MINOS: nuclear MagIc Numbers Off Stability

Alexandre Obertelli, CEA Saclay, IRFU (France)

RIKEN, January 11th-12th, 2011

MINOS

Magic Numbers Off Stability

Research on **very** exotic nuclei

- Quest for the picture of shell evolution

- Develop an **original detection-target system** for **in-beam gamma spectroscopy**

- Dedicated program at **RIKEN** and GSI-FAIR

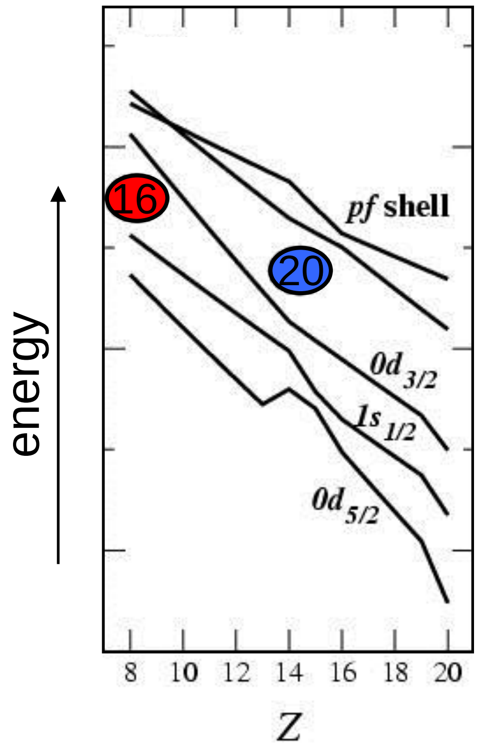
- Project started on October 2010
- **Funded** by the EU (ERC grant) for 5 years

