ACTAR
Direct and Resonant Reactions with an Active Target

Riccardo Raabe

GET Meeting
Caen, 10-12 March 2009

Physics Program

- Measurements with the SPIRAL2 radioactive beams
- Involve other laboratories/facilities

$\Rightarrow$ ISOL and fragmentation beams
$\Rightarrow$ Portable device

Physics Program

- Measurements with the SPIRAL2 radioactive beams
- Involve other laboratories/facilities

⇒ ISOL and fragmentation beams
⇒ Portable device

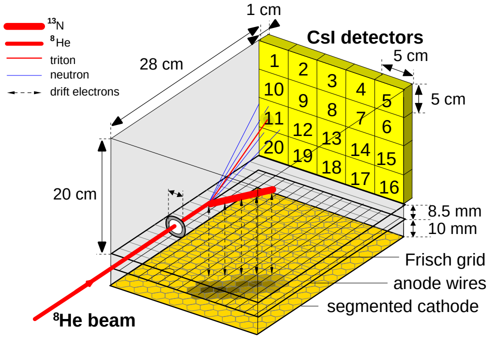
Physics cases

- Light ion beams:
  - one- and multi-nucleon transfer
  - resonant reactions
- Fission fragments:
  - one- and two-nucleon transfer
  - inelastic scattering to GRs

ACTAR design

Maya limitations

- Efficiency
- Multiple tracks
- Dynamic range



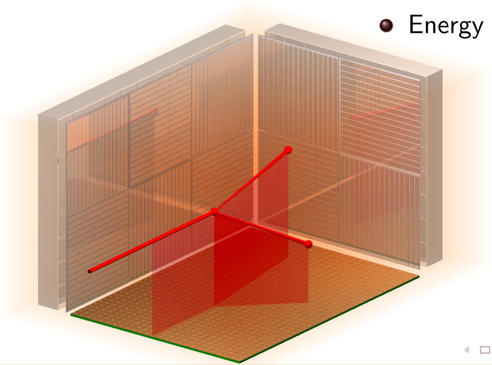
ACTAR design

Maya limitations

- Efficiency
- Multiple tracks
- Dynamic range

ACTAR:
Maya + lateral detection?

- Particle identification:
  particle range
  Si+CsI?
  dE/dx in gas?
- Energy measurement in gas?

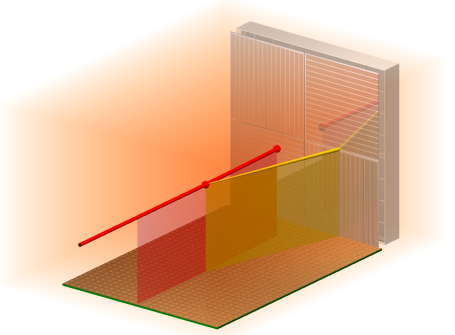


Light nuclei: resonant reactions

- Motivation:
  astrophysics, cluster states, IAS...
- Maya:
  range to determine scattering point
  particle identification in Si+CsI

^{26}Ne+p resonant elastic
$E_{\text{beam}} \approx$4 MeV/A, pressure $\approx$100 mbar C_4H_{10}

1 mm precision on range
$\Rightarrow$ 4-5 mm error on scattering point
Induced error on E_{cm}: $\approx$100 keV



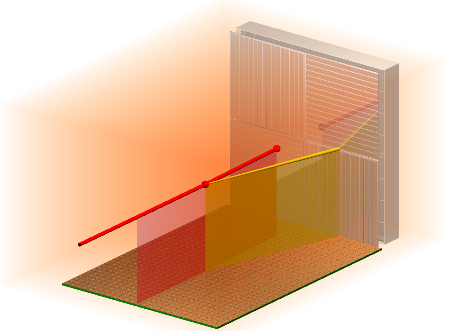
Light nuclei: resonant reactions

- Motivation:
  astrophysics, cluster states, IAS...
- Maya:
  range to determine scattering point
  particle identification in Si+CsI

^{26}Ne+p resonant elastic
E_{beam} ≈4 MeV/A, pressure ≈100 mbar C_4H_{10}
1 mm precision on range
⇒ 4-5 mm error on scattering point
Induced error on E_{cm}: ≈100 keV

ACTAR

- Direct determination
  of the scattering point?
- Light particle detection in gas?
- Particle identification in gas??



