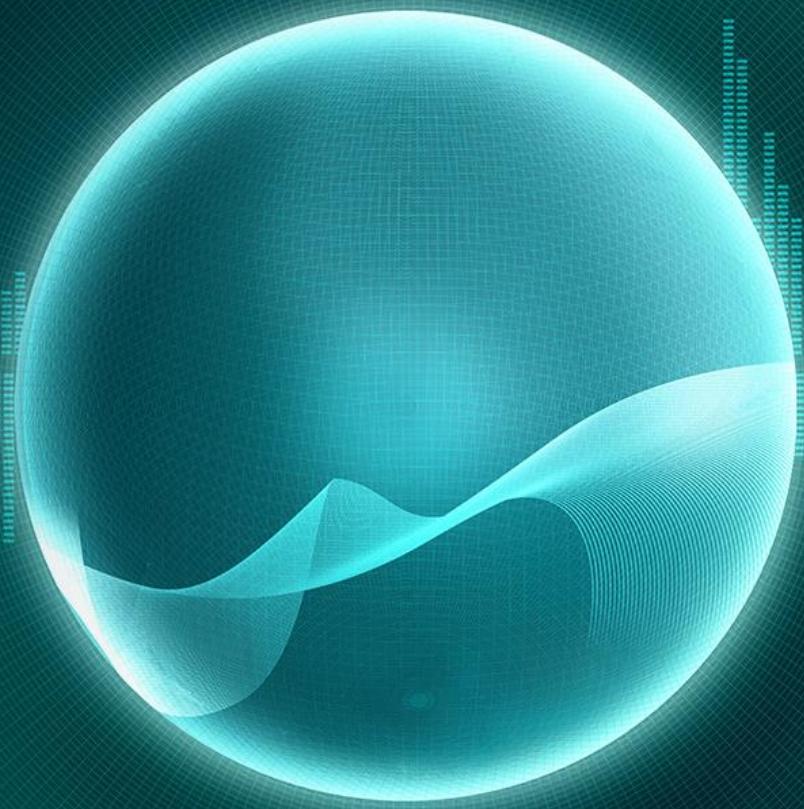
SnT 2019

CTBT: SCIENCE AND TECHNOLOGY CONFERENCE



Unified implementation of NCC analysis algorithms for both current and next generation beta-gamma coincidence based noble gas systems

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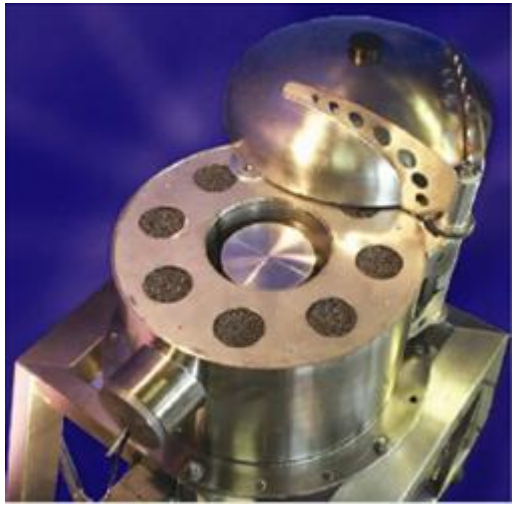
T3.5-O15

Outline

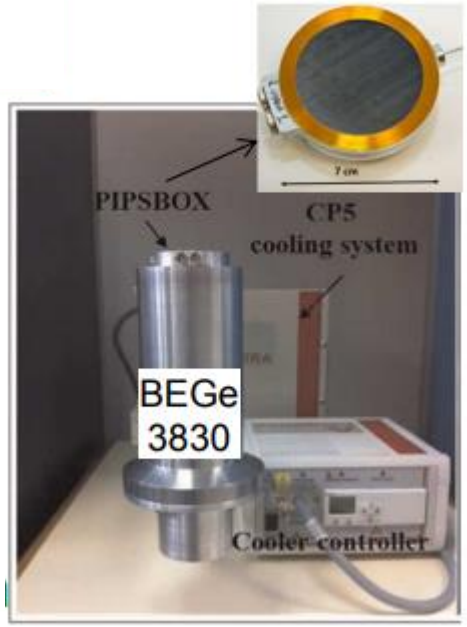
- Introduction
- Specificities of data from different technologies
- Similarities in the analysis
- Decay scheme of Xenon isotopes
- Regions of Interest
- **autoSTRADA** software
- Summary

Introduction (1/2)

- ✓ Currently operated beta-gamma noble gas systems are based on Sodium Iodide (NaI) /plastic scintillation detectors.
- ✓ Among the most promising technologies for next generation of noble gas systems are those based on Silicon PIN diodes for beta.
- ✓ It has been demonstrated that the **high electron energy resolution** of these detectors can significantly **improve the discrimination power between Xe-131m and Xe-133m**.
- ✓ The first next generation noble gas (NG-NG) systems **SAUNA-III** and **SPALAX- NG** developed, respectively, by FOI (Sweden) and CEA (France) are currently undergoing the one –year acceptance testing by CTBTO. **Xenon International** (USA) and **MIKS** (Russian federation) are following.
- ✓ Each system has specific design features that **improve on current operational systems**, which require customized software solutions to process resulting spectral data.



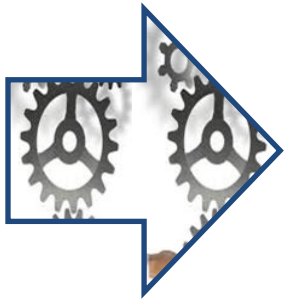
Current detectors

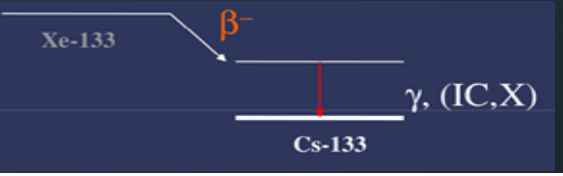


Example of NG detectors

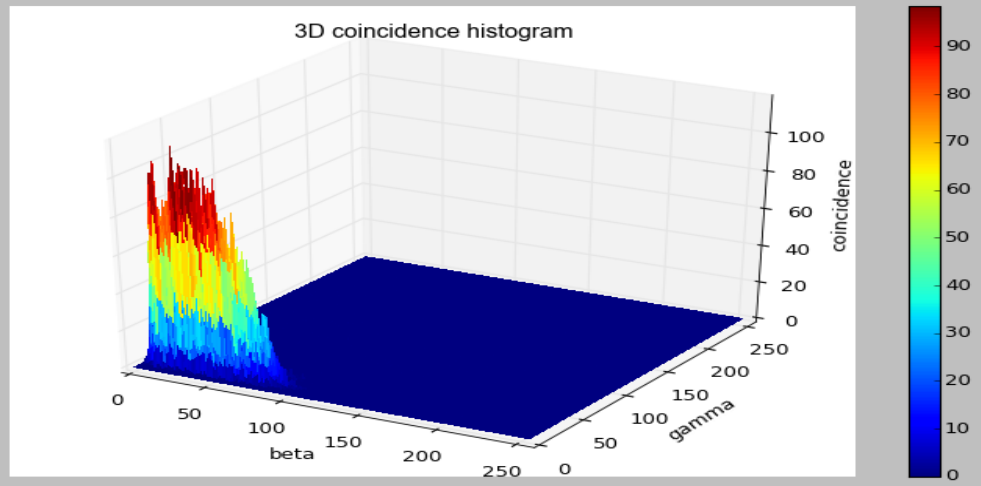
Introduction (2/2)