erc

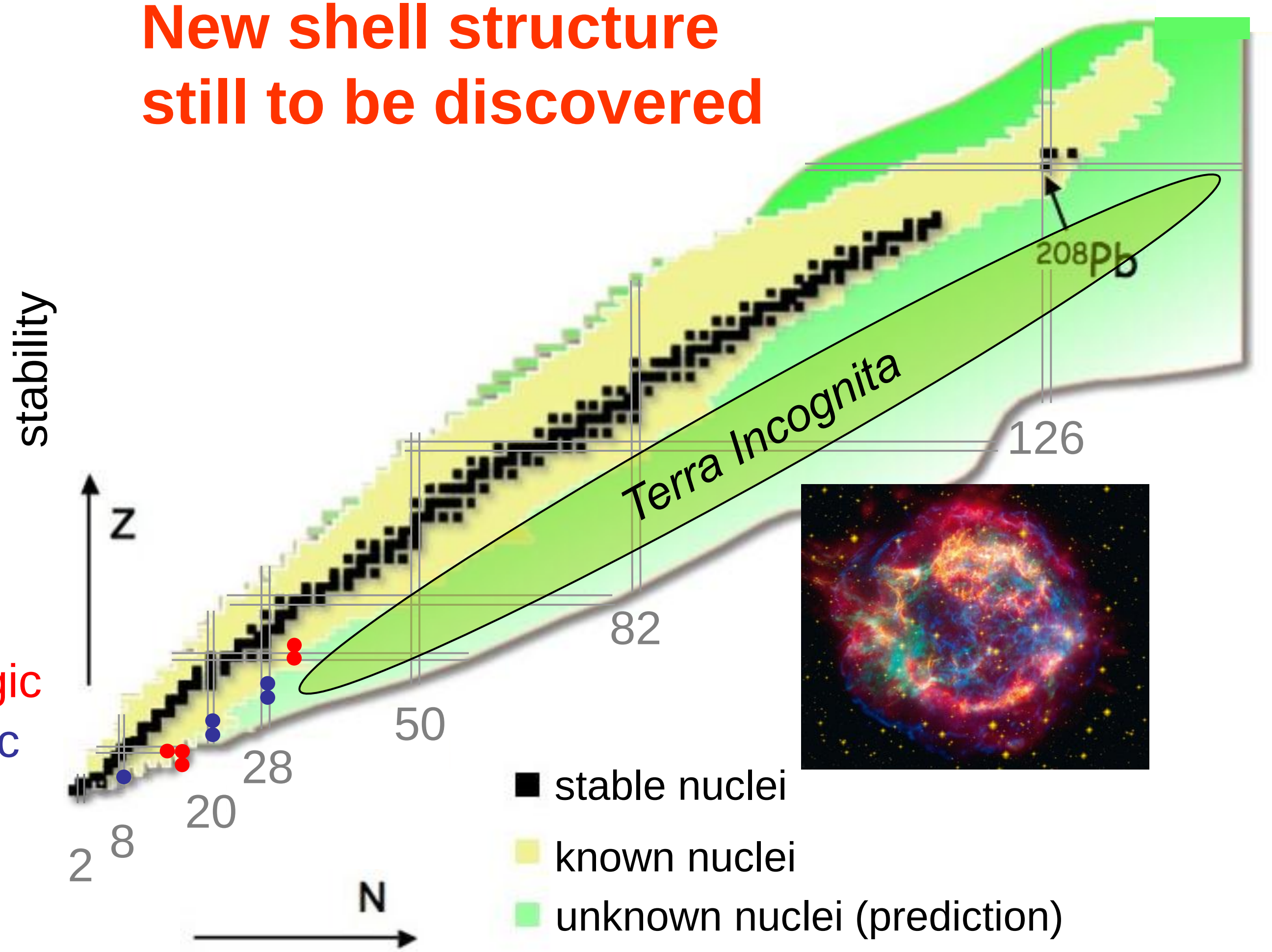
irfu cea saclay

Nuclear structure: a fingerprint of the in-medium NN interaction

from T. Otsuka *et al.*



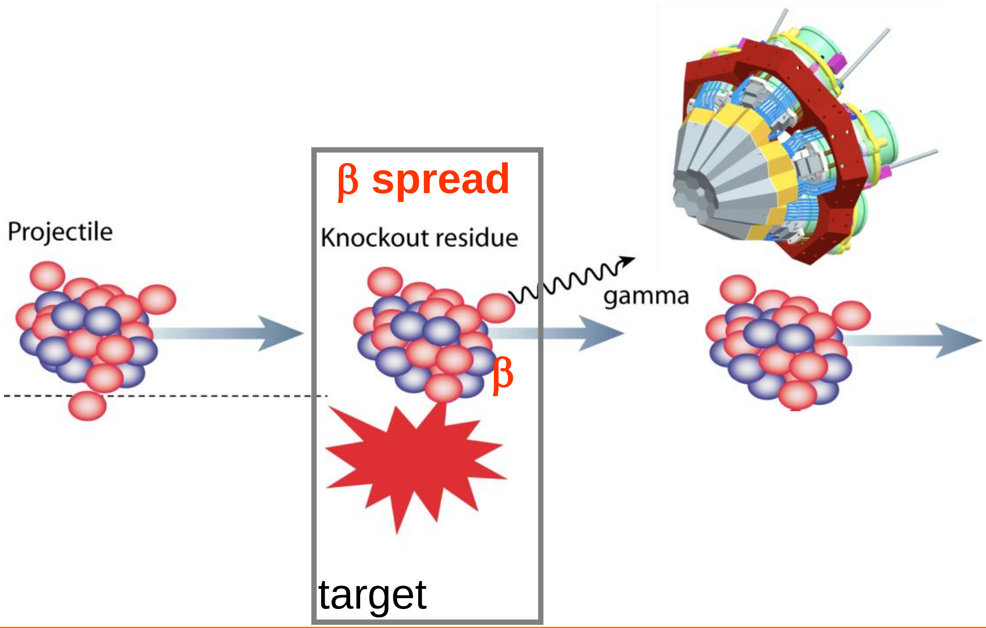
New shell structure still to be discovered



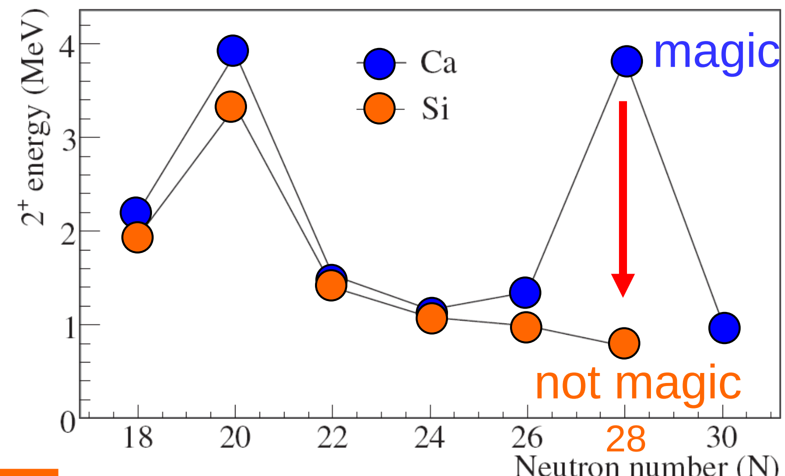
irfu
cea
saclay
MINOS
Magic Numbers Off Stability

In-beam γ spectroscopy and knockout

In-beam γ spectroscopy and **knockout** best to reveal new shell effects



Clear signature for (non-)magic nuclei



from B. Bastin, S. Grévy *et al.*

In-flight: velocity β needed for Doppler correction
β not measured in standard techniques

Target thickness: trade off between statistics and resolution
⇒ a **bottleneck** for experimental sensitivity

irfu cea saclay

MINOS Magic Numbers Off Stability

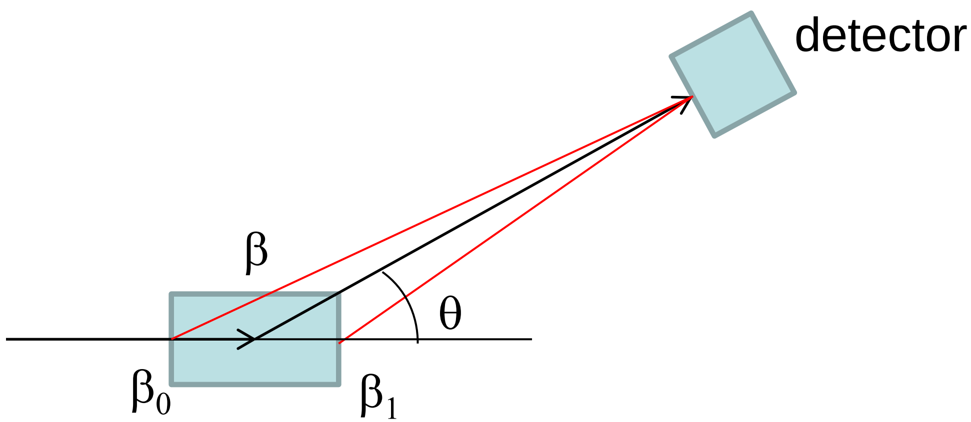
Doppler correction and influence of target

$$E_0 = \gamma(1-\beta\cos\theta_{lab})E_{lab}$$

$$\left(\frac{\delta E_0}{E_0}\right)^2 = \left(\frac{\beta\sin\theta_{lab}}{1-\beta\cos\theta_{lab}}\right)^2(\delta\theta_{lab})^2 + \left(\frac{\beta\gamma^2(\beta-\cos\theta_{lab})}{1-\beta\cos\theta_{lab}}\right)^2\left(\frac{\delta\beta}{\beta}\right)^2 + \left(\frac{\delta E_{lab}}{E_{lab}}\right)^2$$