Light nuclei: resonant reactions

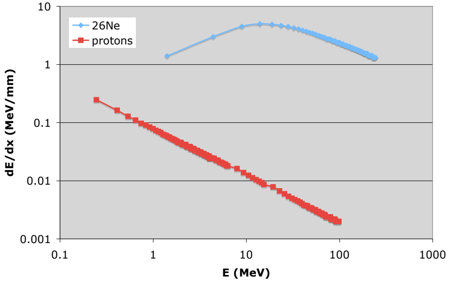
- Motivation:
  astrophysics, cluster states, IAS...
- Maya:
  range to determine scattering point
  particle identification in Si+CsI

ACTAR

- Direct determination
  of the scattering point?
- Light particle detection in gas?
- Particle identification in gas??

Improvements:
factor 4 on accuracy E_{cm}
on 10^3 more statistics

Energy loss (in 1 bar C_4H_{10})



- Three orders of magnitude
  1 keV/mm to 1 MeV/mm
  in 100 mbar
- Noise: at 1 pC (6.25 MeV) is 3000 e^-
  or 1/2000
  gain 10^2 $\Rightarrow$ proton signals $\approx$5000 e^-

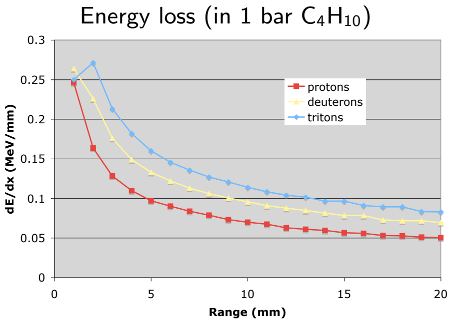
Light nuclei: resonant reactions

- Motivation:
  astrophysics, cluster states, IAS...
- Maya:
  range to determine scattering point
  particle identification in Si+CsI

ACTAR

- Direct determination
  of the scattering point?
- Light particle detection in gas?
- Particle identification in gas??

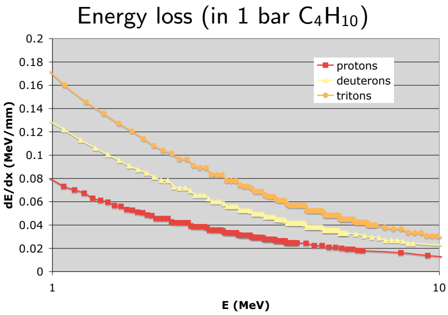
Improvements:
factor 4 on accuracy E_{cm}
on 10^3 more statistics



- From range:
  deuteron vs proton 30% triton vs deuteron 20%

Light nuclei: resonant reactions

- Motivation:
  astrophysics, cluster states, IAS...
- Maya:
  range to determine scattering point
  particle identification in Si+CsI



- From total energy: better

ACTAR

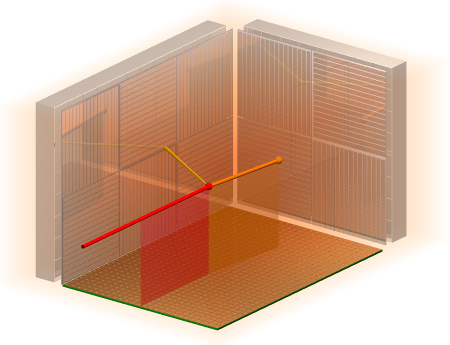
- Direct determination
  of the scattering point?
- Light particle detection in gas?
- Particle identification in gas??