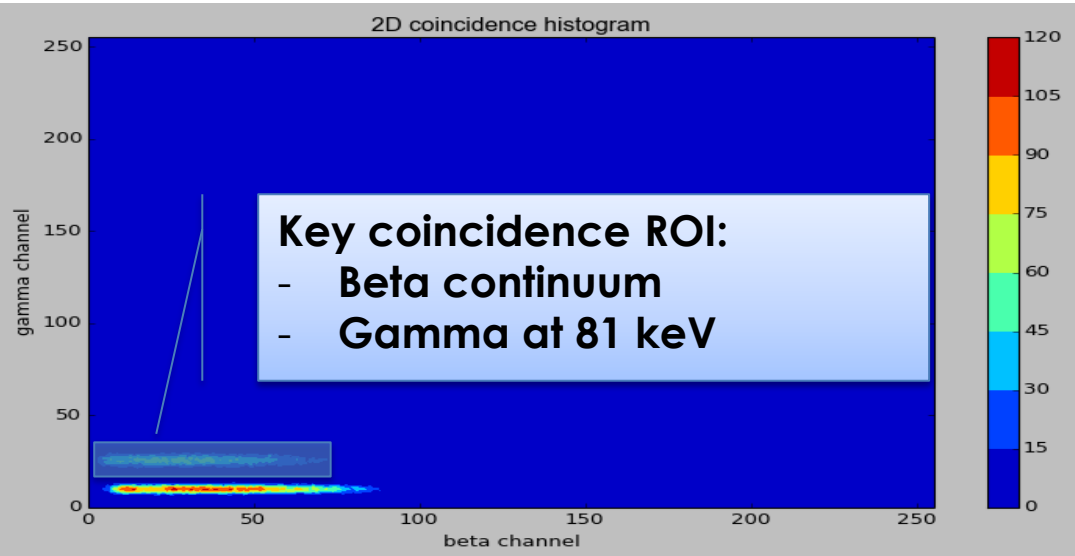
- In order to ensure smooth integration of NG-NG systems, the IDC initiated a new unified software development project for timely deployment into the production environment. The software is based on the Net Count Calculation (NCC) method.
- The implementation allows data from all systems to be automatically processed using the same software tool, taking into account inherent specificities.
- The new software has been rapidly developed and is available already during the acceptance testing period of the new systems.
- The contribution presents the key features of the new unified implementation of NCC algorithms, for handling both current and next generation technologies.

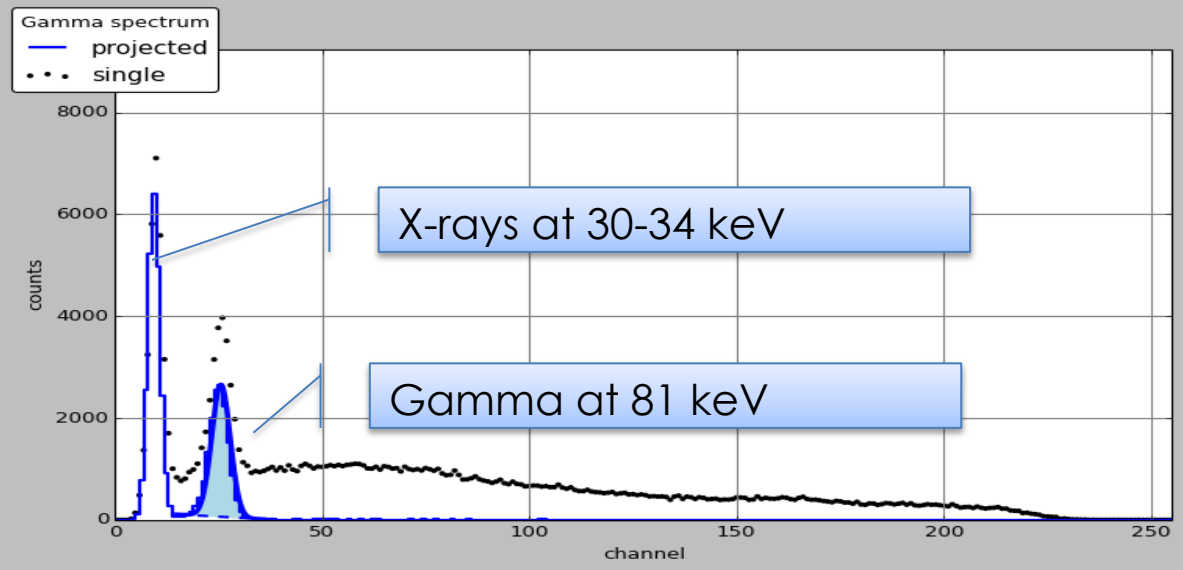


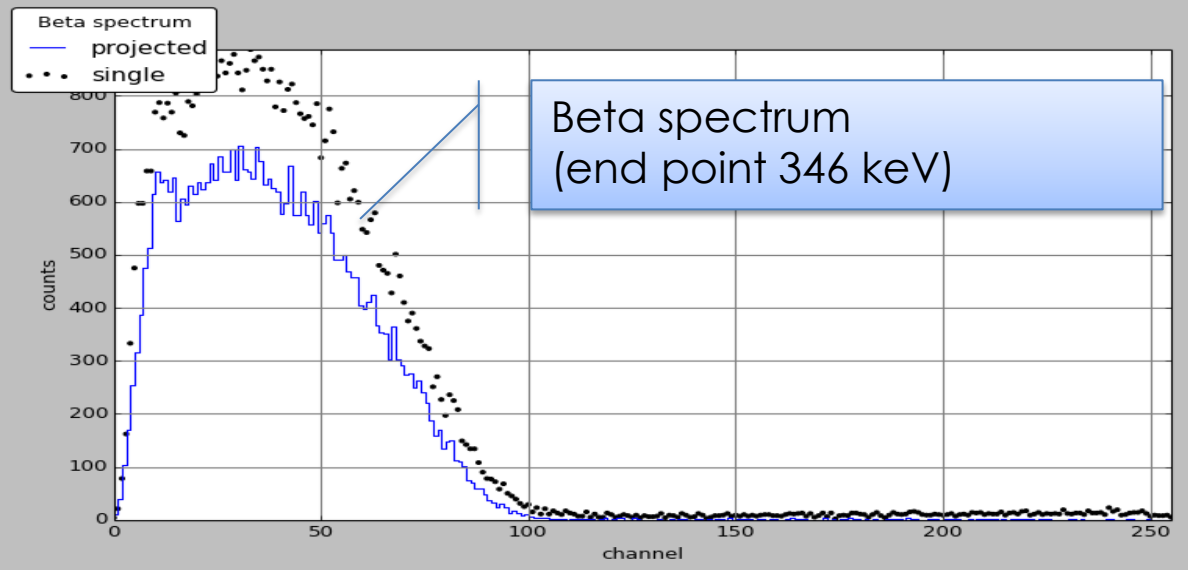


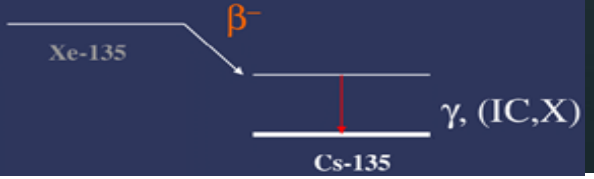
Main emissions of **Xe-133** ($T_{1/2}$: 5.24 d)



