Level Densities and γ Strength Functions in Light Sc and Ti Isotopes

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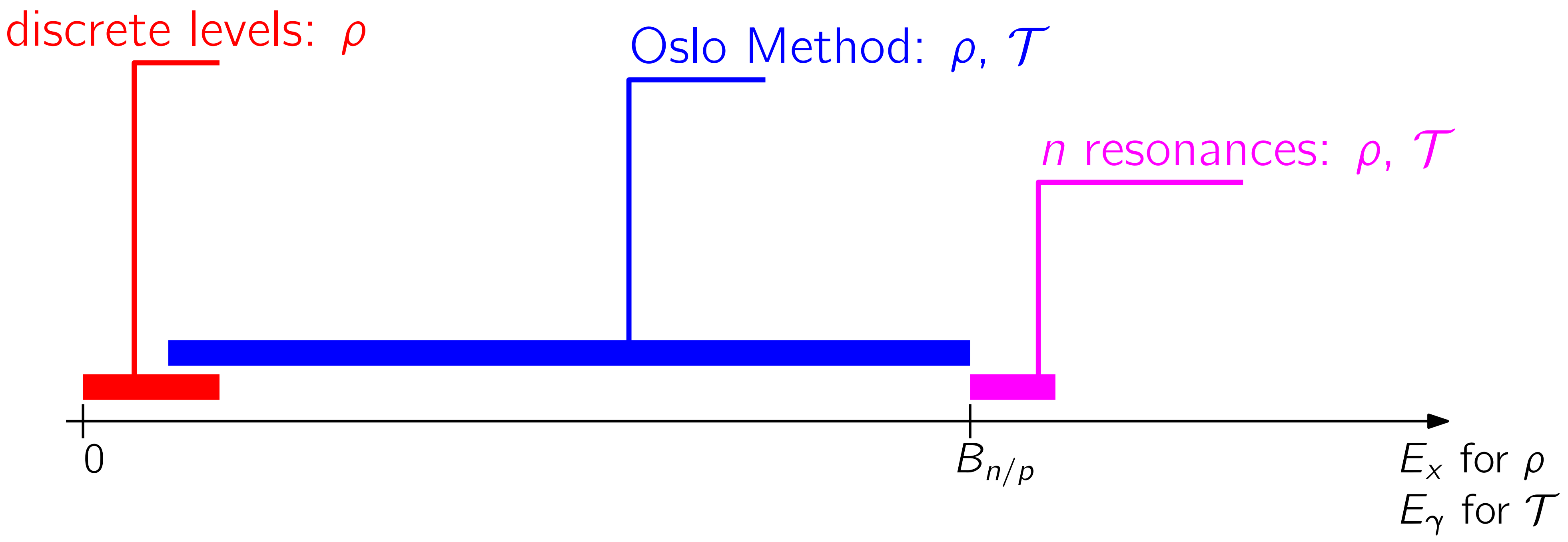
OCL Workshop 'Level Density and Gamma Strength' — Oslo, May 11, 2009

Overview

- The Oslo Method
  - Assumptions
  - Procedure
- Results for light Sc and Ti isotopes
  - ^{43}Sc, ^{44,45,46}Ti
- Outlook

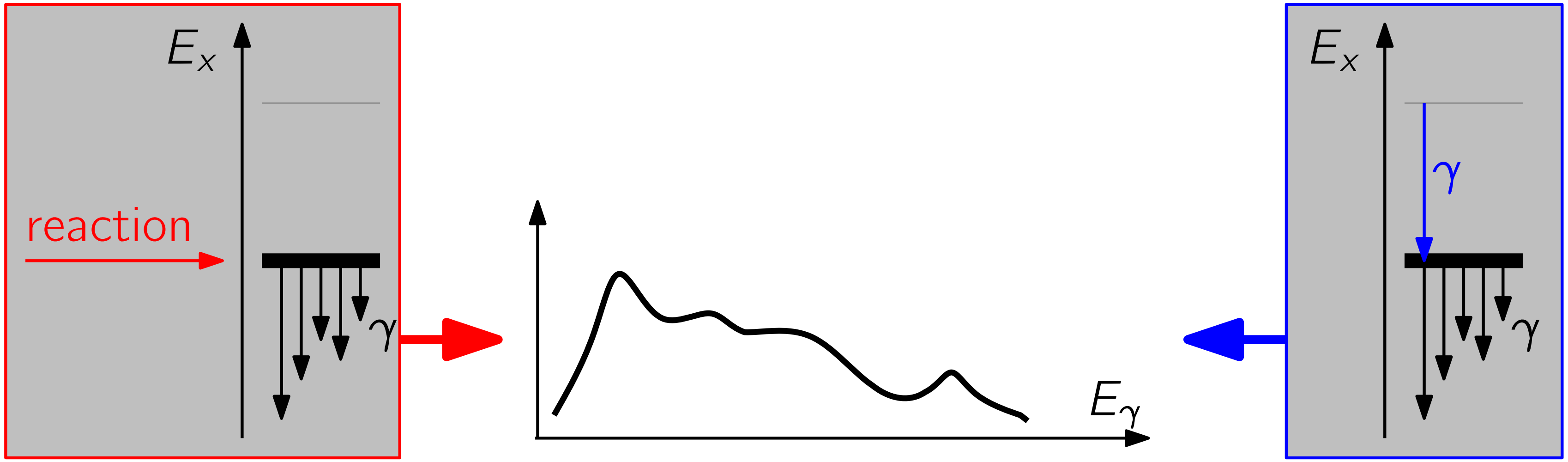
The Oslo Method – Aim

measure ρ and $\mathcal{T}$ simultaneously



The Oslo Method – Assumptions

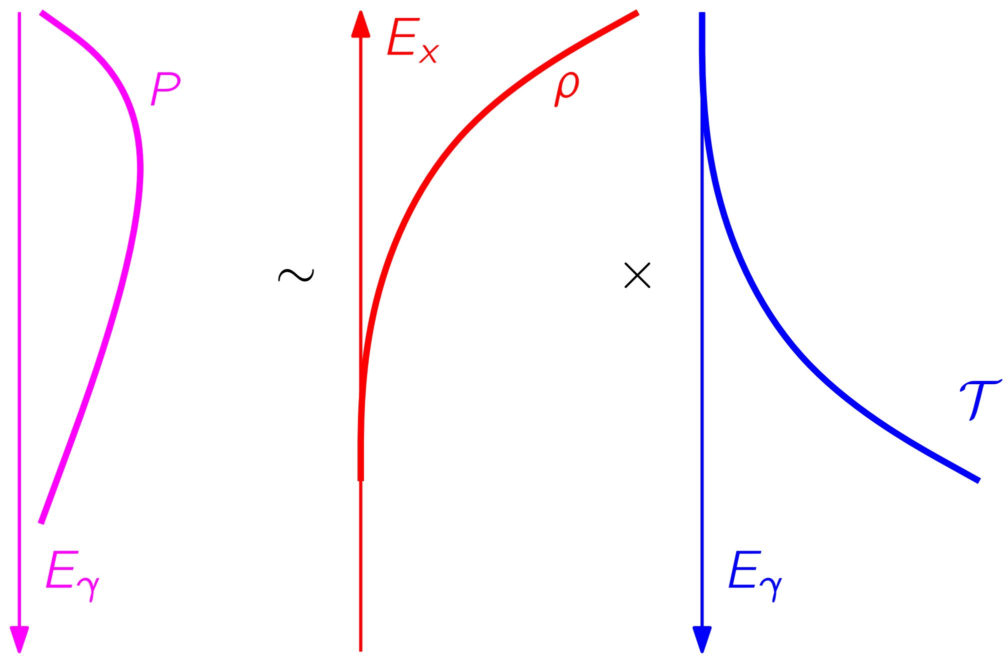
- shape of spectra independent of “population path”



