Radiological Laboratory in Warsaw (1934)

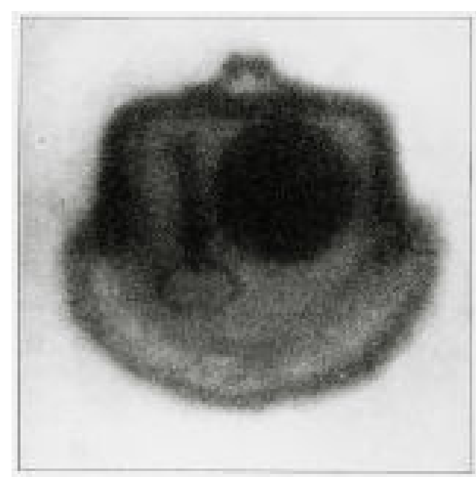
Marian Danysz

$$^{4}He + {}^{14}N \rightarrow {}^{17}F + n$$

$$^{17}F \rightarrow {}^{18}O + e^{+} + \nu$$

Formal leader of the Radiological Laboratory in Warsaw

A girl from Warsaw

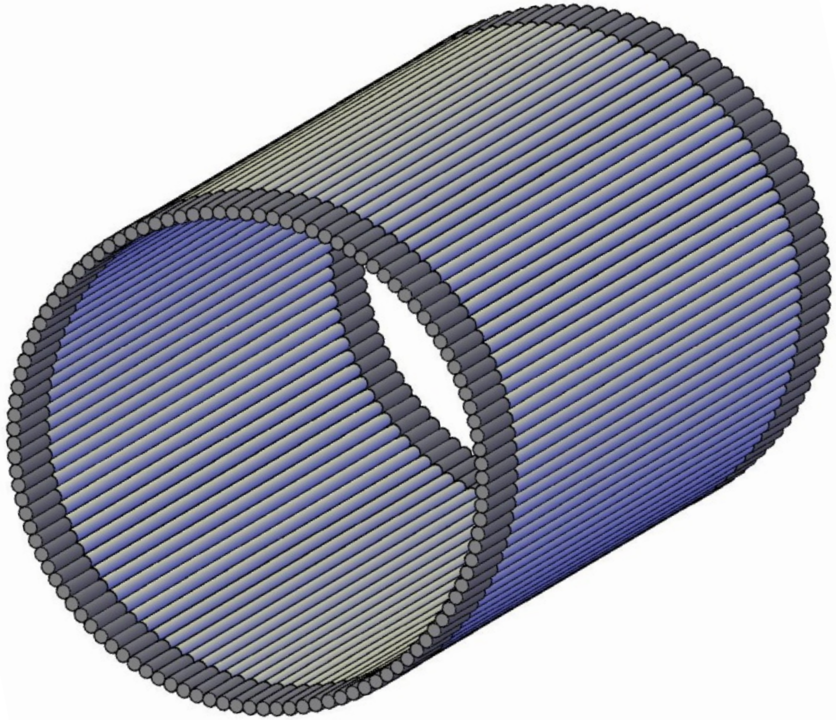


„Radiograph" taken by Maria Curie by exposing a purse to radium.

http://www.galloimages.co.za/

R.F. Mould, The British Journal of Radiology, **71**, 1229 (1998)

Jagiellonian PET project



II Symposium on Positron Emission Tomography
Cracow, 21-24 September 2014

Pawel Moskal

Jagiellonian University, Cracow, Poland

for and on behalf of the J-PET collaboration

Supported by Polish National Center for Development and Research and Foundation for Polish Science

IMAGE

Experimental Group of Advanced Medical Imaging
PET and polarized-MRI

- **Jagiellonian PET (J-PET)**

Jagiellonian University, National Center of Nuclear Reserach

IMAGE

Experimental Group of Advanced Medical Imaging
PET and polarized-MRI

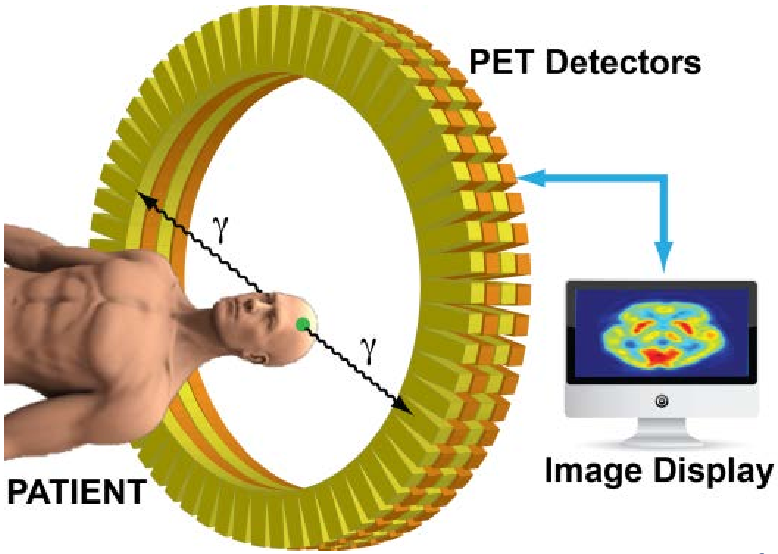
- **Jagiellonian PET (J-PET)**

Jagiellonian University,   National Center of Nuclear Reserach

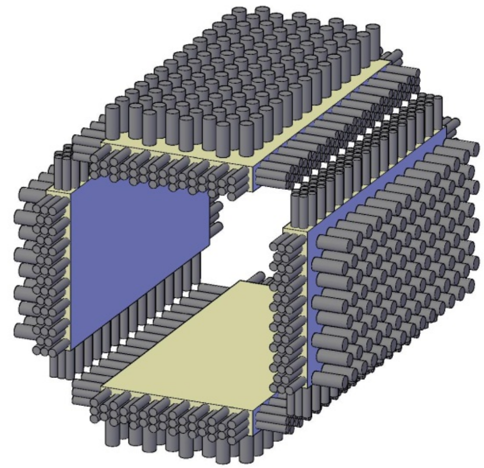
Novel detector systems for the Positron Emission Tomography aiming at the simultaneous, whole body imaging