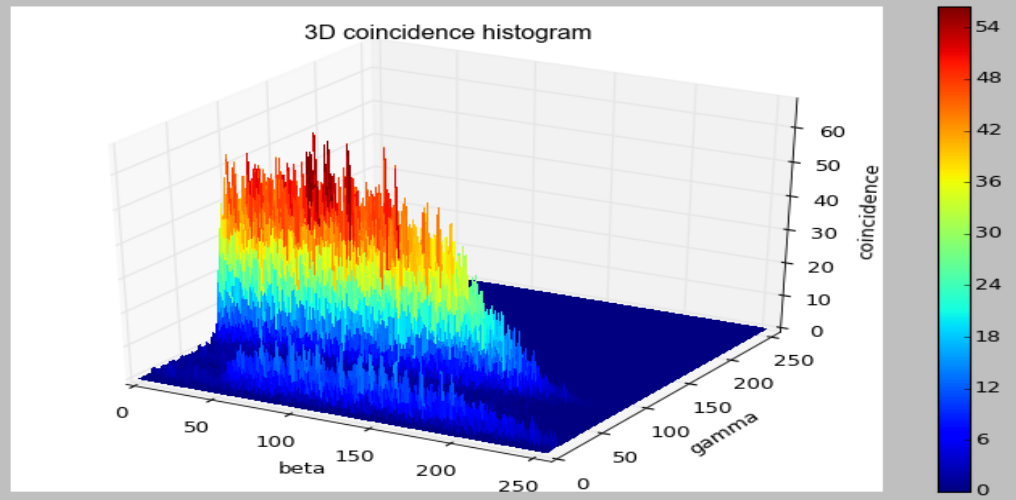


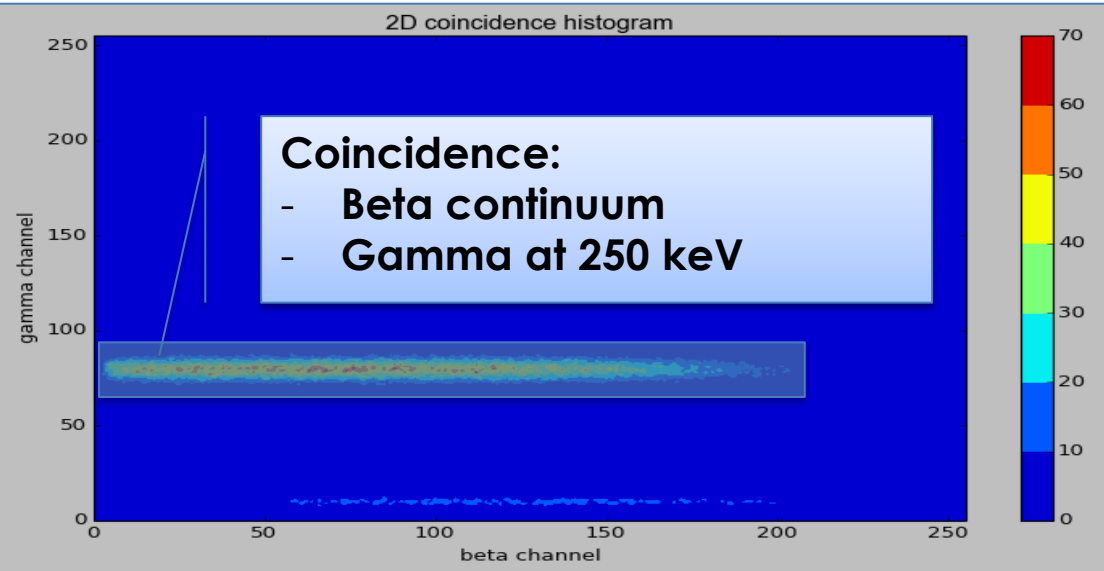


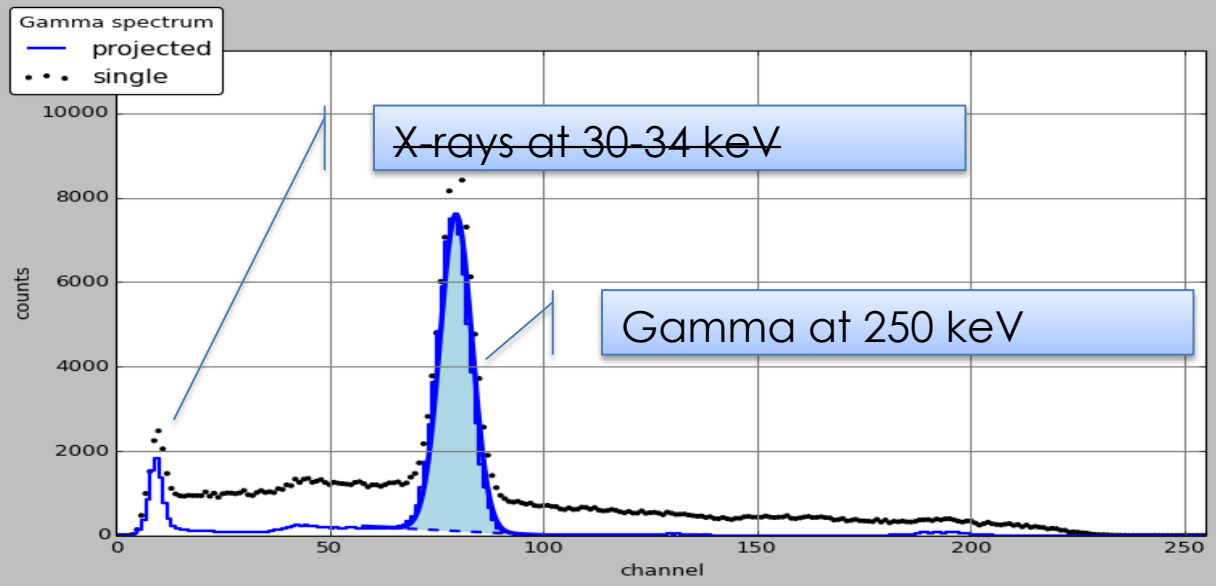


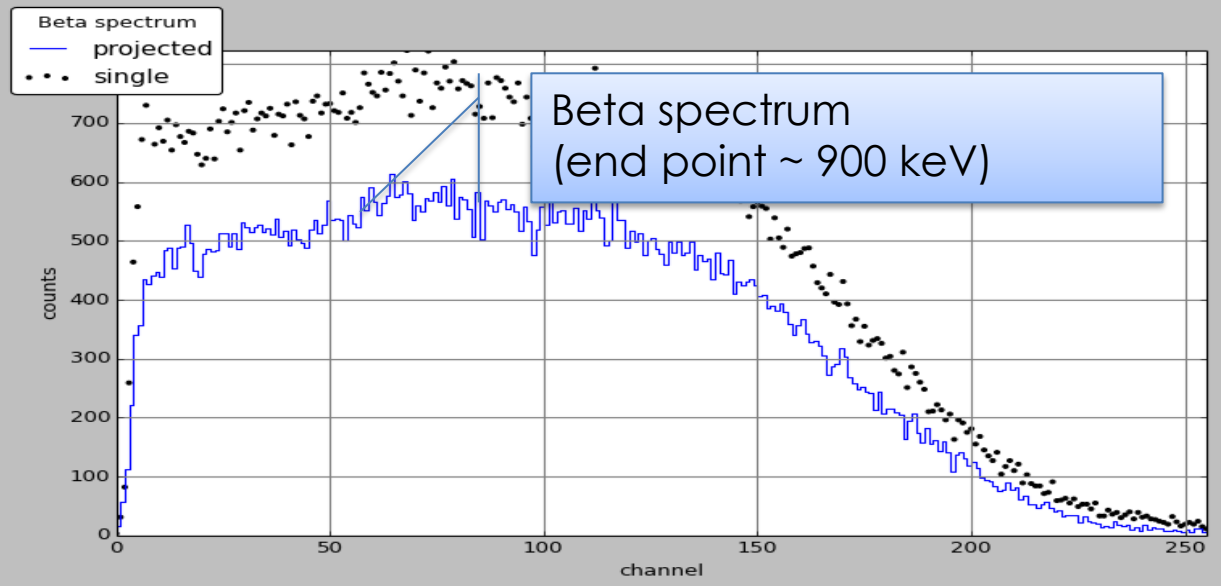


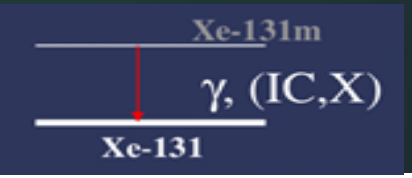
*Main emissions of **Xe-135** ($T_{1/2}$: 9.10 h)*