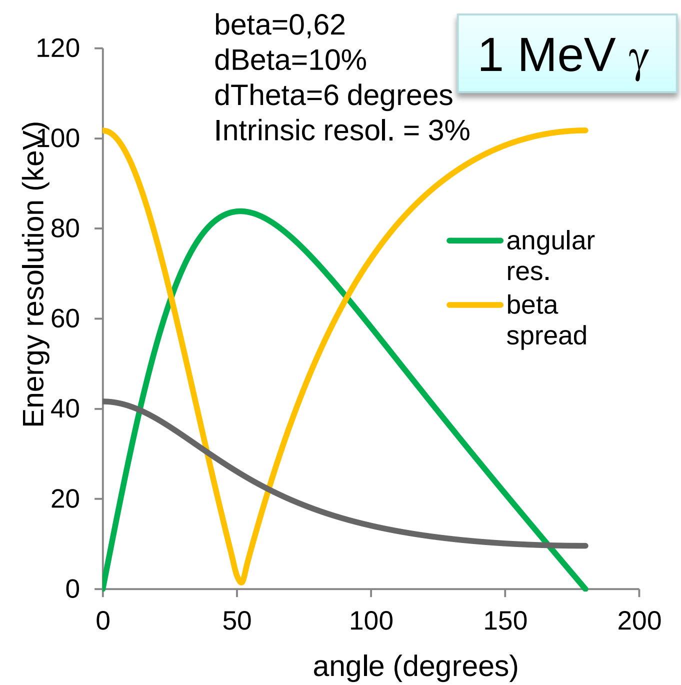
Angular resolution
(detector geometry / technology)

Intrinsic resolution
few % for scintillators



Thick target induces Δβ and Δθ

1 MeV γ



irfu
cea saclay
MINOS Magic Numbers Off Stability

See Heiko Sheit & Satoshi Takeuchi's presentations

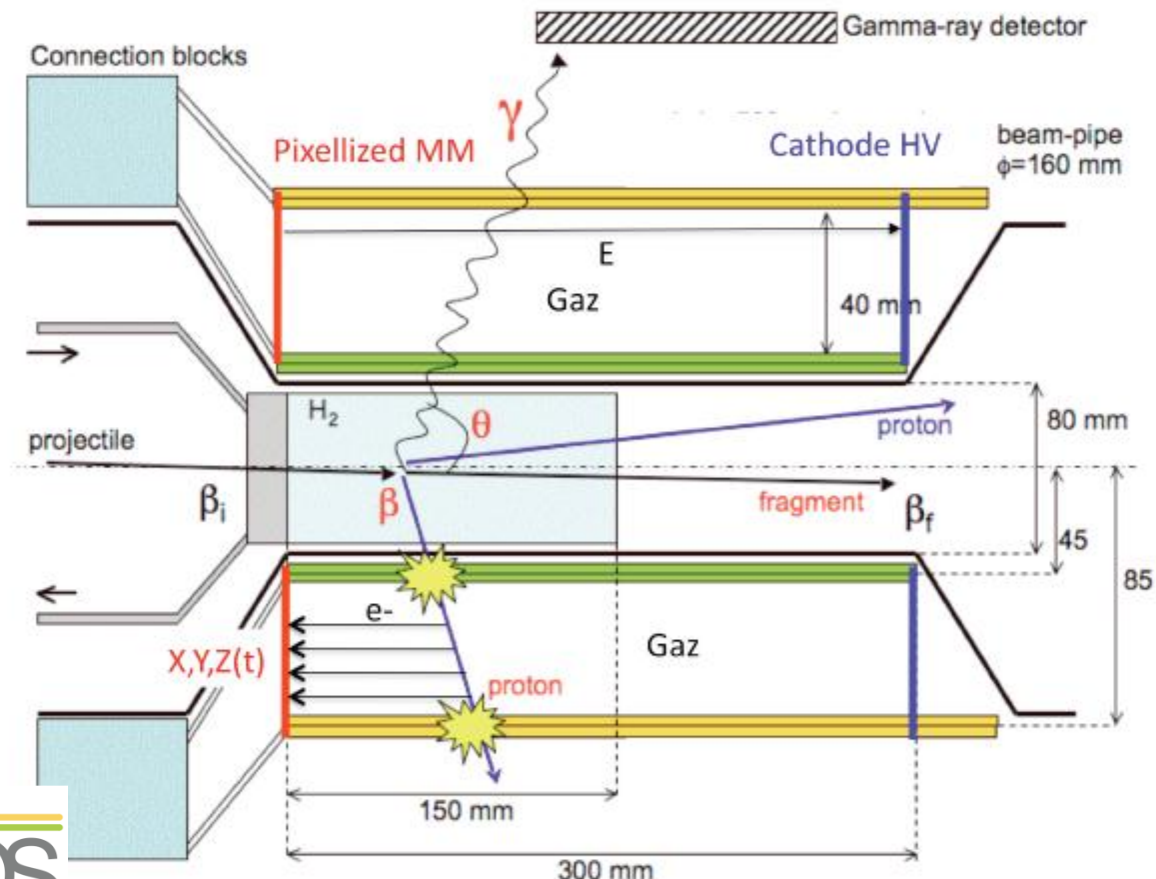
New apparatus for **high-resolution γ spectroscopy at < 1 Hz**