Improvements:
factor 4 on accuracy E_{cm}
on 10^3 more statistics

Light nuclei: one- and multi-nucleon transfer

- Motivation:
  single-particle structure,
  exotic states,
  resonances beyond dripline...
- Maya:
  kinematics identification
  one particle forward

^{14}Be(p,t) at 5 MeV/A
C_4H_{10}, pressure 100 mbar



Light nuclei: one- and multi-nucleon transfer

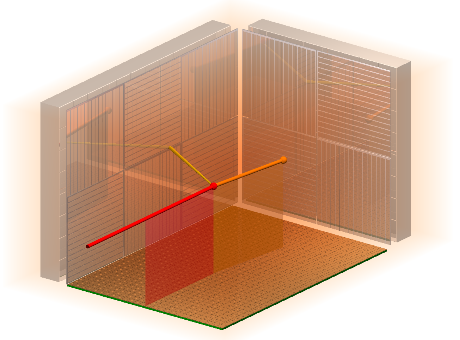
- Motivation:
  single-particle structure,
  exotic states,
  resonances beyond dripline...
- Maya:
  kinematics identification
  one particle forward

ACTAR

- Lateral detection or
  energy in gas
  $\Rightarrow$ higher pressure
- Particle identification?

Improvements:
factor 3-5 on statistics
(+ beam intensity...)

^{14}Be(p,t) at 5 MeV/A
C_4H_{10}, pressure 100 mbar $\longrightarrow$ 500 mbar



Light nuclei: one- and multi-nucleon transfer

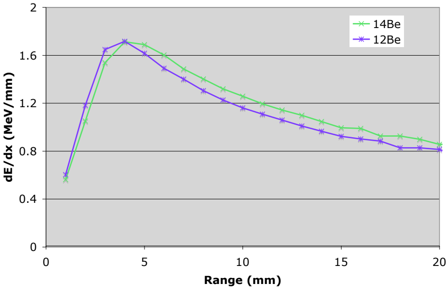
- Motivation:
  single-particle structure,
  exotic states,
  resonances beyond dripline...
- Maya:
  kinematics identification
  one particle forward

ACTAR

- Lateral detection or
  energy in gas
  $\Rightarrow$ higher pressure
- Particle identification?

Improvements:
factor 3-5 on statistics
(+ beam intensity...)

Energy loss (in 1 bar C_4H_{10})

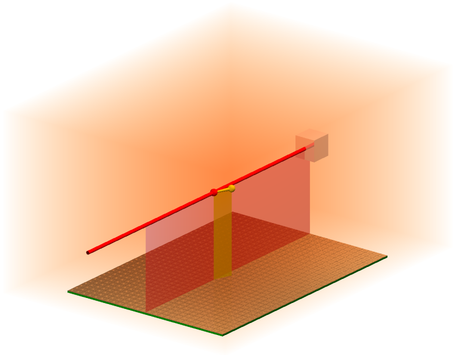


- ^{12}Be vs ^{12}Be: $< 10\%$

Medium mass: inelastic scattering to GRs

- Motivation:
  Giant Resonances
  Nucleus incompressibility
- Maya:
  mask for the beam
  light particle only
  (very low energy)

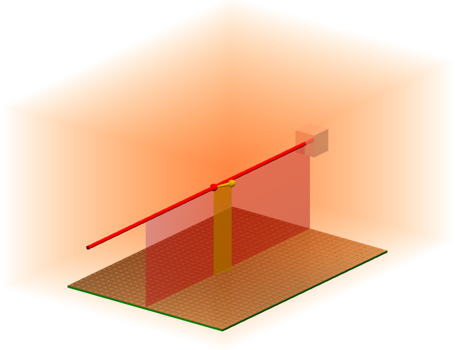
^{68}Ni(α,α') at 50 MeV/A
He + X, pressure $\approx$2 bar
$E_\alpha < 3$ MeV, path < 50 mm



Medium mass: inelastic scattering to GRs

- Motivation:
  Giant Resonances
  Nucleus incompressibility
- Maya:
  mask for the beam
  light particle only
  (very low energy)

^{68}Ni(α,α') at 50 MeV/A
He + X, pressure $\approx$2 bar
$E_\alpha < 3$ MeV, path < 50 mm



ACTAR

- Increase pressure or
  improve range measurement
- Detect beam track
  and scattered particle