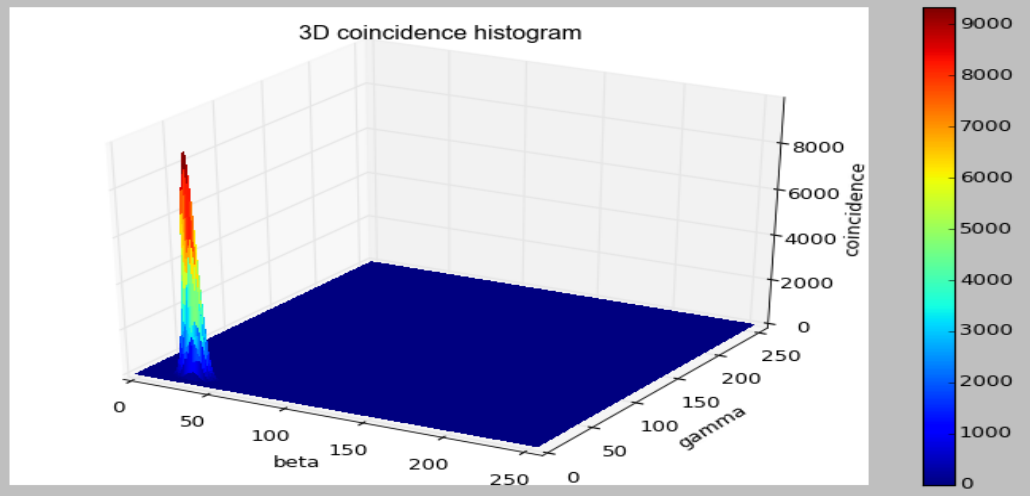


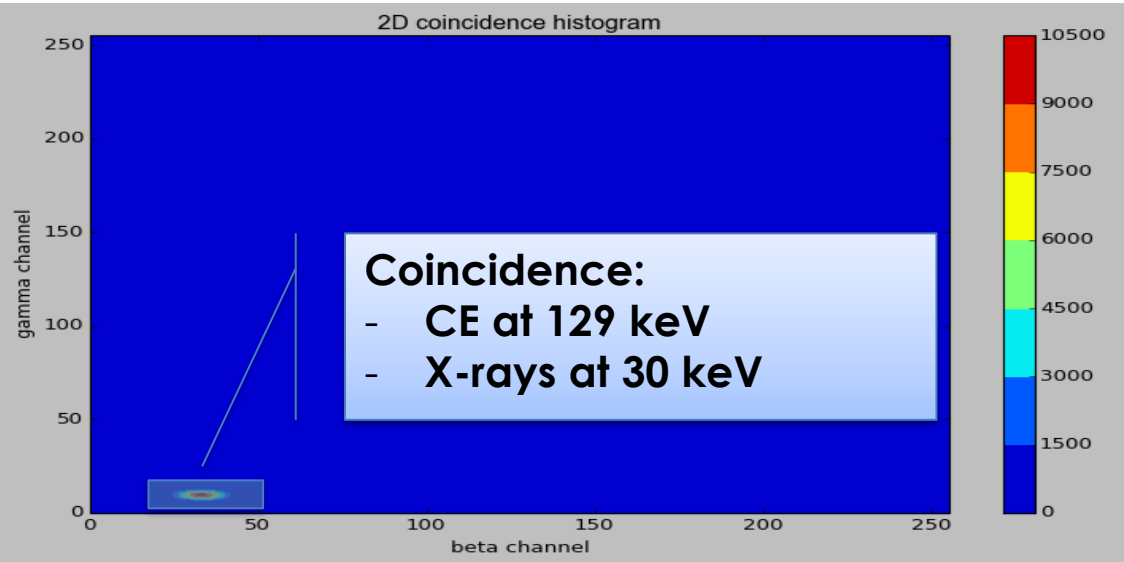


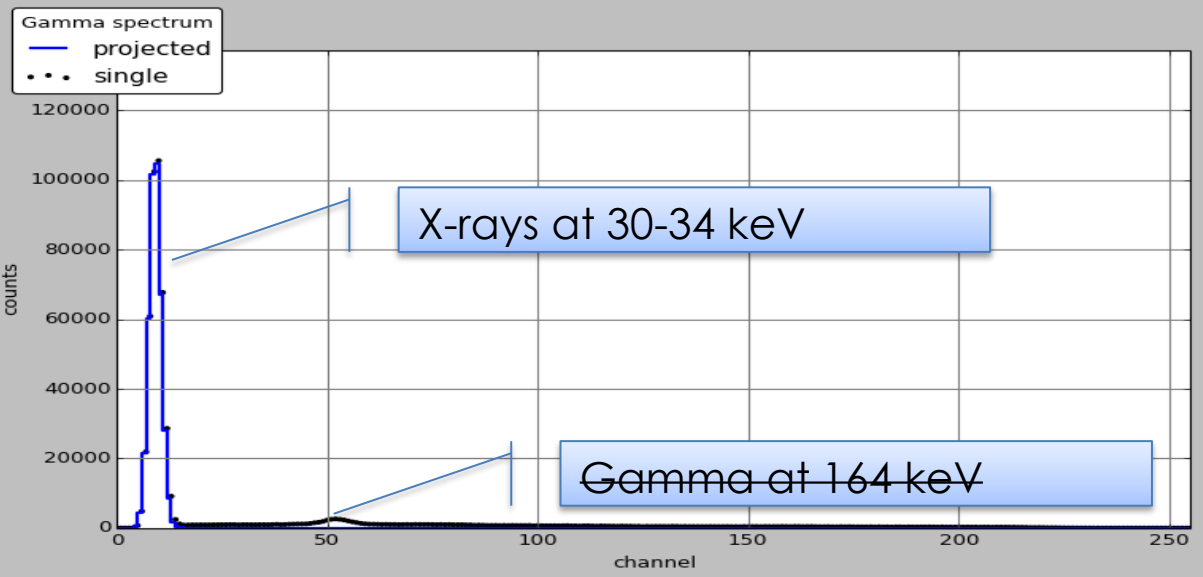


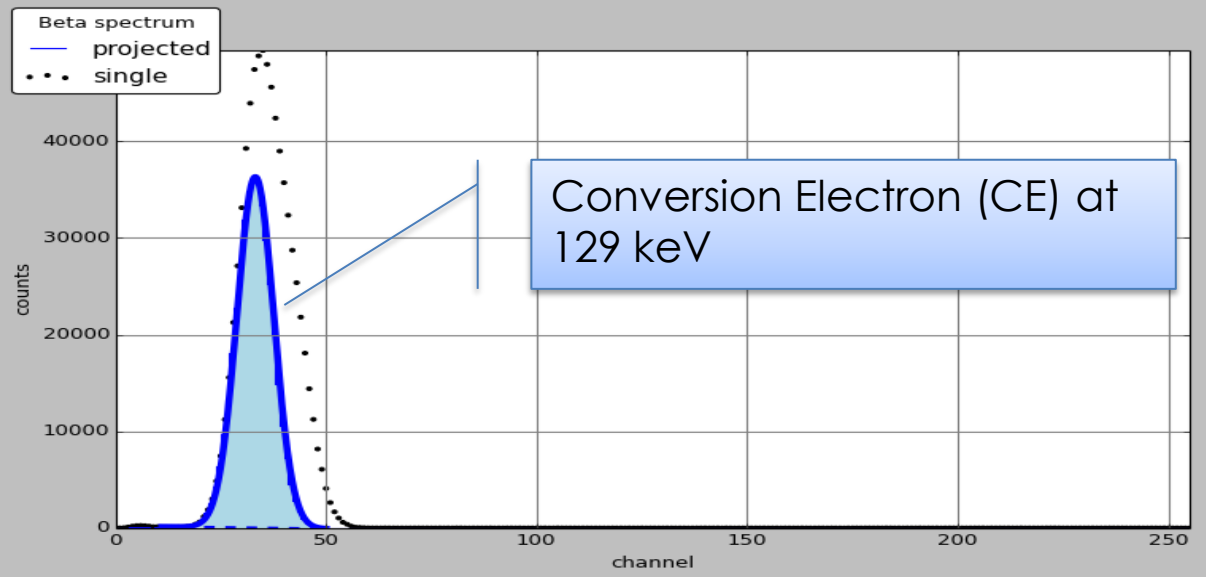


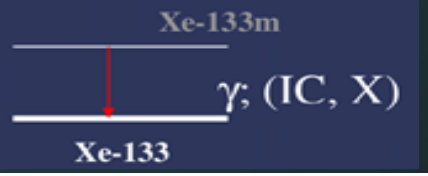
*Main emissions of **Xe-131m** ($T_{1/2}$: 11.9 d)*