http://koza.if.uj.edu.pl

General scheme of the currently used PET tomographs

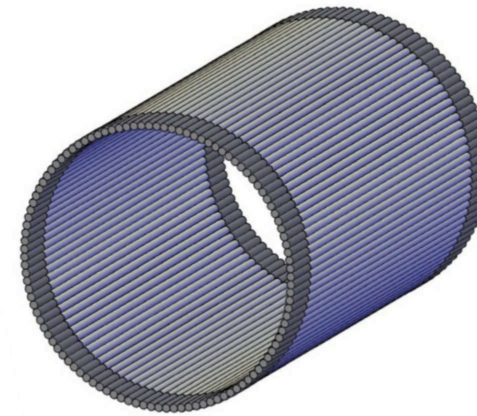


MATRIX-PET



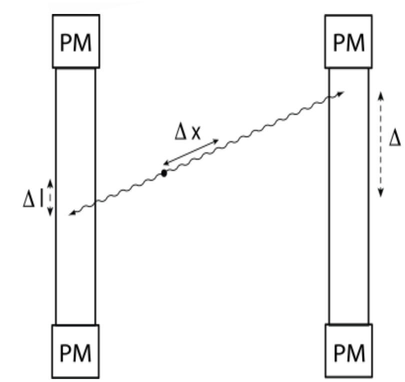
PCT/PL2010/000061

STRIP-PET



PCT/PL2010/000062

$$\Delta l = \frac{(t_2 - t_1) \cdot v}{2} \cong \frac{(t_2 - t_1) \cdot c}{4}$$



$$\Delta x = \frac{(t_l - t_r) \cdot c}{2} \Longrightarrow \Delta x = \frac{\Delta t}{2} \cdot c$$

Utterly new paradigm

Crystal → Polymer
Energy → Timing
High granularity → Low granularity
High efficiency → Low efficiency
Photoeffect → Compton scattering
Low acceptance → High acceptance
Analog electronics → digital sampling
triggering → triggerless DAQ

Currently all PET are based on crystals
PHILIPS → LYSO
SIMENS → LSO
GE Healthcare → BGO

Type: LSO / LYSO / BGO / polymer scintillator

Price per cm^3: 86 / 86 / 35 / 1

Polymer scintillators can be easily produced in large sizes and various shapes

PHILIPS → LYSO
SIMENS → LSO
GE Healthcare → BGO

Why polymers were not considered so far as a material for PET detectors ?

for the 2.5 cm layer the efficiency for the registration of events selected
to reconstruct the image is for the plastic scintillator by

a factor of about 20 smaller in relation to the BGO crystals and about 40 times less compared to the LSO crystals

name	type	density [g/cm^3]	decay time [ns]	photons/ MeV	mean free path [cm]
BGO	crystal	7.13	300	6000	1.04
GSO	crystal	6.71	50	10000	1.49
LSO	crystal	7.40	40	29000	1.15
NE102A	polymer	1.032	2.4	10000	10.2
BC404	polymer	1.032	1.8	10000	10.2
RP422	polymer	1.032	1.6	10000	10.2

Polymers:

low detection efficiency

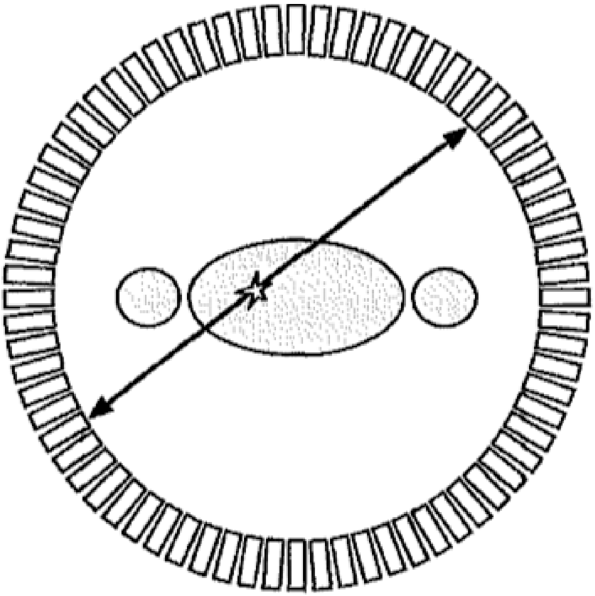
and

no photelectric effect,

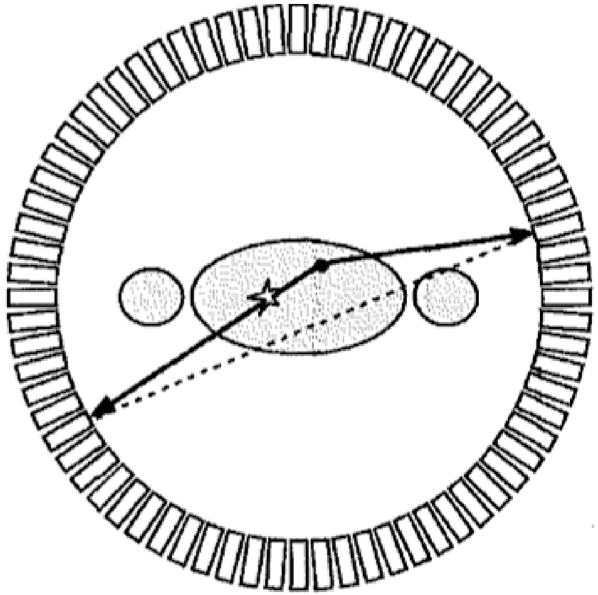
BUT ...

