S254@GSI: Particle filtering in LAND

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- Filtering of charged hits using VETO detector
- Clustering hits – a way to obtain particle numbers on event-by-event basis
  - $^{107}\text{Sn}$ vs. $^{124}\text{Sn}$ – comparison
- Conclusions
S254@GSI: experimental set-up
S254@GSI: LAND detector
Data reduction

• Event selection ➞ Interaction trigger

• Hit selection ➞ Well Measured Hits (about 7%):
  - TDC1>0 & TDC2>0 & ADC1>0 & ADC2>0
  - Calibrated hit position in (-110 cm ,110 cm) range.
We observe in LAND a large fraction (c.a. 30\%) of hits generated by charged particles.

In the first LAND plane this fraction achieves about 50\%.

The number of correlated hits is sensible for projectile isospin.

The charged particles can be partly identified in charge using $\Delta E$ vs. TOF map for VETO.

The charged particles do not disturb significantly the multiplicity vs total visible energy correlation.
Charge identification in VETO

![Graph showing the relationship between velocity (cm/ns) and energy loss (ΔE MeV) for different charges (Z=1, Z=2). The graph highlights regions for different Z values and includes a curve indicating the energy loss for various velocities.]
Study of correlations between VETO and the first LAND plane

Hit correlation is defined by a coincidence in space and time:

\[ x_{\text{min}} < x_1 - x_0 < x_{\text{max}} \]
\[ y_{\text{min}} < y_1 - y_0 < y_{\text{max}} \]
\[ t_{\text{min}} < t_1 - t_0 < t_{\text{max}} \]
Correlated hits in VETO

Cut 1
- $19 < \Delta x < 19$ (cm)
- $19 < \Delta y < 19$ (cm)
- $-1 < \Delta t < 3$ (ns)

$^{107}\text{Sn}$

Uncorrelated hits:
~37.4% of total VETO hits.

62.60%
Correlated hits in VETO

$^{107}$Sn

Uncorrelated hits:
~31.5 % of total VETO hits.

Cut 1
- $-19 < \Delta x < 19$ (cm)
- $-19 < \Delta y < 19$ (cm)
- $-1 < \Delta t < 3$ (ns)

Cut 2
- $-30 < \Delta x < 30$ (cm)
- $-30 < \Delta y < 30$ (cm)
- $-2 < \Delta t < 4$ (ns)
Correlated hits in VETO

$^{107}\text{Sn}$

Uncorrelated hits:
~23.3 % of total VETO hits.

Cut 1
- $-19 < \Delta x < 19$ (cm)
- $-19 < \Delta y < 19$ (cm)
- $-1 < \Delta t < 3$ (ns)

Cut 2
- $-30 < \Delta x < 30$ (cm)
- $-30 < \Delta y < 30$ (cm)
- $-2 < \Delta t < 4$ (ns)

Cut 3
- $-7 < \Delta t < 4$ (ns)
Correlated hits: ~ 77%
Isolated hits: ~18%
Unidentified hits: ~ 5 %

Cut 1
Cut 2
Cut 3

Dead areas between paddles
Other charged particles
Sixth paddle defect
Edge effect

Statistics for VETO hits
Recursive procedure
for correlated hits identification

Hit correlation in two neighboring planes, $i$ and $i-1$, is defined by a coincidence in space and time:

$$x_{\text{min}} < x_i - x_{i-1} < x_{\text{max}}$$

$$y_{\text{min}} < y_i - y_{i-1} < y_{\text{max}}$$

$$t_{\text{min}} < t_i - t_{i-1} < t_{\text{max}}$$

$i = 1, 10$

For each correlated hit one searches correlations in next plane.
Charged hits in LAND

Cut 1
-19 < \(\Delta x\) < 19 (cm)
-19 < \(\Delta y\) < 19 (cm)
-1 < \(\Delta t\) < 3 (ns)

Cut 2*
-30 < \(\Delta x\) < 30 (cm)
-30 < \(\Delta y\) < 30 (cm)
-2 < \(\Delta t\) < 4 (ns)

Cut 3
-7 < \(\Delta t\) < 4 (ns)

Minimum:
All hits correlated with VETO using the cut 1. Only one correlated hit per plane is allowed.

*) Only for correlation between VETO and first LAND plane. For others we use cut 1.

Maximum:
All hits correlated with VETO using cuts 1, 2 and 3 applied sequently.
For each hit in VETO a maximal range is calculated. No correlation is accepted out of this limit. The maximal range for charged particles is set to 5 land planes.
Clustering hits

Correlated hits are clustered to obtain an event-by-event estimation of particle number. All properties of a particle are determined by the first hit in a cluster.

Procedure “1”
minimize number of charged particles and maximize number of neutrons

Procedure “-1”
maximize number of charged particles and minimize number of neutrons

Procedure “0”
Something in between
Clustering hits - procedures

-1

VETO (1)* → 30%
VETO (2)* → 2%
VETO (3)* → 8%
LAND (1)* → 24%
LAND (3)* → 16%
20%

0

VETO (1) → 28%
VETO (2) → 2%
LAND (1)* → 29%
VETO (3) → 3%
LAND (3)* → 10%
28%

1

VETO (1) → 28%
LAND (1)* → 30%
42%

SINGLE HITS

*) Multiple hits per plane allowed
Comparison $^{107}\text{Sn}$ vs. $^{124}\text{Sn}$

To check correctness of our procedures we compare results from $^{107}\text{Sn}$ and $^{124}\text{Sn}$

$^{107}\text{Sn}$: 50 protons and 57 neutrons

$^{124}\text{Sn}$: 50 protons and 74 neutrons

We expect similar results in both systems for:
- number of proton hits per event
- number of protons per event

For neutrons we expect results scaled by neutron number ratio in both systems, at least in the vaporisation limit.
Results

Hit plane distribution

Counts/Event vs Plane

- Red dots: \(^{124}\text{Sn}\)
- Blue dots: \(^{107}\text{Sn}\)

All hits

Charged
Results

Comparison: $^{124}$Sn vs. $^{107}$Sn

**Uncharged**

**Charged**

Surprise!