The Oslo Method – Assumptions

- shape of spectra independent of "population path"
- Brink-Axel hypothesis: $\mathcal{T}$ independent of $E_{i/f}$
- Generalized Fermi's golden rule: transition probability factorizeable as

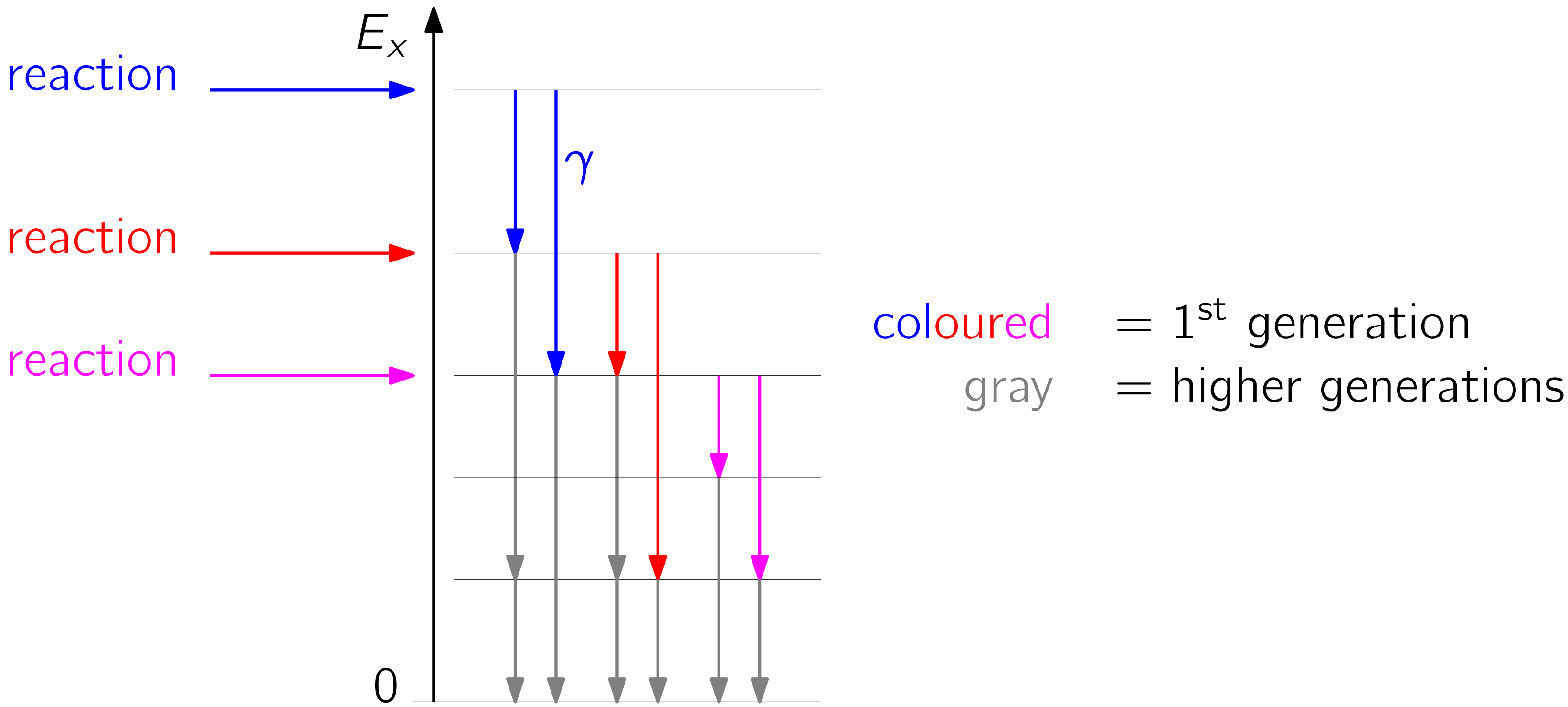
$$P(E_i, E_\gamma) \sim \rho(E_i - E_\gamma)\mathcal{T}(E_\gamma)$$



for $E1$ and $M1$: $\mathcal{T} \sim f(E_\gamma)E_\gamma^3$

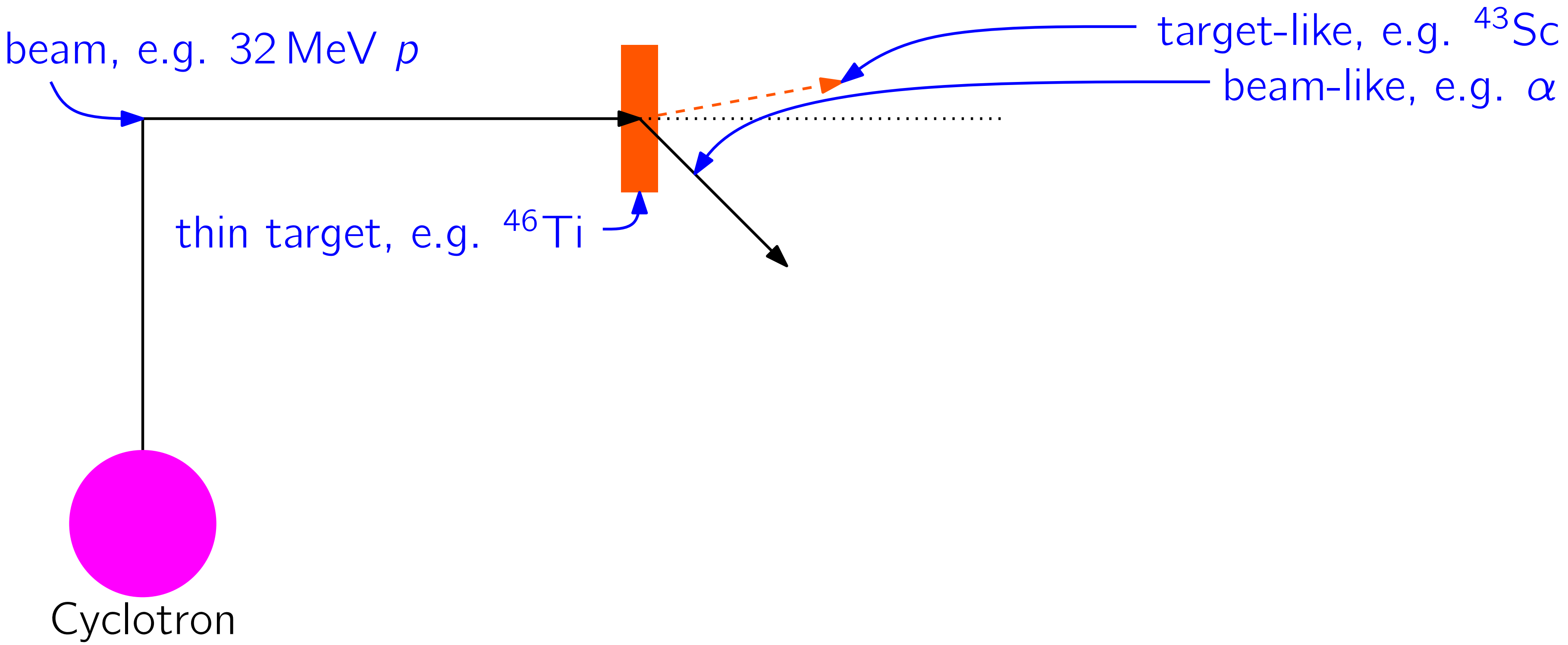
The Oslo Method – Procedure

- measure E_x vs. E_γ matrix
- correct E_γ for detector response function ("unfolding")
- extract 1[st] generation spectra (P)

