An attempt to build a smart real-time system for heavy element research: approaches, mathematical objects, algorithms, equations.

MMCP-2017
DUBNA, 07.07.2017

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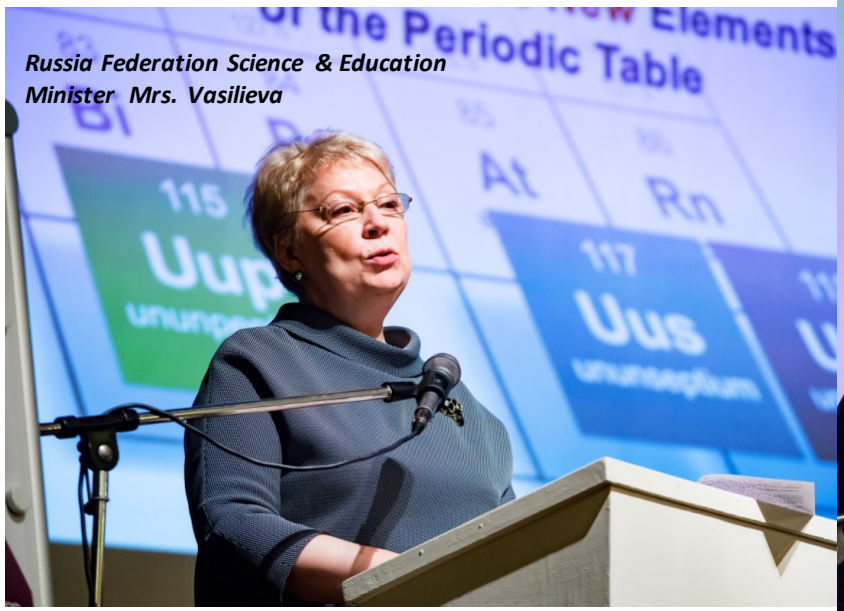
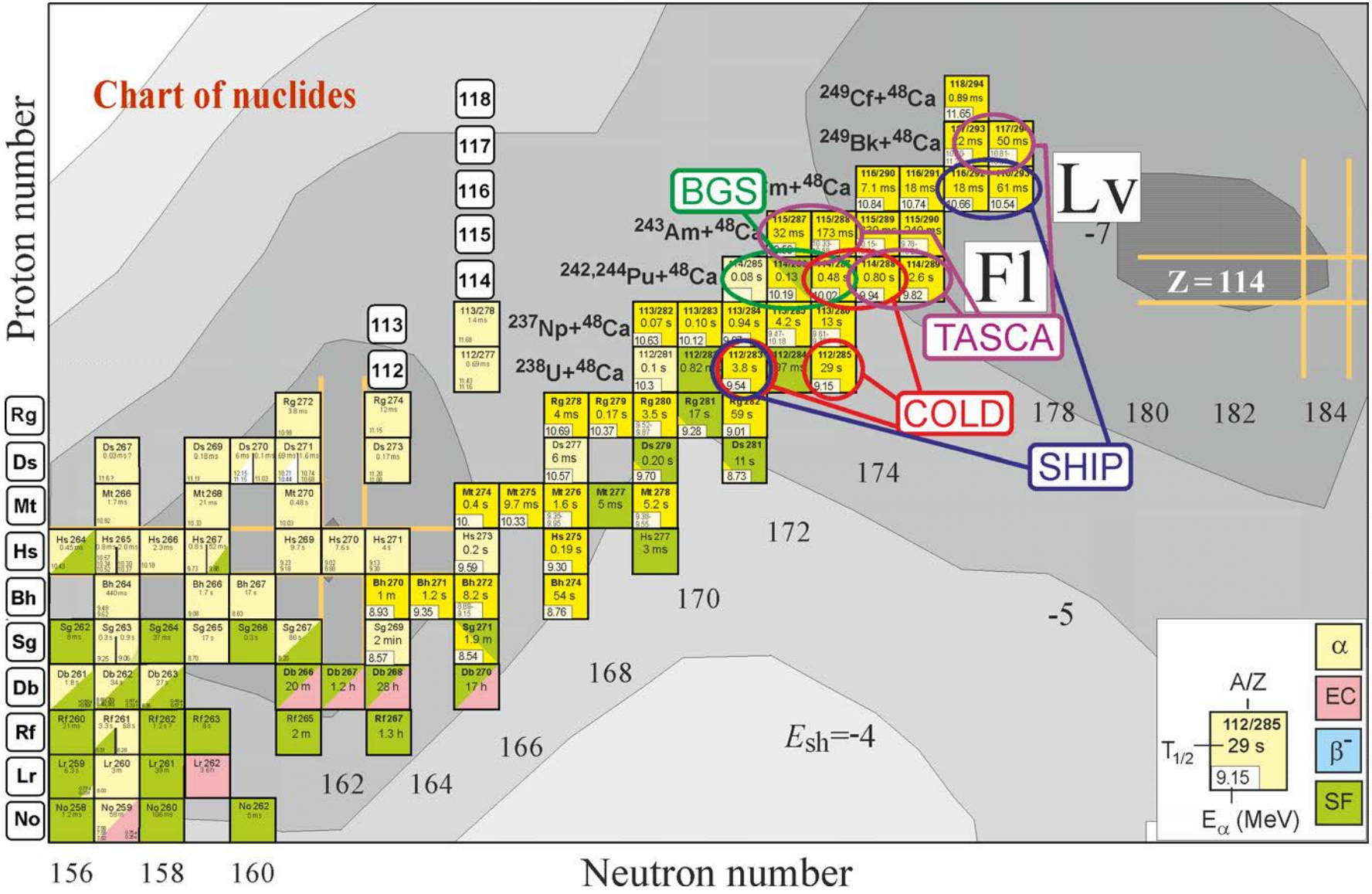


Russia Federation Science & Education Minister Mrs. Vasilieva

SHE synthesis : the DGFRS results



HI experiments data processing (off-line) & Appl. Math.&Software basic

PHD (Pulse Height Defect calculations)

1) EVR registered spectra (normal direction of implantation geometry)

Сейчас не удается отобразить рисунок.

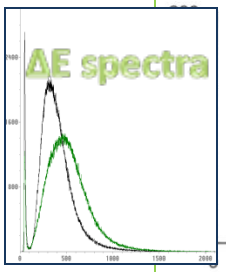
· *Wilkins* formula for stopping component of ***PHD (within LSS)***;
· *Haines&Whitehead* approach for fluctuations of those component (within ***LSS*** theory);
· *Kushniruk, Kharitonov, Tsyganov* ***"Surface recombination"*** concept for recombination component and its fluctuation (with ~0.5 ***form-factor*** for ***EVR*** tracks)
· *Seibt, Sundsröm and Tove* ***SCLC*** model for track destruction and for plasma time calculation.

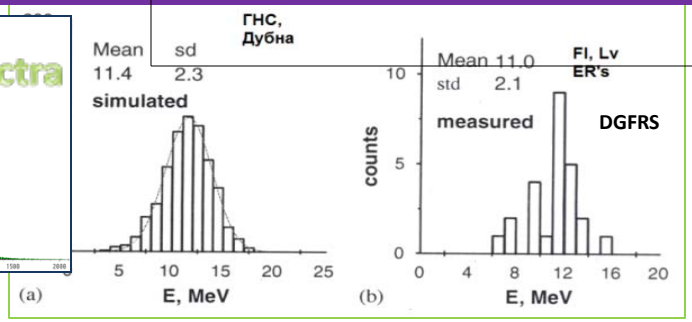
$\lambda = k_F \cdot s \cdot T_P / R$, where: k_F- form factor, T_p- plasma time, **R**-range, s-surface recombination velocity, λ – relative recombination loss.

$$T_P = 1.32 \cdot 10^{-10} \cdot (E^2/R)^{1/3} \cdot 1/F$$

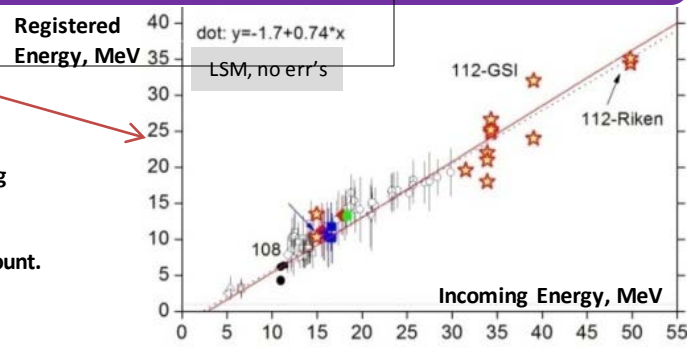
F[V/cm]-electric field, E- particle energy [eV].

5. ***On line, or even real-time programs for data acquisition, searching for any correlation sequences , radical background suppression methods, etc…***





Losses and broadening in working media ,neutrons evaporation, straggling, and PHD and its fluctuations were taken into account.



Surface recombination concept (in brief, for FF simulation PHD)

$$dN = s \cdot n(t) \cdot A(t)dt$$

n- Concentration, A(t) is an effective recombination area

$$\Delta N = \frac{s}{Cos(\Theta)} \cdot \int_0^{Tp} n_L dt$$

n_L – e-h plasma linear density

$$\lambda(T_P) = \frac{s}{R \cdot Cos(\Theta)} \cdot \int_0^{Tp} (1 - \lambda(t))dt$$

It is assumed $T_P(\theta)$ – very slow dependence .

