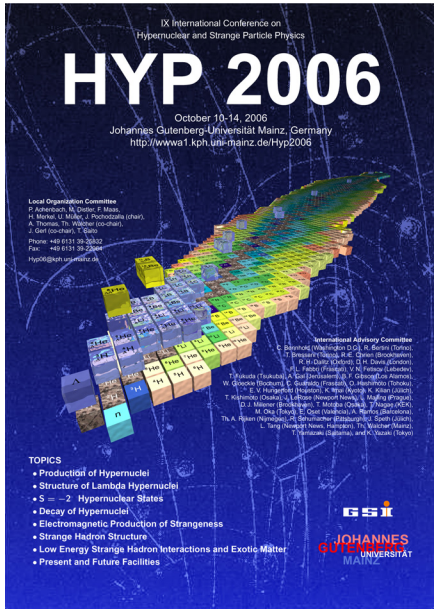
One step beyond: hypernuclear γ-ray spectroscopy with FINUDA



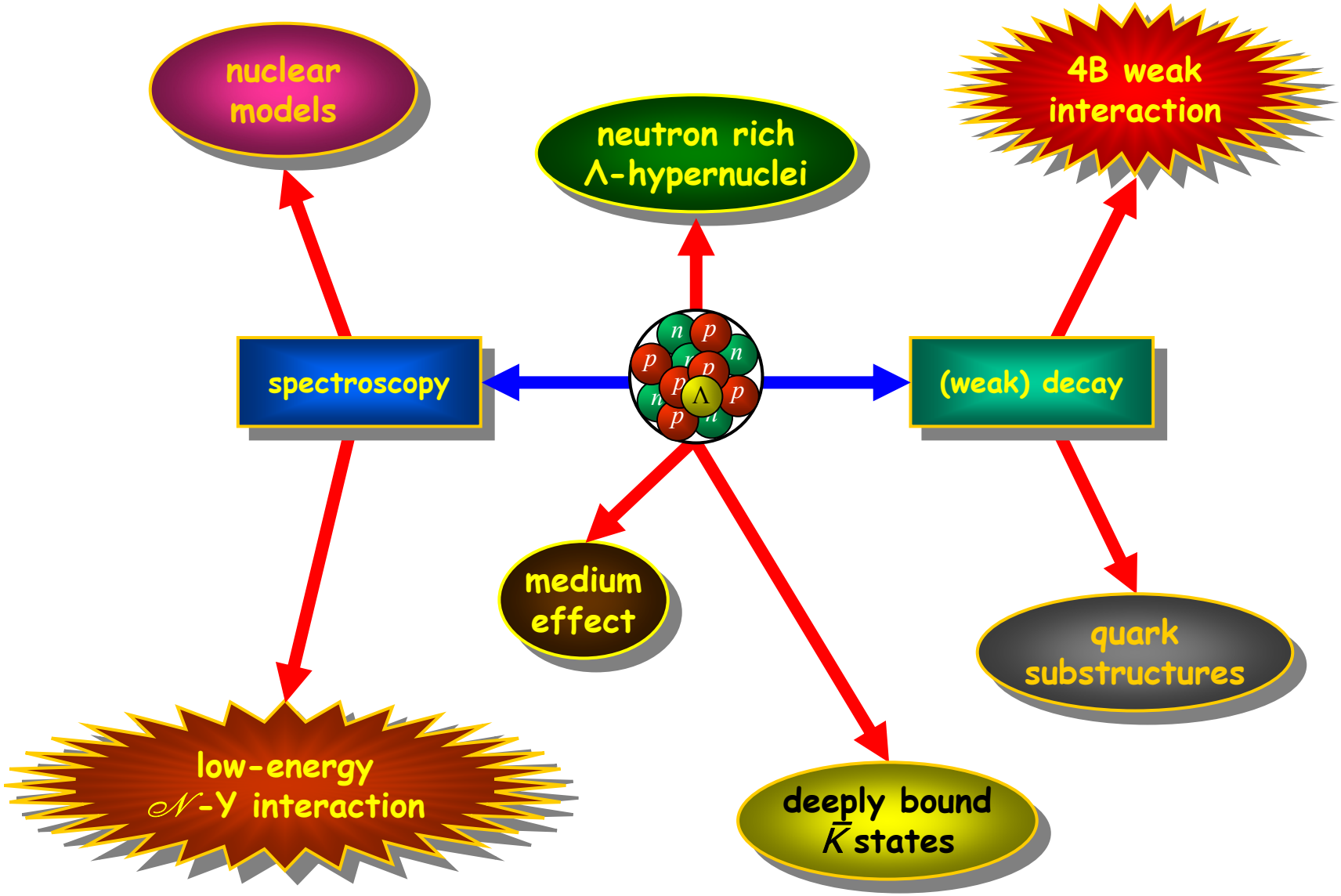
Alessandro Feliciello

I.N.F.N. - Sezione di Torino

Outline

- Discovery potential of the strangeness nuclear physics
  - recent experimental results
  - unexpected effects
- Need of sub-MeV resolution apparatuses
  - γ-ray spectroscopy
- Ideas for FINUDA spectrometer upgrade at DAΦNE/DAΦNE2

Physics output (S=-1)



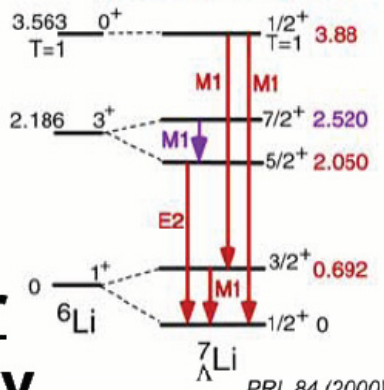
Open questions

- (low-energy) YN interaction
  - detailed knowledge of the hypernuclear fine structure
    - → evaluation of the spin dependent terms of the ΛN interaction
  - measurement of angular distribution of γ-rays
    - → determination of spin and parity of each observed level

Where do we stand?