Piotr Pawłowski (2005)
Results

Hit charge distribution

Counts/Event

Ratio = 1.59

\[ \frac{^{124}\text{Sn}}{^{107}\text{Sn}} = 1.59 \]
Results

Particle charge distribution

Counts/Event

Ratio = 1.48

$^{124}$Sn

$^{107}$Sn

Particle charge
Comparison with S114 experiment

We have larger energy per hit!

Comparison with S114 experiment

We have less hits per neutron!

Comparison with S114 experiment

We have less energy per neutron!

Results

Particle velocity distribution

Counts/Event

$^{124}_{\text{Sn}}$ $^{107}_{\text{Sn}}$

Neutrons

Surprise!

Z=2

Z=1
Results

Comparison: $^{124}\text{Sn}$ vs. $^{107}\text{Sn}$

- Neutrons
- Protons

$\sigma (^{124}\text{Sn}) / \sigma (^{107}\text{Sn})$ vs. Velocity (cm/ns)

- $74/57$
- $50/50$
Results

Comparison: $^{124}\text{Sn}$ vs. $^{107}\text{Sn}$

![Graph showing the comparison between $^{124}\text{Sn}$ and $^{107}\text{Sn}$]
Land data vs Zmax

- Neutron Hit Number vs Zmax
- Neutron Number vs Zmax
- Neutron Evis vs Zmax
- Comparison $^{124}\text{Sn}$ vs $^{107}\text{Sn}$
Land data vs Zbound

**Neutron Hit Number vs Zbound**
- Data for $^{124}\text{Sn}$ and $^{107}\text{Sn}$
- Zbound range from 0 to 50

**Neutron Number vs Zbound**
- Data for $^{124}\text{Sn}$ and $^{107}\text{Sn}$
- Zbound range from 0 to 50

**Neutron Evis vs Zbound**
- Data for $^{124}\text{Sn}$ and $^{107}\text{Sn}$
- Neutron Evis range from 0 to 250

**Comparison $^{124}\text{Sn}$ vs $^{107}\text{Sn}$**
- Hits and Clusters data
- Zbound range from 0 to 50

Piotr Pawlowski (2005)
Friend tree for LAND data

Global variables

class LandEvent: public TAGdata{
public:

  Int_t    Nhit;       // Total number of valid hits
  Float_t Evis;       // Total visible energy

  Int_t    NeutHitMin; // Min. number of neutron hits
  Int_t    NeutHitAve; // Ave. number of neutron hits
  Int_t    NeutHitMax; // Max. number of neutron hits

  Int_t    NeutNumMin; // Min. number of neutrons
  Int_t    NeutNumAve; // Ave. number of neutrons
  Int_t    NeutNumMax; // Max. number of neutrons

  Float_t NeutEvisMin; // Min. neutron visible energy
  Float_t NeutEvisAve; // Ave. neutron visible energy
  Float_t NeutEvisMax; // Max. neutron visible energy

  TClonesArray *Hit;  //-> Hit table
};
Friend tree for LAND data

Hit variables

class LandHit: public TObject{
public:
Int_t ID; // Hit identifier
Float_t Time; // Hit time in [ns]
Float_t X, Y, Z; // Hit position in [cm]
Float_t Evis; // Hit visible energy in [MeV]
UShort_t info; // Hit description
};
Friend tree for LAND data
Useful global methods

```cpp
Int_t LandEvent::GetNhit(Int_t Type = 0, Int_t Charge = 0);
//Returns the number of hits of charge "Charge"
//selected by the procedure "Type"

Int_t LandEvent::GetNpart(Int_t Type = 0, Int_t Charge = 0);
//Returns the number of particles of charge "Charge"
//selected by the procedure "Type"

Float_t LandEvent::GetEvis(Int_t Type = 0, Int_t Charge = 0);
//Returns total visible energy generated by particles
//of charge "Charge" selected by the procedure "Type"
```

Type = -1, 0, 1
Charge = 0, 1, 2
Friend tree for LAND data

Useful hit methods

```cpp
Int_t LandHit::Plane();
// Returns LAND plane number for a hit; 0 for VETO

Bool_t LandHit::Particle(Int_t Type = 0);
// Returns 1 if a hit is the leading hit (in procedure "Type")

Int_t LandHit::Charge(Int_t Type = 0);
// Returns hit charge attributed by procedure "Type"

TVector3 LandHit::Position();
// Returns hit position in form of TVector3;

Float_t LandHit::Theta();
// Returns hit theta angle in degrees

Float_t LandHit::Phi();
// Returns hit phi angle in degrees

Float_t LandHit::Velocity();
// Returns hit velocity in cm/ns
```
Summary

- Charged particle hits were filtered using analysis of correlations between hits of VETO and hits detected in LAND.
- Three methods for hit clustering were proposed to obtain an estimation of minimum, maximum and mean neutron hit numbers in LAND.
- The clustering method provides also an estimation of neutron number on event-by-event basis, as an alternative for other estimators, like total hit number or total visible energy.
- All three estimators give similar results when one studies cross section ratios from $^{107}$Sn and $^{124}$Sn reactions.
- Velocity spectrum for clustered neutrons exhibits two components. The low-velocity component is similar to that of protons, independently of reaction.