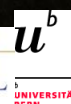


# Superheavy Element Research at the Gas-filled Separator TASCA

**Alexander Yakushev**  
**(GSI Helmholtzzentrum für Schwerionenforschung GmbH)**  
**for TASCA collaboration**



# Outline

- Introduction: TASCAs – a gas-filled recoil separator for SHE research
- Status 2009: synthesis and chemical study of element 114, flerovium
- TASCAs research areas
- Recent technical developments at TASCAs
- Main goal for 2011 and 2012: search for new elements with Ti-50 beam
- Preliminary results of search for E120 and E119
- Verification of TASCAs capability: synthesis of E117 and spectroscopy studies of E115



# TransActinide Separator and Chemistry Apparatus – a Separator for Actinide Based Reactions

# TASCA

[www.gsi.de/tasca](http://www.gsi.de/tasca)



**GSII**

M. Schädel, Eur. Phys. J. D 45 (2007) 67

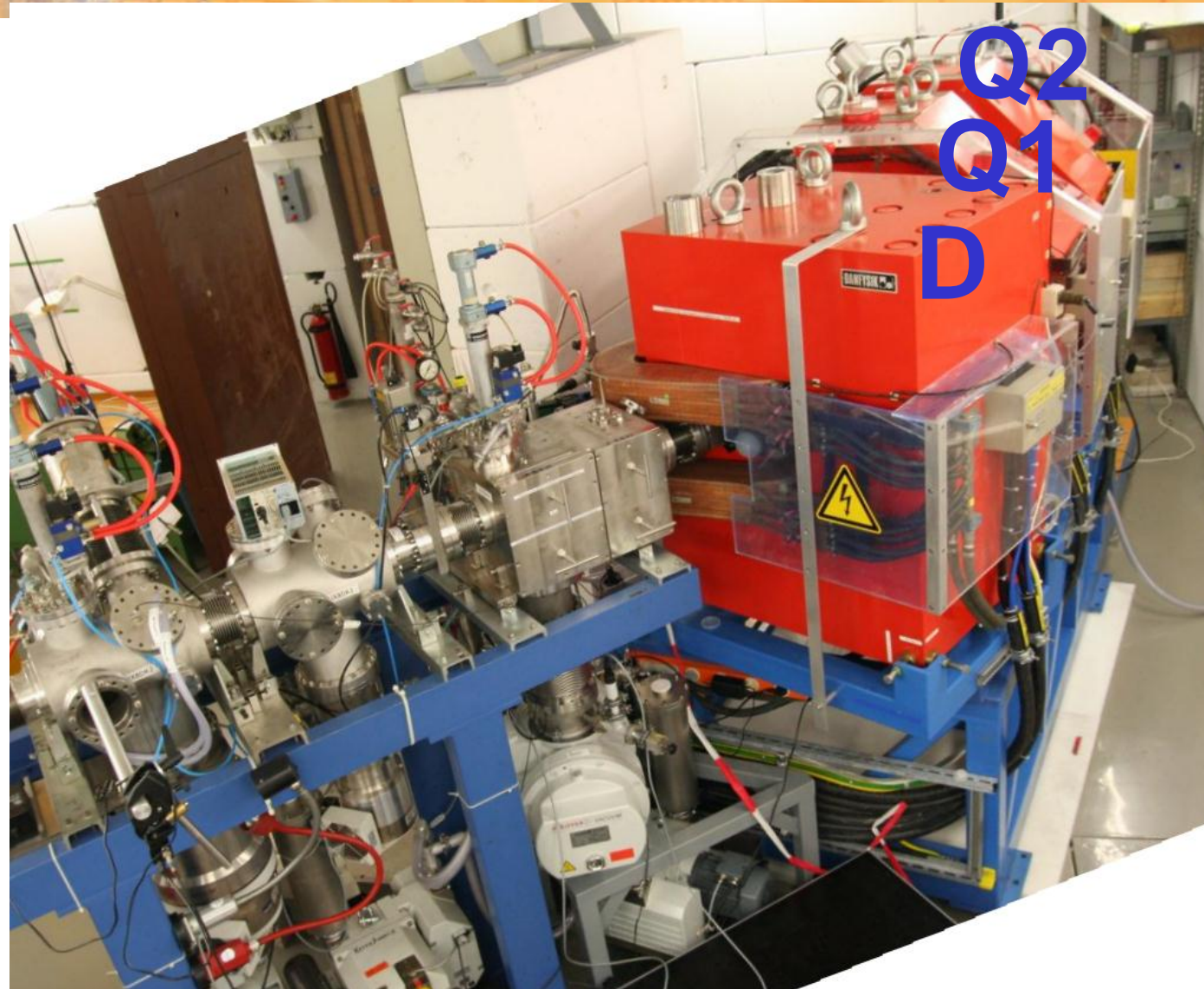
A. Semchenkov et al., NIMB 266 (2008) 4153

## Timeline

- 2002 goals defined
- 2003 community formed
- 2004 decision: gas-filled sep.
- 2005 start building TASCA  
definition of commissioning prog.
- 2006 (Jan.) first beam in cave (Apr.)  
first EVR measurements in FPD
- 2006-2008 TASCA commissioning
- 2008 The SHE region is reached!
- 2009 From ~nb ( $Z=104$ ) to ~pb ( $Z=114$ ) cross section
- 2011-2012 Search for new elements with  $^{50}\text{Ti}$

**GSII**

TASCA is a separator for SHE  
from asymmetric reactions...



$DQ_h Q_v$

**HTM - High  
Transmission  
Mode**

$DQ_v Q_h$

**SIM – Small  
Image Mode**

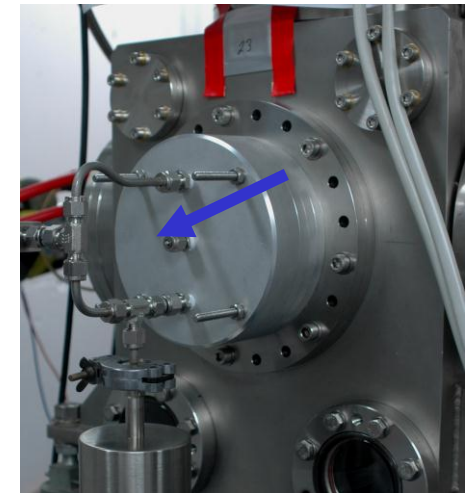
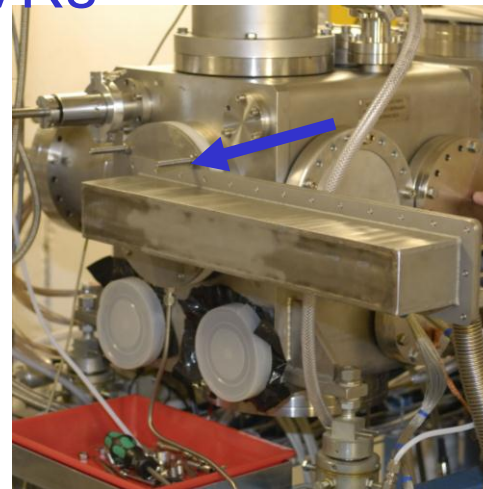


# ...and a preseparator for SHE chemistry

☺TASCA deflects the primary beam and suppresses background from transfer reaction products

☺Transmitted through a window EVRs are stopped in a gas and transported to a chemical or detection device

Next talk by Dr. J. Even



# Current International Collaboration Partners

(SHE Chemistry / TASCA)



LBNL/UCB Berkeley (USA)

LLNL Livermore (USA)

Vanderbilt U (USA)

ORNL Oak Ridge (USA)

UNAL Bogota (Columbia)

U Liverpool (UK)

U Surrey (UK)

U Lund (Sweden)

U Jyväskylä (Finland)

U Oslo (Norway)

Chalmers U Gothenburg (Sweden)