[or low cross-section processes, such as *(p,3p),* with higher intensities]

Charged-particle TPC coupled to a thick H_2 target:
determine the emitter velocity at the vertex inside the target

DALI2

PPACs

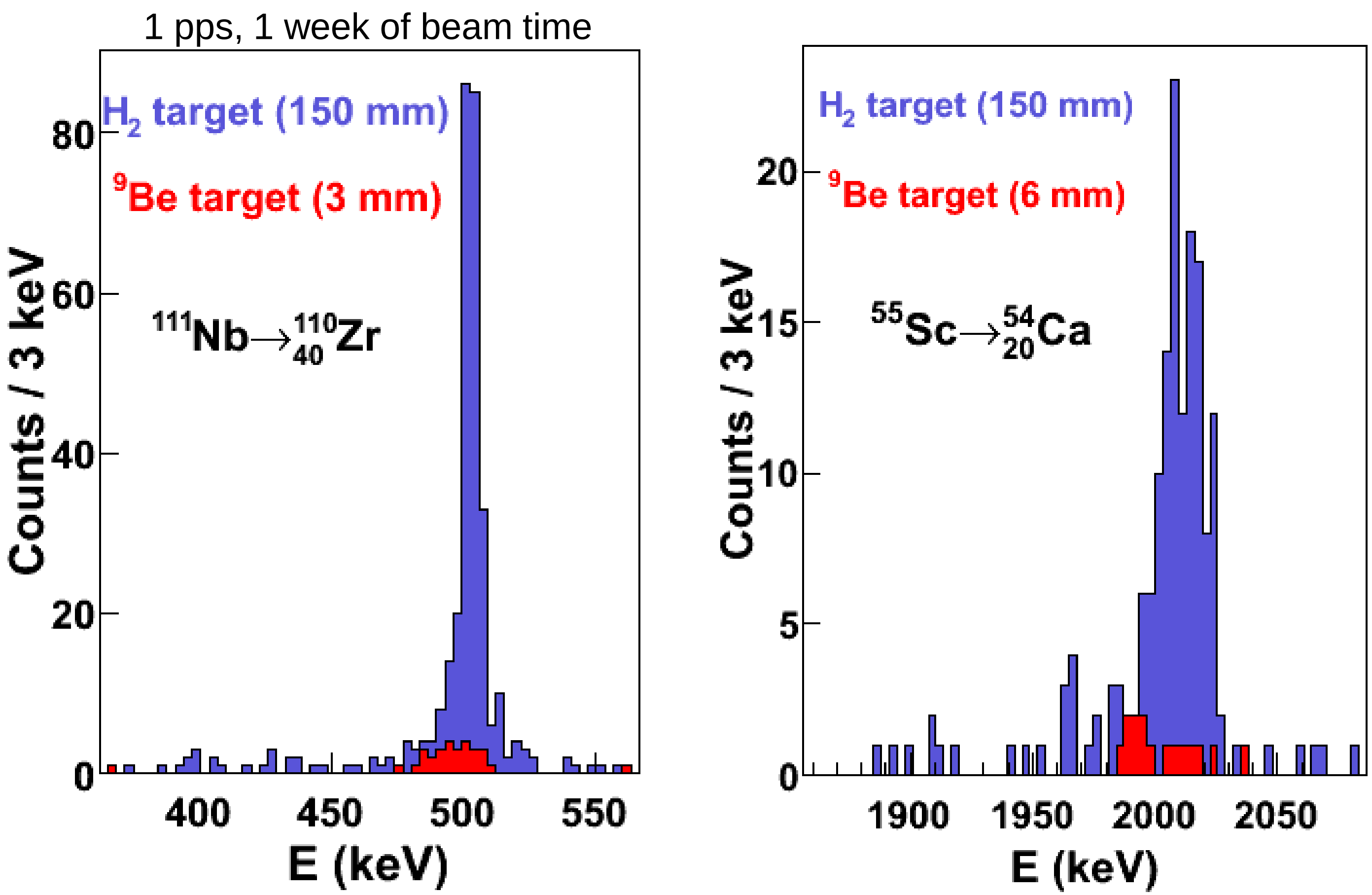


Zero Degree Spectrometer

irfu cea saclay

MINOS Magic Numbers Off Stability

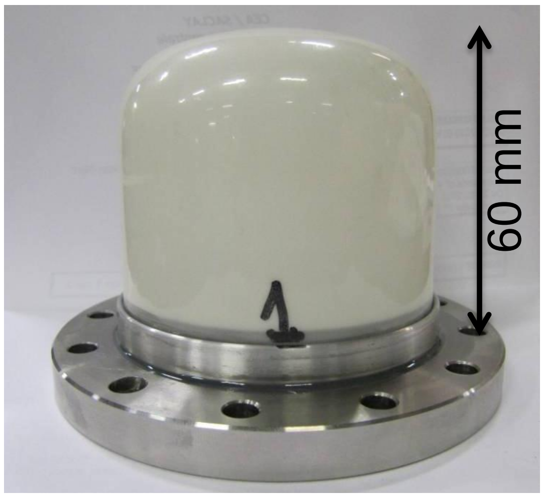