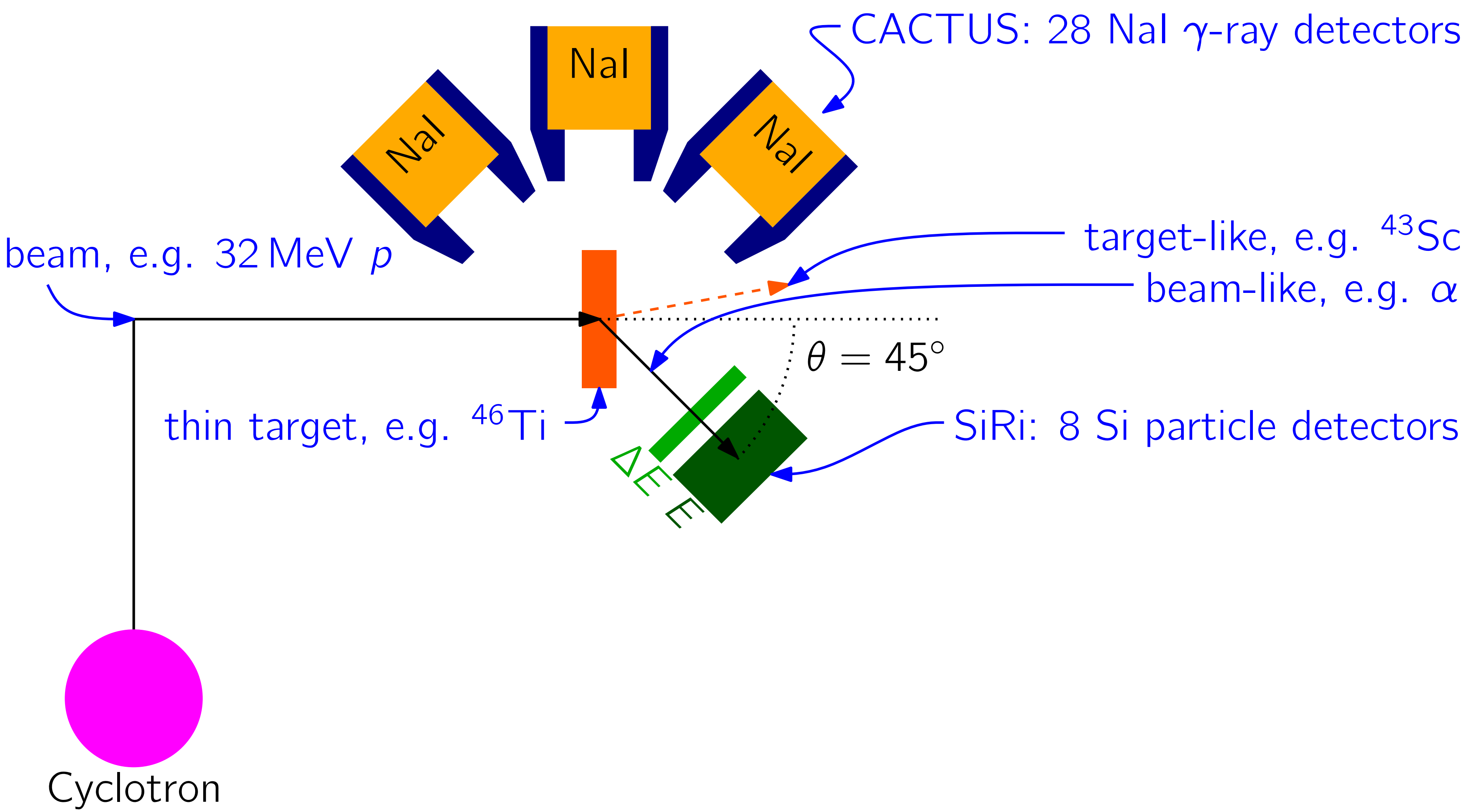


- derive ρ and $\mathcal{T}$ according to factorization $P(E_i, E_\gamma) \sim \rho(E_i - E_\gamma)\mathcal{T}(E_\gamma)$
- normalize ρ and $\mathcal{T}$

The Oslo Method – Experiment

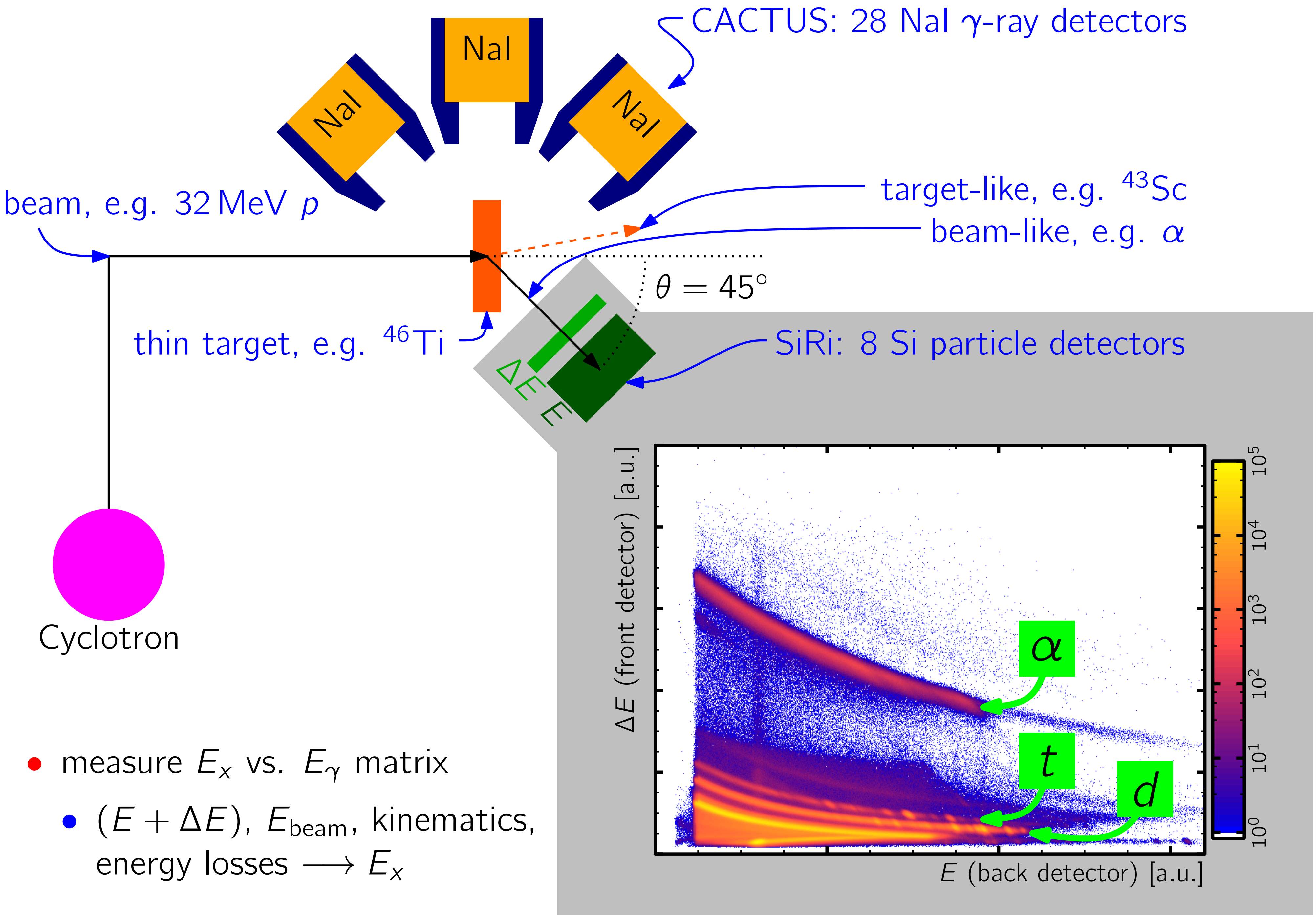


The Oslo Method – Experiment



- measure E_x vs. E_γ matrix
  - $(E + \Delta E)$, E_{beam}, kinematics, energy losses $\longrightarrow E_x$