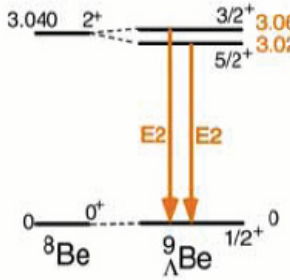
Status of hypernuclear γ spectroscopy

^{7}Li (π^+,K$^+\gamma$) KEK E419



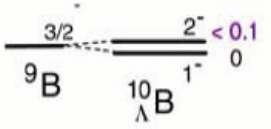
PRL 84 (2000) 5963
PRL 86 (2001) 1982
PLB 579 (2004) 258
PRC 73 (2006) 012501

^{9}Be (K$^-$,$\pi^-\gamma$) BNL E930('98)



PRL 86 (2002) 082501
NPA 754 (2005) 58c

^{10}B (K$^-$,$\pi^-\gamma$) BNL E930('01)

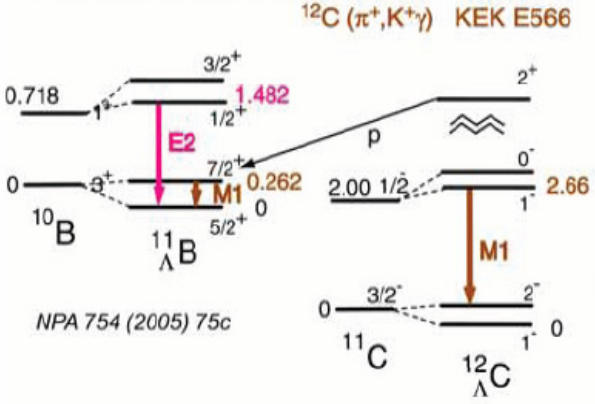


NPA 754 (2005) 58c

=> "Table of Hyper-Isotopes"

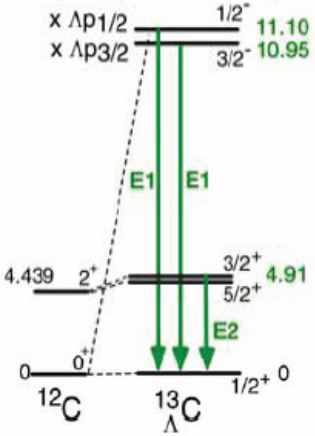
^{11}B (π^+,K$^+\gamma$) KEK E518

^{12}C (π^+,K$^+\gamma$) KEK E566



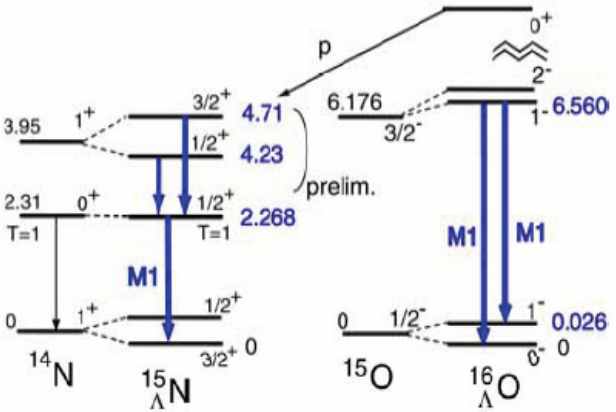
NPA 754 (2005) 75c

^{13}C (K$^-$,$\pi^-\gamma$) BNL E929 (NaI)



PRL 86 (2001) 4255
PRC 65 (2002) 034607

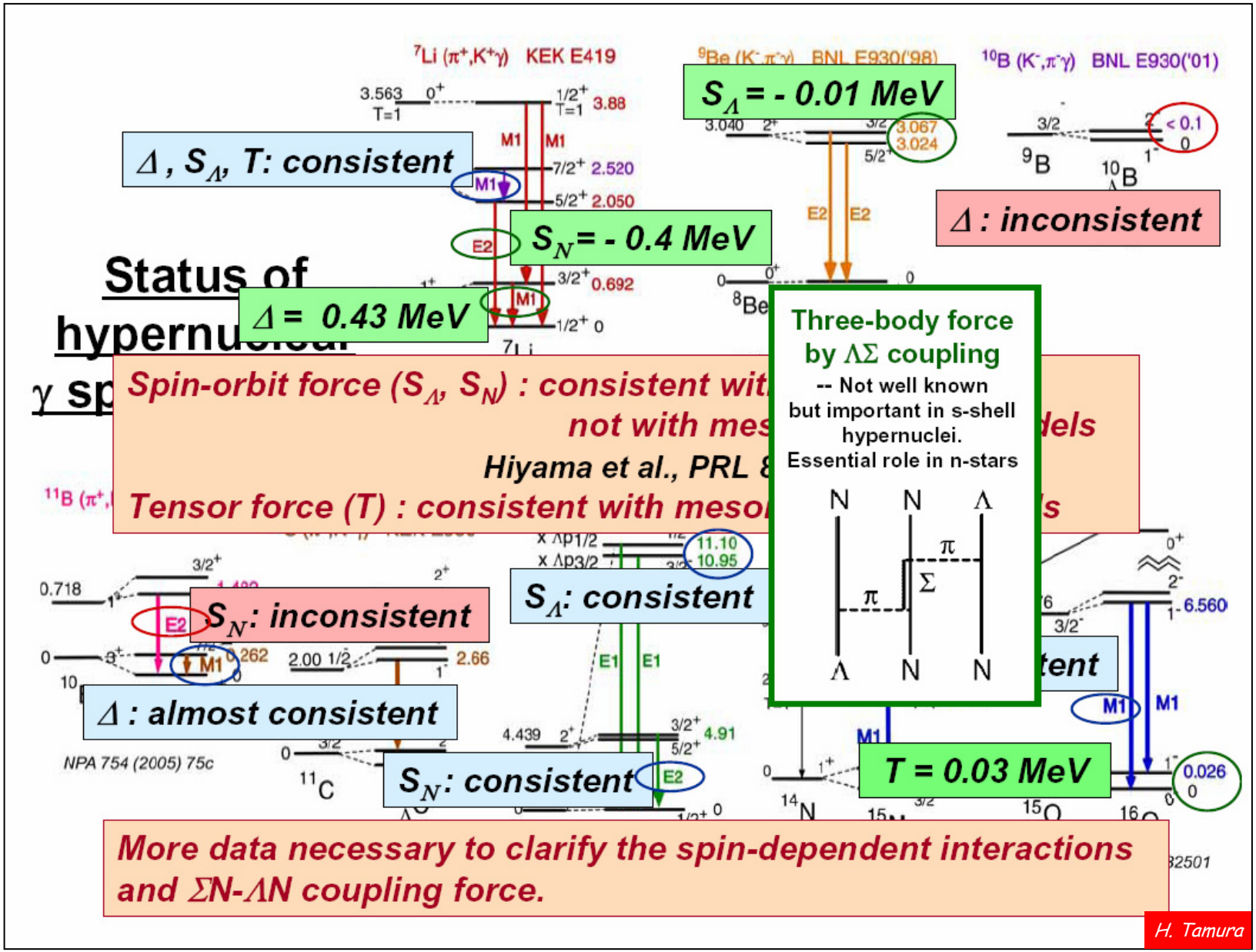
^{16}O (K$^-$,$\pi^-\gamma$) BNL E930('01)



PRL 93 (2004) 232501

H. Tamura

Where do we stand?



