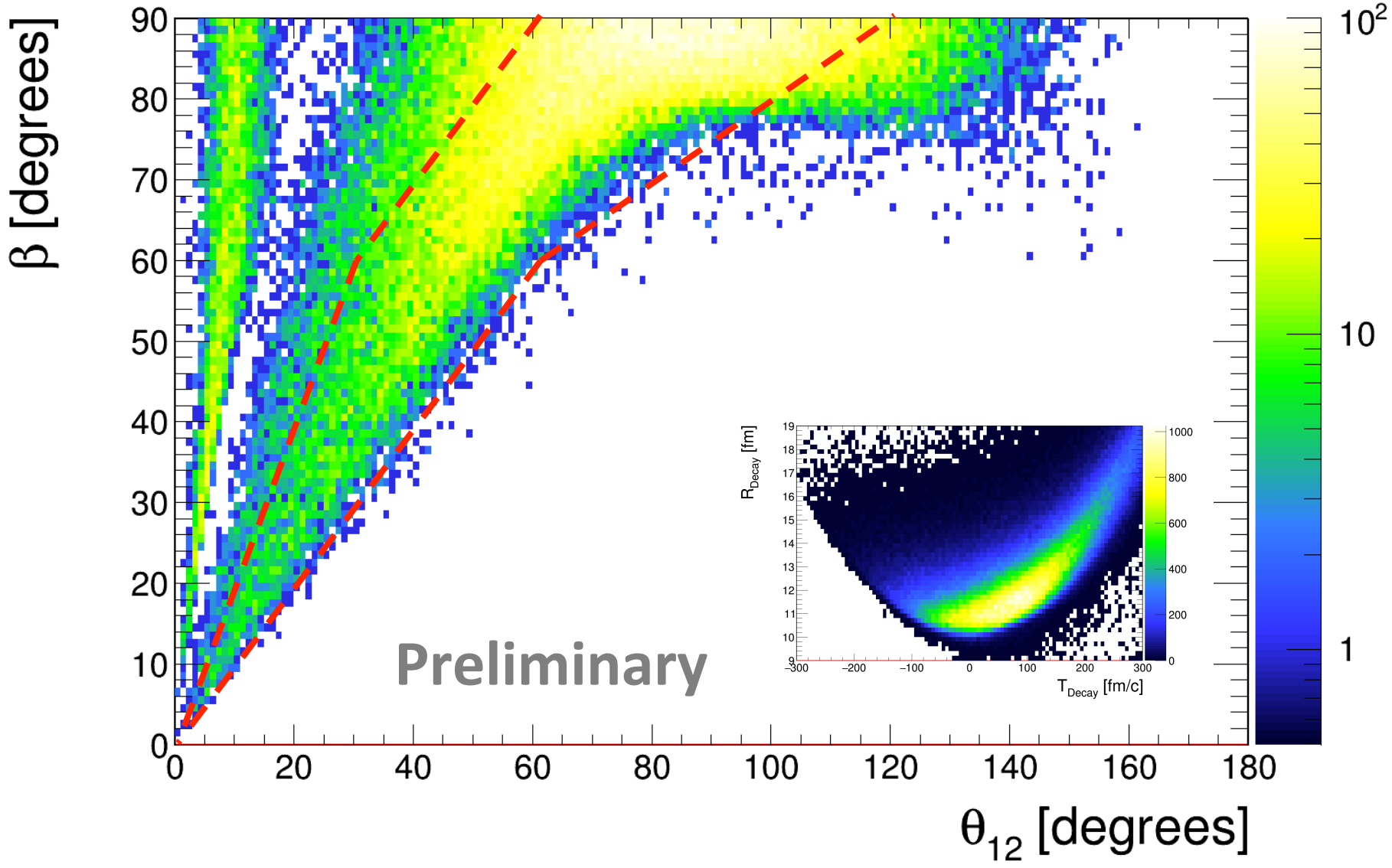
Simulation incorporating lifetime



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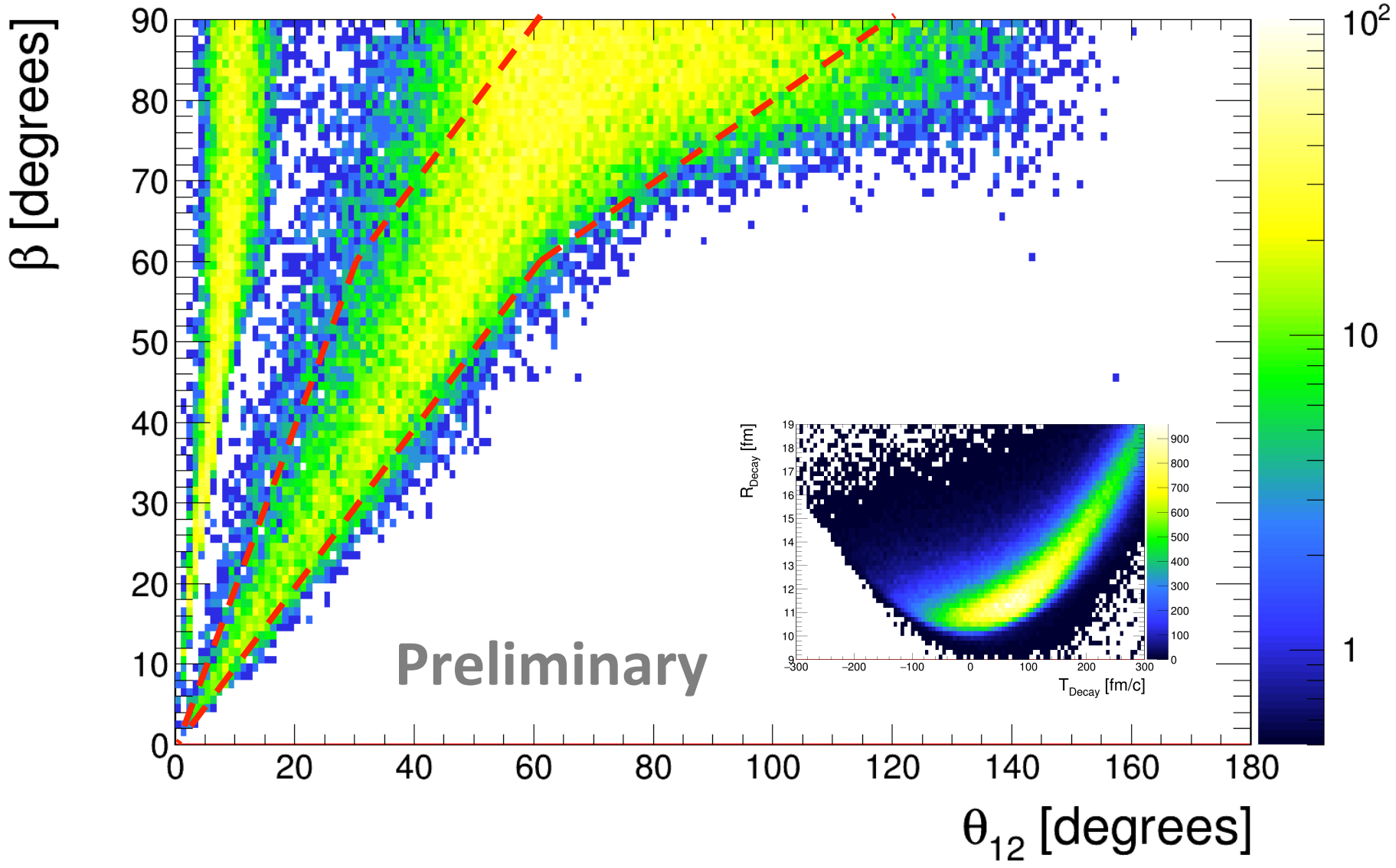
Doubled input lifetime



Summary and further work

Summary

- Results suggest much of the observed breakup at sub-barrier energies occurs when the projectile is receding from the target
- This has consequences for fusion – can the break up happen fast enough to cause fusion suppression, contribute to ICF?

Outlook

- Limits of the model - with an immutable ^{8}Be, the delayed breakup will clearly affect incomplete fusion - how important are tidal forces?
- Can we systematically understand sub-barrier breakup for other light projectiles such as ^{6}Li and ^{9}Be? What do we predict for ICF?
- Stable weakly bound more challenging than exotic nuclei – we must understand the reaction mechanisms involved

Acknowledgements

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Backup slides

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Comparison to 7Li → α + d