EVENTS

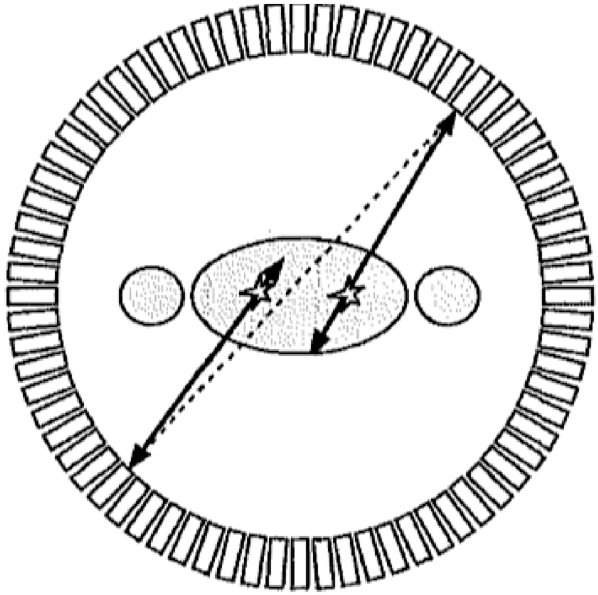
„true”

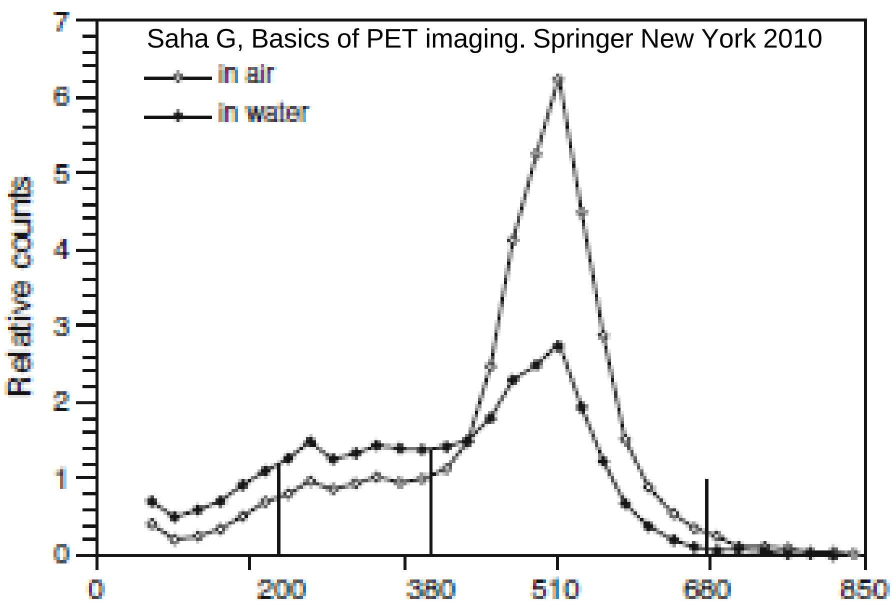


„scattered”

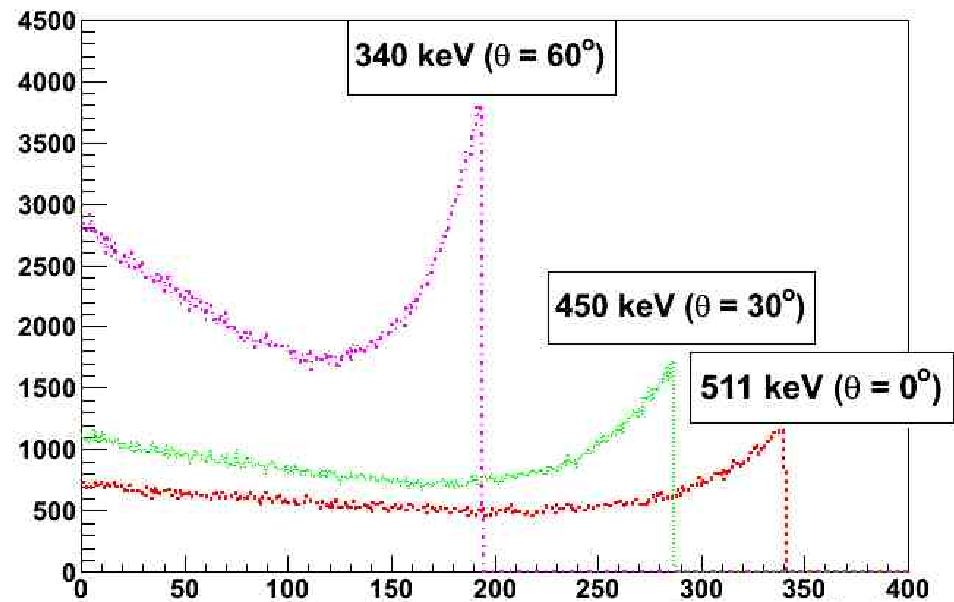


accidental





Energy [keV]



Energy [keV]

LIGHT SIGNALS FROM POLYMERS ARE MUCH „FASTER” !!!

name	type	density [g/cm^3]	decay time [ns]	photons/ MeV	mean free path [cm]
BGO	crystal	7.13	300	6000	1.04
GSO	crystal	6.71	50	10000	1.49
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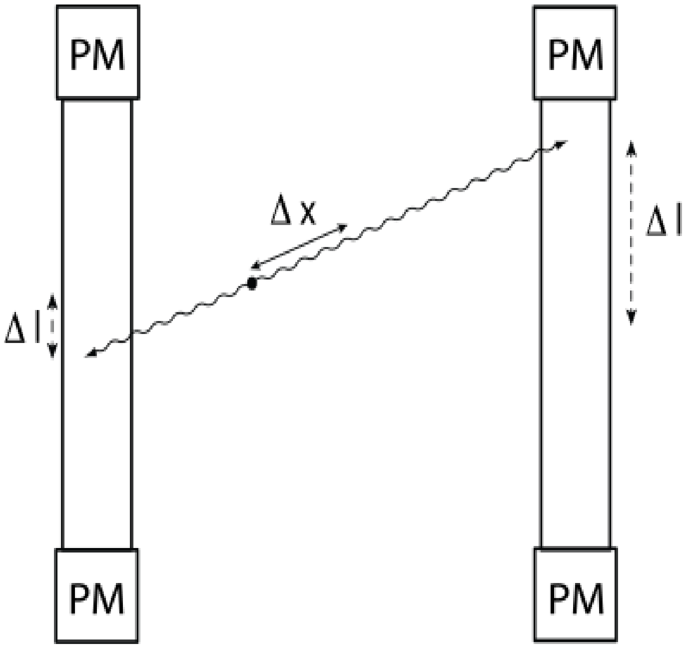
RP422	polymer	1.032	1.6	10000	10.2