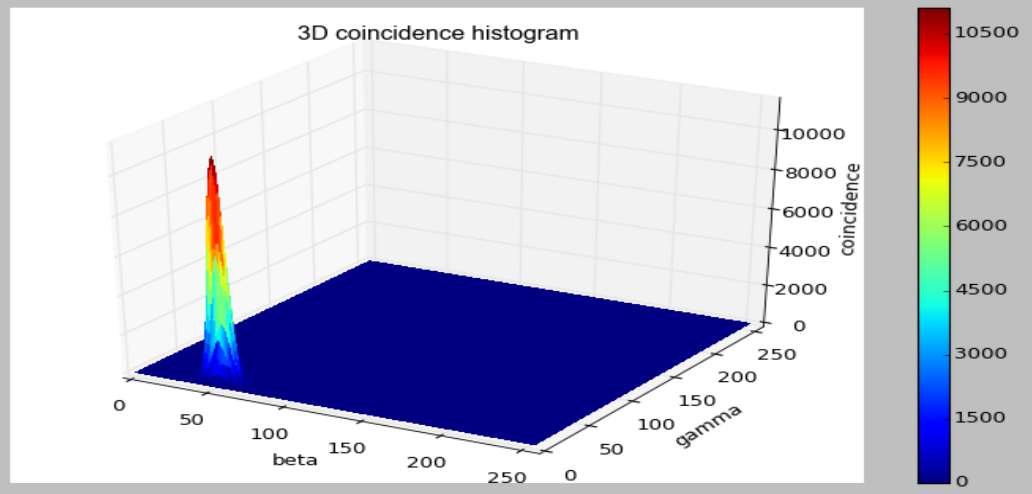


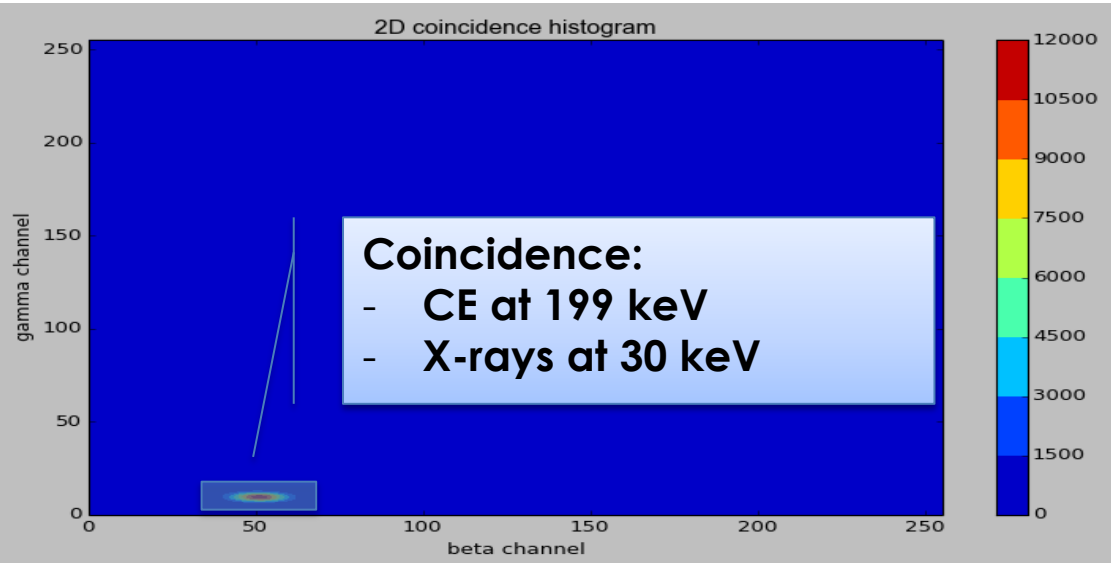


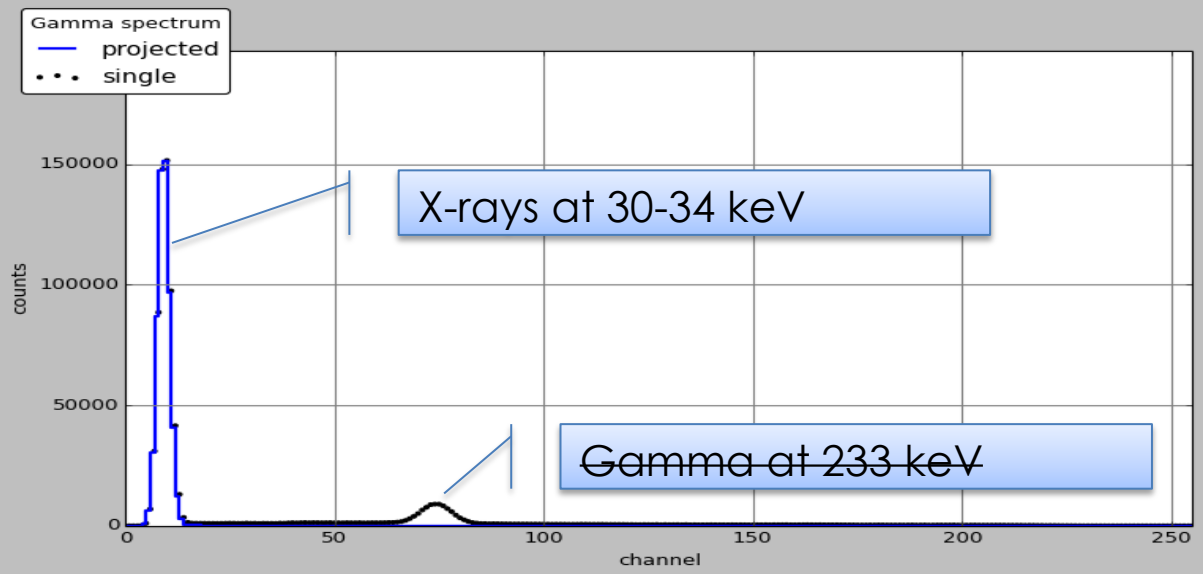


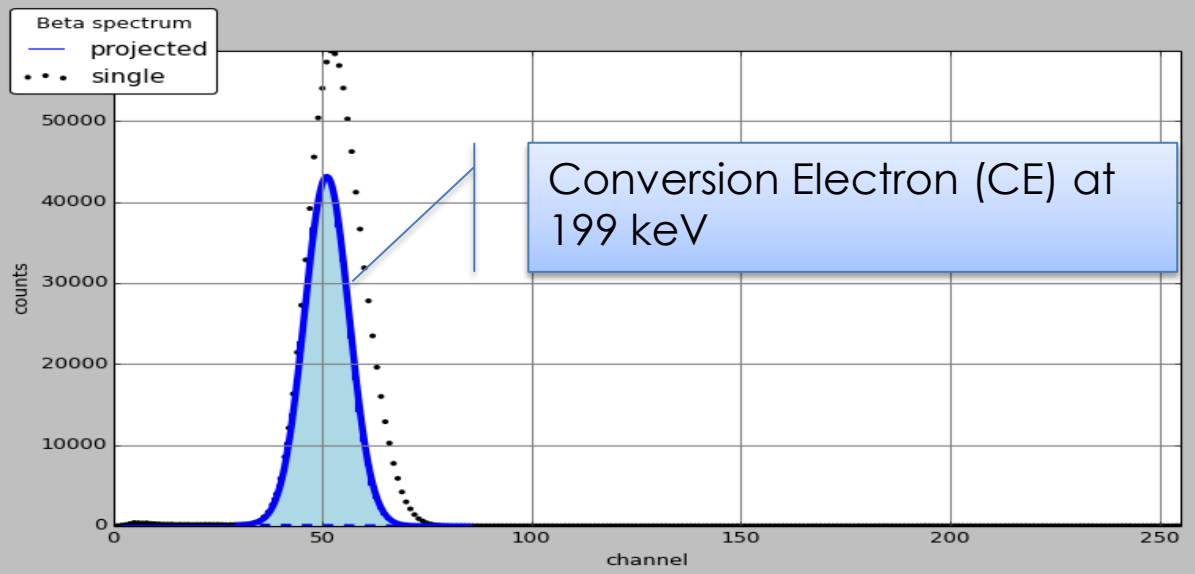


Main emissions of **Xe-133m** ($T_{1/2}$: 2.19 d)





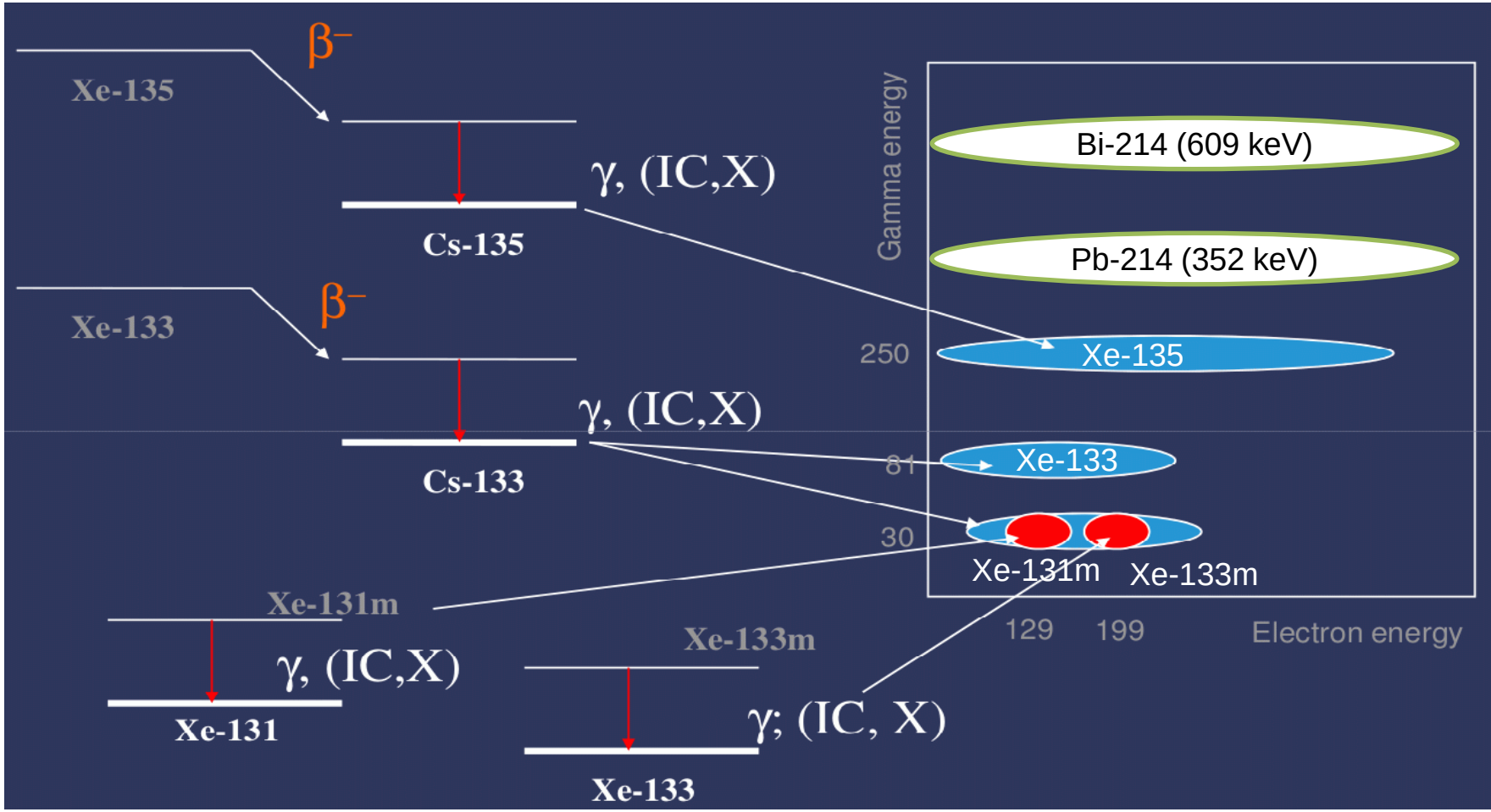




Decay scheme of Xenon isotopes

Coincidence events from: (γ lines, beta) and (X-rays, conversion electrons)

- ^{133}Xe and ^{135}Xe:
  81 keV and **250** keV **γ lines and beta continuum**
- ^{131m}Xe and ^{133m}Xe:
  129 keV and **199** keV **conversion electrons** from IC
- ^{131m}Xe and ^{133m}Xe:
  weak γ lines due to internal conversion (IC)
- ^{131m}Xe, ^{133}Xe and ^{133m}Xe:
  30 - 34 keV **X-rays**



Specificities: *data vs. technology*

1. Key Regions of Interest (ROIs)
   - **0 (Bi-214)**
   - 1 (Pb-214)
   - 2 (Xe-135)
   - 3 (Xe-133)
   - 5 (Xe-131m)
   - 6 (Xe-133m)
2. **Coincidence histogram block**
3. **Beta-gamma channel spans**