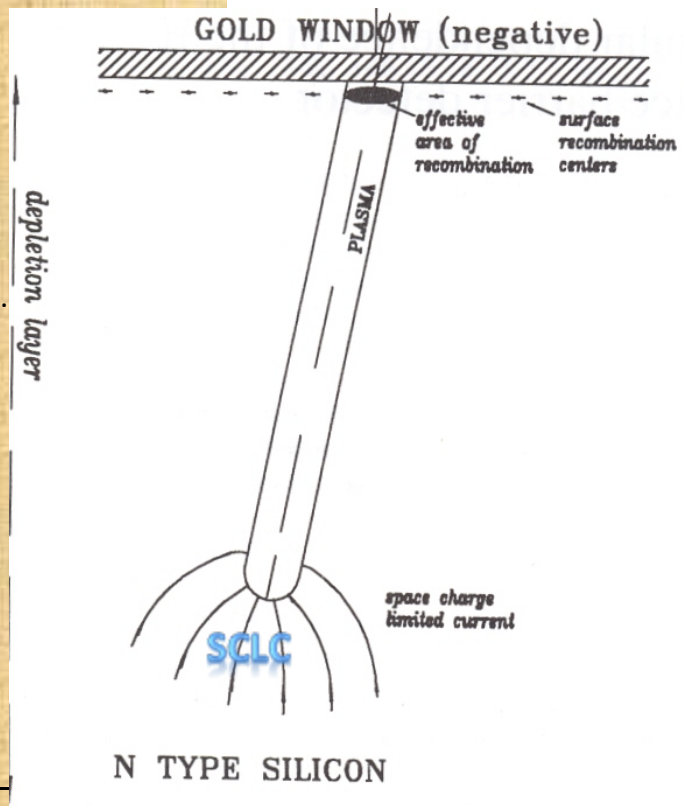
Yu.S.Tsyganov and A.N.Polyakov NIM A363(1995) 611-613

With upper limit: (***Yu.Tsyganov, Appl. Radiat. & Isotopes, Vol.48, No.9 (1997)1211-1213)***

$$\lambda_{MAX} \approx 2sR \int_0^{Tp} dt \int_0^{} n(r,t)dr$$

, and, after integration: $\lambda_{MAX} \approx \lambda_{)} \cdot \frac{R}{R_P \sqrt{\pi}}$

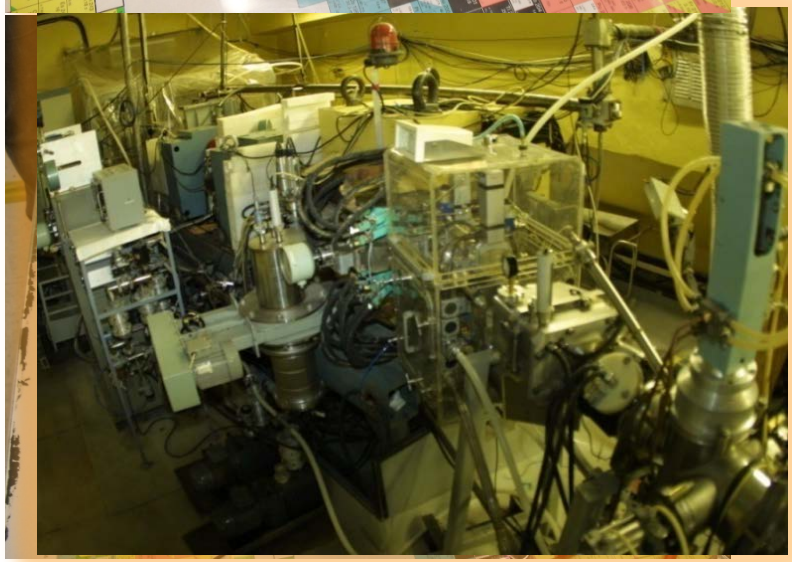
Where $R_P = \sqrt{DT_P}$, D- ambipolar diffusion coefficient fo e-h plasma

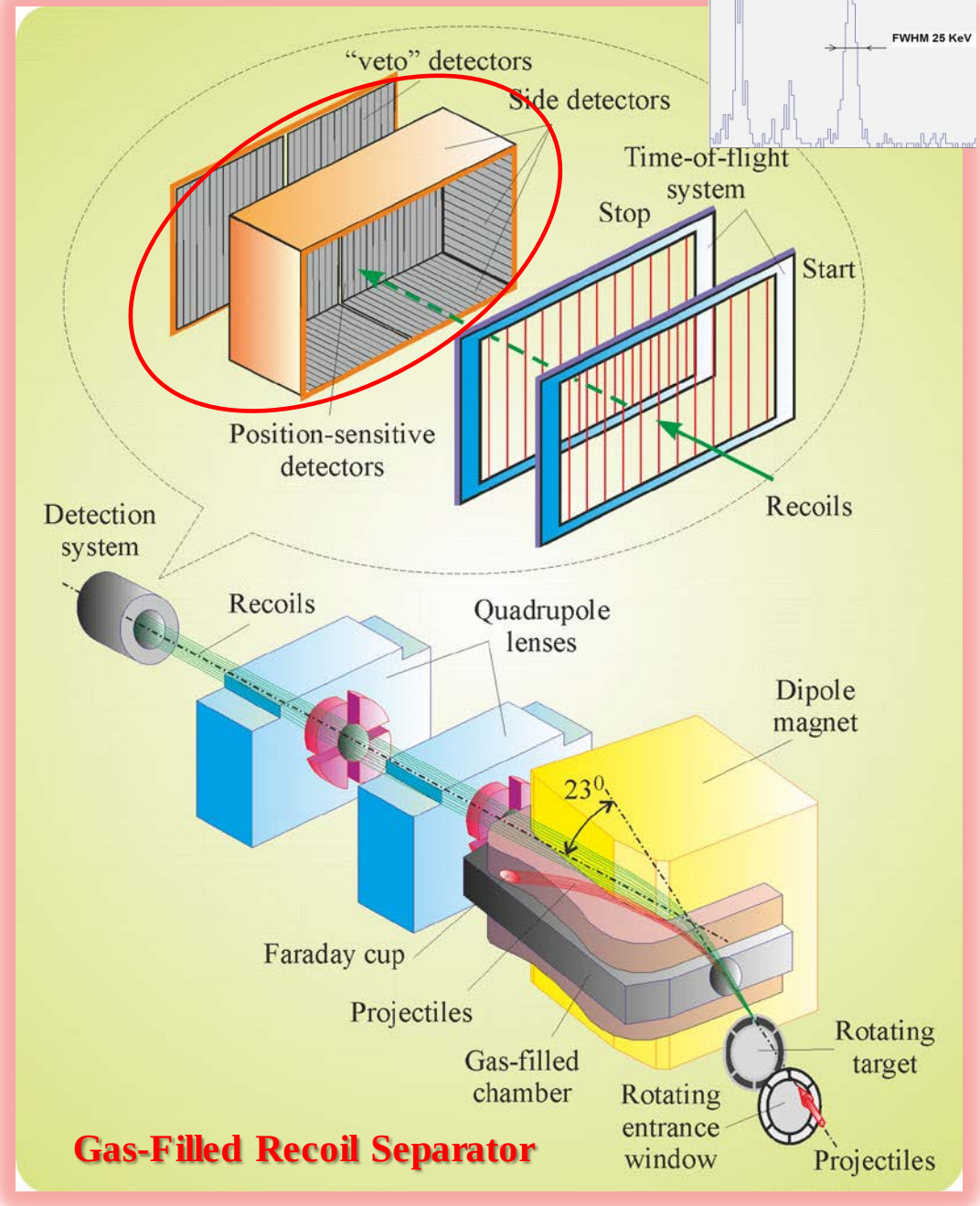


Parameter λ_0 corresponds to normal direction with respect to detector surface

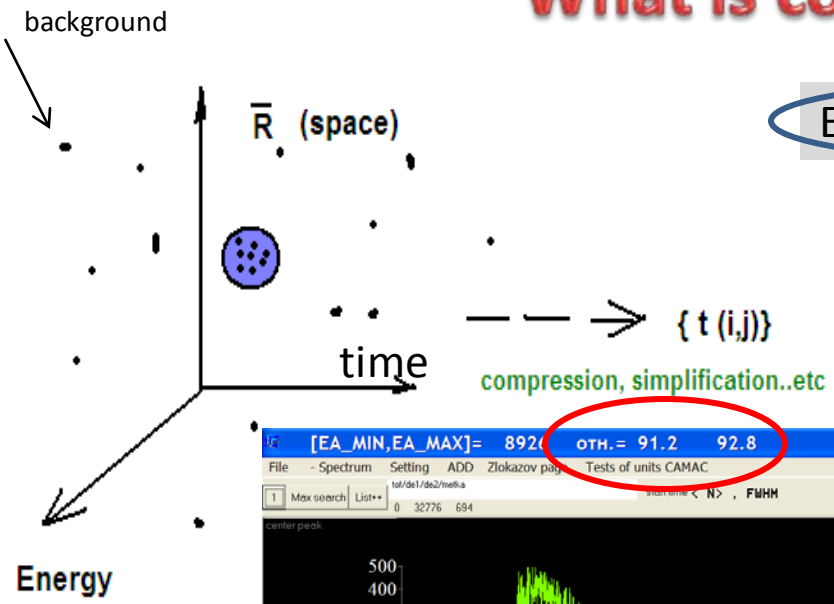
** In fairness : angular dependence is actual for ρ(n-Si) < 1 kOhm · cm, if ~ 10 then mean value*

New FPD:
48 by 128 strips (48*128 mm^2) DSSSD,
6*(48*128 mm^2) side detectors + 1 "veto"
And two independent registering systems





What is correlation?