The Oslo Method – Experiment

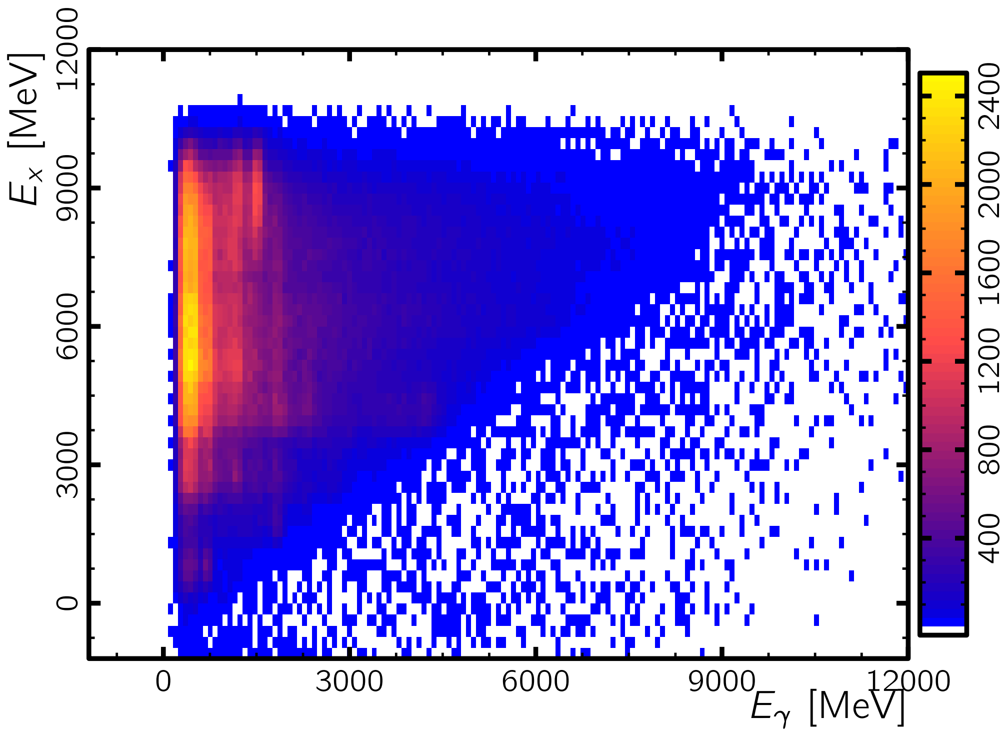


- measure E_x vs. E_γ matrix
  - $(E + \Delta E)$, E_{beam}, kinematics, energy losses $\longrightarrow E_x$

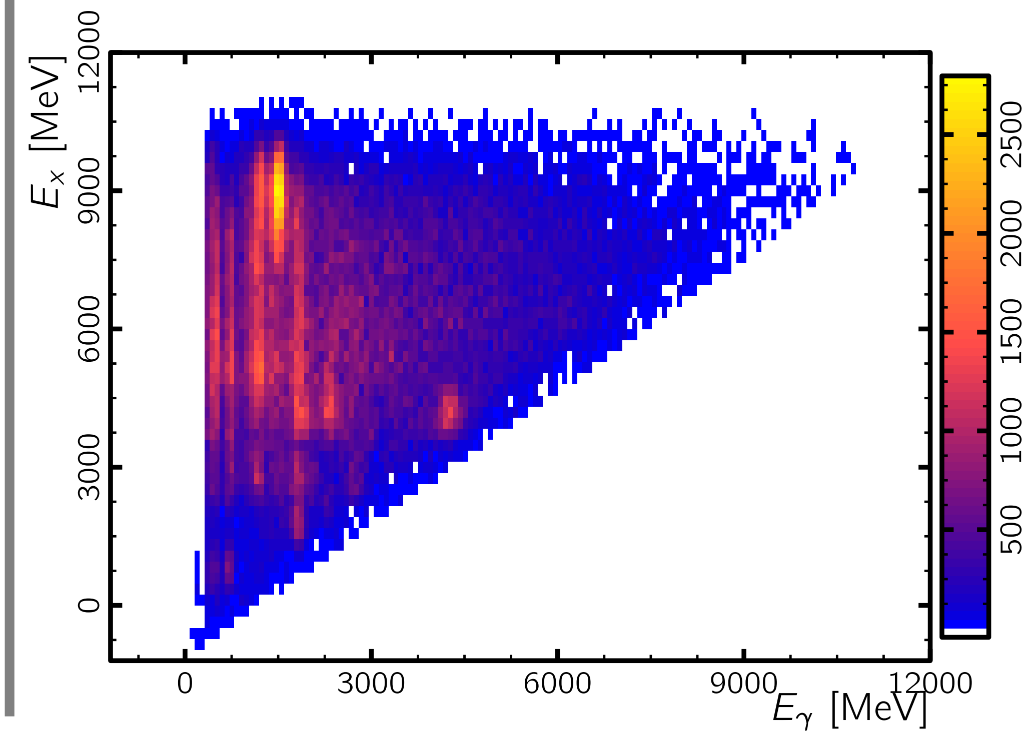
The Oslo Method – Unfolding

- "unfolding" — correct E_γ for detector response function:
  - remove Compton background, pair production effects, ...
  - correct for E_γ dependence of NaI efficiency