PSI Villigen (Switzerland)

ITE Warschau (Poland)

SINP Kolkata (India)

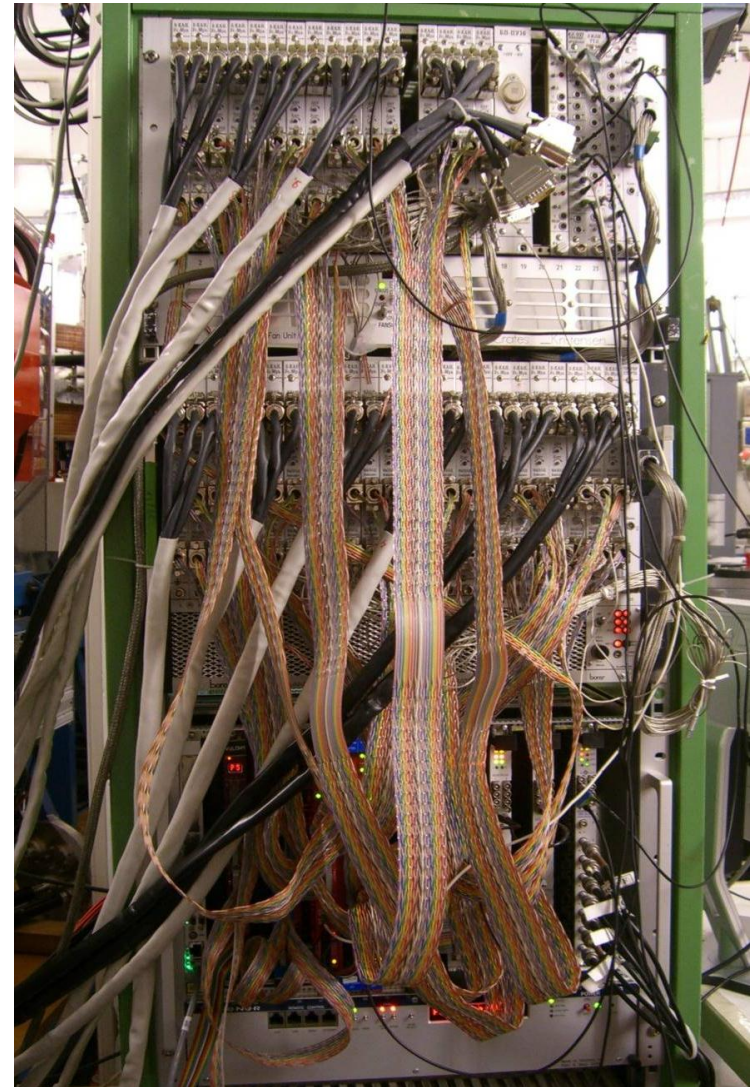
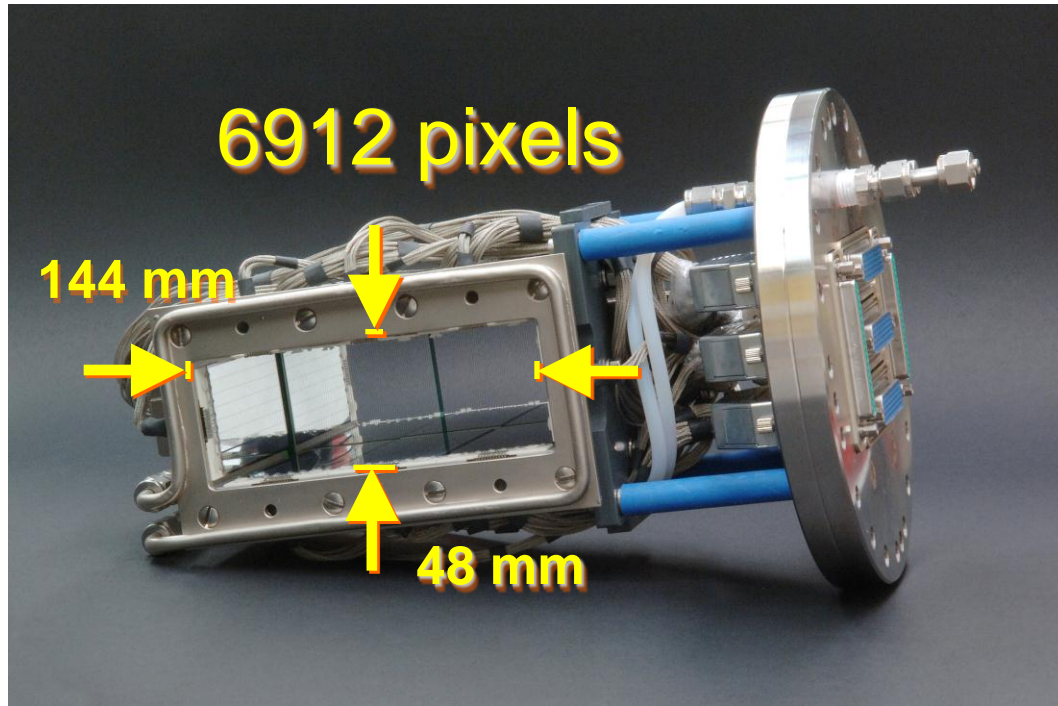
IMP Lanzhou (China)

JAEA Tokai (Japan)



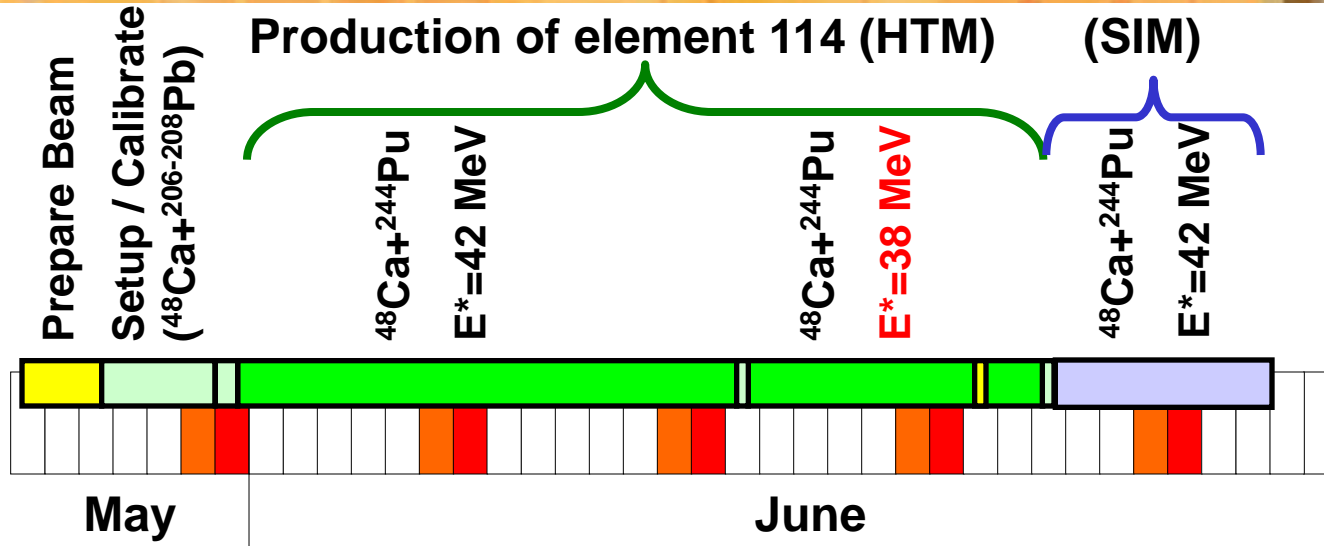


# 2009: new focal plane detector and DAQ



Stop detector: 144 “X” strips and 2x48 “Y” strips  
Backward array: 72 mm deep, 8x 8 strips  
Punch through: 2x 8 strips  
In total: 320 signals from silicon  
40x 8-ch. amplifiers with multiplexers  
80 ADC channels + 4 32-ch. I/O registers