Open questions

- (low-energy) $Y\mathcal{N}$ interaction
  - detailed knowledge of the hypernuclear fine structure
    → evaluation of the spin dependent terms of the $\Lambda\mathcal{N}$ interaction
  - measurement of angular distribution of γ-rays
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- Impurity nuclear physics
  - measurement of transition probability B(E2)
    → information on the size and deformation of hypernuclei
    → measurement of nucleus core shrinking → glue-like role of Λ

Open questions

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- Impurity nuclear physics
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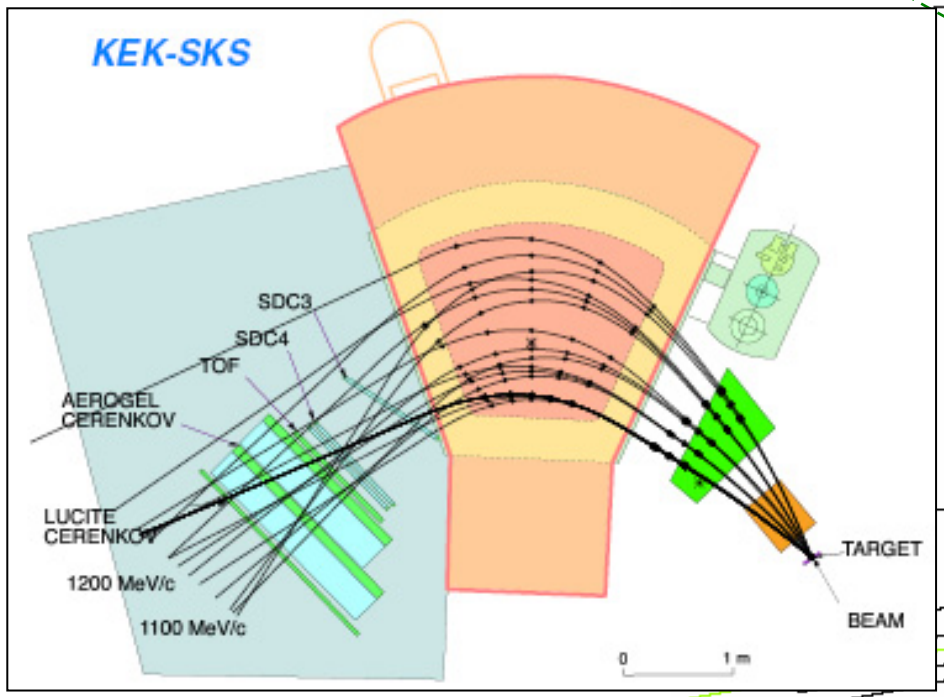
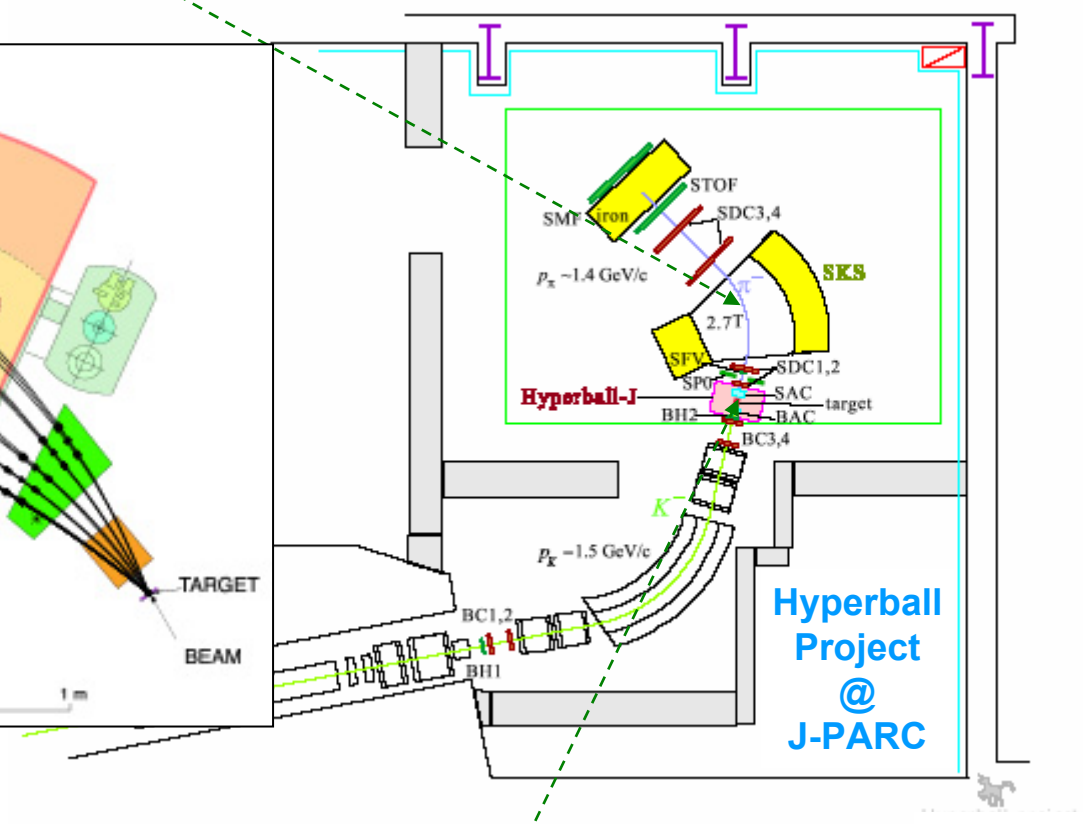
- Properties of hyperons in nuclear matter (medium effect)
  - measurement of transition probability B(M1)
    → g-factor value for Λ in nuclear matter