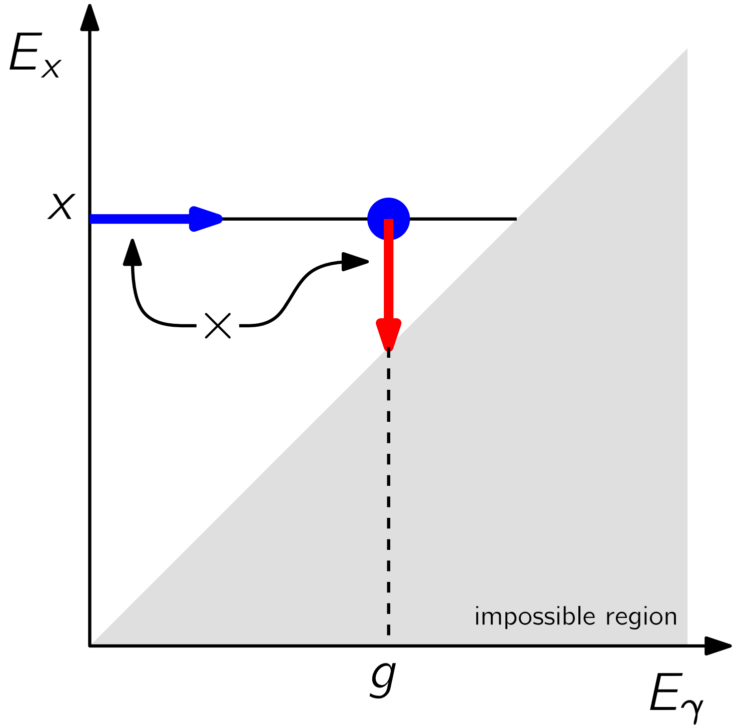
"raw" matrix



"unfolded" matrix



The Oslo Method – 1^{st} Generation

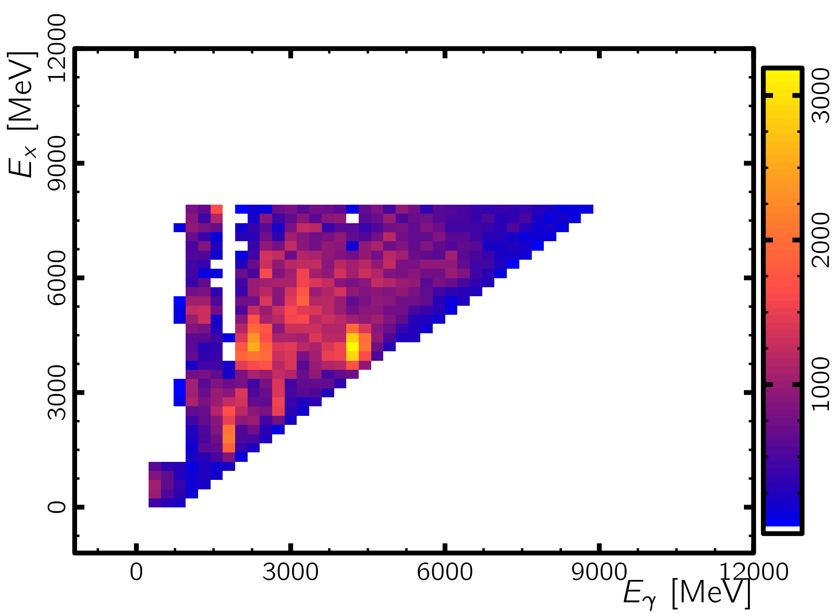


- extract 1^{st} generation spectra
  - $u(g, x)$: unfolded matrix, contains 1^{st} + all higher generations
  - $p(g, x)$: 1^{st} generation matrix

$$u(g, x) = p(g, x) + \sum_{g'} p(g', x) u(g, x - g')$$

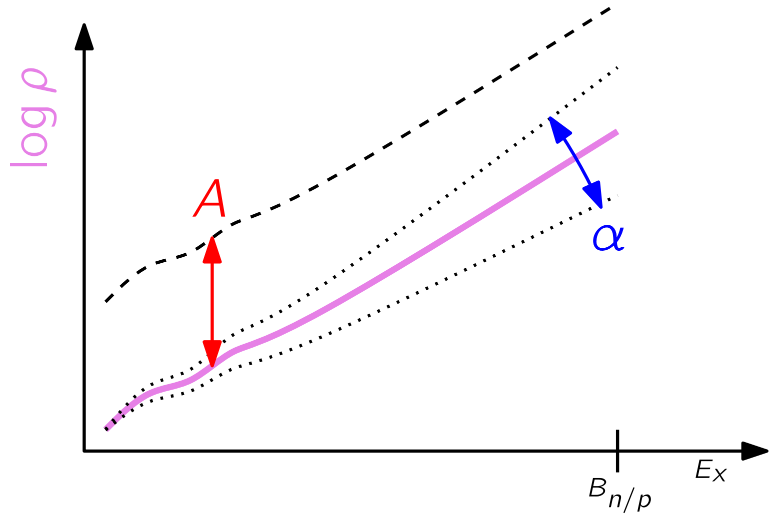
"weight" higher generations

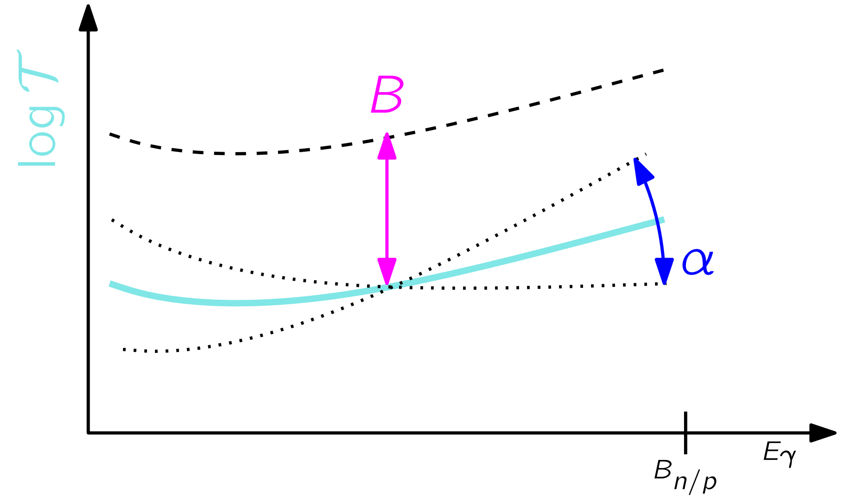
- find $p(g, x)$ iteratively



The Oslo Method – ρ and T

- derive level density and strength function from 1st generation spectra
  - more data points than variables, iterative χ^2 minimization
- solutions can be re-normalized
  - $\rho(E_f) \longrightarrow A \exp(\alpha E_f)\rho(E_f)$
  - $\mathcal{T}(E_\gamma) \longrightarrow B \exp(\alpha E_\gamma)\mathcal{T}(E_\gamma)$

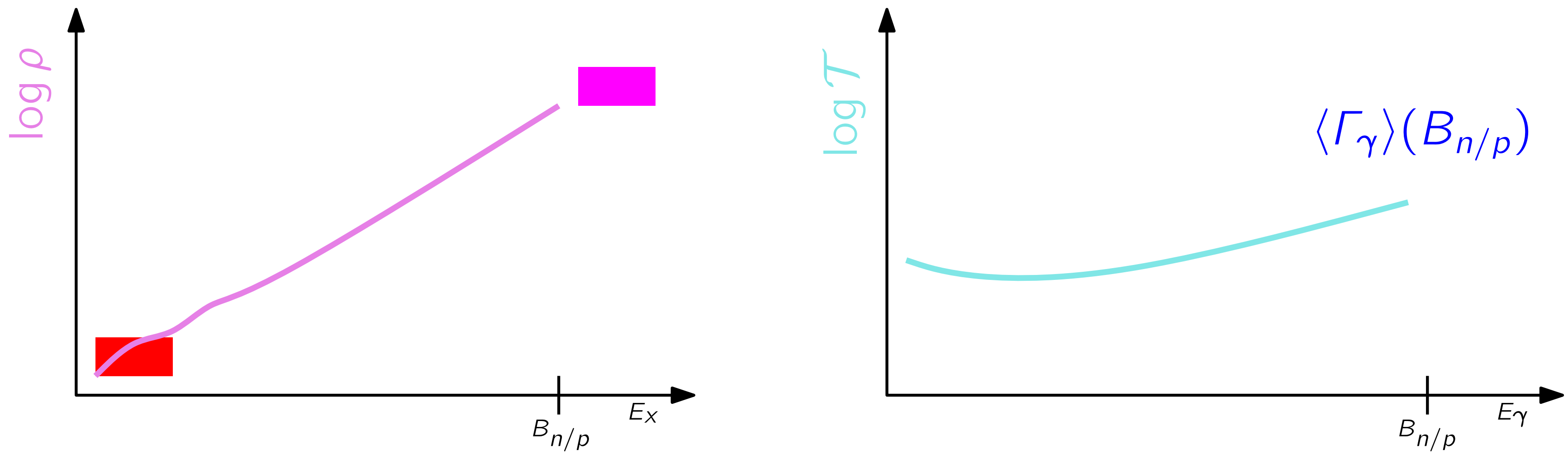




A. Schiller *et al.*, NIM A 447, 498 (2000)

The Oslo Method – ρ and $\mathcal{T}$

- derive level density and strength function from 1^{st} generation spectra
  - more data points than variables, iterative χ^2 minimization
- solutions can be re-normalized
  - $\rho(E_f) \longrightarrow A \exp(\alpha E_f) \rho(E_f)$
  - $\mathcal{T}(E_\gamma) \longrightarrow B \exp(\alpha E_\gamma) \mathcal{T}(E_\gamma)$
- $\Rightarrow$ need "external" normalization
  - discrete levels at low energy
  - resonance spacings and γ widths near B_n