J-PET (**J**agiellonian **PET**)

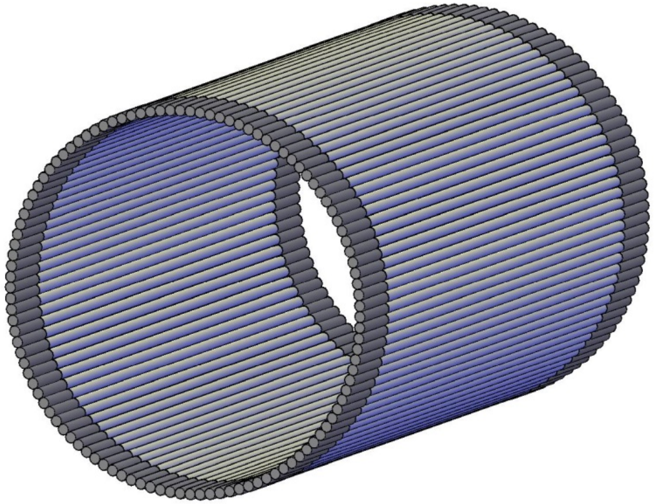
$\Delta l = (t_2 - t_1)\, v / 2$



$\Delta x = (t\_l - t\_r)\, c / 2$

$FWHM(\Delta l) \approx FWHM(\Delta t) * c/4$

$FWHM(\Delta x) \approx FWHM(\Delta t) * c / 2\sqrt{2}$



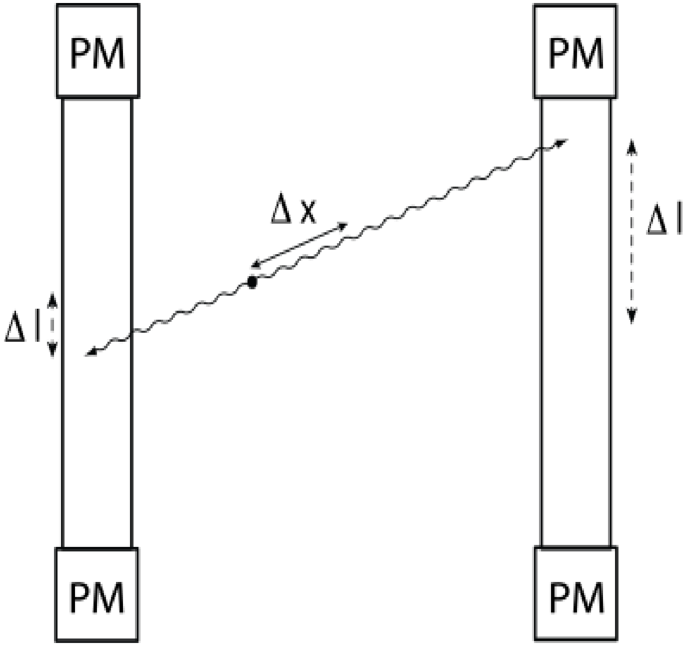
Lets take advantage of TIME resolution not only for TOF but also for the determination of hit positions

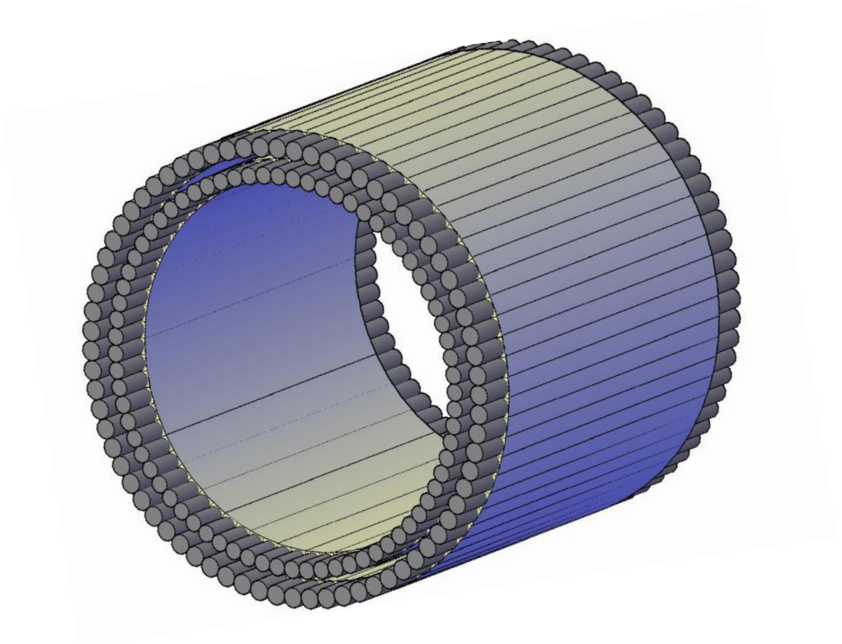
Thus for example:

$FWHM(\Delta t) = 100ps \rightarrow FWHM(\Delta l) = 0.7cm \rightarrow FWHM(\Delta x) = 1\ cm$

J-PET (**J**agiellonian **PET**)