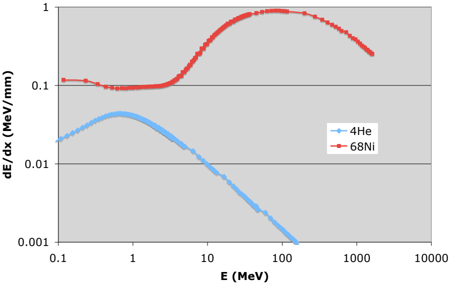
Medium mass: inelastic scattering to GRs

- Motivation:
  Giant Resonances
  Nucleus incompressibility
- Maya:
  mask for the beam
  light particle only
  (very low energy)

ACTAR

- Increase pressure or
  improve range measurement
- Detect beam track
  and scattered particle

Energy loss (in 1 bar He)



- Two orders of magnitude

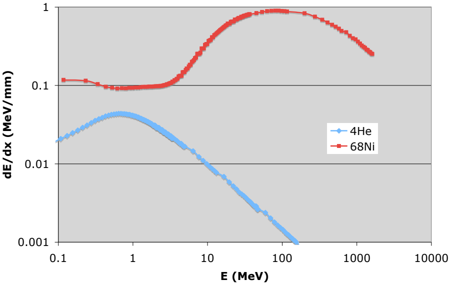
Medium mass: inelastic scattering to GRs

- Motivation:
  Giant Resonances
  Nucleus incompressibility
- Maya:
  mask for the beam
  light particle only
  (very low energy)

ACTAR

- Increase pressure or
  improve range measurement
- Detect beam track
  and scattered particle

Energy loss (in 1 bar He)



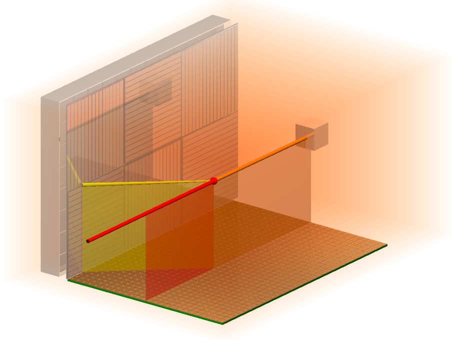
- Two orders of magnitude

Improvements:
Resolution: 1 mm on range
$\Rightarrow$ $\approx$100 keV on E^*

Fission fragments: one- and two-nucleon transfer

- Motivation:
  Single particle structure, pairing
- Protons at backward angles
  $E_\mathrm{p} < 5$ MeV

^{68}Ni(d,p) at 5 MeV/A
D_2, pressure $\approx$1 bar
(1 MeV protons $\rightarrow$ range 20 cm)



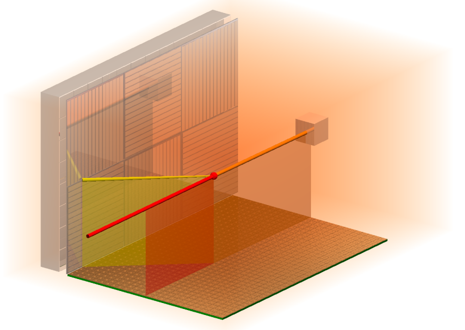
Fission fragments: one- and two-nucleon transfer

- Motivation:
  Single particle structure,
  pairing
- Protons at backward angles
  $E_p < 5$ MeV

ACTAR

- Lateral detection
- Interaction point:
  detection beam
  and recoil particles
- Particle identification?

^{68}Ni(d,p) at 5 MeV/A
D_2, pressure ≈1 bar
(1 MeV protons → range 20 cm)



Fission fragments: one- and two-nucleon transfer

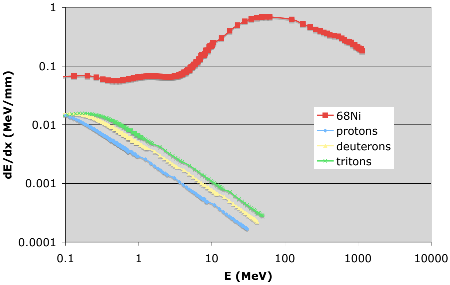
- Motivation:
  Single particle structure, pairing
- Protons at backward angles
  $E_p < 5$ MeV

ACTAR

- Lateral detection
- Interaction point: detection beam and recoil particles
- Particle identification?