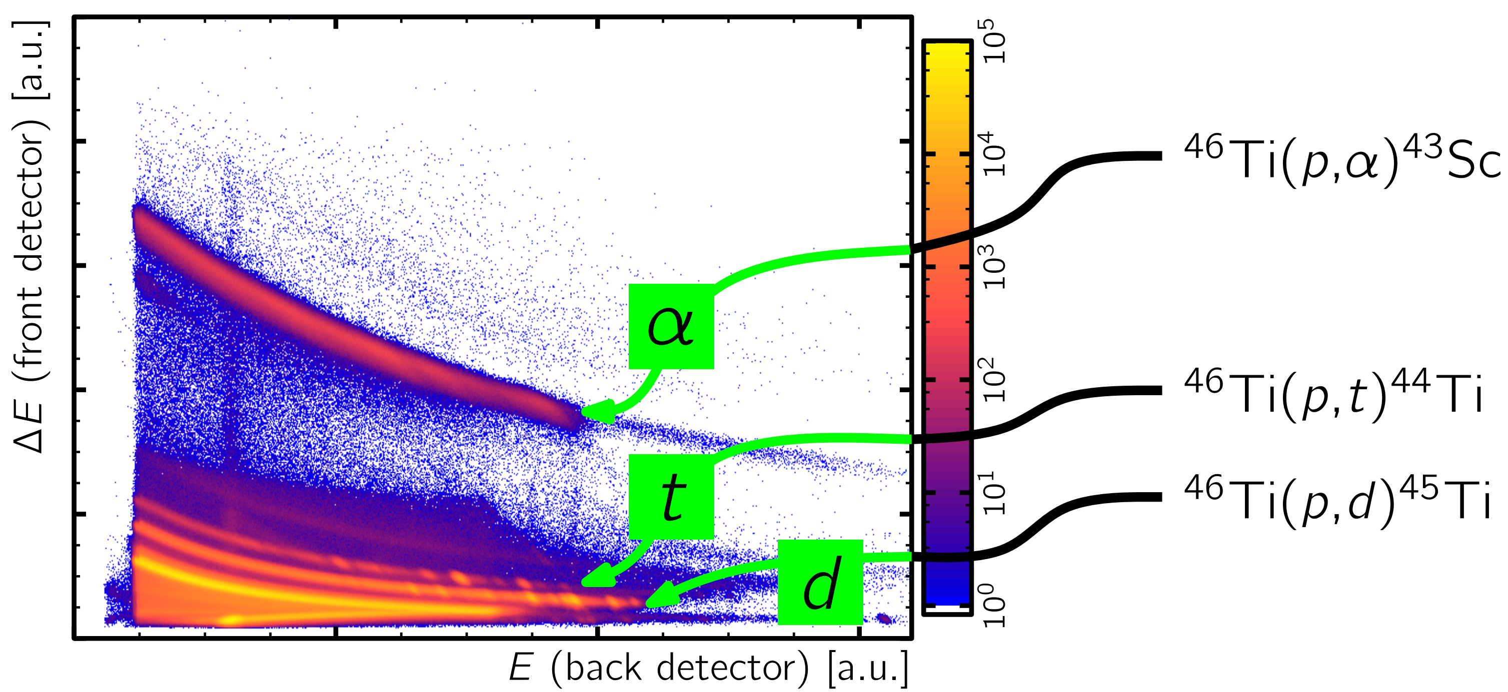


A. Schiller *et al.*, NIM A 447, 498 (2000)

^{46}Ti(p,X) Experiment

Aim:

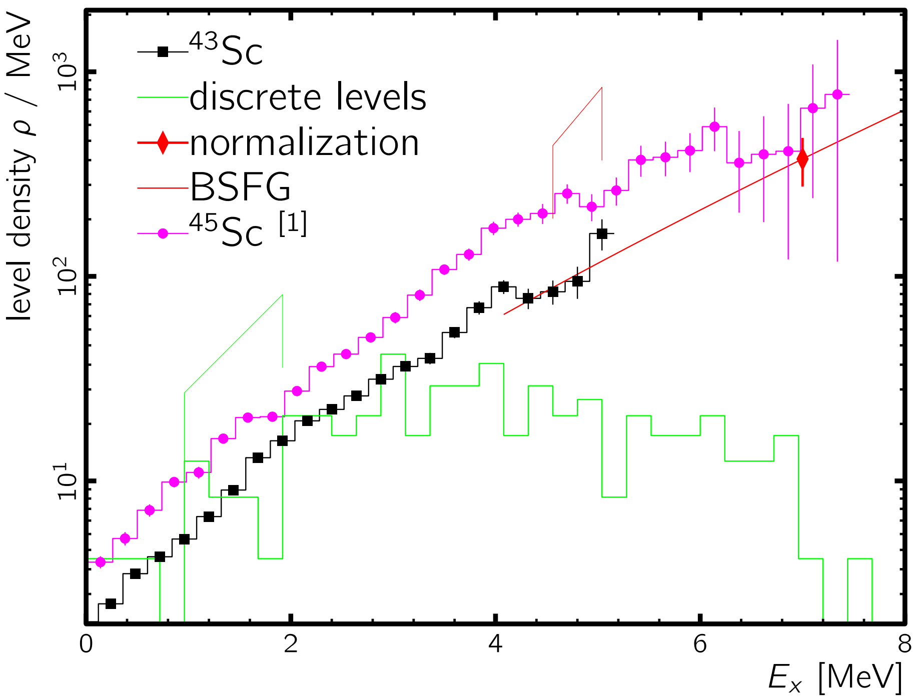
- investigate level density of ^{44}Ti
    - astrophysical interest — large ^{44}Ti abundance not understood
- study other reaction channels, and compare with previous results (e.g. (p,α) reaction)



^{43}Sc Preliminary Level Density

Normalization:

- p resonances at $B_p + 2\,\text{MeV}$
  - distribution of known spins extrapolated for unassigned levels
- discrete levels at $1 \cdots 2\,\text{MeV}$



Comparison with ^{45}Sc:

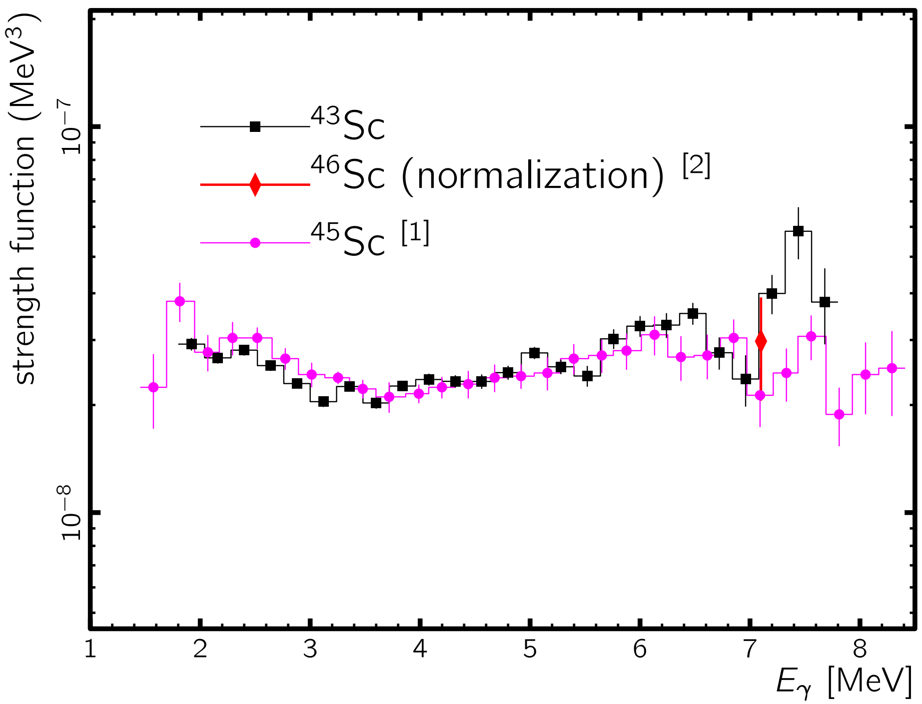
- level density slightly lower
  - usually ρ very similar for neighbours
  - possible reason: fewer particles outside core — but why at low E_x?