Gain in sensitivity

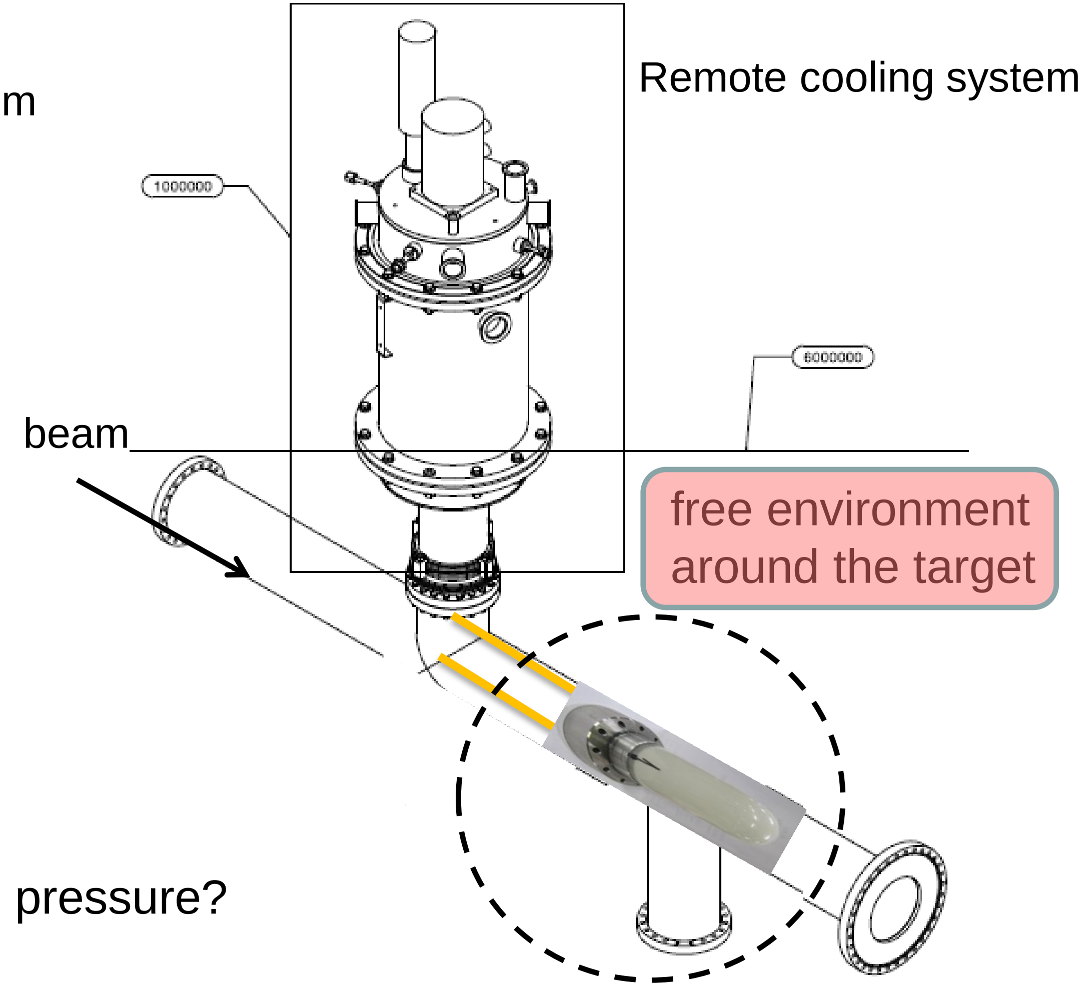


Larger statistics, better energy resolution & cleaner spectra

Cryogenic system

Existing new LH2 target
Current thicknesses: from 20 to 60 mm
Working conditions: 20 K





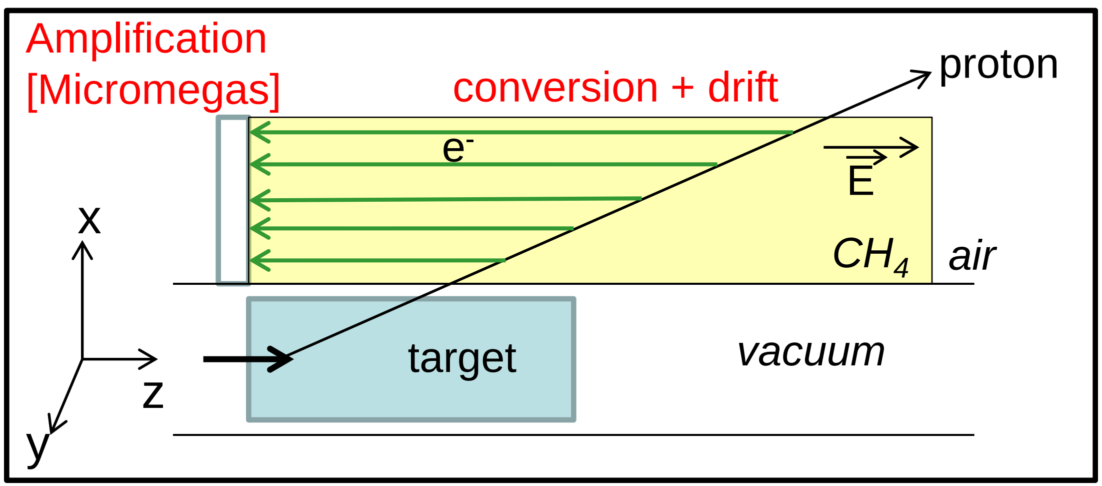
Q: Safety rules at RIKEN?
General rules for control valves, pressure?