$\Delta l = (t_2 - t_1)\, v / 2$

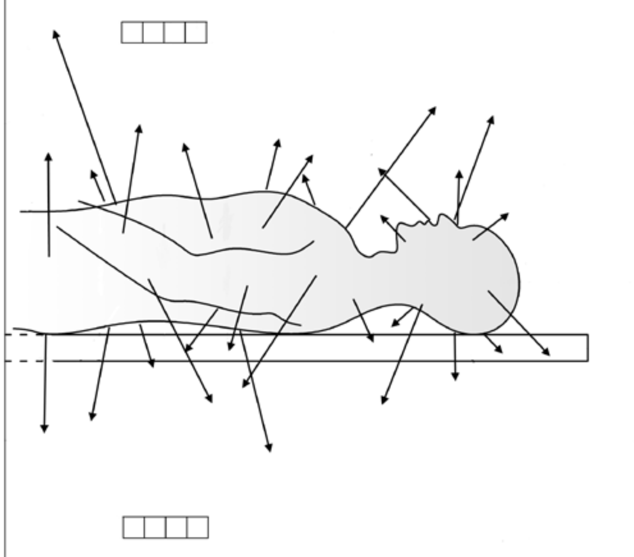


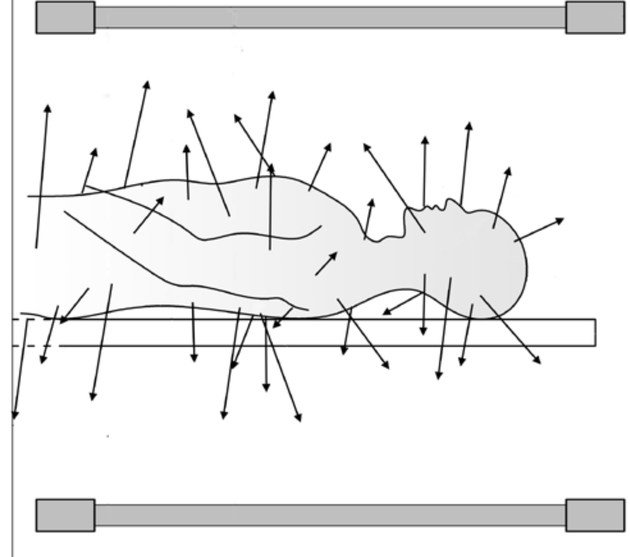


$\Delta x = (t\_l - t\_r)\, c / 2$

$\mathrm{FWHM}(\Delta l) \approx \mathrm{FWHM}(\Delta t) * c/4$
$\mathrm{FWHM}(\Delta x) \approx \mathrm{FWHM}(\Delta t) * c / 2\sqrt{2}$

Thus for example:
FWHM(Δt) = 100ps → FWHM(Δl) = 0.7cm → FWHM(Δx) = 1 cm





It is important to note that the cost of J-PET does not increase with the increas of the FOV

epsilon^2 = 20 to 40 smaller efficiency

But

2D --> 3D -------------------- > factor of ~5

600ps --> 100ps – 200ps --> factor of 6 -- 3

1m instead of 20cm ---------> factor of 9

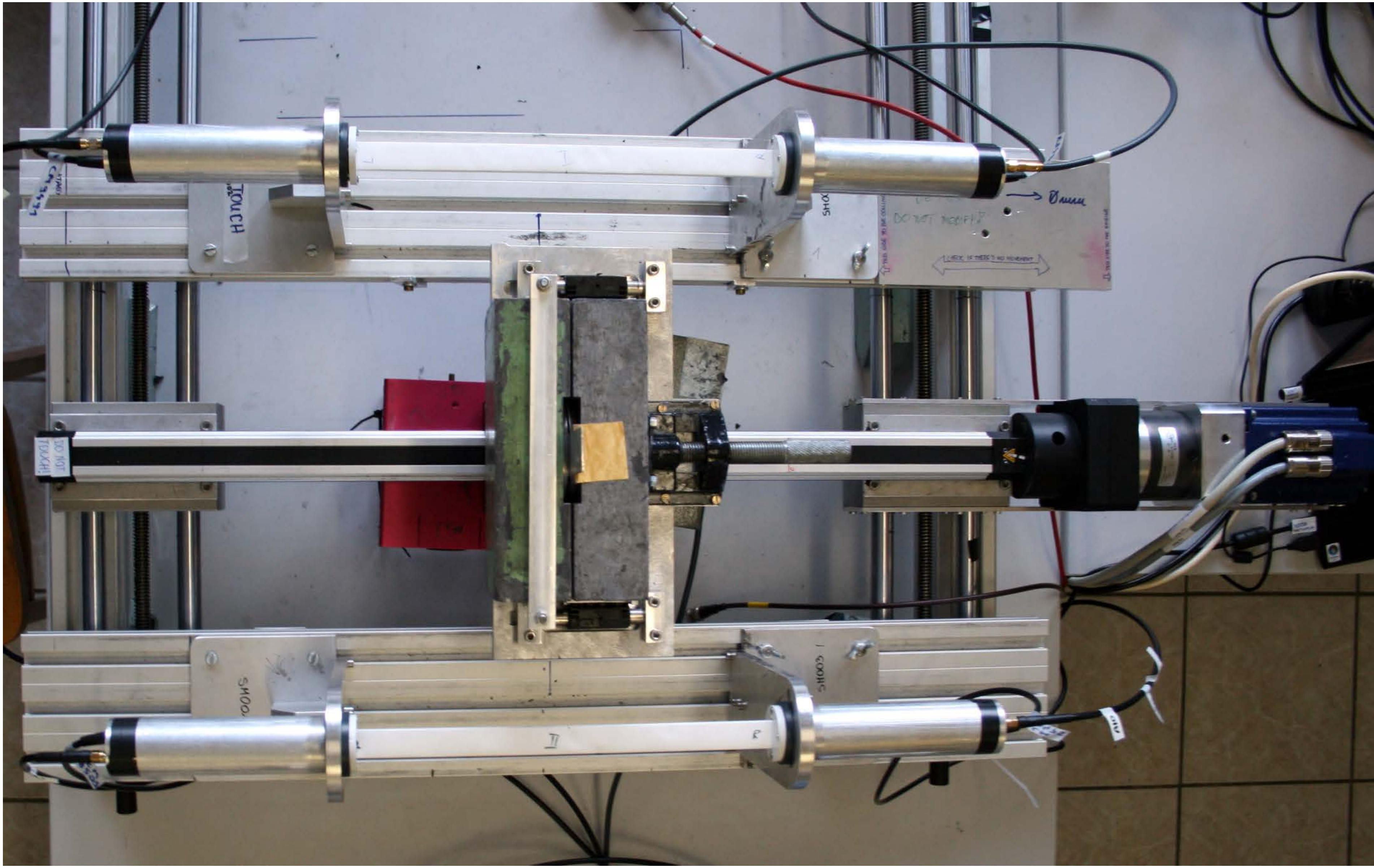
N layers in the strip-PET --> factor **N^2**