# 2009: Synthesis of $^{288,289}114$ at TASCA



Beam preparation	3 days
Setup / Calibration	5 days
<b>Element 114 Experiment</b>	<b>29 days</b>
<b>Total</b>	<b>30 days</b>

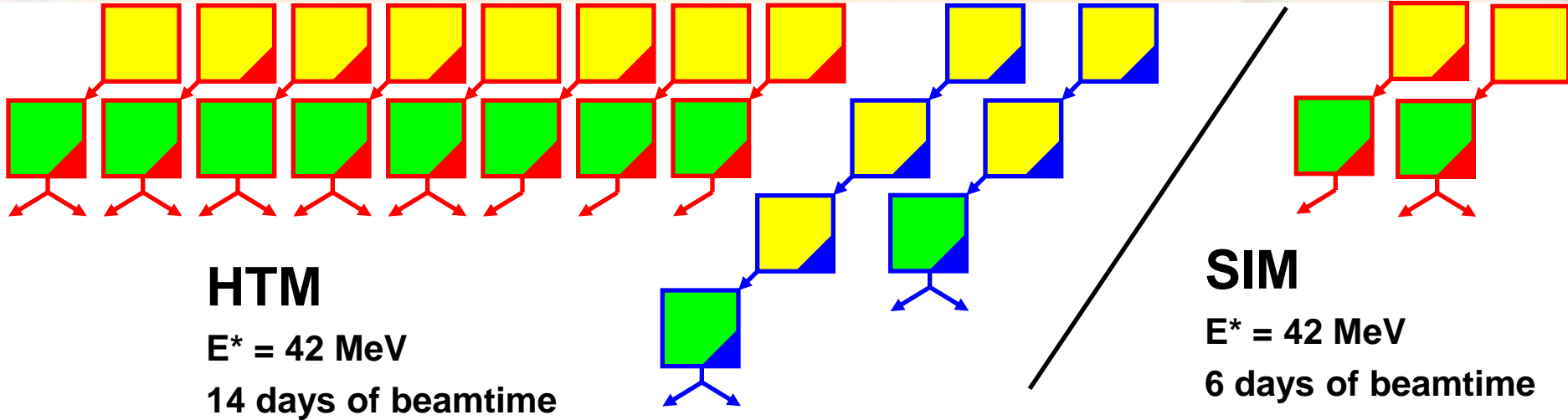


# Observed decay chains

8 x  $^{288}\text{114}$  (4n)

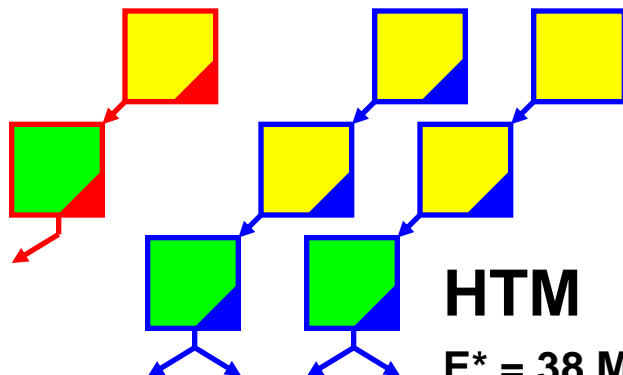
2 x  $^{289}\text{114}$  (3n)

2 x  $^{288}\text{114}$  (4n)



1 chains from  $^{288}\text{114}$  (4n)

2 chains from  $^{289}\text{114}$  (3n)

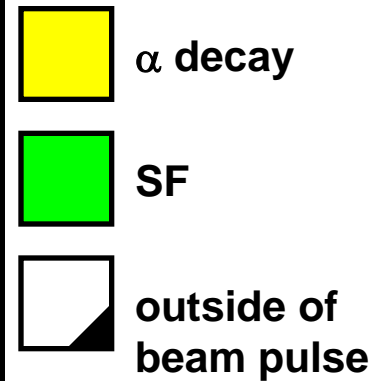


Summary:

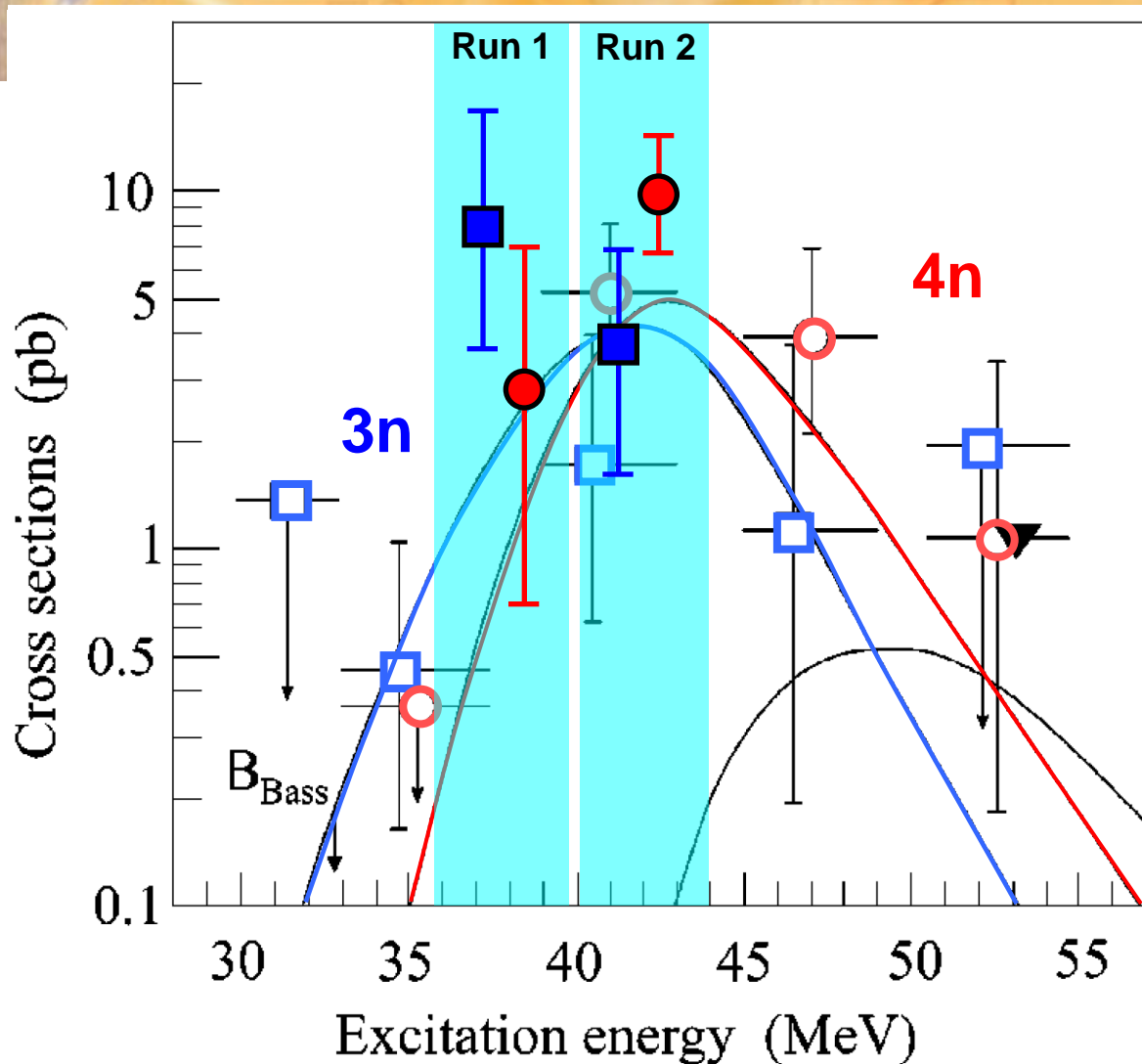
11x  $^{288}\text{114}$

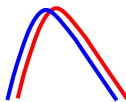
4x  $^{289}\text{114}$

**HTM TASCA:**  
 $\epsilon_{E114} = (60 \pm 6)\%$



# Measured cross sections



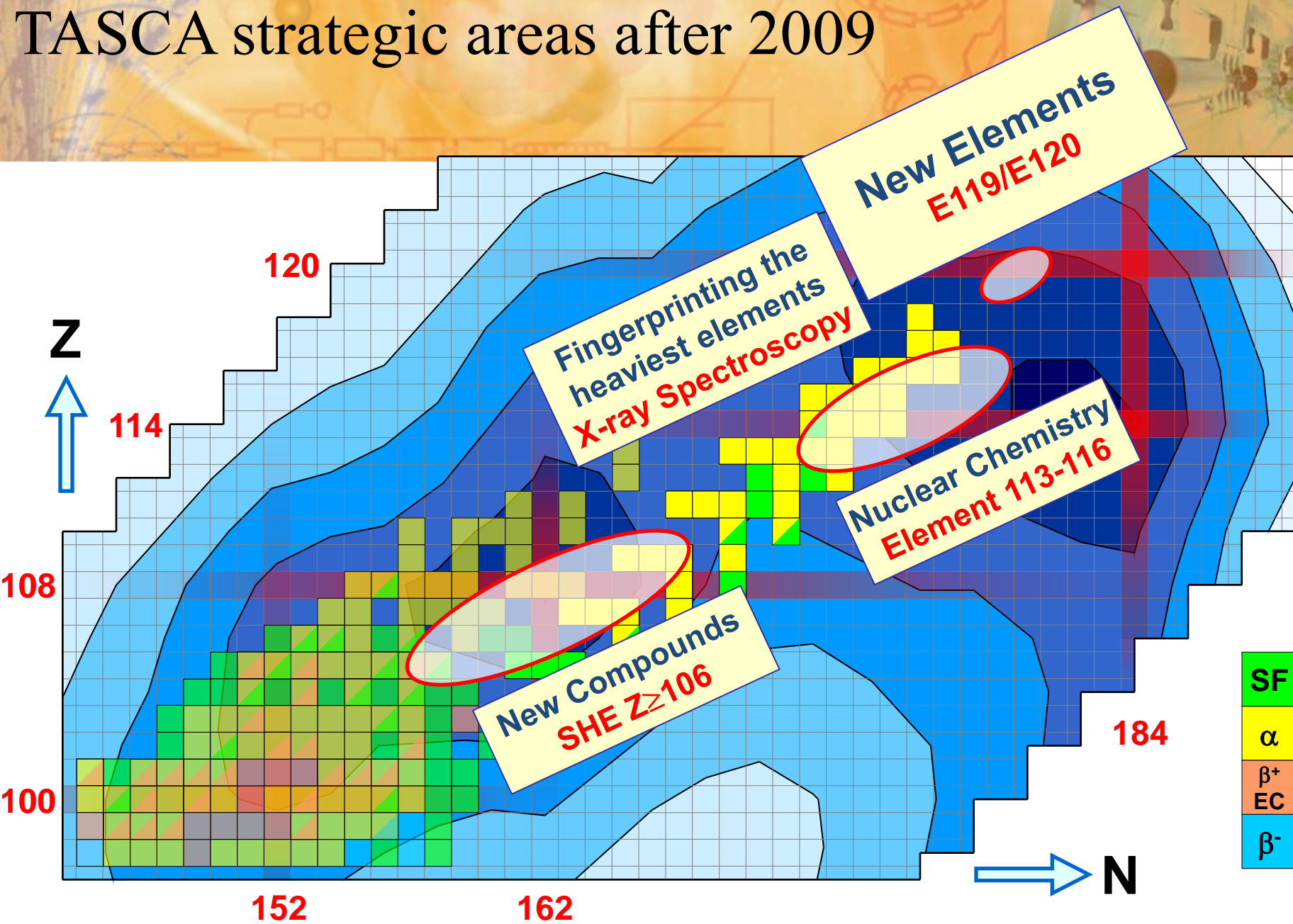
- □ **Dubna Data**  
Oganessian *et al.*,  
J. Phys. G, 2008
- ■ **TASCA HTM**  
 $\varepsilon(E114): (60 \pm 6)\%$   
Ch.E. Düllmann *et al.*,  
PRL 104 (2010) 252701
-  **Theory**  
V. Zagrebaev,  
NPA 734 (2004) 164

**10 pb! Largest  $\sigma$   
for predicted  
spherical SHE**

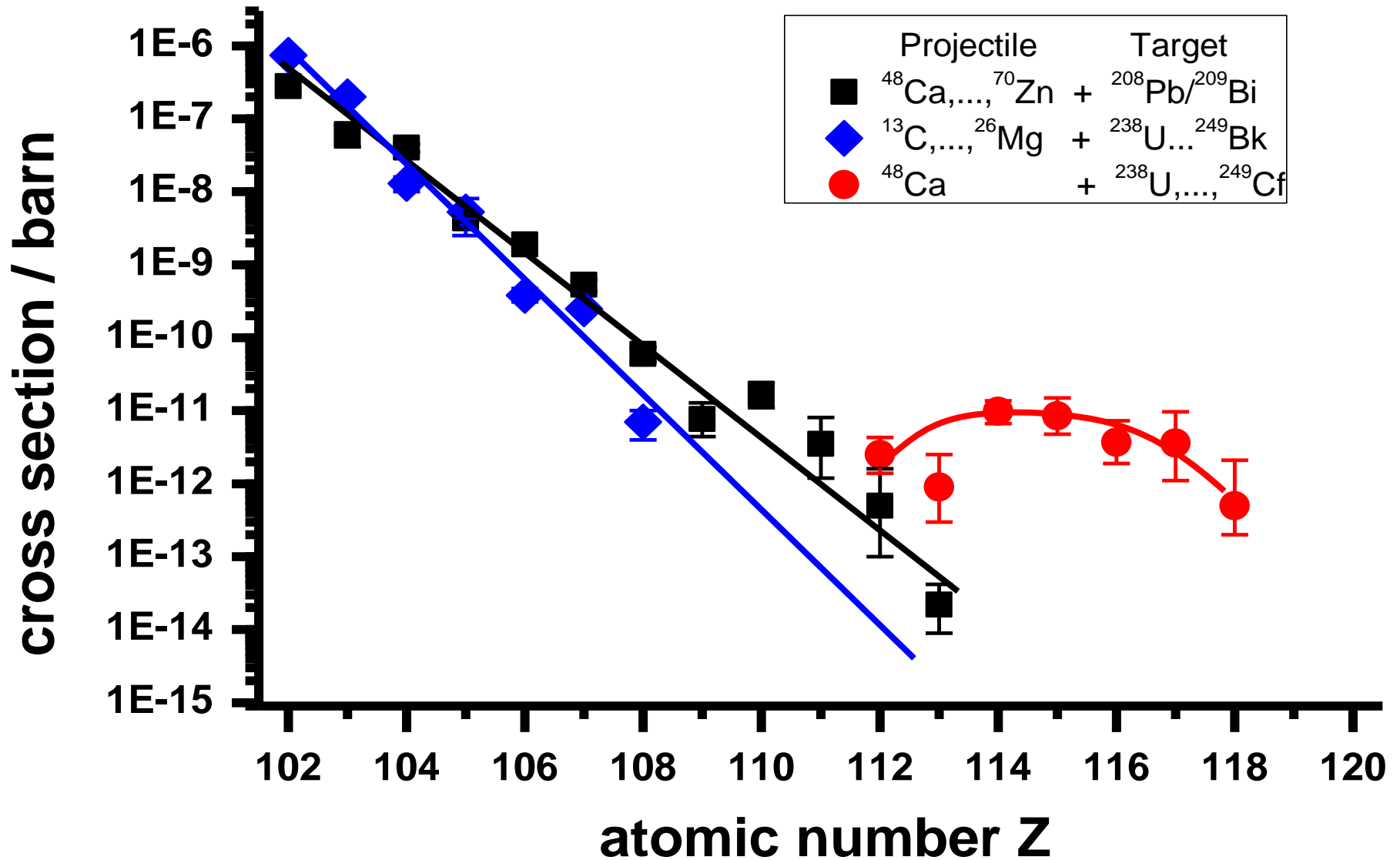
TASCA systematic error is estimated to 14%.