Contact person for design, support and compatibility?

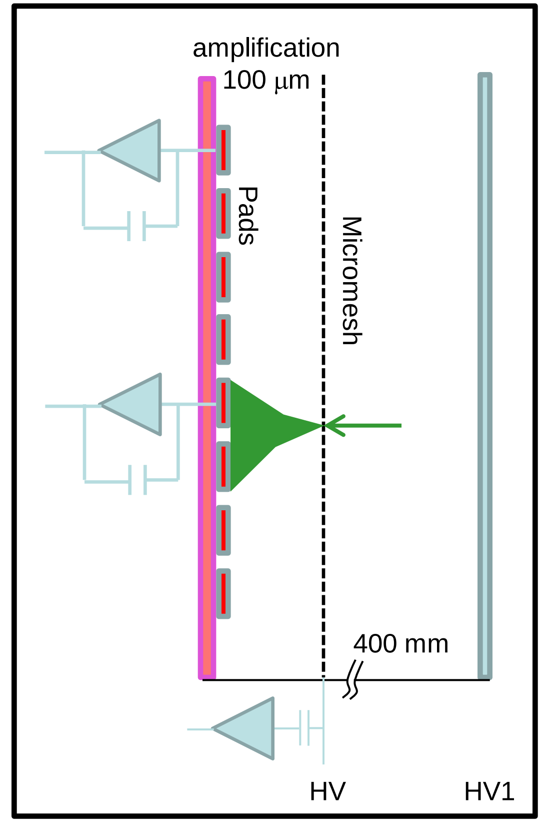
TPC detection

Detection of protons
Gaseous detector + amplification with MICROMEGAS

Experimental requests
- Detector rate up to several 10^4 Hz
- Final vertex position resolution < 3 mm FWHM



Micromegas principle



See Alain Delbart's presentation

Q: Amplification with Micromegas at SAMURAI. Sharing experience - tests?

Electronics

See E. Delagnes' presentation
See E. Pollacco's presentation

- **Experimental requests**

$10^{3\text{-}4}$ triggers/s requested (much less with use of ZDS)
~ 2-8k channels
TPC: time sampling / 100 MHz

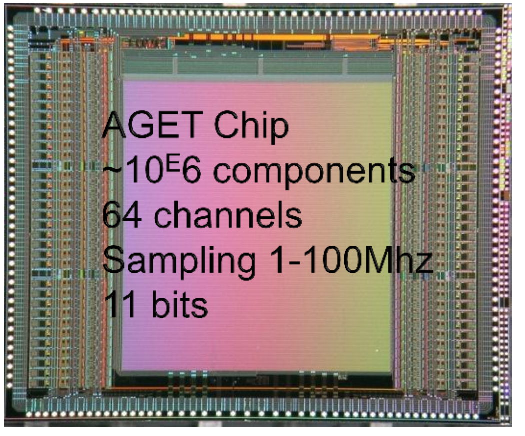
- Digital & ASIC-based electronics needed
- AGET or DREAM chips are two possibilities to be studied
- Dedicated back-end electronics may be developed

See D. Calvet' presentation

GET: General Electronics for TPCs
CEA-IRFU, CENBG, GANIL and NSCL collaboration

DREAM: electronics for proton tracker at JLAB
CEA-IRFU development

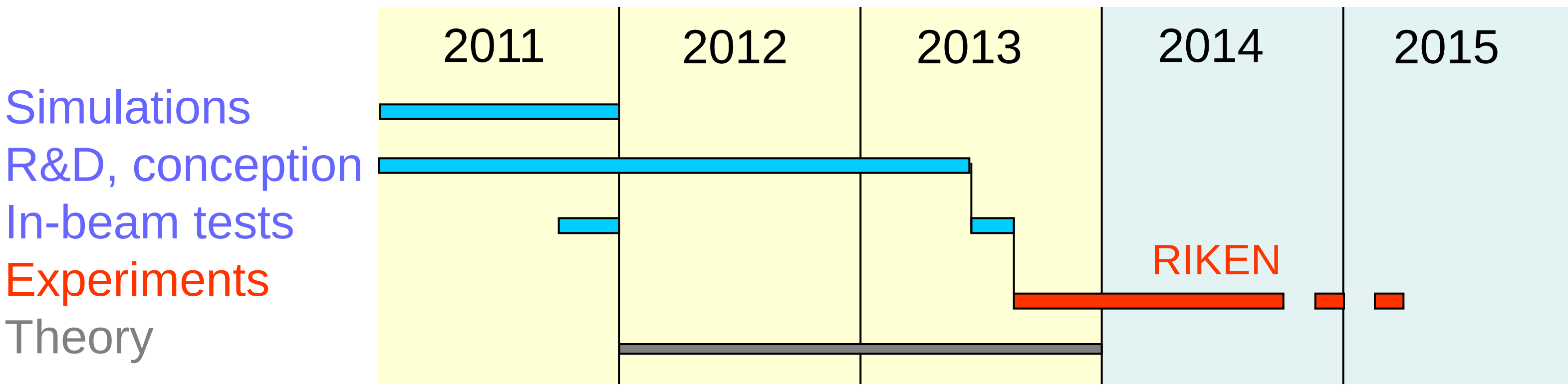
- **SIMULATIONS** are a priority to define achievable resolutions (dedicated postdoc to be hired)



irfu cea saclay
MINOS Magic Numbers Off Stability

Agenda

Project officially started on October 20th, 2010



Q: Agenda for LOIs, proposals, beam test?