Parallel vs. serial

one-arm spectrometer → small acceptance

- ΔE ~ 4 MeV (FWHM)
- ΔΩ ~ 110 msr

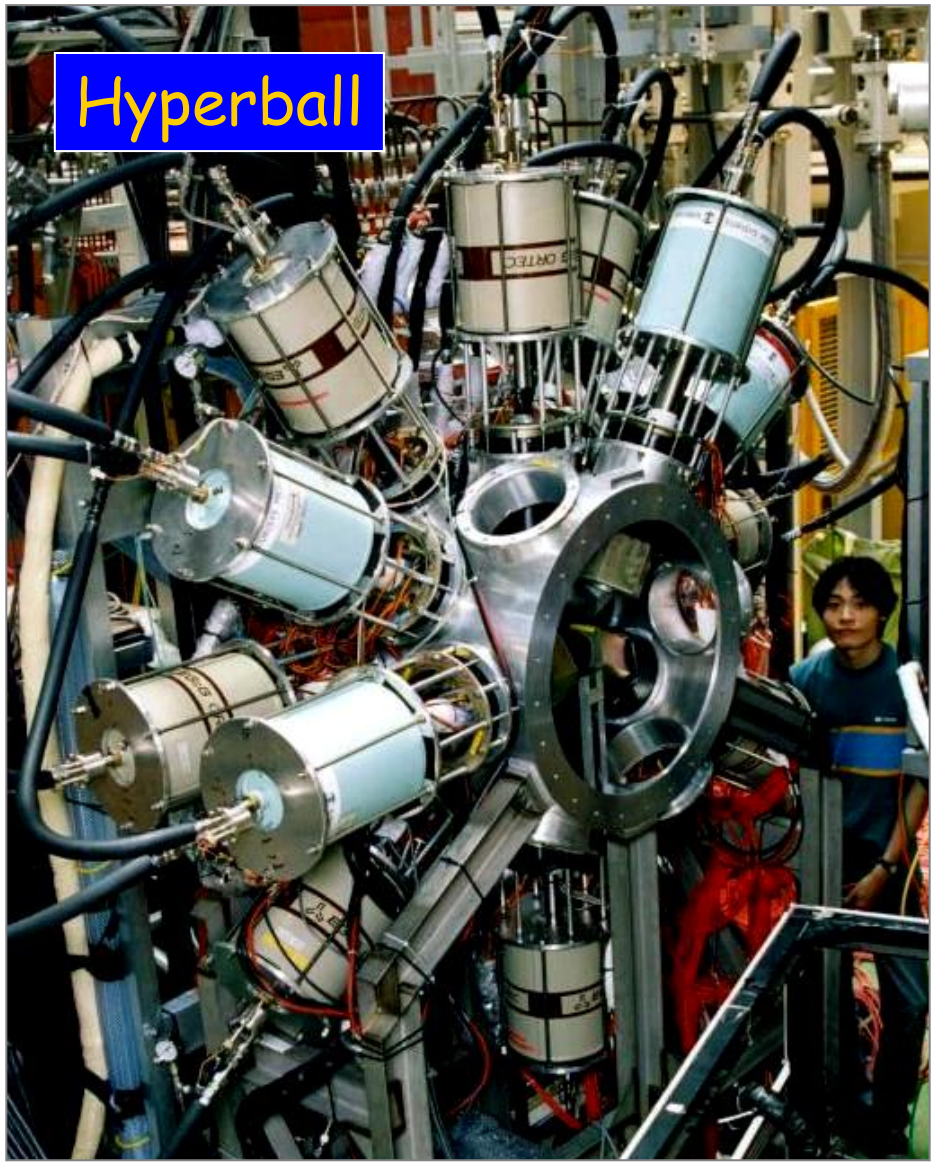


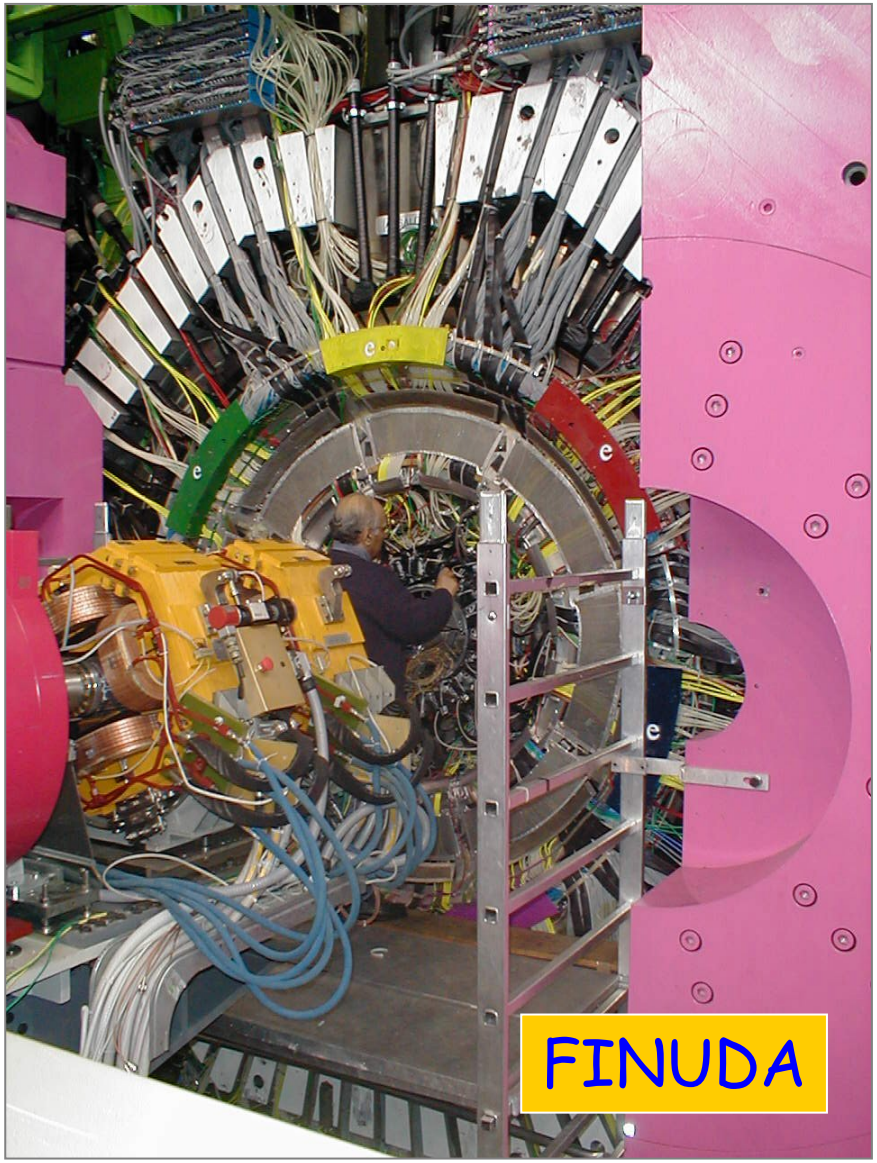


HPGe array → large acceptance

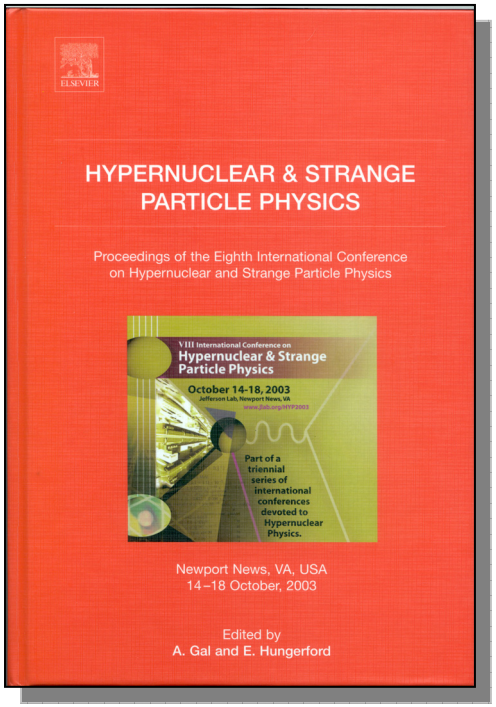
- ΔE ~ 1 ÷ 2 keV (FWHM)
- ε ~ 7% (@ 1 MeV)