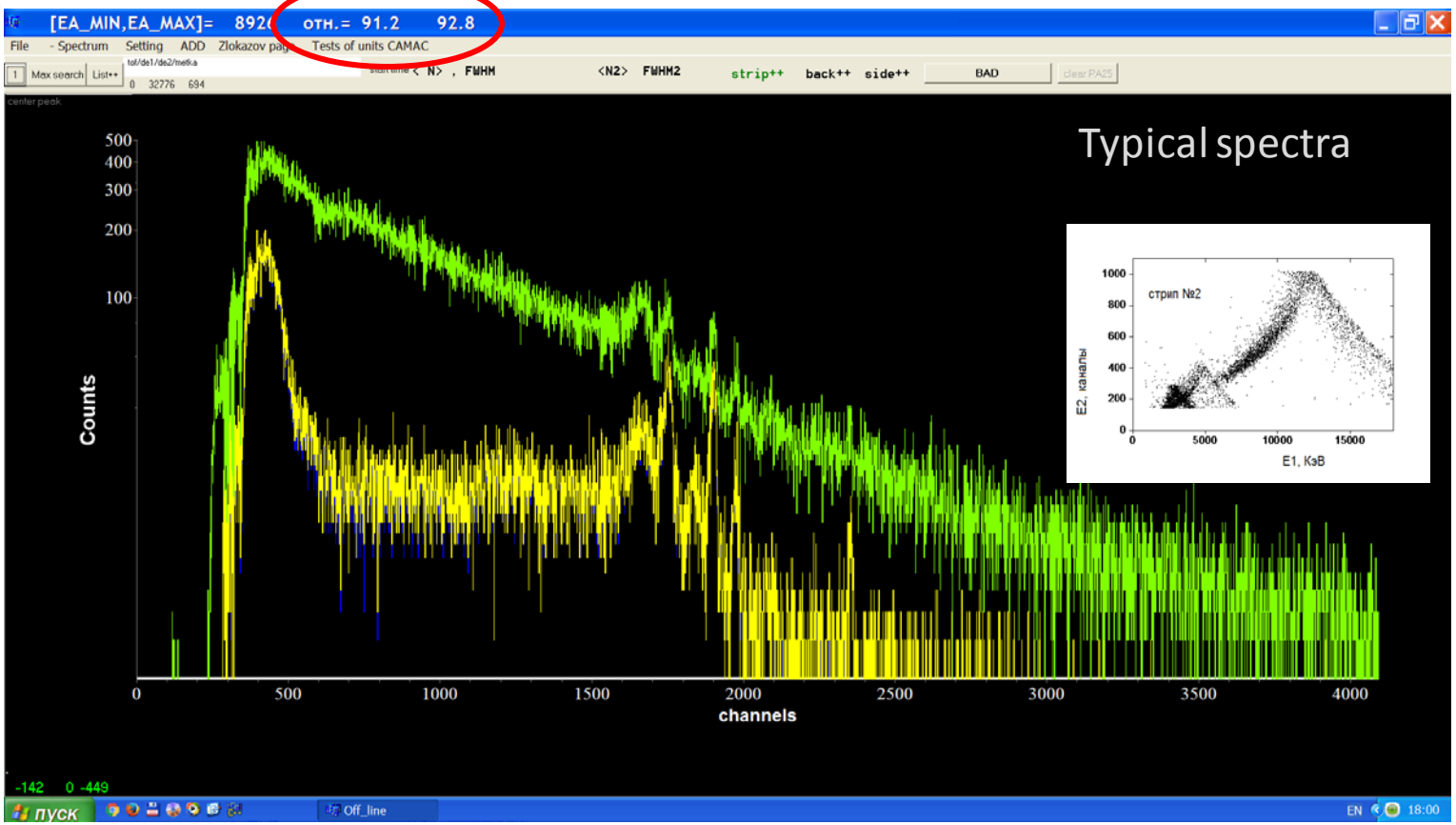


0 – Alpha-like

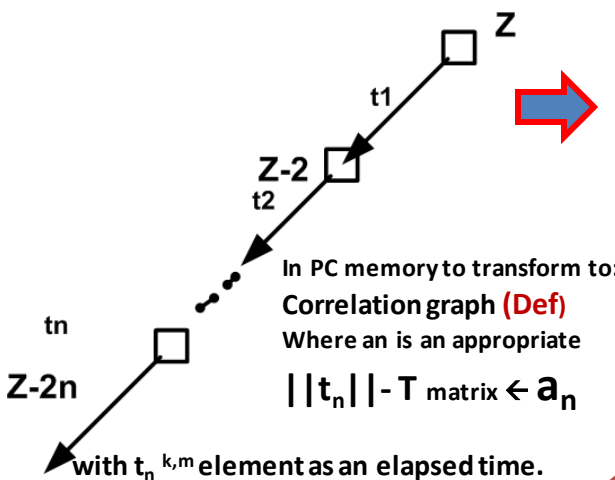
Energy-time-position-TOF-$\Delta E_{START,STOP}$

EVR - LIKE

$$F(TOF, \Delta E) = 1 : TOF \in (TOF_{MIN}, TOF_{max}) \& \Delta E \in (\Delta E_{MIN}, \Delta E_{MAX}),$$

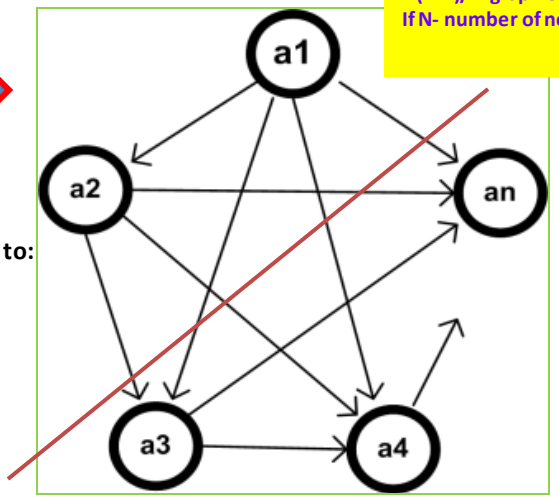


General philosophy of "active correlations" method

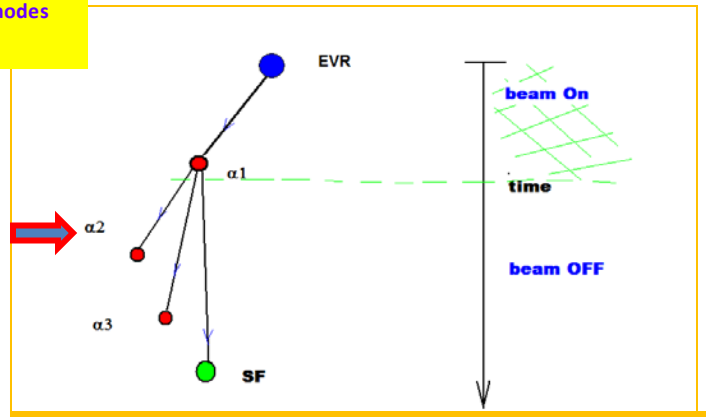


In PC memory to transform to:
Correlation graph **(Def)**
Where an is an appropriate
$||t_n||$ - T matrix ← a_n

with $t_n^{k,m}$ element as an elapsed time.
k,m indexes are correspond horizontal and vertical strip numbers, respectively



N(N-1)/2 graph edges
If N- number of nodes

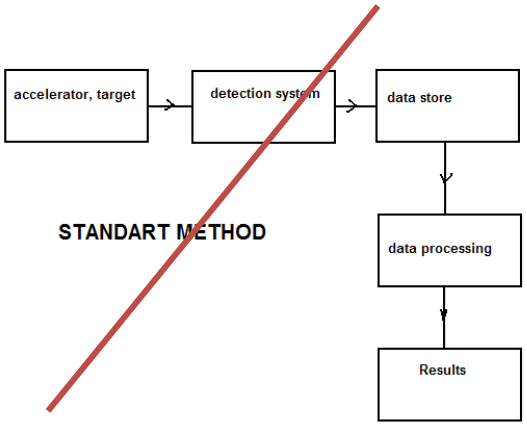


Beam stop →EVR *(α_1+α_2+...)

Correlation : 3D+1 (in our case) = energy-position(x,y)- time. If to "kill" (=localize) e-(x,y) ➔ it will be very simple structure (~one dimensional)
+1 means that whether TOF || ΔE 1,2 > 0 or both parameters =0 (EVR like or alpha-like signals)

$\Delta t_{i,j} = t_j - t_i, \quad t_j > t_i$ t ← elapsed time from electronics $\quad \Delta t_{i,j} \leq \varepsilon_{i,j}$ →correlation YES!
Required but not sufficient condition

...but, it is not our goal !

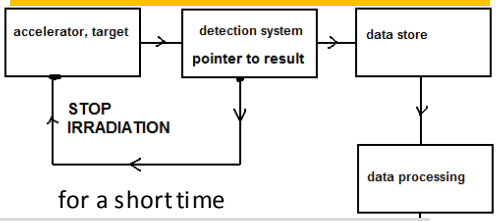


STANDART METHOD

except...

1)

J(cyclotron) = 1 pμA, if no pointer
= 0, if pointer to correlation YES



for a short time

2) Integrated system should be→
DAQ, control system – the same standard
// not necessary, but preferable!

Results in

!!!

$\sum_{i=1}^{N} \Delta t_i << T_{experiment}$

ER-alpha

History in brief

XVII INTERNATIONAL SYMPOSIUM ON NUCLEAR ELECTRONICS

Chairmen: Prof. I.Vankov,
Dr. I.N. Churin
1997, Varna

HPC ASIA '97 SEOUL

High Performance Computing

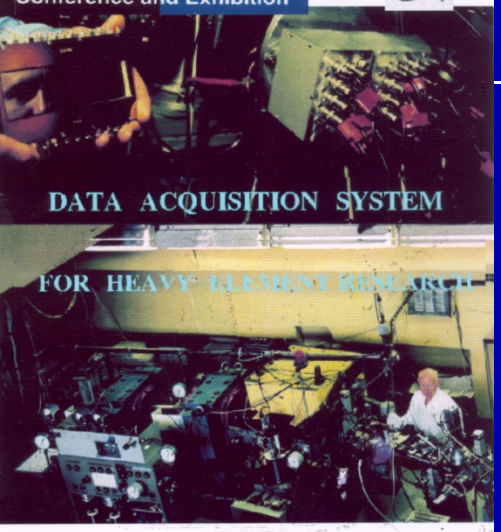
on the Information Superhighway

April 28–May 2, 1997
Seoul, Korea

HPC ASIA '97 Conference and Exhibition

TS 25

Yu. Tsyganov
Flerov Laboratory
of Nuclear Reactions,
Dubna,
Russia



Seoul Hilton Hotel, May 02 11:00

et SetUp Scale Alarm Strip Pulser U-400

Yu.Tsyganov v.01 - 1995

T = 0.360 ms
E = 9.063 MeV

NEC'97, VARNA + HPC ASIA'97 SEOUL, KOREA
IDEA OF METHOD

First in-beam test
1995-1997
"soft real-time mode"

time = 0.00160 s
position = 1.0 mm
E min = 0.8 MeV
E max = 7.0 MeV
any changes ? y/n