Target thickness 5×10^{20} at/cm^2
Angular resolution ≈2 deg

Energy loss (in 1 bar D_2)



- Three orders of magnitude

Fission fragments: one- and two-nucleon transfer

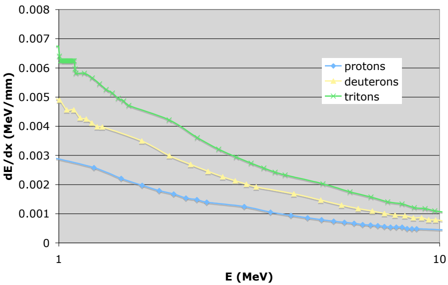
- Motivation:
  Single particle structure, pairing
- Protons at backward angles
  $E_p < 5$ MeV

ACTAR

- Lateral detection
- Interaction point: detection beam and recoil particles
- Particle identification?

Target thickness 5×10^{20} at/cm^2
Angular resolution ≈2 deg

Energy loss (in 1 bar D_2)



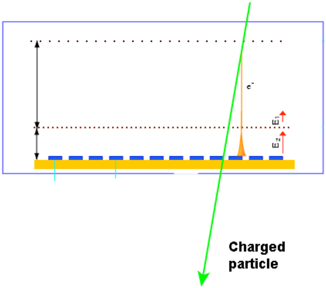
- From total energy: should be possible

Technology

Micromegas, GEMs, wires

electron detection vs induction

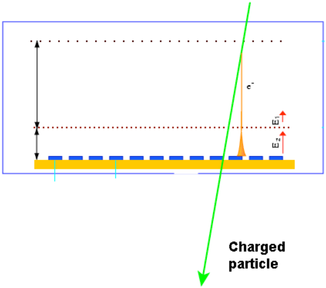
- Theoretical resolution with induction: 1/10 pad size
  Real life: $\approx$ 1/5 pad size
- Micromegas/GEMs: no induction
  $\Rightarrow$ direct image of electron cloud
- Diffusion? Very small?
  $\Rightarrow$ few pads touched?
- (Fit of the Bragg peak still possible for heavy particles)



Technology

Micromegas, GEMs, wires
electron detection vs induction

- Theoretical resolution with induction: 1/10 pad size
  Real life: $\approx 1/5$ pad size
- Micromegas/GEMs: no induction
  $\Rightarrow$ direct image of electron cloud
- Diffusion? Very small?
  $\Rightarrow$ few pads touched?
- (Fit of the Bragg peak still possible for heavy particles)

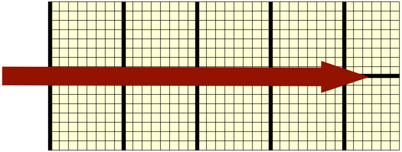


Configuration

- Limit in the ADC 680 events/s
  if all 72 channels are read out
- “Intelligent” (level 2) trigger:
  must rely on something away from the beam
  $\Rightarrow$ limitation of the efficiency
- For beams at $\approx 10^3$ pps, can we detect all beam particles?
- ASAD element: 288 pads $\Rightarrow 72 \times 4$, 36×8...
  should not be placed along the beam path