For N=1 --- -> total factor of ~ 200

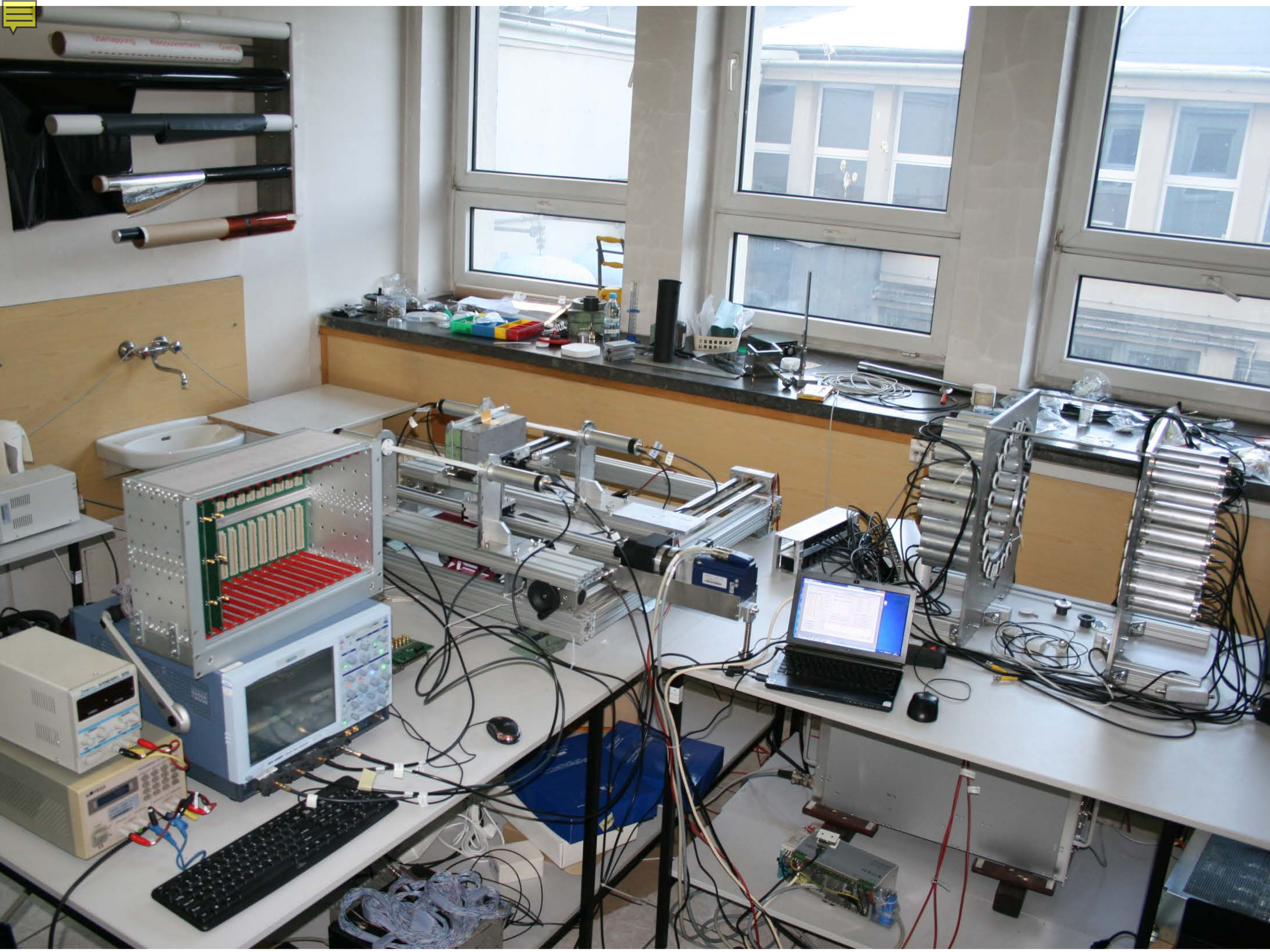
Lower dose by factor of 7

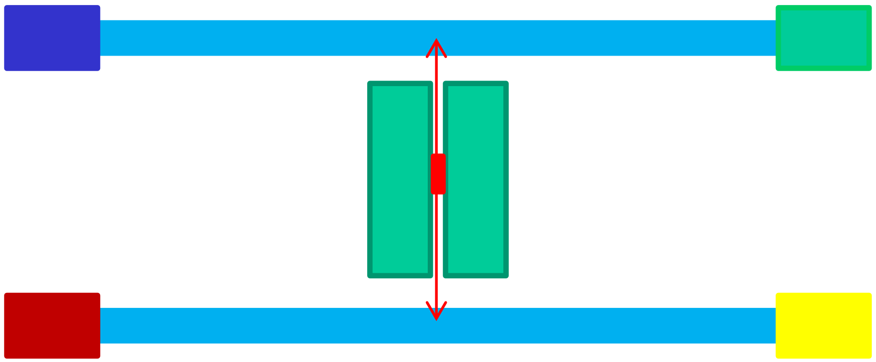
Accidental coincidences less by factor of about 1000

(epsilon * 7)^2



J-PET: Nucl. Instr. & Meth. A764 (2014) 317
J-PET: Nucl. Instr. & Meth. A764 (2014) 186