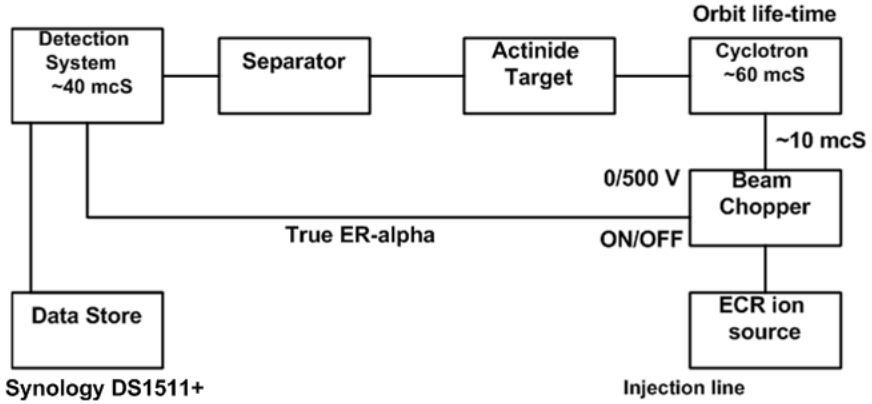
Test reaction Au+Ne→Ac+xn

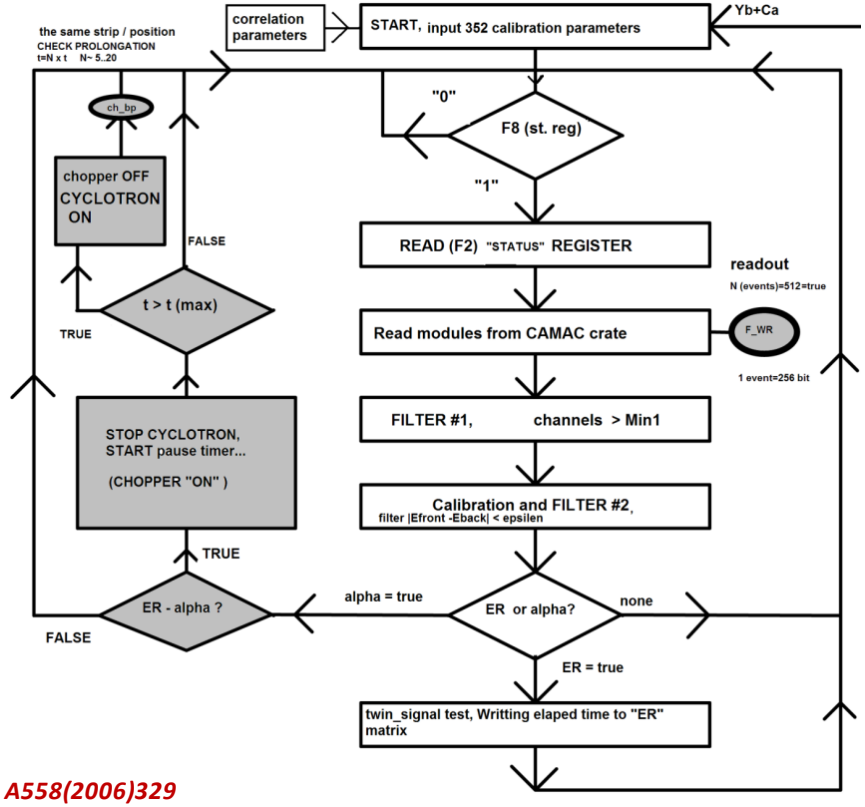
^{216}Ac

5 6 7 8 9 10 11 12 [MeV]

METHOD OF "ACTIVE CORRELATIONS"

//**New – 17** mcS (fifo internal memory 8 X2.5 μS)



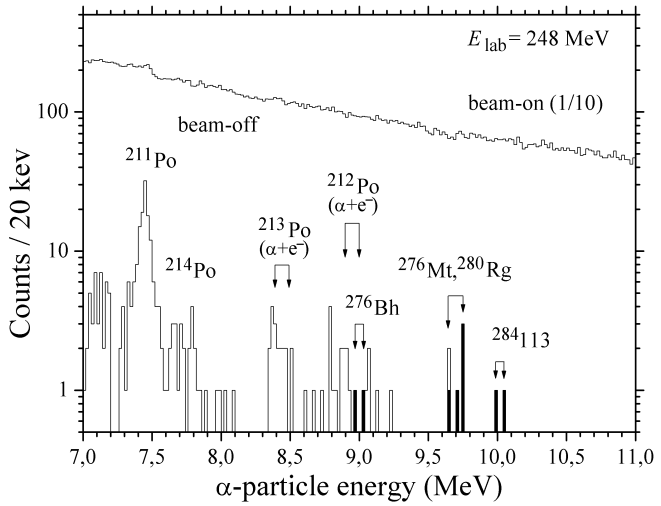


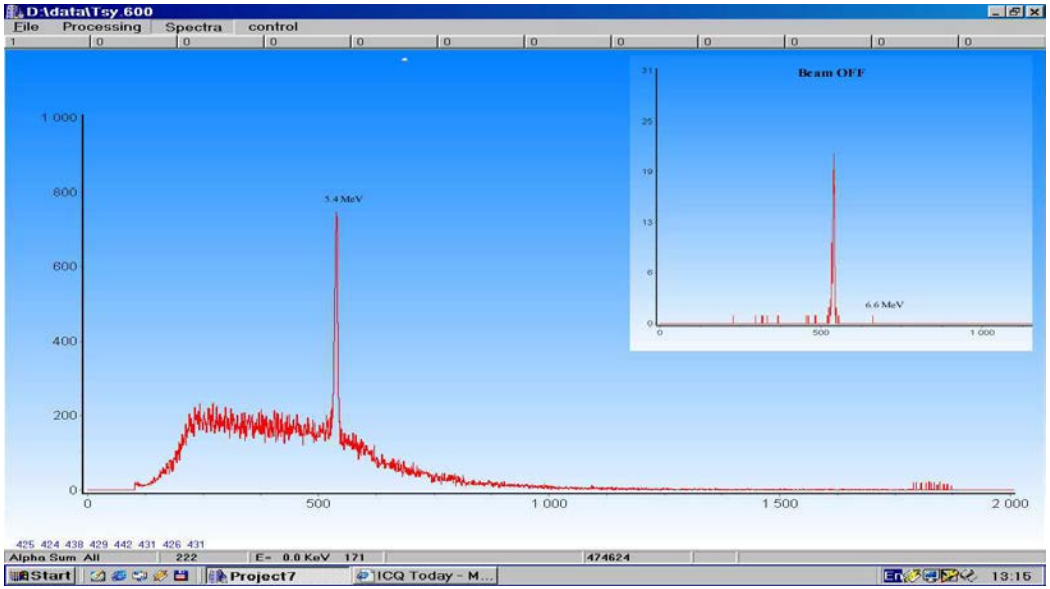
Time-energy-position correlation ER-alpha detected in a real-time mode
Provides beam stop for a short time. In the case of detecting next alpha decay signal in the same position "beam-off" interval is prolonged for a few times. Beam interrupting is performed at the position of injection line (~ 18 kV)

Yu.S.Tsyganov // J. Phys. G: Nucl. Part. Phys. 25(1999) 937-940

Yu.Tsyganov & A.Polyakov// Appl. Rad. &Isotopes v.47 No.4(1996)451-454

Moreover modern versions are: Yu.Tsyganov et al. NIM A525(2004)213; A513(2003)413; A558(2006)329



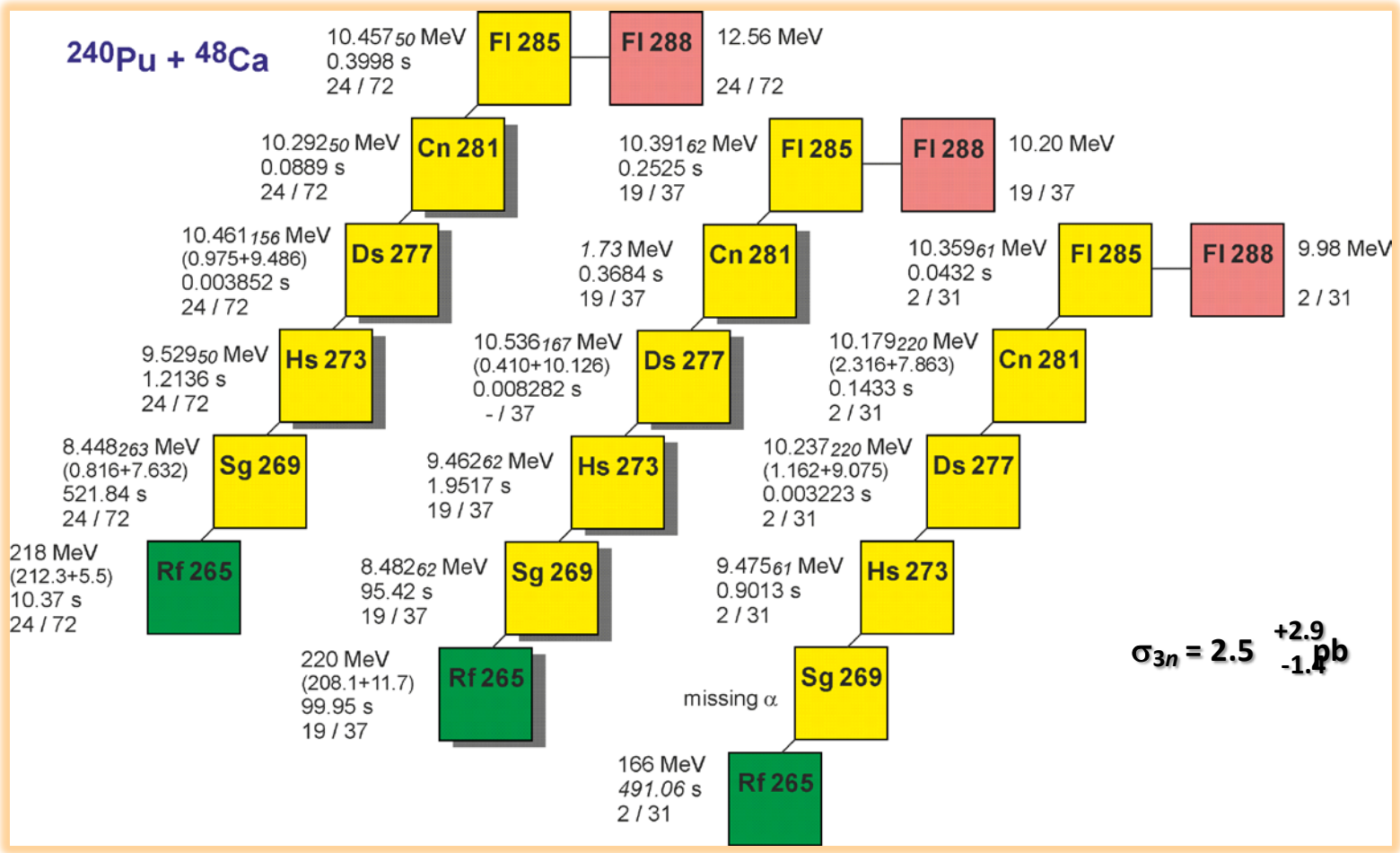


Example #1
2016-2017

Synthesis of neutron-deficient isotopes

$^{240}Pu+^{48}Ca$ reaction

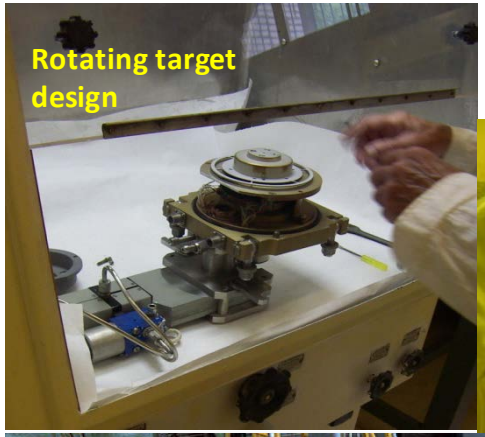
Target 0.49 mg/cm^2
Energy of ^{48}Ca 245 MeV
Excitation energy 36.5 – 41.1 MeV
Beam dose $4.0*10^{18}$