# TASCA strategic areas after 2009

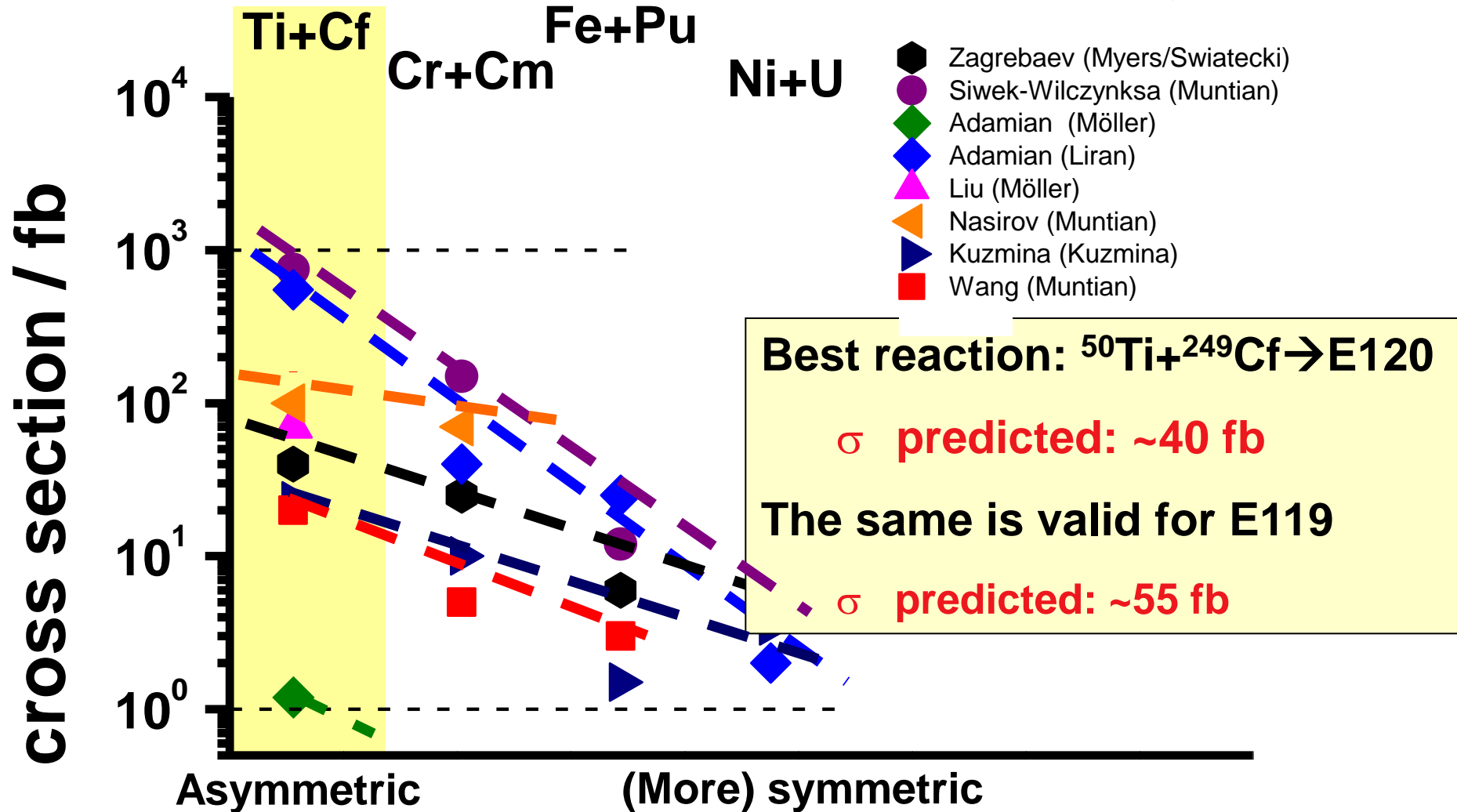


# Cross Sections in Hot / Cold / $^{48}\text{Ca}$ Induced Fusion Reactions





# E120 cross sections: current predictions from theory

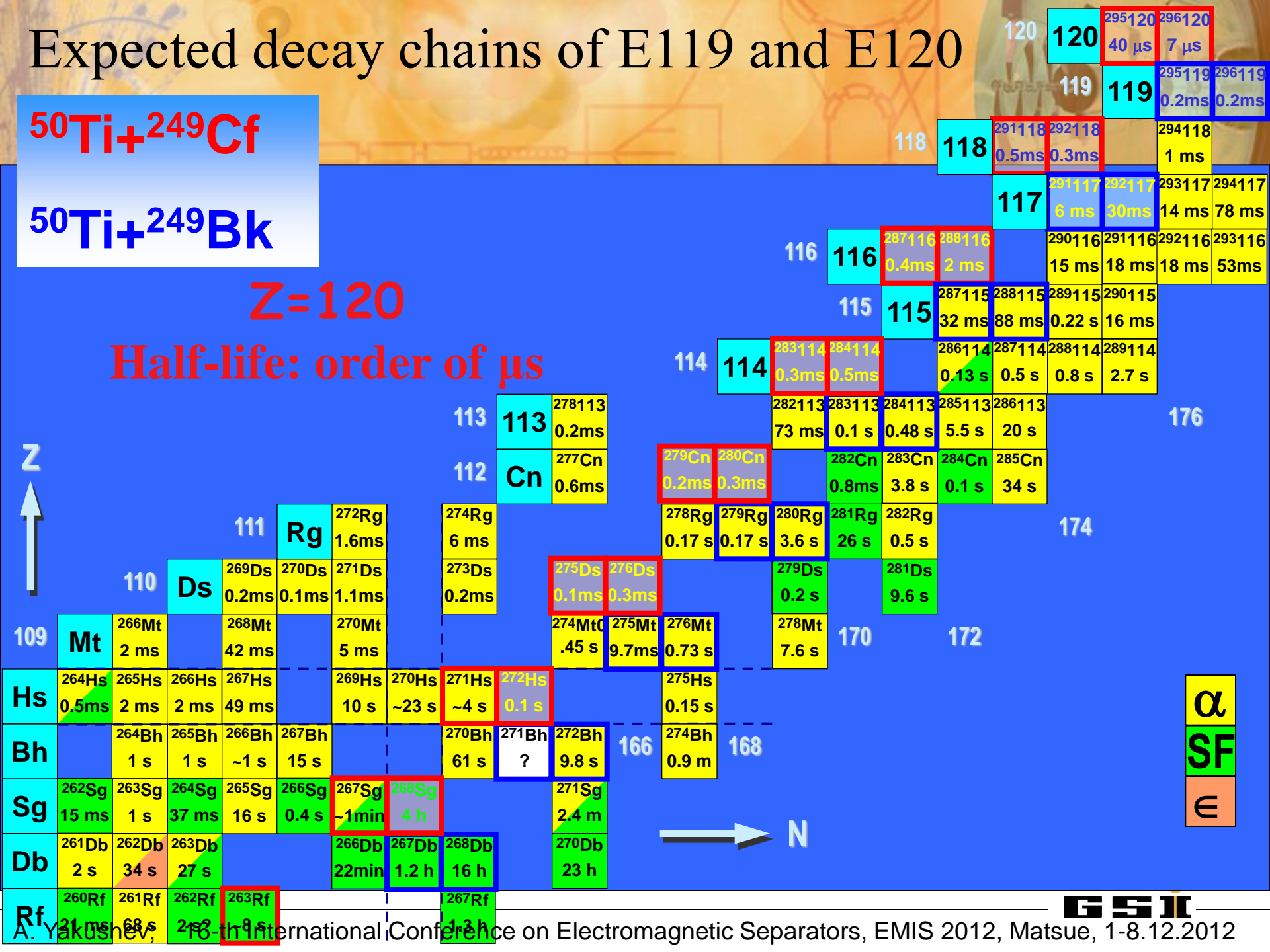


# Expected decay chains of E119 and E120

$50\text{Ti} + {}^{249}\text{Cf}$   
 $50\text{Ti} + {}^{249}\text{Bk}$

**Z=120**

**Half-life: order of  $\mu\text{s}$**

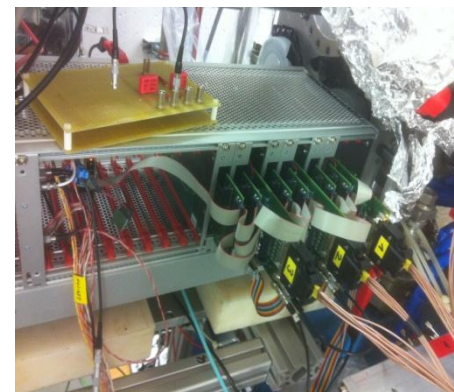
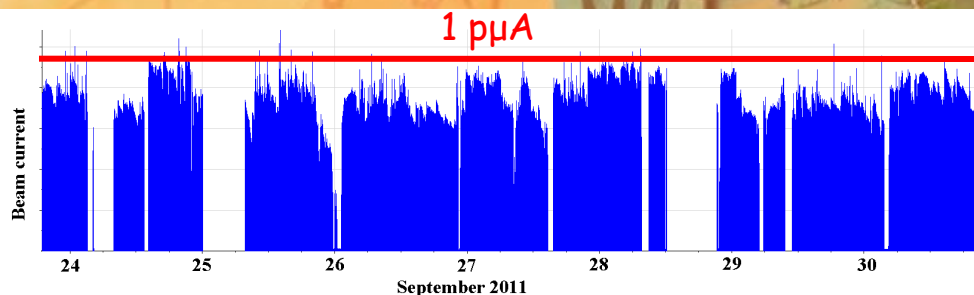


**GSI**



# Experimental challenges

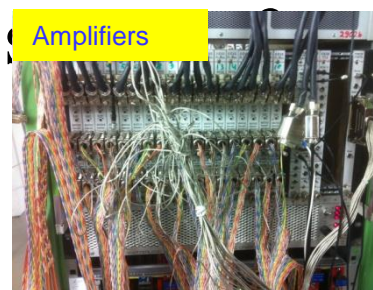
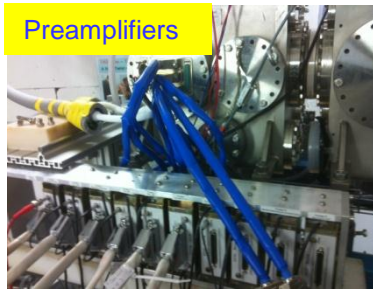
- ✓ 1) Stable and reliable  $^{50}\text{Ti}$  beam  
Ion source + UNILAC groups, Target lab  
GSI + HIM
- ✓ 2) New target wheel for high  
intensity beam  
TASCA, GSI experimental electronics