SAUNA/ MIKS/ XeInternational

1. ROIs
   - **NO**
   - YES
   - YES
   - YES
   - YES
   - YES
2. **ASCII**
3. **256 x 256**

SPALAX NG

1. ROIs
   - **YES**
   - YES
   - YES
   - YES
   - YES
   - YES
2. **Encoded/ compressed**
3. **1024 x 4096**

```
#Histogram
  256   256  700 1000
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0
```


```
#Histogram
1024  4096  900  700
begin-base64 666 SPX81-QCPHD-2018110123-5094-FULL.gz
H4sICGeZ21sCC1NQWDgxLVFDUEhELTIwMTgxMTAxMjMtNTA5NC1GVUxMAOzd
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ABgAAADAAAAAAAYAAAAwAAAAgAEAAAAMAAAAYAAAAAADAAAAGAAAAMAAAAAA
BgAAADAAAACAARiU6AMAAAMAAAAYAAAAwAAAAAAGwIwAAAAYAAAAsKABuM/o
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yEoI4NDGKQ3H6uWfk5kBgO4GYG0Zz22f/I4SHL83ABiA+oEjFa6eCq3OEAFW
```

Specificities: *data vs. technology*

1. Interference correction (IC) from:
   - **Bi-214**
   - Pb-214
   - **Xe-135**
   - Xe-133
   - **Xe-133m**
2. **Correction for memory effect**
3. **Xe-131m and Xe-133m gating X-rays** for deriving beta-gamma branching ratios

SAUNA/ MIKS

1. IC:
   - **NO**
   - YES
   - **NO**
   - YES
   - **NO**
2. **YES**
3. **K_α+K_β**

XeInternational

1. IC:
   - **NO**
   - YES
   - **YES**
   - YES
   - **NO**
2. **YES**
3. **K_α+K_β**

SPALAX NG

1. IC:
   - **YES**
   - YES
   - **YES**
   - YES
   - **YES**
2. **NO**
3. **K_α**

Similarities: *NCC analysis flowchart*

NCC processing flowchart

1. ROI limits conversion from energy to channel
2. Gross ROI counts
3. Detector background subtraction
4. Interference corrections (when available)
5. Memory effect (if applicable)
6. Net counts
7. LC and LD
8. Decision on detectability
9. Activity and MDA
10. Activity concentration and MDC
11. Uncertainty budget
12. Results reporting

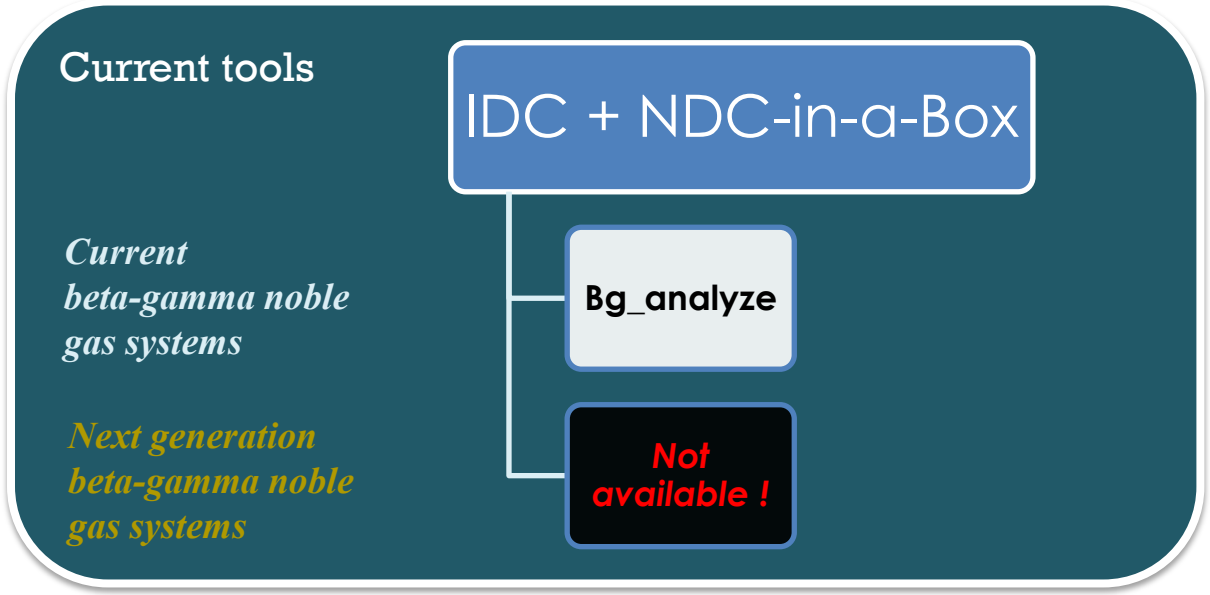
The project

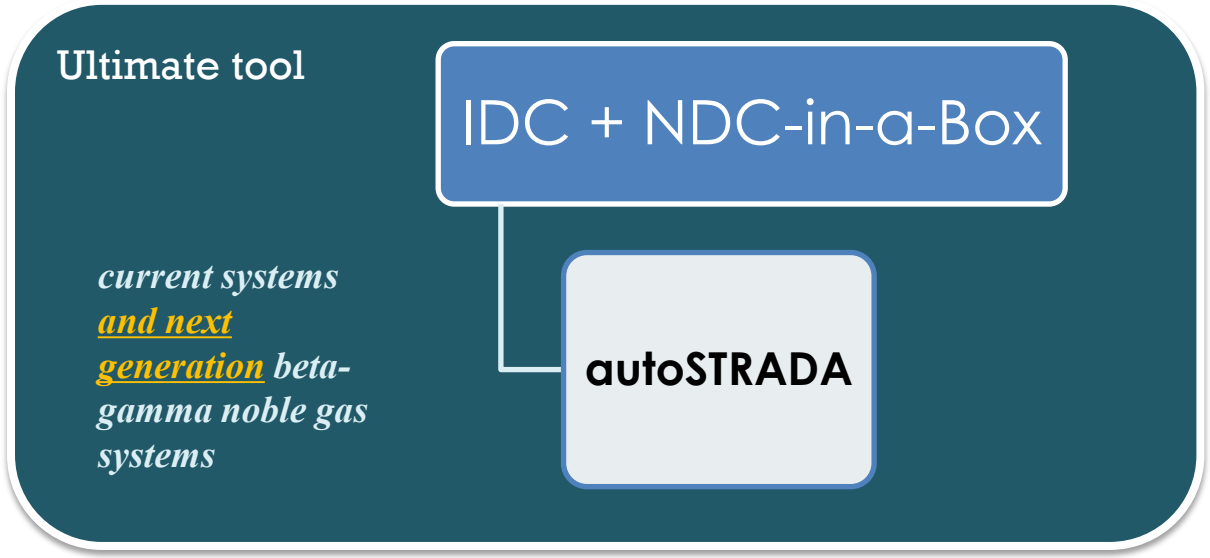
Goals

- To **support** new generation of Noble Gas systems.
- To **support** new analysis methods in parallel to current ones.
- To **unify** the automatic processing tools for beta-gamma coincidence based noble gas systems in a single software application.

The new project (initiated in October 2018) **autoSTRADA** (automatic Software Tool for RAdionuclide Data Analysis) uses open source license free modern software development framework technology.

It shares the same library with iNSPIRE.





autoSTRADA software

What is *autoSTRADA* ?

Software application for automatic processing of Noble Gas beta-gamma coincidence based Noble Gas spectra (low and high resolution).