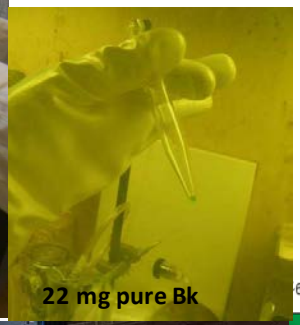


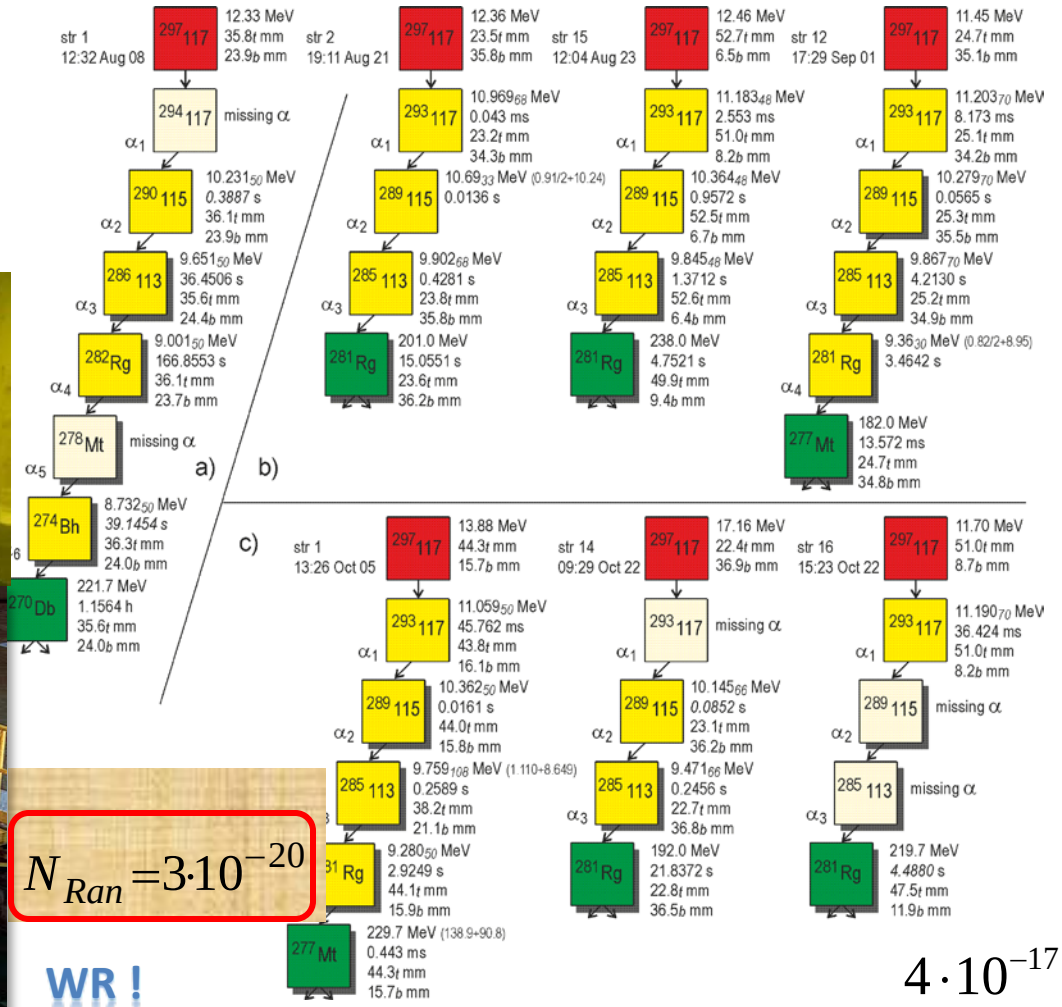
Example #2

$^{249}Bk+^{48}Ca \rightarrow Ts^*$

Isotopes ^{249}Bk and ^{249}Cf were produced in ORNL (USA)
By 250 days irradiation of targets Cm and Am
With thermal neutrons flow 2.5×10^{15} n/см²·с of HFIR reactor



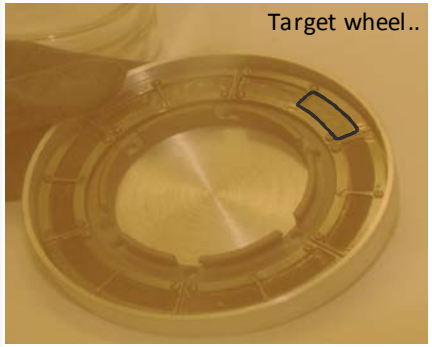




$N_{Ran} = 3 \cdot 10^{-20}$

WR !

$4 \cdot 10^{-17}$



Yu.Oganessian et al.
PRC 87, 054621(2013)

SHE-factory: High-current cyclotron DC280

High voltage injection system
(2 platforms)

DC280 (expected) E=4÷8 MeV/A		
Ion	Ion energy [MeV/A]	Output intensity
^{7}Li	4	1×10^{14}
^{18}O	8	1×10^{14}
^{40}Ar	5	6×10^{13}
^{48}Ca	5	$0,6\text{-}1,2\times10^{14}$
^{54}Cr	5	2×10^{13}
^{58}Fe	5	1×10^{13}
^{124}Sn	5	2×10^{12}
^{136}Xe	5	1×10^{14}
^{238}U	7	5×10^{10}

^{48}Ca, ^{50}Ti ~ 5-10 pμA

Main setups:

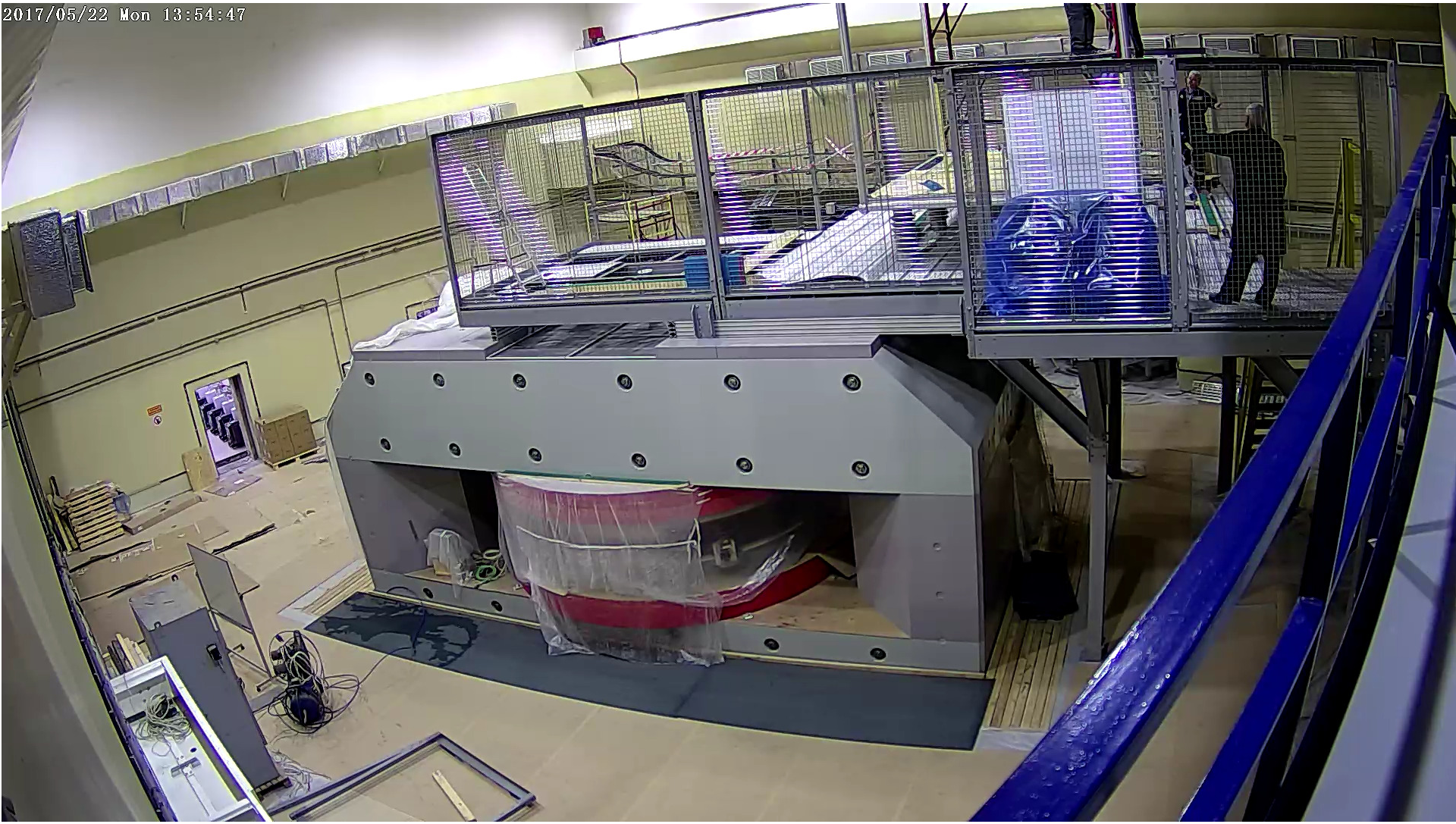
DGFRS (synthesis), GRS (chemistry), SHELS