- ✓ 3) Production of  $^{249}\text{Cf}$  and  $^{249}\text{Bk}$  targets  
LBNL, Berkeley; ORNL Oak Ridge; Inst. f.  
Kernchemie, Uni Mainz; GSI target lab
- ✓ 4) New „fast“ electronics for  $\mu\text{s}$ -activities  
GSI experimental electronics, Univ. Lund, Sweden, HIM
- ✓ 5) Improved background suppression of **TASCA**  
TASCA, GSI and LBNL, Berkeley, USA



J. Khuyagbaatar, 2012

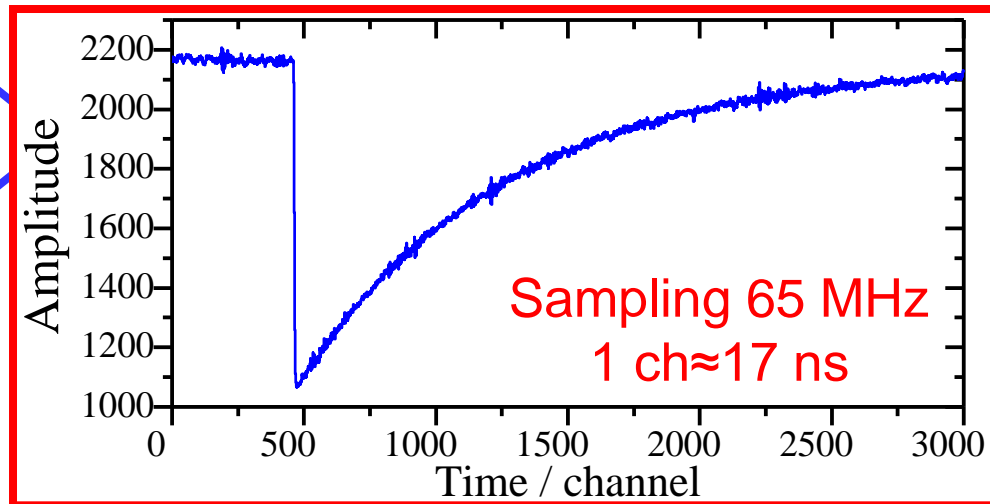
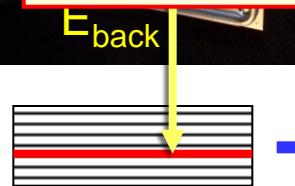


# A new Analog/Digital (AN<sub>D</sub>I) DAQ



ADC

**Dead-time free!**  
**Lifetimes down to about 100 ns**  
**can be measured**

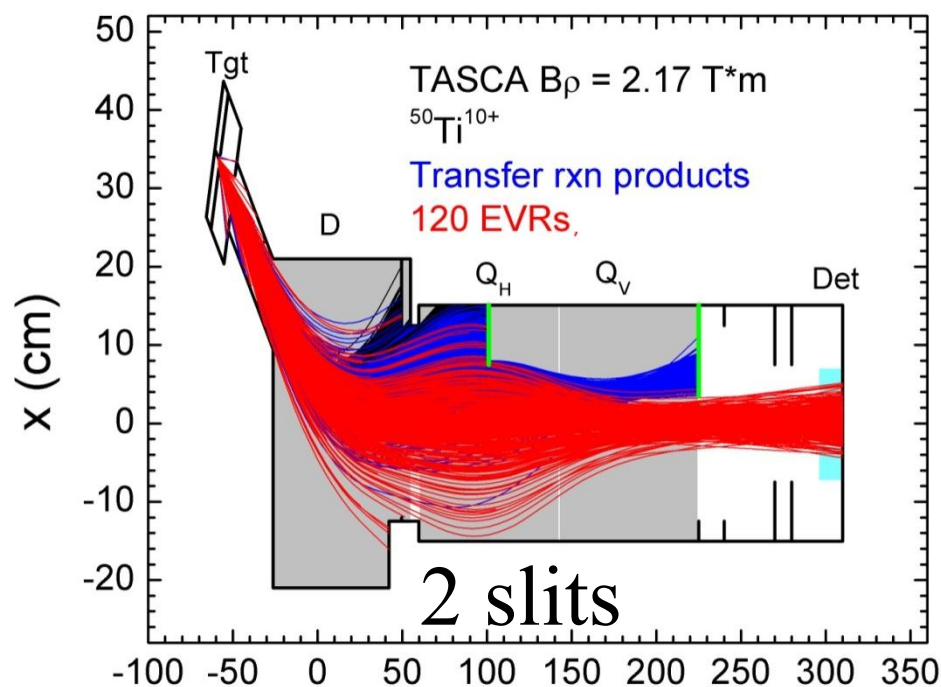


Event Builder



J. Khuyagbaatar, 2012

# Background reduction



J.M. Gates, 2010

Efficiency loss for EVRs minimal, as confirmed in  $^{48}\text{Ca}+^{208}\text{Pb}$