Funding from ERC (5 years): **~1 M€**

Project covers

- **Investment :** Target, TPC-tracker, electronics, slow control, mechanics
- **Postdoc**

Summary

1- **Physics program**
Participate to the quest for shell evolution away from stability

2- **Unique**
original experimental approach / new TPC-H_2 target for *(p,2p)* vertex location coupled to existing or upcoming gamma arrays (DALI2, SHOGUN, AGATA)

3- Dedicated program and collaboration at **RIKEN** to assemble

4- Ready to run **from mid-2013**

First questions

1-Hydrogen target: Safety rules at RIKEN? Available space upstream the target position (F7)?

2-Detector: Amplification with Micromegas at SAMURAI. Sharing experience - tests?
Simulations: DALI2 configurations in Geant4 / beam profiles / gamma background ?
Light particles/halo issues ?

3-Acquisition: framework of coupling BigRIPS, DALI2 and MINOS?

4-Agenda: LOIs, proposals, in-beam test?

5- Contact person for the different parts of the setup / MINOS contact person at RIKEN?

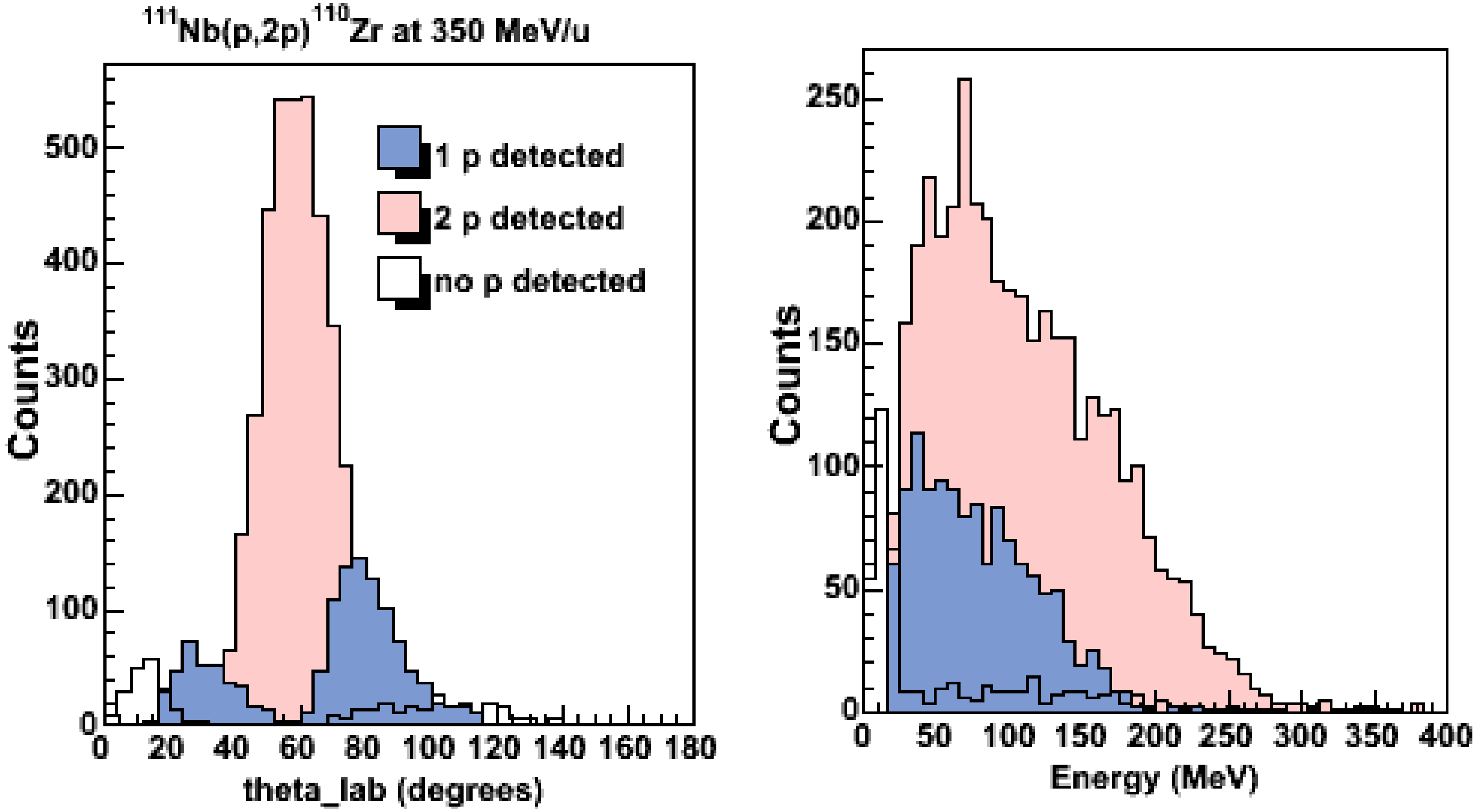
Numerical details on a specific example

Example: $^{63}V(p,2p)^{62}Ti$ @ 300 MeV/nucleon

H2 target of 150 mm (6. 10^{23} cm^{-2}, to be compared to 5 mm of ^{9}Be, 6. 10^{22} cm^{-2})