Main tasks:

- ***Synthesis of SHE.***
- ***Properties and Spectroscopy of SHE;***
- ***Chemistry of SHE;***
- ***Searching for new reactions leading to SHE***

The main building of the SHE-Factory (May 2017)

The hall of DC-280 of the SHE-Factory



ADP-16 1M unit ("TekhInvest", free economy zone "Dubna")

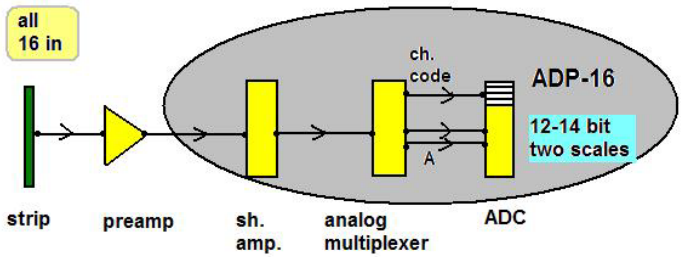
Basic improvements in a nearest future

1) *"TekhInvest" ADP-16 1M CAMAC+* high integration unit
   - 16 in from 16 out preamp
   - two scales (alpha + FF)
   - 8 x 2.5 µS hash internal memory (with time stamps),

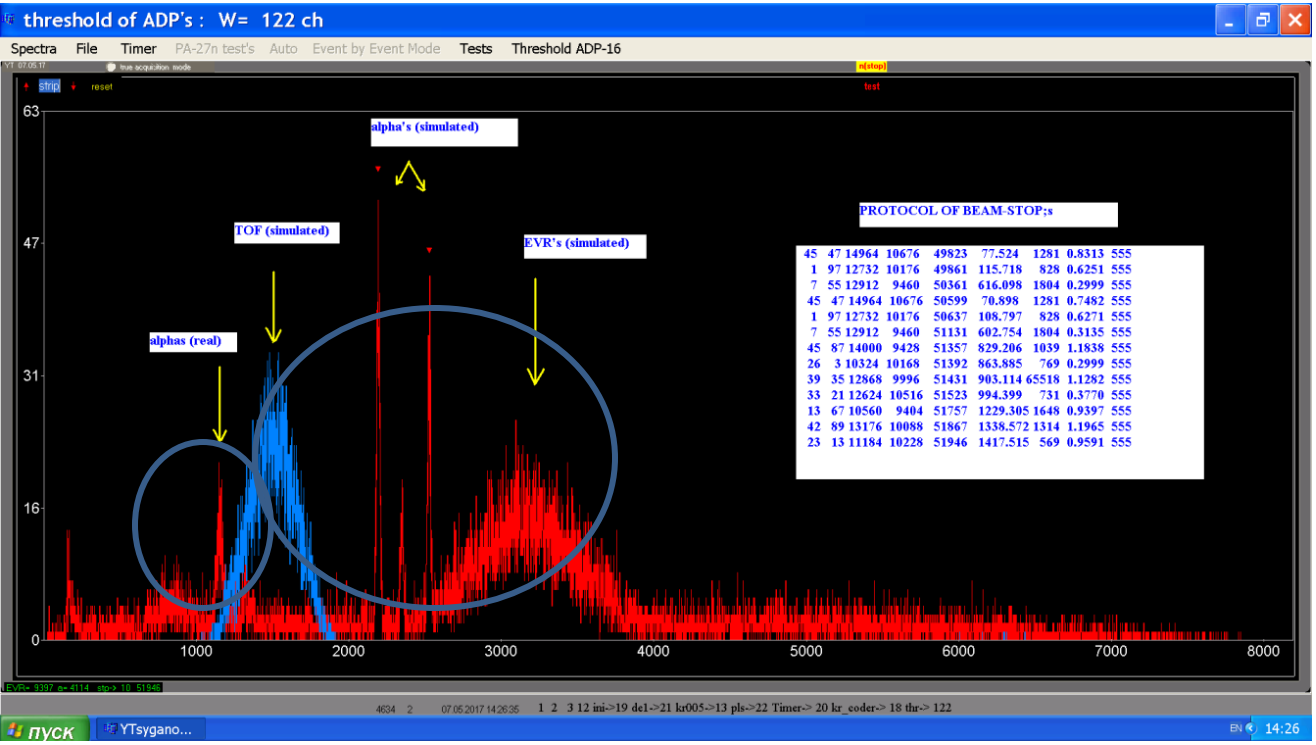
   i.e. sequence like 2.5-2.5-2.5-2.5-2.5-2.5-2.5-2.5 µS is detectable *(~15-17 µS regular dead time)*

2) More extended RT algorithms

3) First test at alpha particle source in 2017 April – June…



48(fr) +128(bc)+48(s) =224 div 16= 14 units



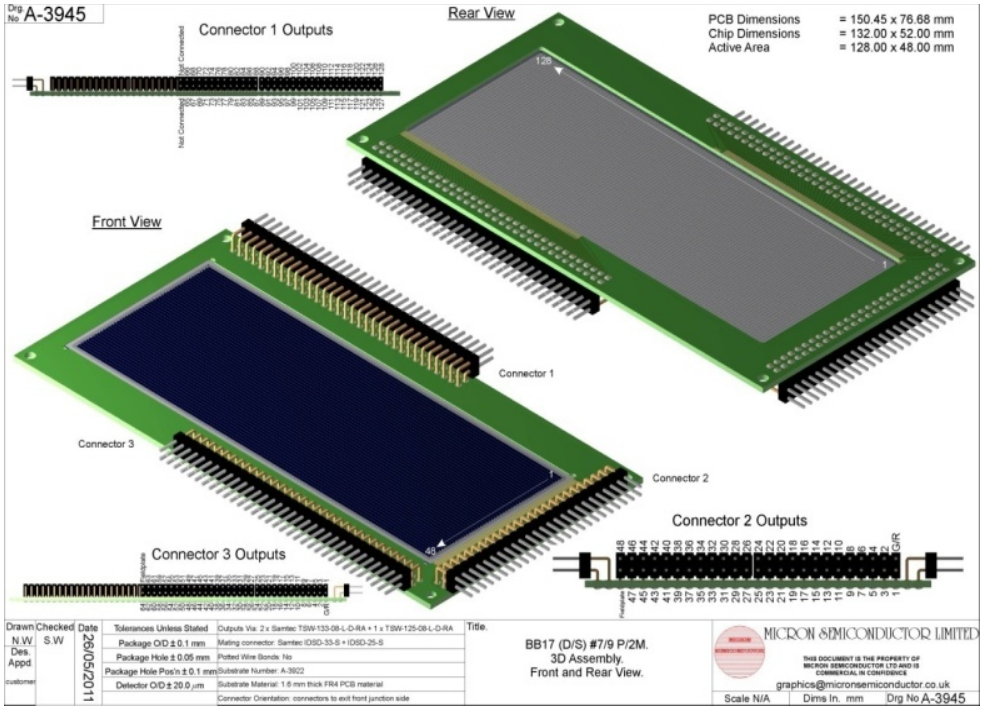
DSSSD Micron Semiconductors (UK) –ORNL (USA, TN) application

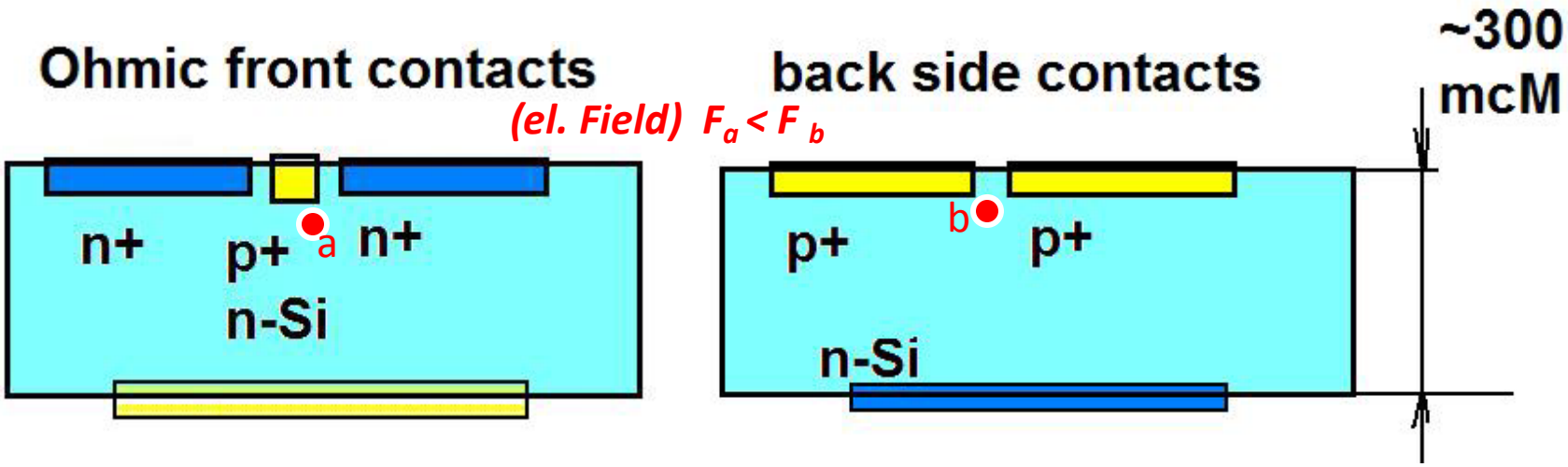
Main advantage – lover area of "elementary" cell (~1/10 83% cases !) and
(*significantly for the method of "AC"*) – practically ready ER matrix for use.

But… from p-n junction side (back) → edge effects between the neighbor strips
~10% (α 5.5 MeV, close to 2π geometry) 128 strips.

(*as to ohmic contact side*) edge effect is suppressed due to → **P+** separation guard layer
(*Dr. Susanne Welsh, Micron Scd's , UK// 2014. private comm. // ~ 0.1% ORNL*
Front side.