## Improvement compared to E114 run:

Event rate in FPD at  
 $B\rho=2.28 \text{ T}\cdot\text{m}$  (E114 value)

**E114**

312 pA  $^{48}\text{Ca}$

438  $\mu\text{g}/\text{cm}^2$   $^{244}\text{Pu}$

Rate: 1230 Hz

per 100 pA / 0.5  $\text{mg}/\text{cm}^2$

450 Hz

**E120**

750 pA  $^{50}\text{Ti}$

$\sim 500 \mu\text{g}/\text{cm}^2$   $^{249}\text{Cf}$

Rate: 300 Hz

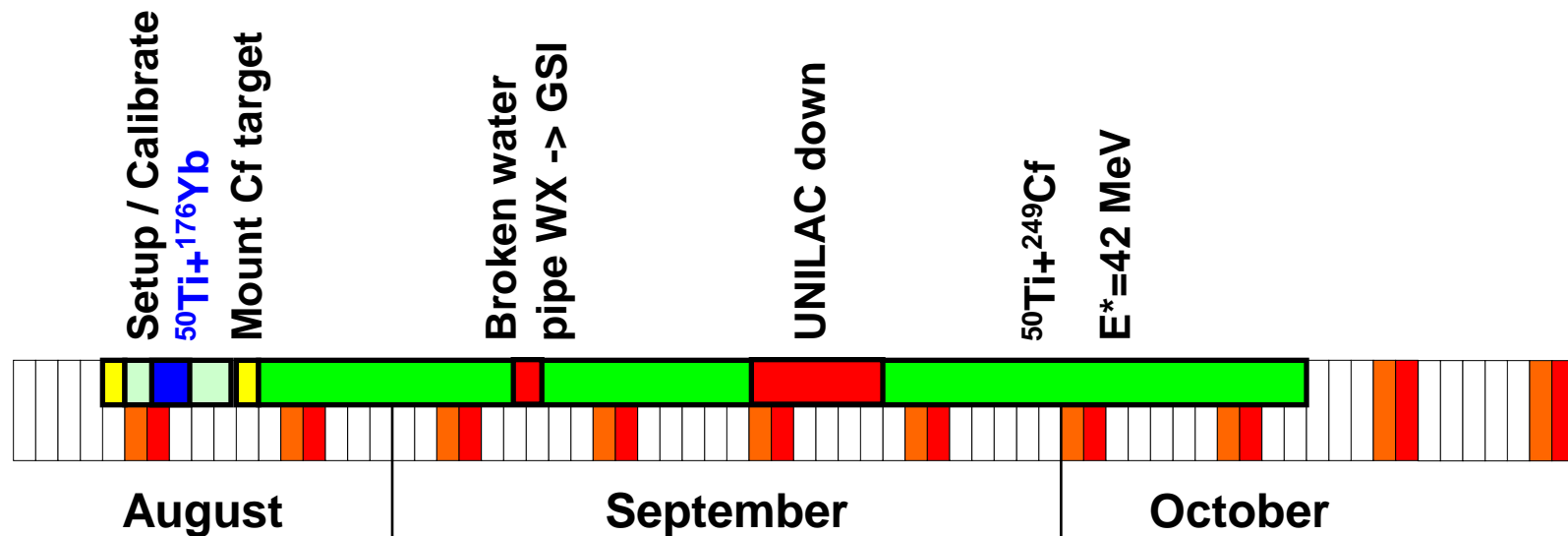
per 100 pA / 0.5  $\text{mg}/\text{cm}^2$

40 Hz

**Background reduction by factor  $\geq 10$**



# 2011: The search for E120 ( $^{50}\text{Ti} + ^{249}\text{Cf}$ )



Setup / Test / Calibrate

7 days

UNILAC operational for Cf

~39 days

2.4 days **No E120 events**

**were found**

0.9 days **One event cross**

**section limit 160 fb**

0.9 days

Ion source service

Misc. breakdown

Standby (e.g., for SIS tuning)



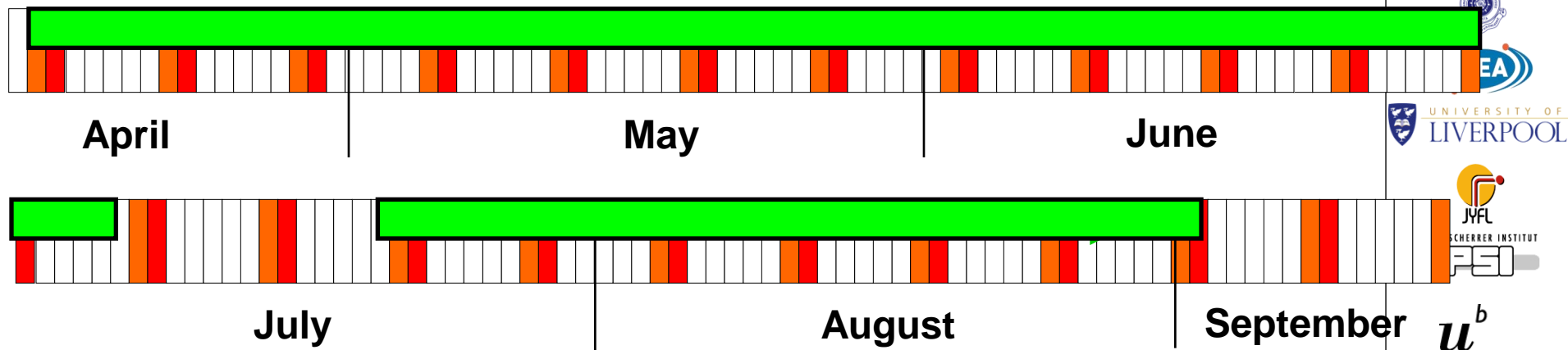
**Beam on target, data taking**

# 2012: The $^{50}\text{Ti} + ^{249}\text{Bk}$ run to search for element 119

- March 7 Arrival of 12,7 mg of  $^{249}\text{Bk}$  from Oak Ridge
- March 25 Arrival of  $^{249}\text{Bk}$  target from JGU to GSI
- April 4-8 Test reactions with  $^{50}\text{Ti}$  beam
- April 13 Mounting of  $^{249}\text{Bk}$  target into TASCA
- Sep 2 Beam dose 4,2E19