File
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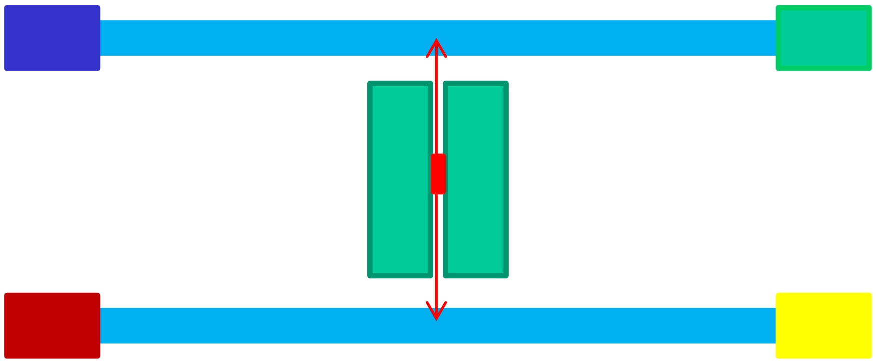
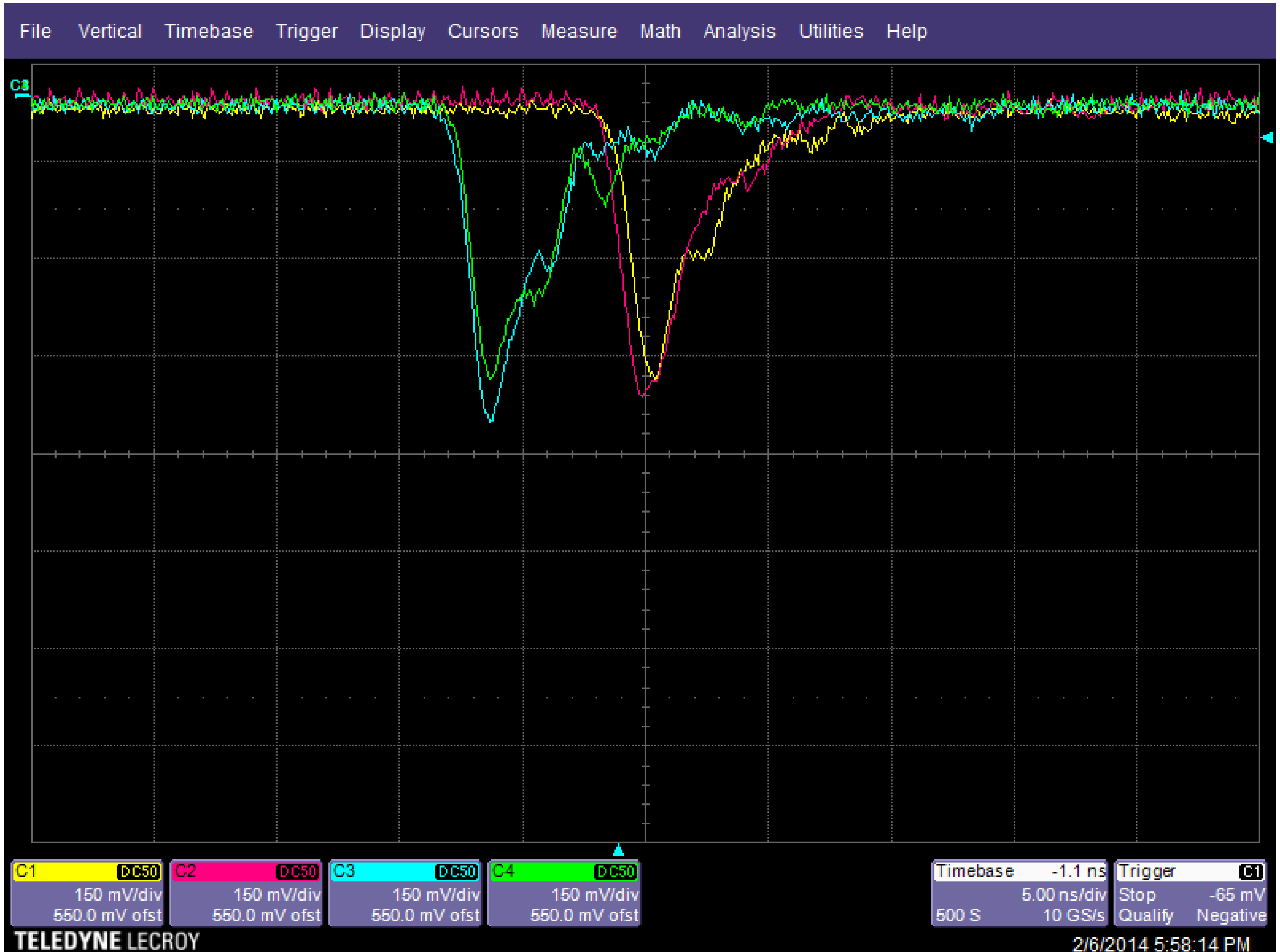
C1 DC50
150 mV/div
550.0 mV ofst
C2 DC50
150 mV/div
550.0 mV ofst
C3 DC50
150 mV/div
550.0 mV ofst
C4 DC50
150 mV/div
550.0 mV ofst
Timebase -1.1 ns
5.00 ns/div
500 S 10 GS/s
Trigger C1
Stop -65 mV
Qualify Negative
TELEDYNE LECROY
2/6/2014 5:55:32 PM