Yu.Tsyganov Lett. to ECHAYA 2015. v.12, no.1(192) 128-135, v.12 no.4 (195), pp.885-894
& Cybernetics and Physics 2014. No.3 . Pp.85-90

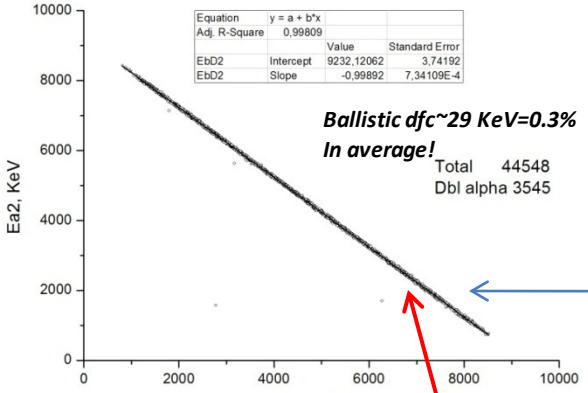




~0.1% sharing ←*As a result* → ~10% α-source 5.5 MeV ; close to 2π geometry

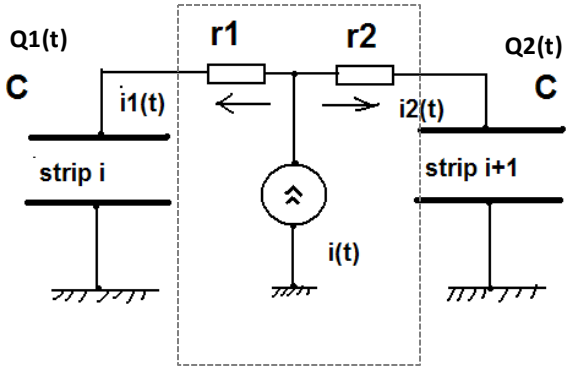
Neighbor strips edge effect (from p-n side)

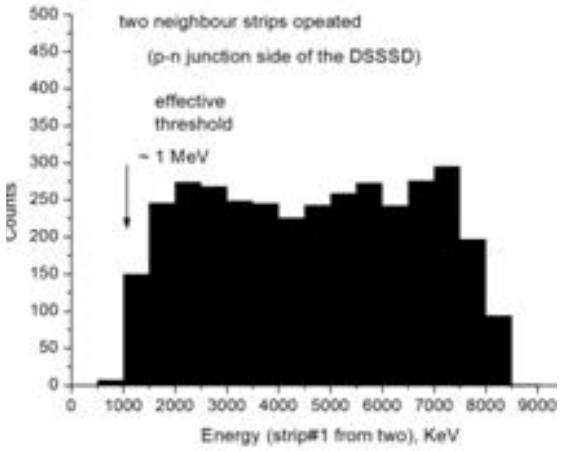
Extracted via ER-alpha



p-n junction side

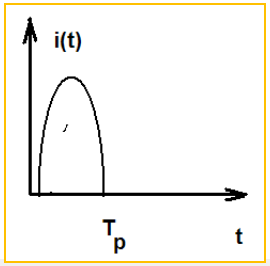
interstrip gap





$$i(t) = i_1(t) + i_2(t)$$

$$\frac{Q_1(t)}{C} + i_1(t)\cdot r_1 = \frac{Q_2(t)}{C} + i_2(t)\cdot r_2$$

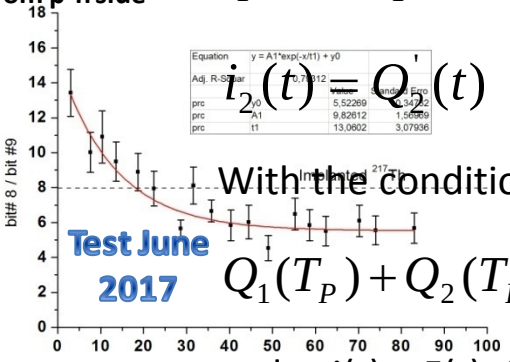


! Of course: $r_{1,2} = f(V)$

% of double signals From p-n side

$$i_1(t) = Q_1'(t)$$

$$i_2(t) = Q_2'(t)$$



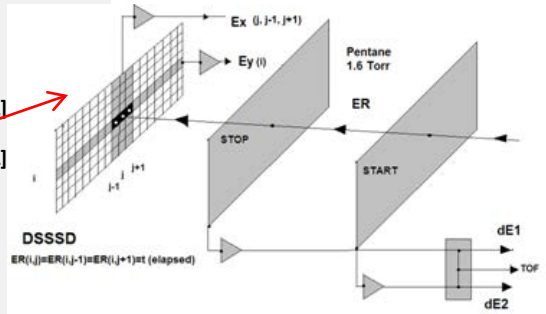
With the conditions:

$$Q_1(T_P) + Q_2(T_P) = Q_0$$

and: i(t) = F(t), 0<t <T_P.

Test for distance alpha source

```
State register (positional code, test)powers of 2 – single signal

if (strip>=0 &&strip< 48) energy = (aa[strip]*float(wa)) +bb[strip];
if (strip_1 >=0 && strip_1 < 128) enb1=EAB1[strip_1]*float(wab) +EAB0[strip_1];

if (strip_2 >=0 && strip_2 < 128) enb2=EAB1[strip_2]*float(wab) +EAB0[strip_2]
enb = enb1+enb2+ballistic_dfc;

// ---------- начинаем фильтровать begin filtering ----------
EVR=false; ALFA=false;

if (tof > TOF_MIN && tof < TOF_MAX && energy > ER_MIN && energy <=ER_MAX ) EVR
= true;
if (tof==0 && energy > MINALFA && energy < EA_MAX) ALFA= true;

if (fabs(energy-enb) > D_ENERGY)      ALFA=false;
```



C++ program fragment

Another

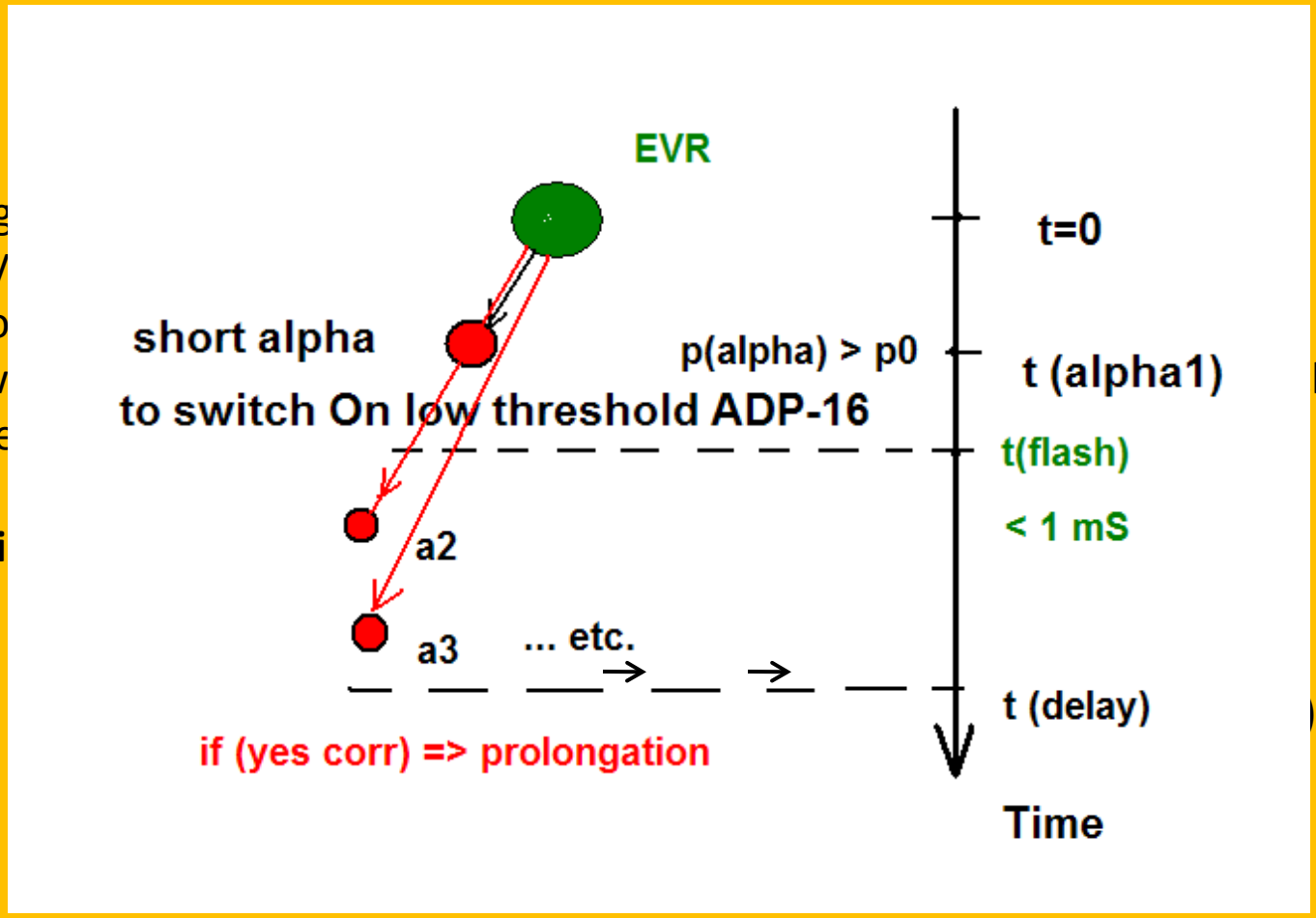
If very short time (roug
As a first step single EV
Then, if in the same po
prorogated up to a few
is detected in the same