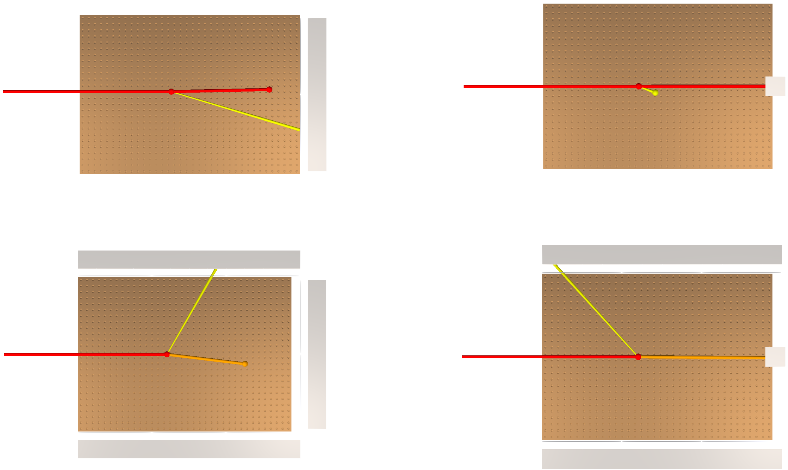
Configuration

- Limit in the ADC 680 events/s
  if all 72 channels are read out
- "Intelligent" (level 2) trigger:
  must rely on something away from the beam
  $\Rightarrow$ limitation of the efficiency
- For beams at $\approx 10^3$ pps, can we detect all beam particles?
- ASAD element: 288 pads $\Rightarrow 72 \times 4$, 36×8...
  should not be placed along the beam path



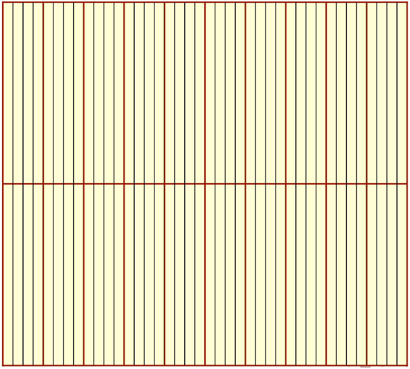
$\approx$10 pads per ADC
$\Rightarrow$ up to 5k events/s?

Configuration



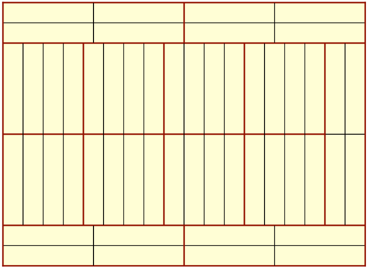
Configuration

Module	pads W	pads L	Channels	CoBos	Size
72×4	144	160	23040	20	288×320
36×8	104	144	14976	13	208×288
36×8	88	144	12672	11	$220 \times 360^*$
36×8	72	128	9216	8	$180 \times 320^*$



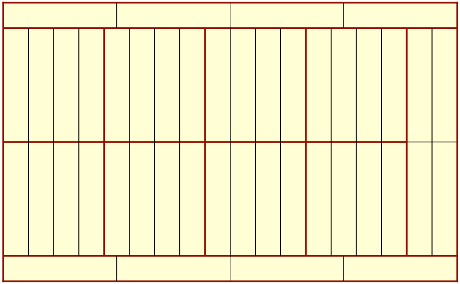
Configuration

Module	pads W	pads L	Channels	CoBos	Size
72×4	144	160	23040	20	288×320
36×8	104	144	14976	13	208×288
36×8	88	144	12672	11	$220 \times 360^*$
36×8	72	128	9216	8	$180 \times 320^*$



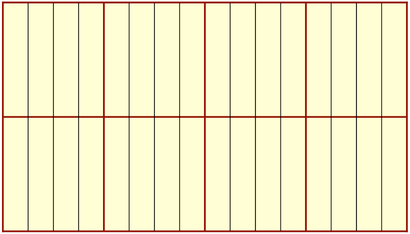
Configuration

Module	pads W	pads L	Channels	CoBos	Size
72×4	144	160	23040	20	288×320
36×8	104	144	14976	13	208×288
36×8	88	144	12672	11	$220 \times 360^*$
36×8	72	128	9216	8	$180 \times 320^*$



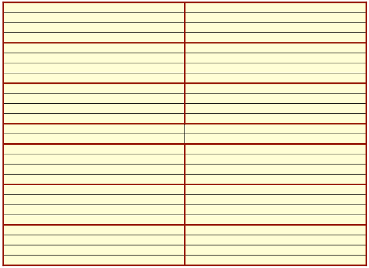
Configuration

Module	pads W	pads L	Channels	CoBos	Size
72×4	144	160	23040	20	288×320
36×8	104	144	14976	13	208×288
36×8	88	144	12672	11	$220 \times 360^*$
36×8	72	128	9216	8	$180 \times 320^*$