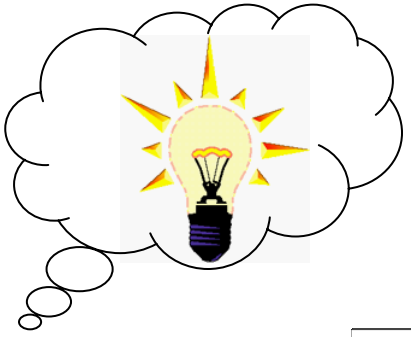
Parallel vs. serial



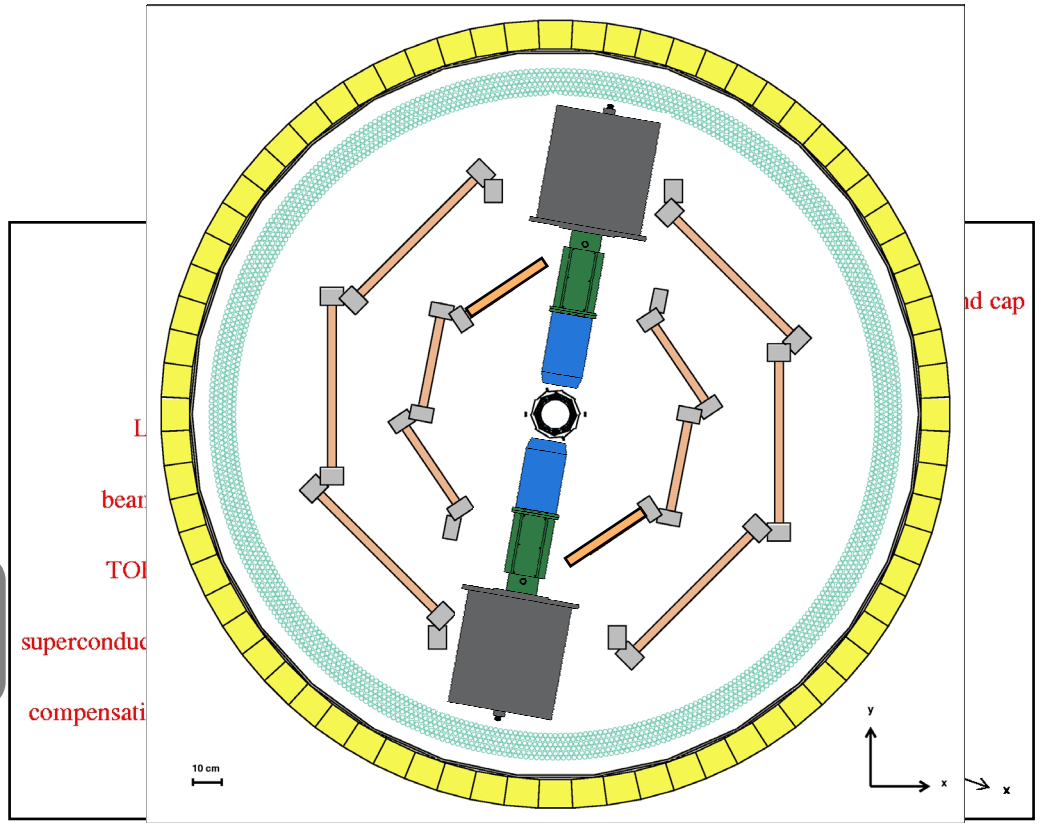


The first approach





The FINUDA spectrometer



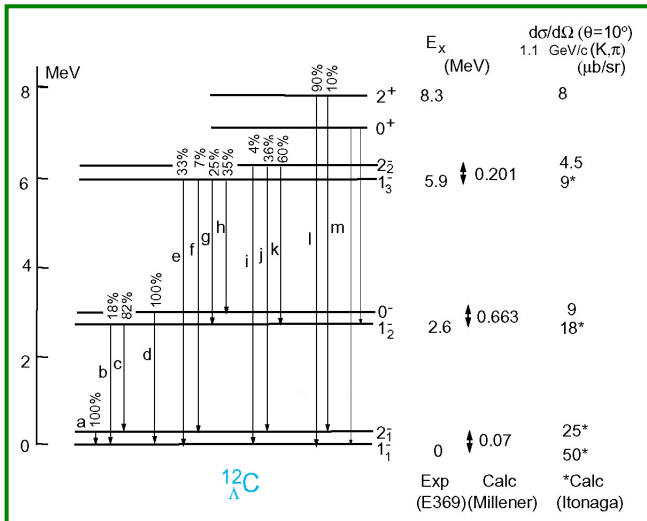
Geometrical acceptance reduced to 72%

Expected rates (first approach)

@ $\mathscr{L} = 10^{34}$ cm^{-2} s^{-1} FINUDA can observe ~ 1.6×10^4 ev/h from YN g.s.

- machine duty cycle: 75%
- spectrometer acceptance: 72%
- Ge acceptance: ~ 30%
- ε_{Ge}: ~ 30%

~ 1.87×10^4 ev/d



Expected Yield (5 days)

single						γγ coincidnece					
						with a		with c		with d	
a	112000	h	1700			c	1900	a	1900	h	55
b	2600	i	64			f	50	g	39		
c	12000	j	580			g	150	k	50		
d	7500	k	1400			j	94				
e	1100	l	2000			k	170				
f	240	m	230			m	31				
g	1300										