**! (significant) for the ti
milliseconds..**

Using specific feature

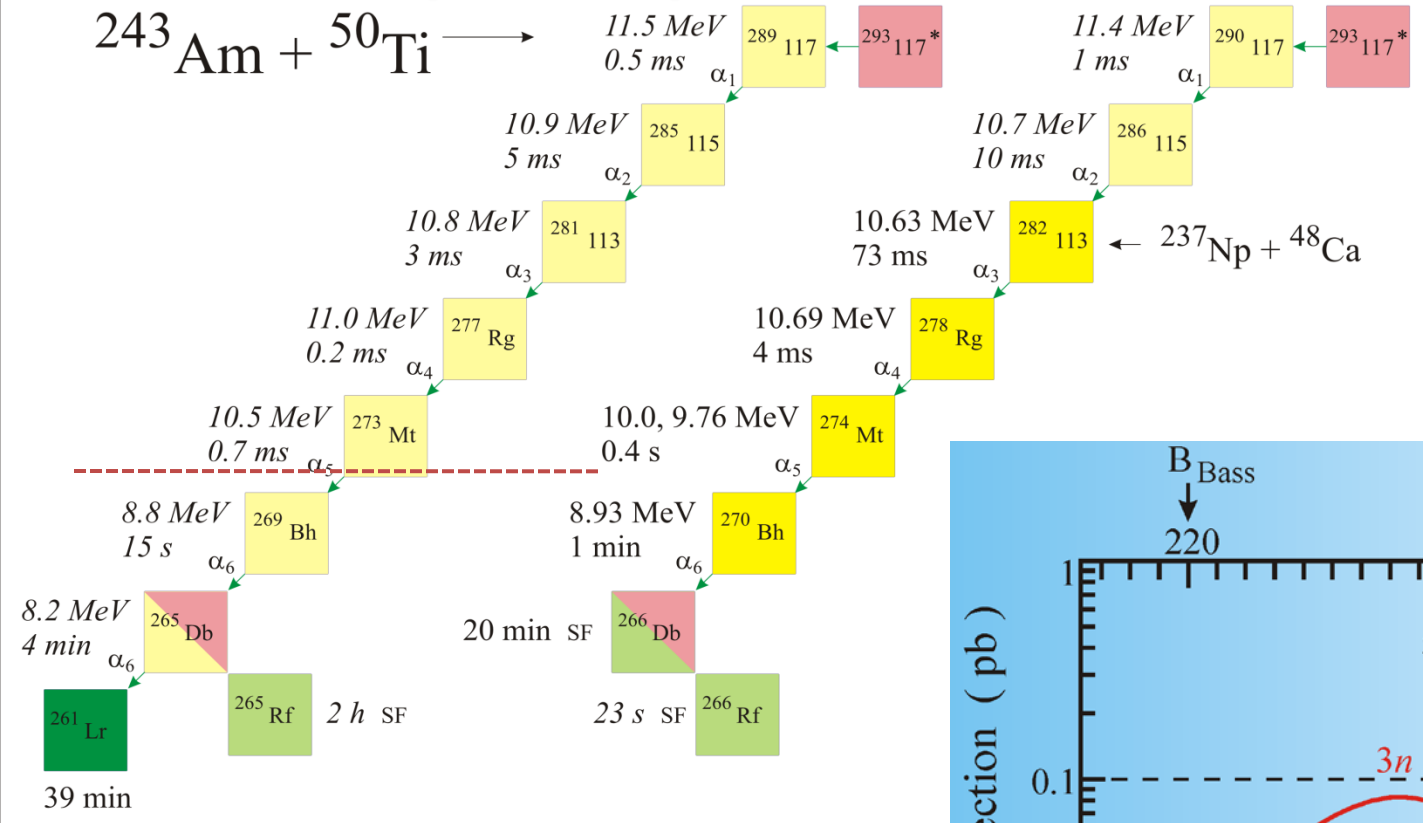
```
  Class tim
{
 public:
 float t_evr; // recoil elapsed time
 float t_a1;
 float t_a2;
} ;
```

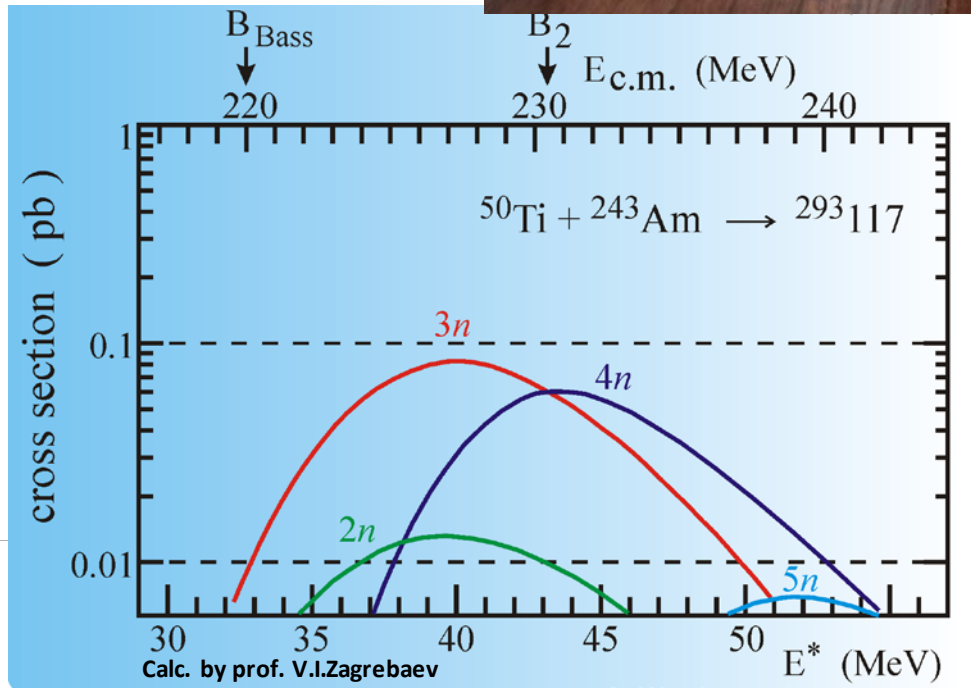
tim event_matrix [48][128] ;



Example : α_1 and α_2 both shot time (calculation/prediction)

Estimated by V.K.Utyonkov





To apply more flexible scenario, except for piecewise smooth assignment for Δt_{corr}

So, if we have any correlation sequence: it should be p_{ERR} (this sequence) < ε, 1/s

Eg.: *EVR – α_1- α_2* as a triggering sequence to switch a beam off.
For instance: ***K-H. Schmidt LDSC*** simplified formula (**n=3**) ref. ***Z. Phys. A 316 (1984) 25. // formula (21)*** :

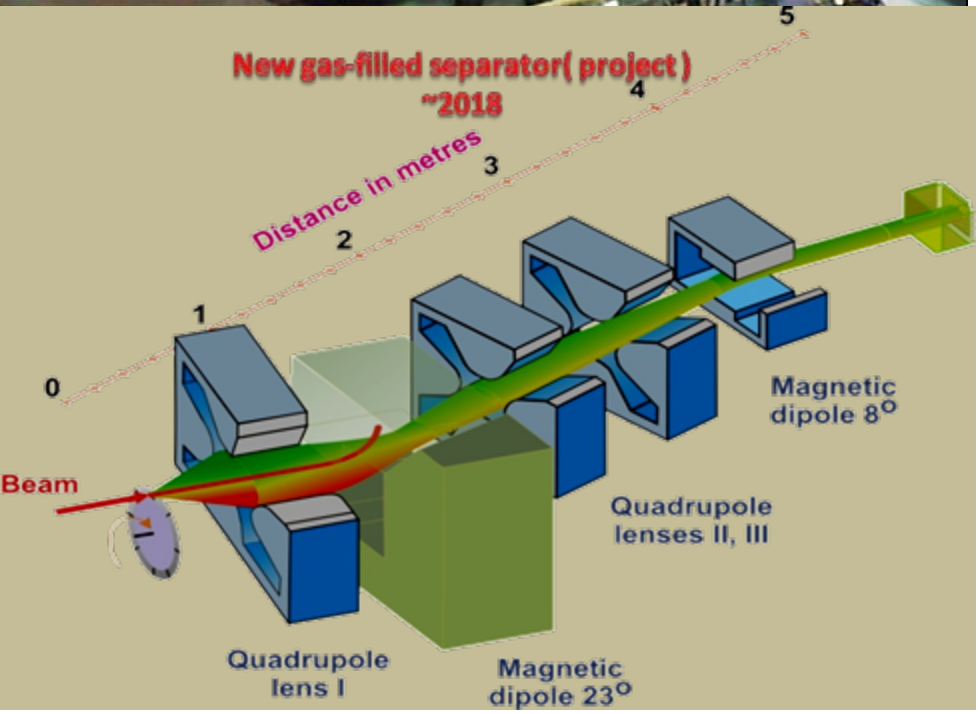
$$P_{ERR} \approx T \cdot \lambda_{EVR} \cdot \lambda_{\alpha 1} \cdot \lambda_{\alpha 2} \cdot \Delta t_{EVR,1} \cdot \Delta t_{EVR,2}$$

$$p_{ERR} \approx \lambda_{EVR} \cdot \lambda_{\alpha 1} \cdot \lambda_{\alpha 2} \cdot \Delta t_{EVR,1} \cdot \Delta t_{EVR,2}, s^{-1}$$

Parameter ε can be chosen according to acceptable value of the whole experiment efficiency losses not only for a given "pixel", but for all DSSSD.

Usually : units of percents

(another): V.B.Zlokazov's BSC method can be used..



SUMMARY:

MMCP'2017, LIT, Dubna

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1) Since beginning of the millennium six new superheavy elements and more than 50 new isotopes of the heaviest elements were synthesized for the first time at our Laboratory employing one and only experimental setup -- the Dubna Gas-filled Recoil Separator.

2) It was namely method of active correlations which allowed to detect decays of superheavy nuclei in fact in background free mode

3) "AC" method is extended for DSSSD. First experiment $^{240}Pu+^{48}Ca \rightarrow {}^{*}Fl$ is successfully finished。

4) Prototype of new GFS (DC-280 project) smart detection system (incl. software) is designed and successfully tested at U-400 main FLNR cyclotron HI beam and alpha particle source

5) New FLNR DC-280 ultra intense cyclotron will put into operation in 2018 and requirement for a new RT algorithm for backgrounds suppression development will be very actual


THANK YOU
FOR YOUR
ATTENTION!
Nearest future plans ~ 1st December 2017 : 244Pu + 50Ti → Lv*
→ if it will be 1 event or even more(!)
in month or two→ then Cf+Ti→120* for a few months..
If null effect → till new separator will put into operation at DC-280 su
FLNR cyclotron…Taking into account: -TASCA - cr sections -rot. tar
=
It is not a problem "how to obtain"
(high intensity beam, but, it is the problem " how to apply"!
→ step by step as a reasonable scenario.
Flerov Laboratory of Nuclear Reactions, JINR, Dubna