Standard integrated environment:

- *autoSTRADA* is a Python language based license-free software application. Its output is accessible to *iNSPIRE* review tool for interactive analysis.
- Tested on Linux Operating System
- Uses Oracle/MySql databases
- Runs under standard configuration of the IDC and NDC-in-a-BOX environment:
  - *Integrated automatic processing pipeline*
  - *Structured file system*
  - *Database schema (IDC/NDC-in-a-Box)*

In addition

- autoSTRADA also runs in stand alone mode
- autoSTRADA also runs on Windows

NCC algorithms in autoSTRADA

NCC uses (up to) 3 components of the data set:
Detector background ***(D)****, Gas background* ***(G)*** *and Sample* ***(S)*** to derive "*corrected*" Net counts for each ROI.

Main steps:

1. Unzip and decode the coincidence histogram (as appropriate)

2. Detector background subtraction from sample (and gas background – if applicable);

2. ROI interferences when factors are available;

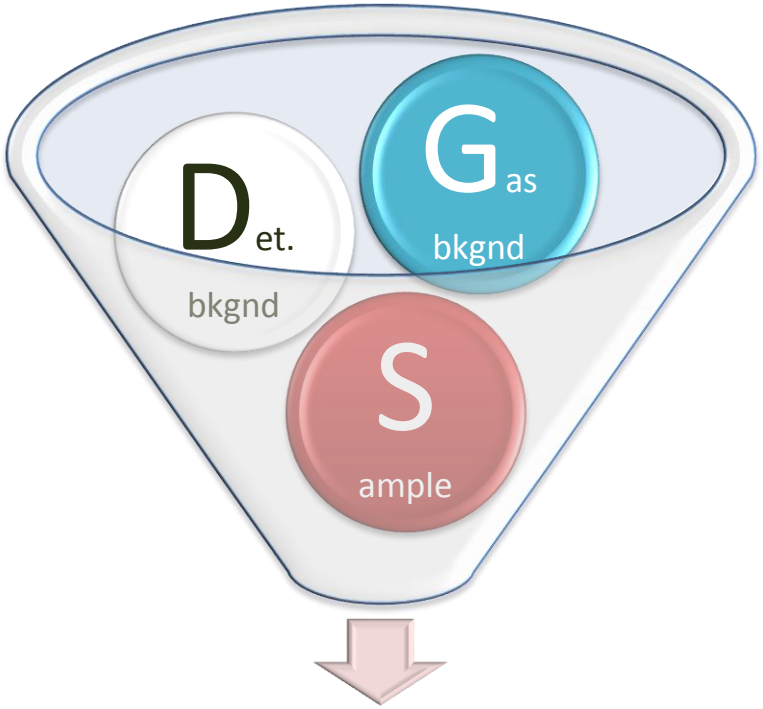
3. Correction for memory effect (if applicable)

4. Net counts, LC for the sample

5. Xe isotopes detected or not ?

6. Activity, LC, MDA at acquisition start

7. Activity concentration, LC, MDC



Net counts, LC, LD

autoSTRADA software

Input data:

autoSTRADA software processes spectral data sets from PHD messages, *which have already been parsed into the database and the file system:*

- Detector background,
- Gas background (as applicable),
- QC spectra,
- Sample measurement data.

Configuration and processing parameters are read from the database.

Output:

Analysis results for the 4 Xenon isotopes (^{131m}Xe, ^{133m}Xe, ^{133}Xe, ^{135}Xe) of relevance for CTBT verification:

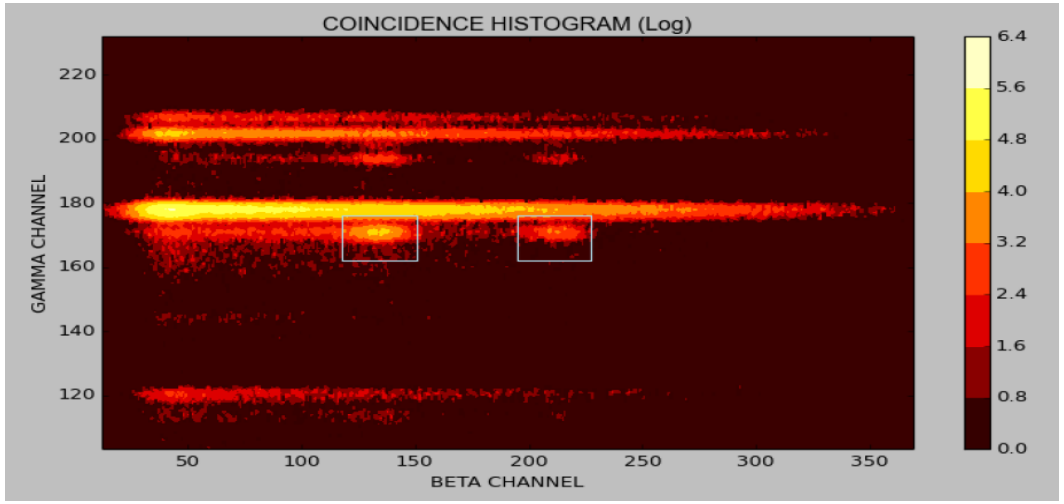
- *Present or not ?*
- LC, MDA and activity (with uncertainty) at acquisition start
- LC, MDC and activity concentration (with uncertainty) at sampling time

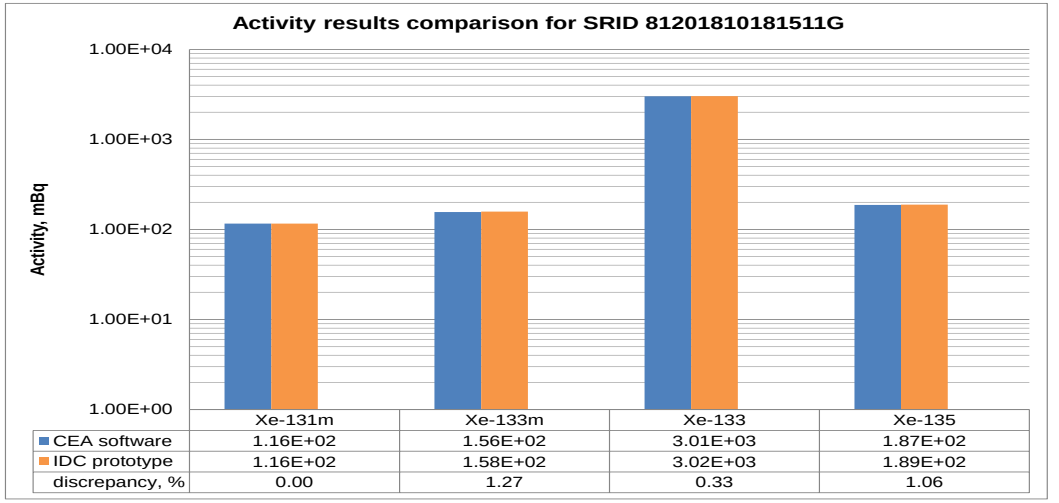
Analysis results are stored in the database and log files are written into the file system.

Summary

Achieved progress

- autoSTRADA prototype is developed by the IDC using internal resources.
- It is currently under integration stage in the IDC development environment.
- The software handles both currently operated (Sodium iodide, plastic scintillator) detectors and next generation high resolution (HPGe, SiPIN; NaI, SiPIN) detectors.
- Successfully tested with data from SAUNA II and SPALAX Next Generation systems.
- autoSTRADA preliminary analysis results are in excellent agreement with CEA software.





	Xe-131m	Xe-133m	Xe-133	Xe-135
CEA software	1.16E+02	1.56E+02	3.01E+03	1.87E+02
IDC prototype	1.16E+02	1.58E+02	3.02E+03	1.89E+02
discrepancy, %	0.00	1.27	0.33	1.06

Outlook

The new IDC tool will be used for automatic processing and further benchmarking throughout the second half-year acceptance testing period, when the SPALAX NG system is installed at IMS location (Canada).

THANK YOU