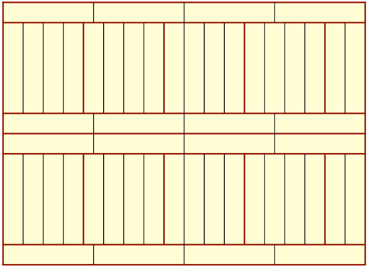
Configuration

Module	pads W	pads L	Channels	CoBos	Size
72×4	104	144	14976	13	208×288
36×8	104	144	14976	13	208×288
36×8	88	144	12672	11	$220 \times 360^{*}$



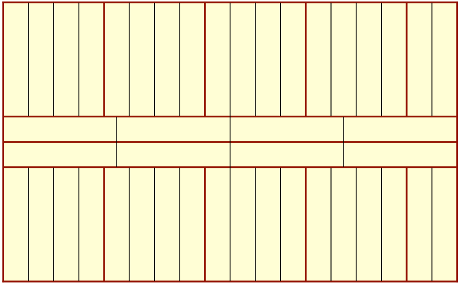
Configuration

Module	pads W	pads L	Channels	CoBos	Size
72×4	104	144	14976	13	208×288
36×8	104	144	14976	13	208×288
36×8	88	144	12672	11	$220 \times 360^*$

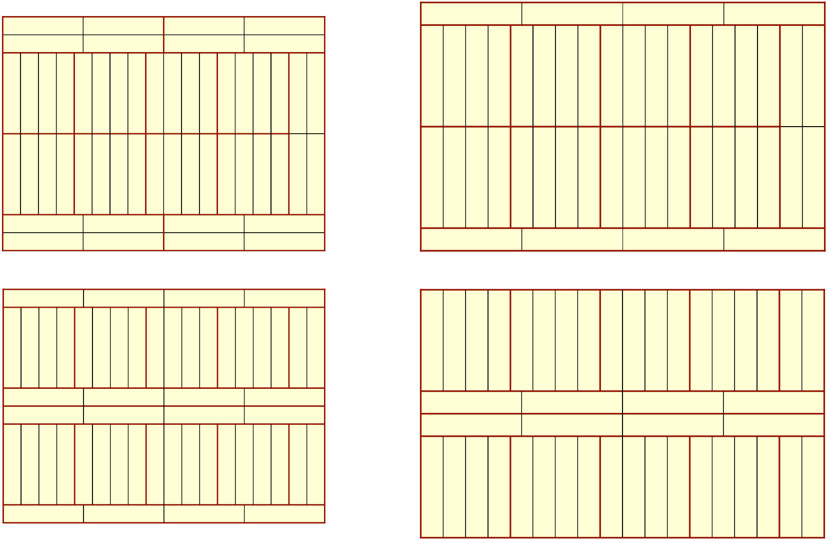


Configuration

Module	pads W	pads L	Channels	CoBos	Size
72 × 4	104	144	14976	13	208 × 288
36 × 8	104	144	14976	13	208 × 288
36 × 8	88	144	12672	11	220 × 360*



Configuration



Summary of modes

	Drift time	Dynamic range	Trigger	Event rate	Hit pattern	CoBo flow
Resonant reactions, transfer light nuclei						
All beam particles	5 μs $\rightarrow$ 100 MHz	$\sim 10^3$	Ext or Int Level 1	1 kHz	10 pads/AGET on all AsAd	1 Gbit/s (511 cells)
Selected events			Level 2	$<$ 100 Hz	1 full CoBo +4 CoBos at $\sim$20%	$<$ 0.5 Gbit/s $\sim$0.1 Gbit/s
Inelastic scattering to GR						
Selected events	25 μs $\rightarrow$ 20 MHz	$< 10^2$	Int Level 1	$>$ 1 kHz	(2 Cobos at 50%) 1 CoBo at $\sim$15%	$<$ 1 Gbit/s
Transfer fission fragments						
Selected events	25 μs $\rightarrow$ 20 MHz	$\sim 10^3$	Ext or Int Level 1	$<$ 1 kHz	2 CoBos at 50% 2 CoBos at $\sim$25%	$\sim$2 Gbit/s $\sim$1 Gbit/s