[1] A.C. Larsen *et al.*, PRC 76, 044303 (2007)

^{43}Sc Preliminary γ Strength Function

Normalization:

- no data available for ^{43}Sc
- use ^{46}Sc (as for ^{45}Sc in [1])



Comparison to ^{45}Sc:

- almost identical — different reactions!
  - ^{43}Sc: $(p,\alpha\ \gamma)$
  - ^{45}Sc: $(^3\mathrm{He},^3\mathrm{He}'\ \gamma)$
- upbend at low E_γ, minimum at $E_\gamma \approx 3\,\mathrm{MeV}$
  - origin unknown

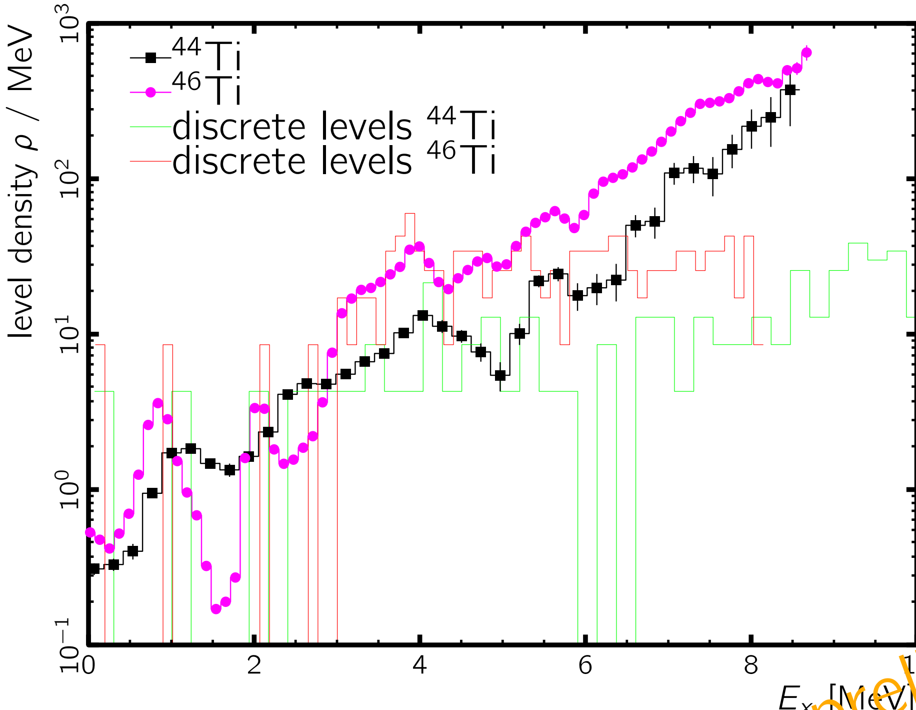
[1] A.C. Larsen *et al.*, PRC 76, 044303 (2007) [2] RIPL-2

^{44,46}Ti Preliminary Results

Ann-Cecilie Larsen

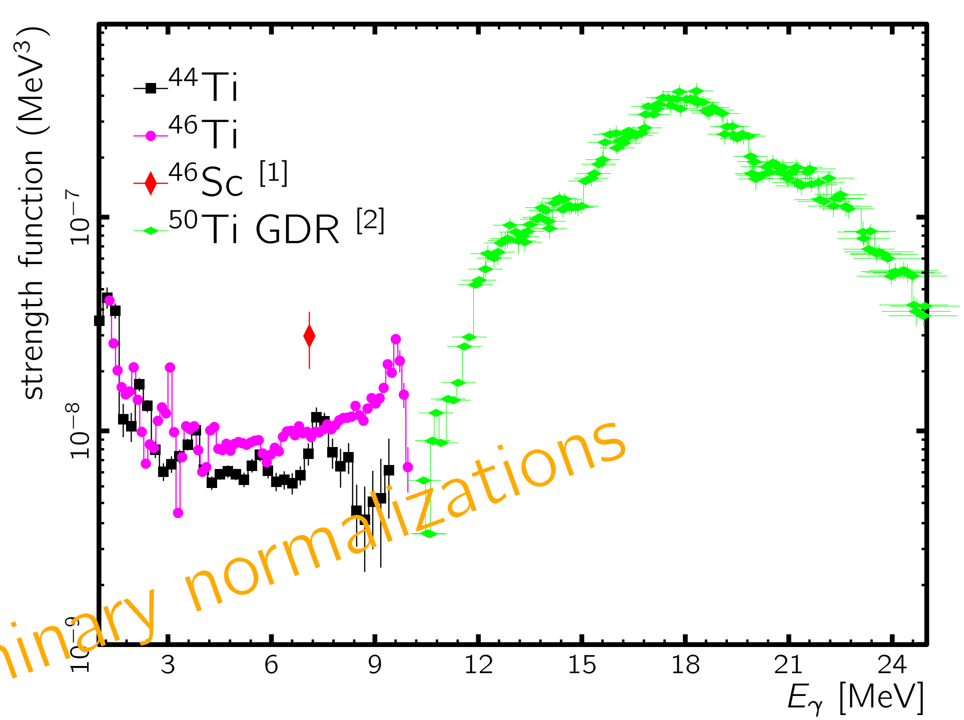
Level density:

- normalized to theoretical value
- very good agreement with discrete levels
- $\rho(^{44}\text{Ti})$ smaller than $\rho(^{46}\text{Ti})$



Strength function:

- no normalization point yet . . .
- ^{46}Ti seem to match well to the ^{50}Ti GDR data
- upbend at low E_γ