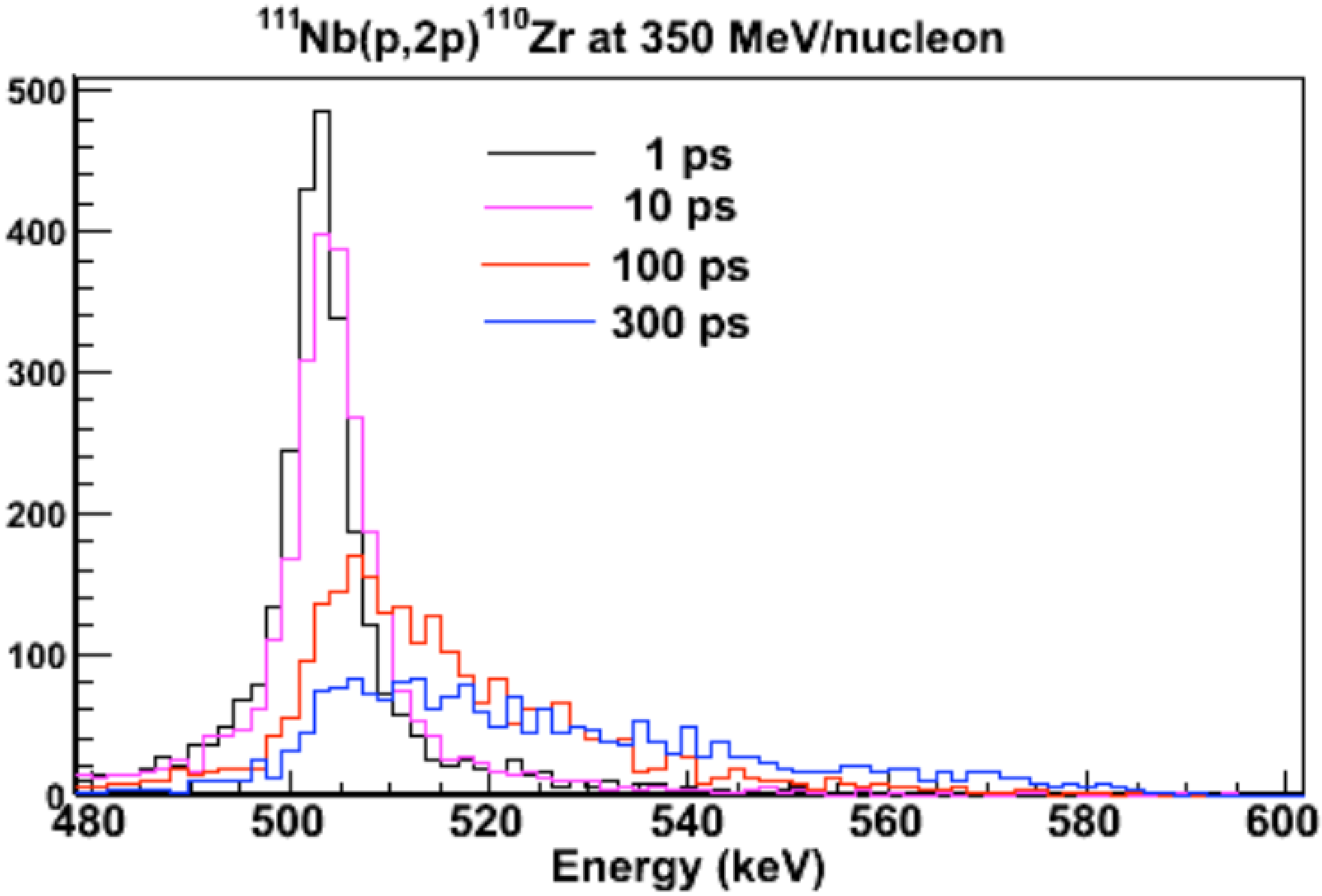
$\Delta E/E=24\%$, $\Delta\beta=10\%$
Vertex position resolution 3mm FWHM $\Rightarrow$ $\delta\beta<2‰$ FWHM

Kinematics and detection efficiency



> 90% events present at least one proton detected

Lifetime



^{111}Nb(p,2p)^{110}Zr at 350 MeV/nucleon
1 ps
10 ps
100 ps
300 ps
0
100
200
300
400
500
480
500
520
540
560
580
600
Energy (keV)

Comment on rates

External trigger
At RIKEN, Zero Degree spectrometer: high rejection (not the case at GSI)

A quick rate estimate for the most 'requiring' conditions : secondary beam of 10^4 pps
Beam: 10^4 pps
Reaction rate: 10^4 pps
TPC traces: 3. 10^4 Hz

FEE: 3 traces × 10^4 Hz × (100 pads / 10 AGET) × 512 time samples = 1.5 10^8 Hz
Each sample coded over 10 bits: 1.5 Gbits / second [2 Tb / day]

Without rejection (no spectrometer) such a rate is achievable with electronics such as GET (CoBo / μTCA)
With spectrometer(s) rejection, (much) lower trigger rate is expected

irfu cea saclay
MINOS Magic Numbers Off Stability

See D. Calvet's presentation