J-PARC MC data

5 day data taking

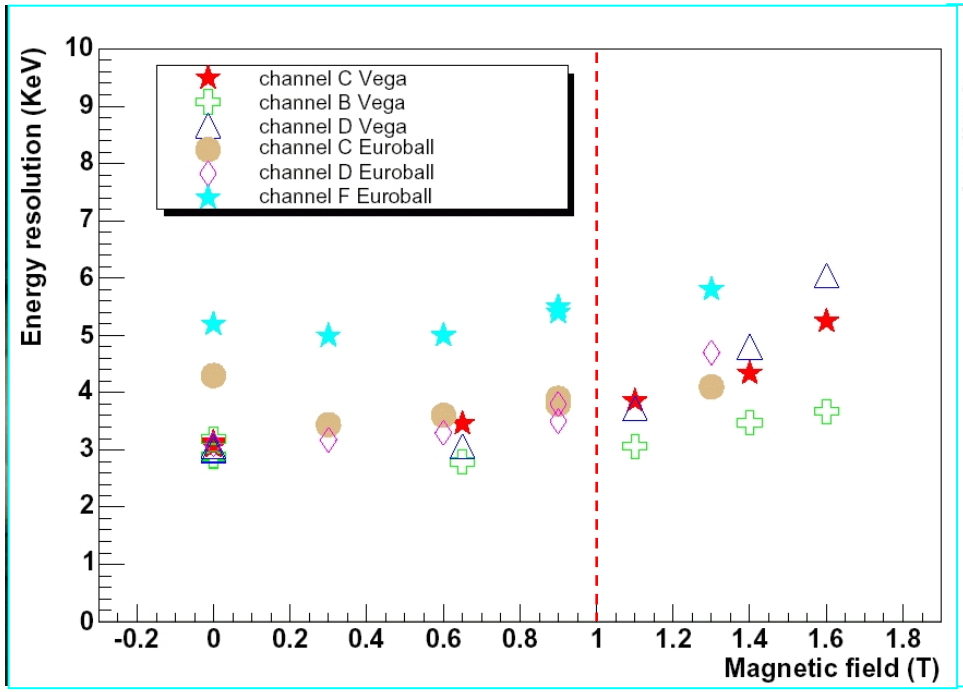
~ 9.33×10^4 ev

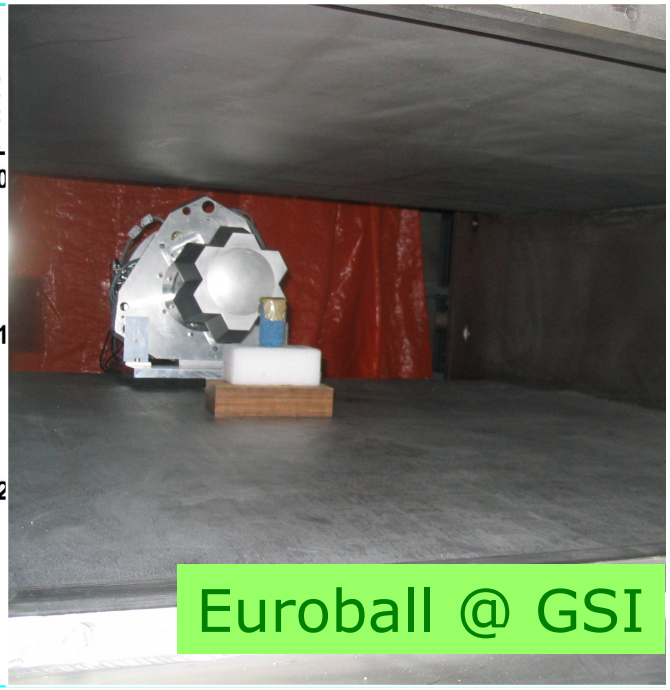
Experimental challenges

HadronPhysics I3
Study of Strongly Interacting Matter

JRA6

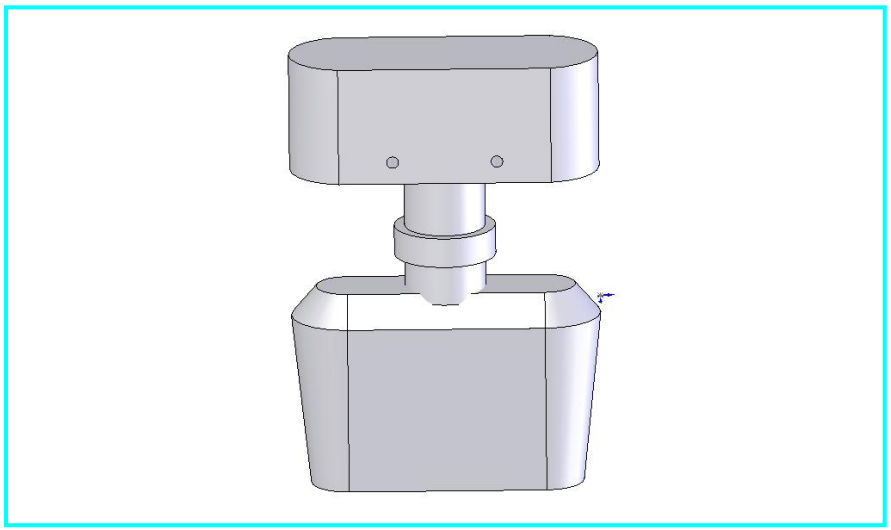
- Do HPGe crystals work in (strong) magnetic field?