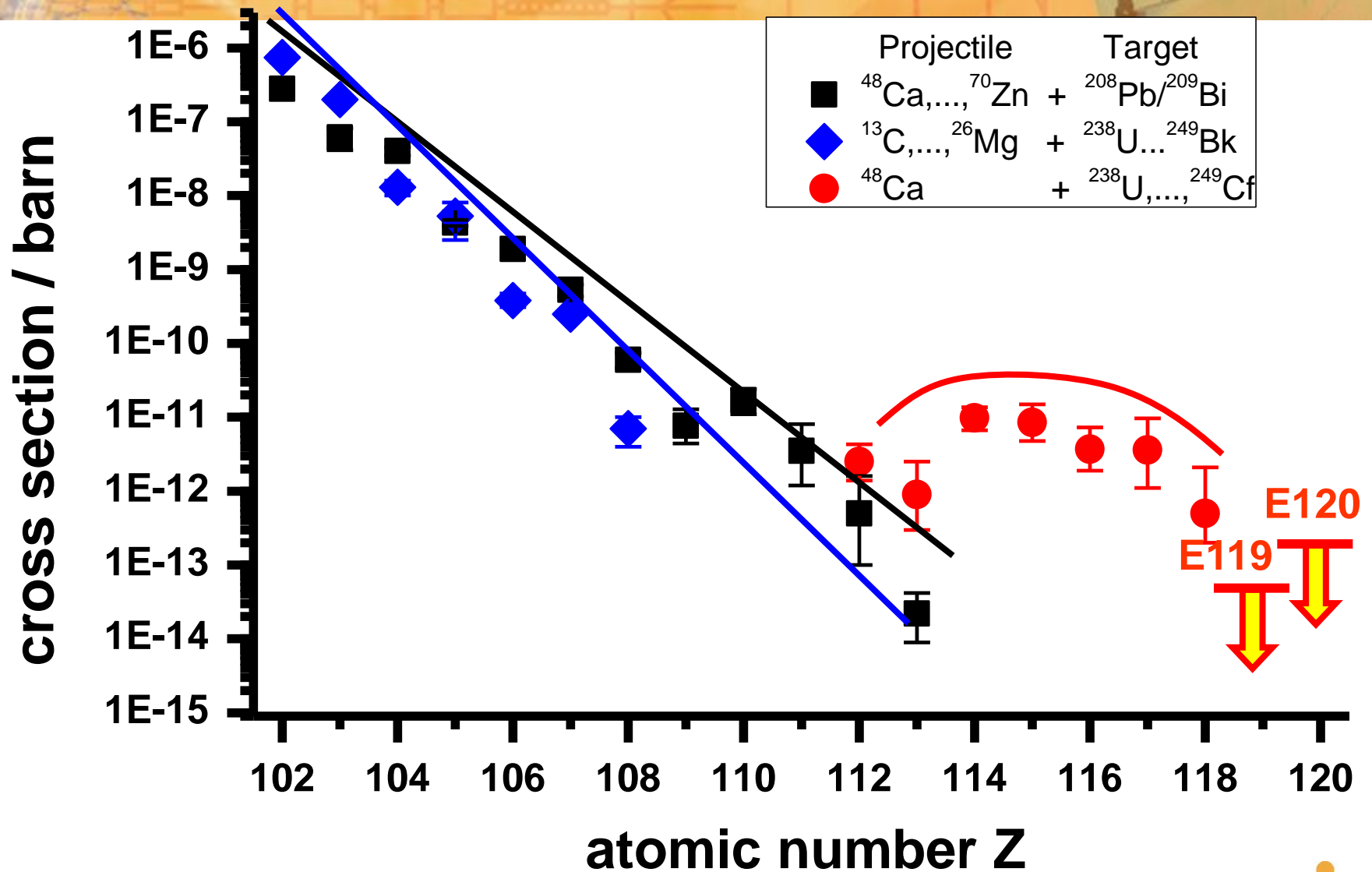
$^{50}\text{Ti}$  beam 750 nA<sub>p</sub> and  $^{249}\text{Bk}$  targets with initial thickness  $\approx 0.44 \text{ mg/cm}^2$ .



**No E119 events were found. Cross section limit 55 fb**



# Search for E119 and E120: results





# Confirmation experiments

## Element 117: $^{48}\text{Ca} + ^{249}\text{Bk}$

Oganessian et al.,  
PRL 2012 (accepted)

117-294  
50 ms  
10.81-10.97

117-294  
55.9 ms  
11.0 MeV

115-290  
0.24 s  
9.78-10.28

115-290  
2.98 s  
10.2 MeV

113-286

113-286

Analysis is ongoing

5.2 s  
9.38-9.55

6.79 s  
9.4 MeV

Bh-274  
54 s  
8.69-8.80

Bh-274  
45.1 s  
8.8 MeV

28.09.2012

Strips: X=103 / Y=41

Db-270  
22 h  
SF  
DGFRS

Db-270  
5.13 h  
SF  
TASCA

marks events registered in beam-off periods

## Element 115: $^{48}\text{Ca} + ^{243}\text{Am}$



LUND  
UNIVERSITY



TASISpec

2 events in 4 weeks

25+ events in 3 weeks



September

October

November

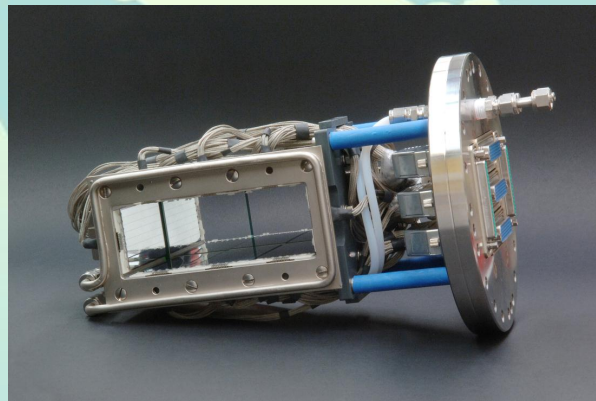
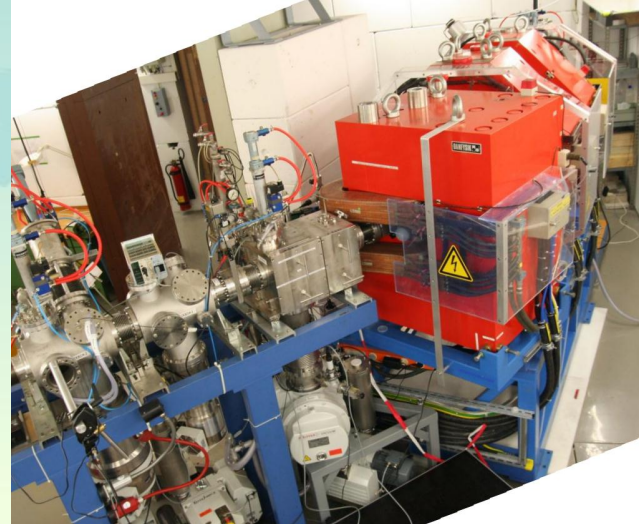
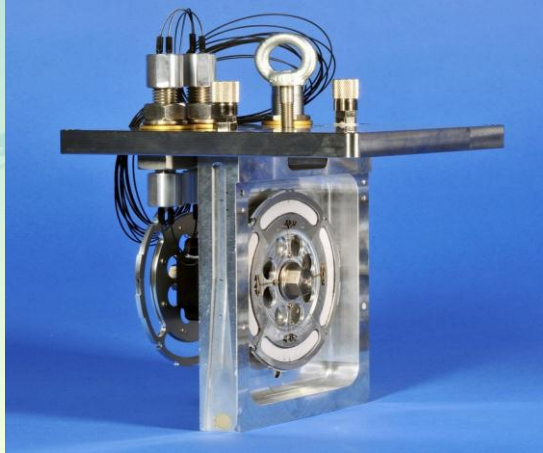


# Conclusions

- **Many improvements of TASCA have been done since 2009:**
  - new target wheel and safety system
  - background reduction
  - new digital electronics
  - stable and intense Ti-50 beam....
- **First search for E119 and E120 with  $^{50}\text{Ti}$  beam**
  - 2011:  $^{50}\text{Ti}+^{249}\text{Cf}$ ; a cross section limit of 160 fb reached in 39 days
  - 2012:  $^{50}\text{Ti}+^{249}\text{Bk}$ ; a cross section limit of 55 fb reached in 4 months
- **Confirmation experiments: synthesis of E117 and spectroscopy of E115**
  - 2 events of E117 in 4 weeks
  - 25+ events of E115 in 3 weeks



# Thank you for your attention!



On behalf of the whole TASCA collaboration