very preliminary normalizations

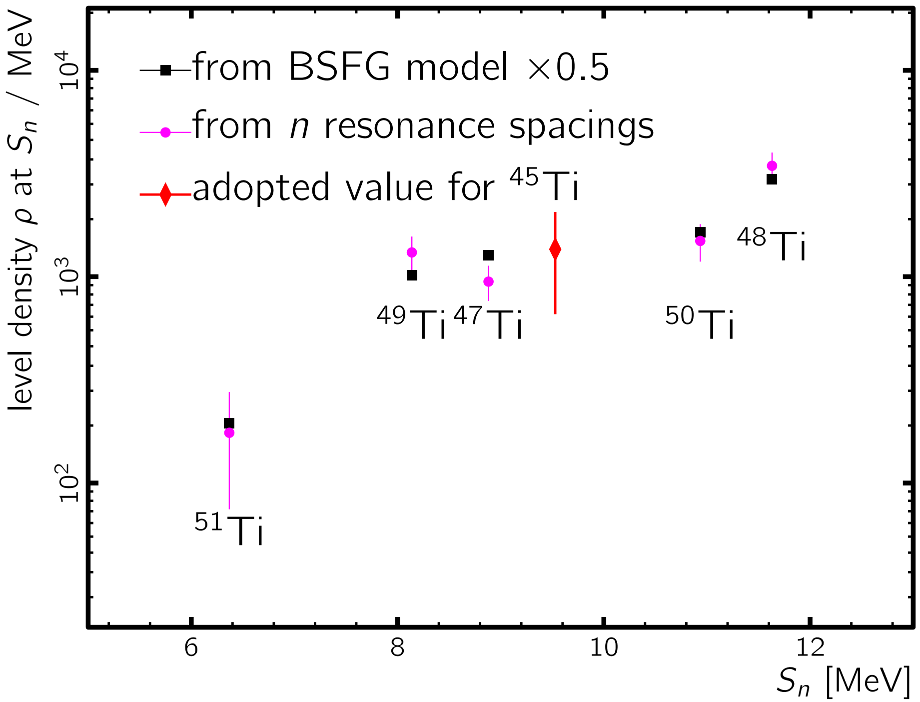
[1] RIPL-2 [2] Pywell *et al.*, NPA 325, 116 (1979)

^{45}Ti Level Density

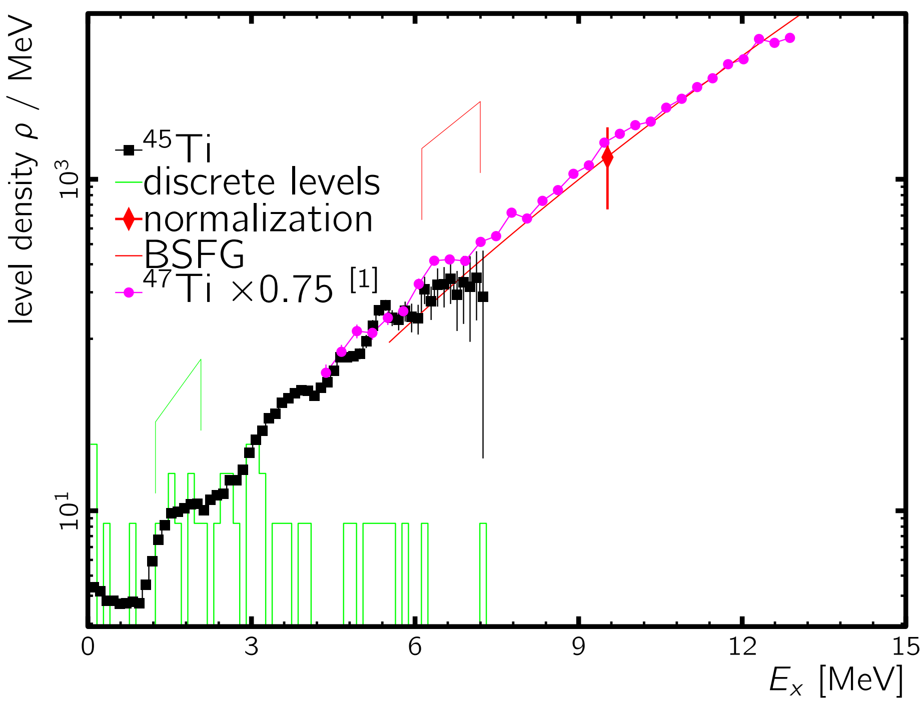
Naeem U.H. Syed *et al.*
(submitted to PRC)

- normalization at B_n:
  - no data available for ^{45}Ti
  - derive estimate from neighbouring nuclei
- step structures
  - correspond to pair-breaking

Normalization:



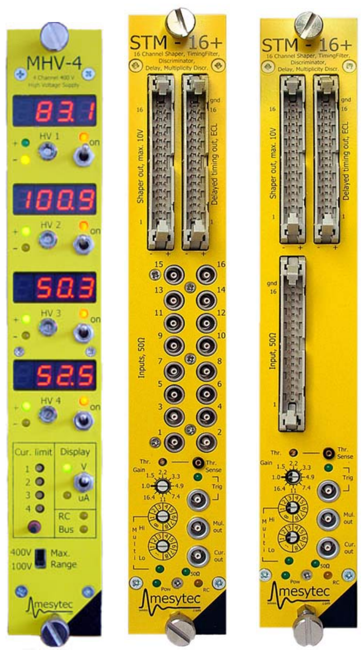
Level density:

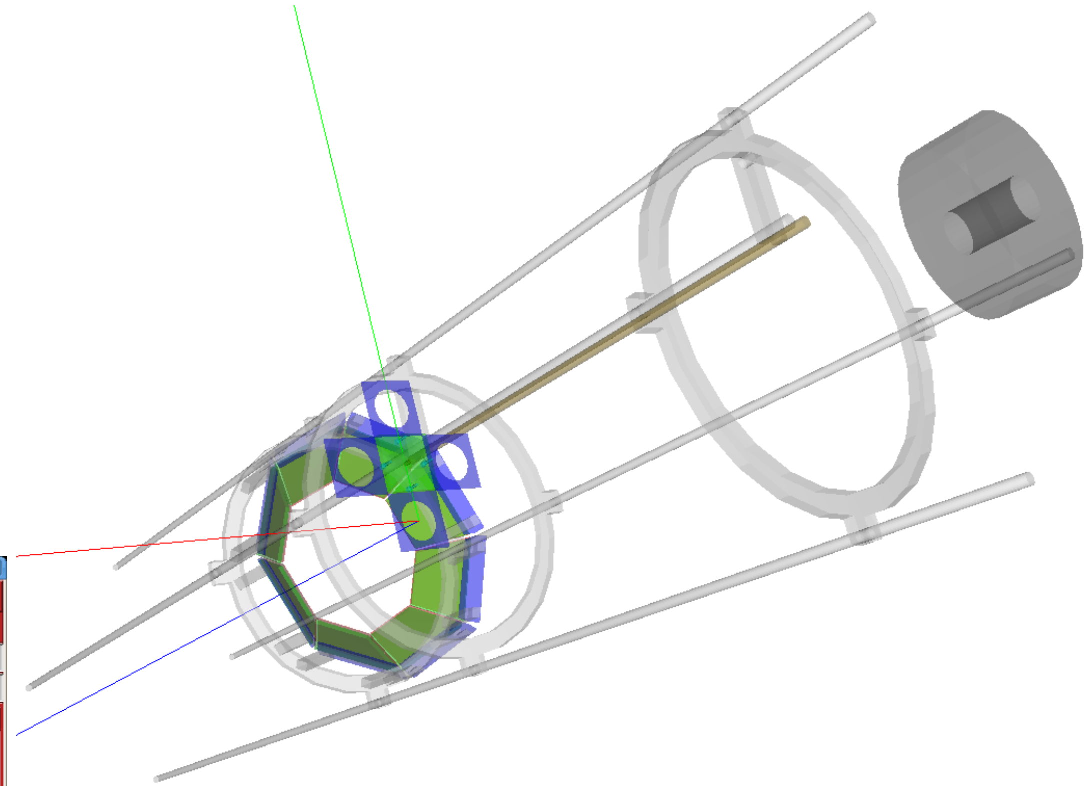


[1] A. Voinov *et al.*, PRC 77, 034613 (2008)

Outlook – New SiRi Detectors

- new Si detectors
  - 8 segments in θ, each $\approx 40^\circ$ coverage in ϕ
- new electronics
- updated data acquisition





Come and see it — today 18:00, pizza at the lab!

Collaboration:

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fin – Ende – end

PHYSICAL REVIEW C **76**, 044303 (2007)

Nilsson level scheme ^{45}Ti