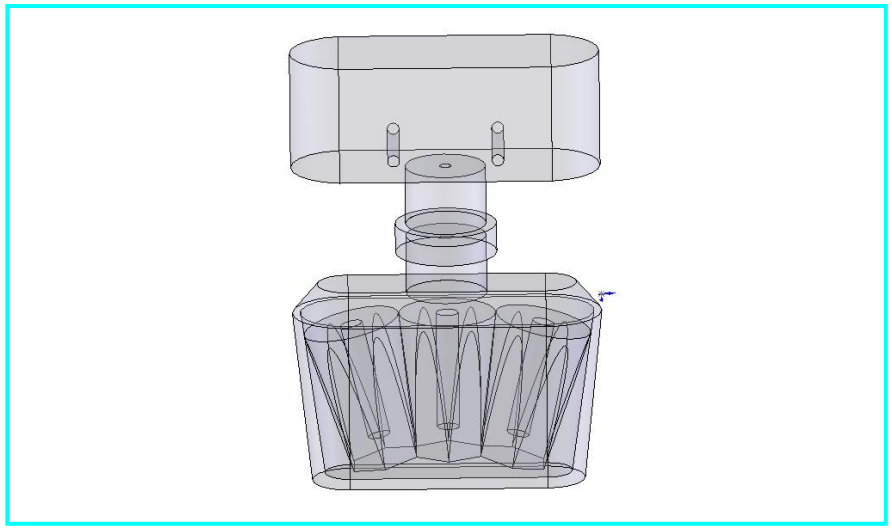




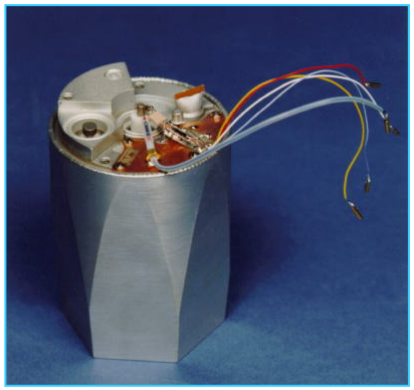
The hyper-triple cluster concept design

X – COOLER II, AMETEC, ORTEC

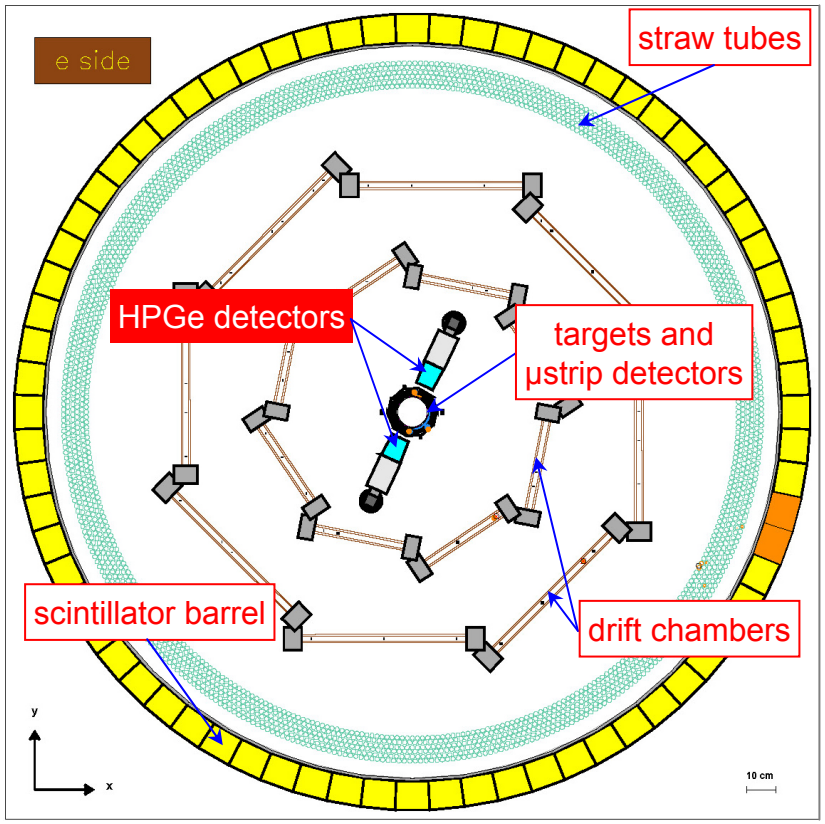


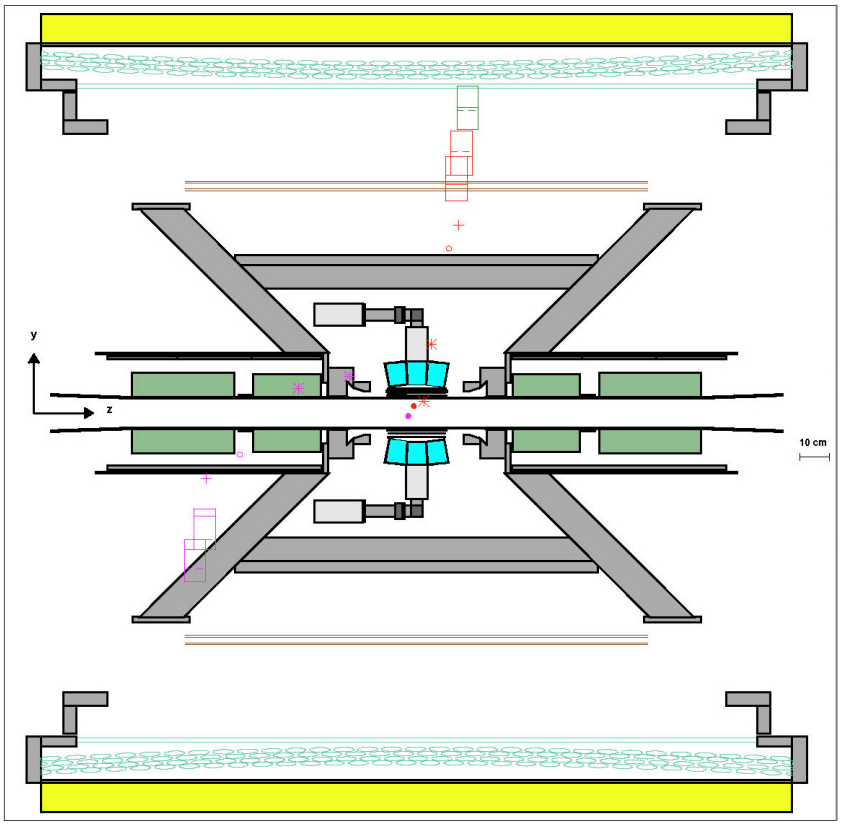


An exacting integration (new approach)



Geometrical acceptance reduced to 82%





FINUDA key features

- very thin nuclear targets (0.1 ÷ 0.3 g/cm^2)
  - → high resolution spectroscopy
- coincidence measurement with large acceptance
  - → decay mode study
- irradiation of different targets in the same run
  - → high degree of flexibility

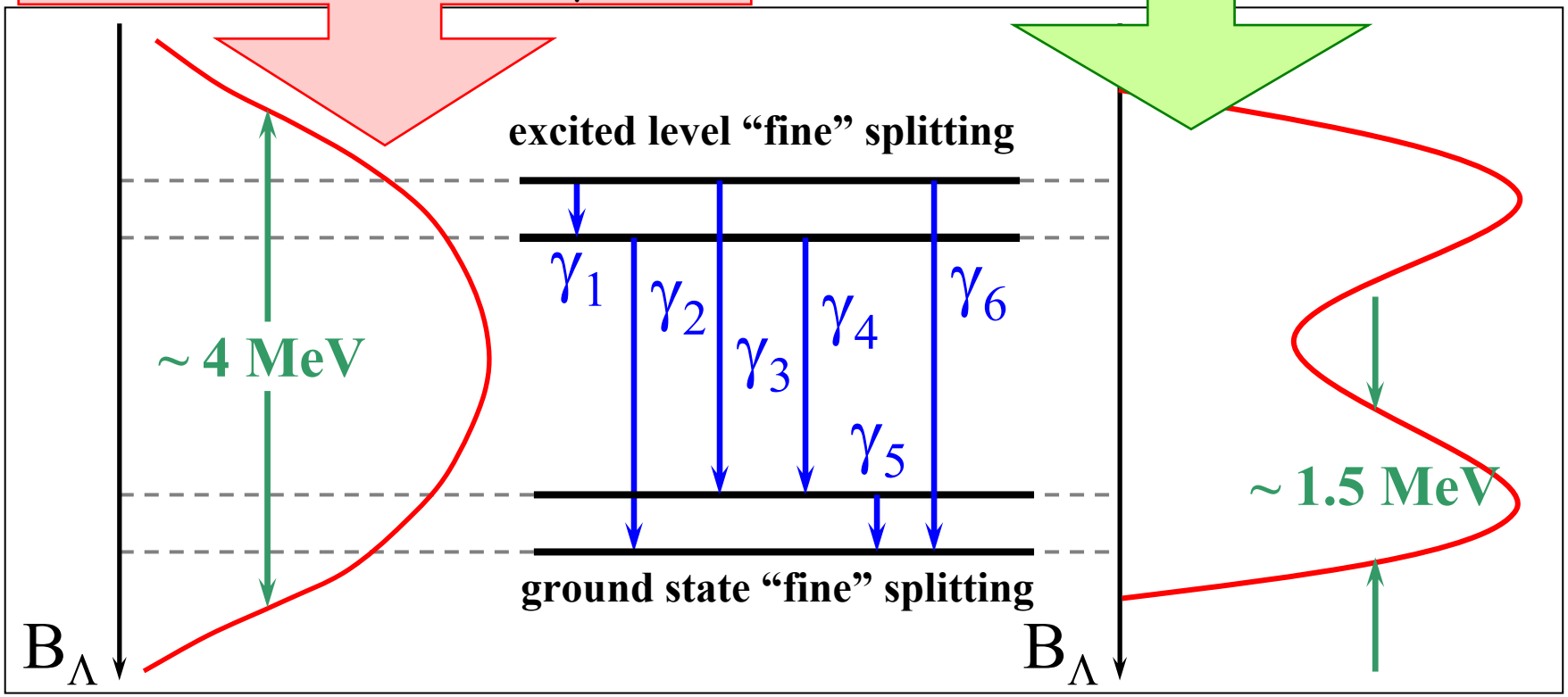
Quality vs. quantity

KEK, JPARC

high energy K^- beam
→ K^- stopping efficiency 10÷20%
→ massive targets (20 g/cm²)
→ $\gamma\gamma$ coincidence mandatory

DAΦNE (DAΦNE2)

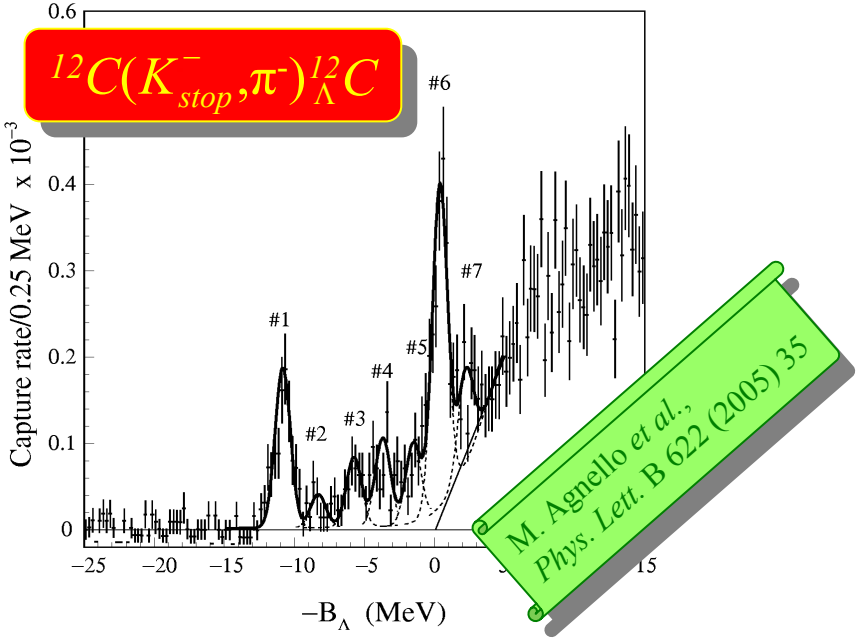
very low energy K^- beam
→ K^- stopping efficiency 90%
→ thin targets (0.2 g/cm²)
→ independent γ measurement



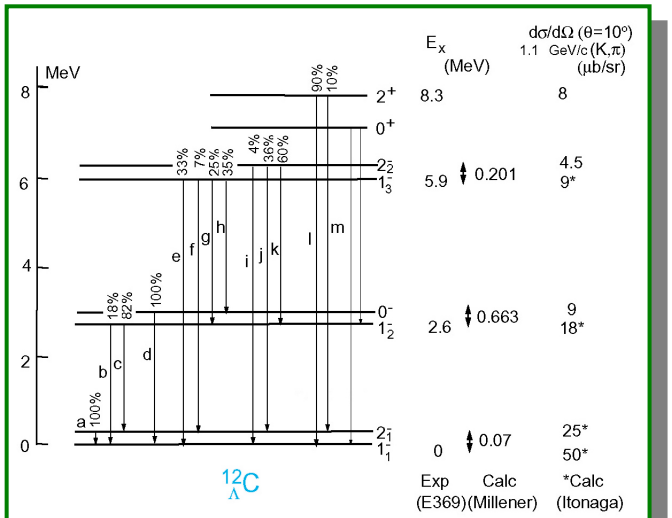
once more the DAΦNE K^- characteristics make our setup competitive

Expected rates (new approach)

with 500 pb^{-1} FINUDA can observe ~ 2.5 × 10^4 ev from $^{12}_{\Lambda}C$ g.s.



8 targets



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f	240	m	230		m	31					
g	1300										

J-PARC MC data

- spectrometer acceptance: 82%
- Ge array acceptance: ~ 12%
- ε_{Ge}: ~ 10%

~ 1500 γ transitions

Strategy

Total synergy with the I3HP JRA6 project

- study of HPGe crystal performance in strong magnetic field

Close collaboration with TORTOLISO experiment, approved by INFN CSN 5

- Cagliari-Torino Collaboration
- production of LYSO crystals by an Italian firm

Contacts with INFN Groups, with solid experience on HPGe

- exploitation of previous INFN investment

PRIN dedicated to an operative test of final HPGe configuration in magnetic field

- last step before to go

Interested community

HadronPhysics I3

Study of Strongly Interacting Matter

JRA6

INFN Istituto Nazionale di Fisica Nucleare

INFN Istituto Nazionale di Fisica Nucleare

KEK 高エネルギー加速器研究機構

RIKEN

GSI

universitätmainz

SHAHID BEHESHTI UNIVERSITY TEHRAN-IRAN Founded 1960

KUNGL TEKNISKA HÖGSKOLAN

Hyper Gamma

Time schedule

- 2007: Letter of Intent
- 2008: completion of FINUDA physics program
- 2009: FINUDA upgrade pilot run at DAΦNE (500 pb^{-1})
- 201X: ???

Summary

- strangeness nuclear physics still has a great discovery potential
- explorative run on γ-ray spectroscopy is feasible with:
  - present DAΦNE machine
  - minor investment on FINUDA apparatus
- DAΦNE luminosity upgrade will allow to the (enlarged) FINUDA community to maintain a main role in the field