File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
C3
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C2 DC50
150 mV/div
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C3 DC50
150 mV/div
550.0 mV ofst
C4 DC50
150 mV/div
550.0 mV ofst
Timebase -1.1 ns
5.00 ns/div
500 S 10 GS/s
Trigger C1
Stop -65 mV
Qualify Negative
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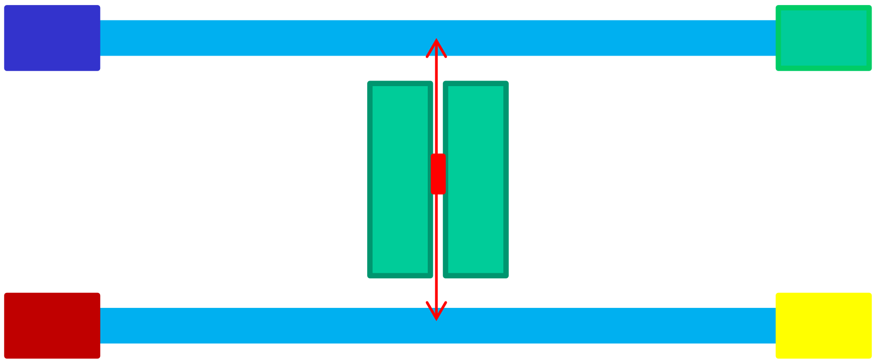
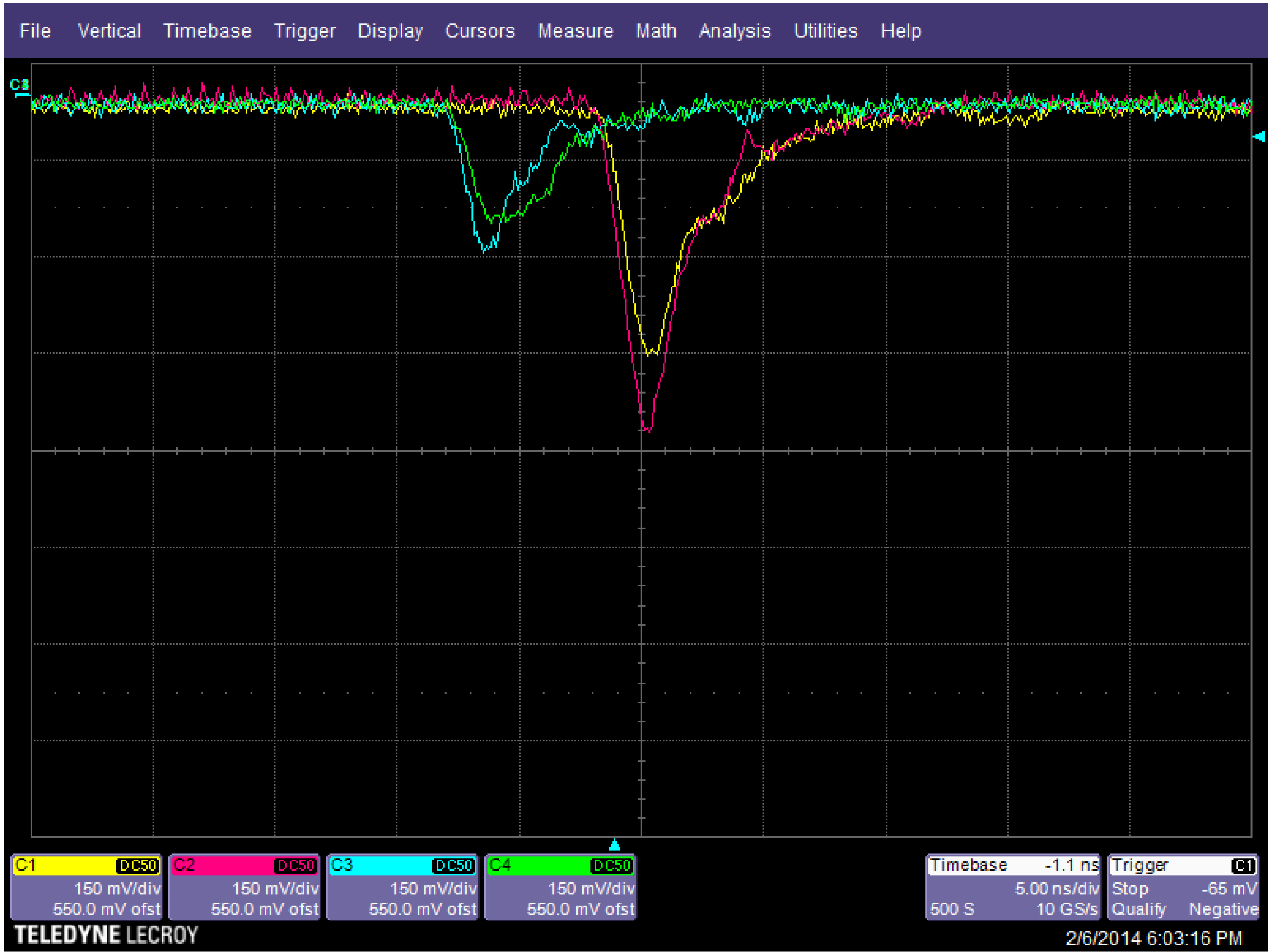
2/6/2014 5:58:14 PM



- 

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C1 DC50
150 mV/div
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550.0 mV ofst
C4 DC50
150 mV/div
550.0 mV ofst
Timebase -1.1 ns
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500 S 10 GS/s
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Stop -65 mV
Qualify Negative
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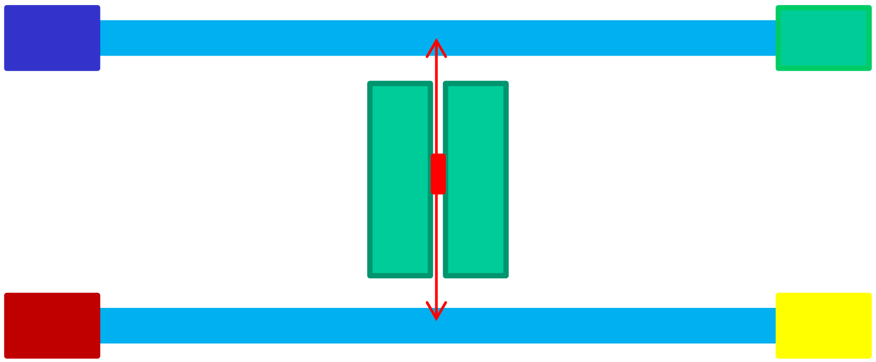
2/6/2014 6:03:16 PM



File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
C1 DC50 150 mV/div 550.0 mV ofst
C2 DC50 150 mV/div 550.0 mV ofst
C3 DC50 150 mV/div 550.0 mV ofst
C4 DC50 150 mV/div 550.0 mV ofst
Timebase -1.1 ns 5.00 ns/div 500 S 10 GS/s
Trigger C1 Stop -65 mV Qualify Negative
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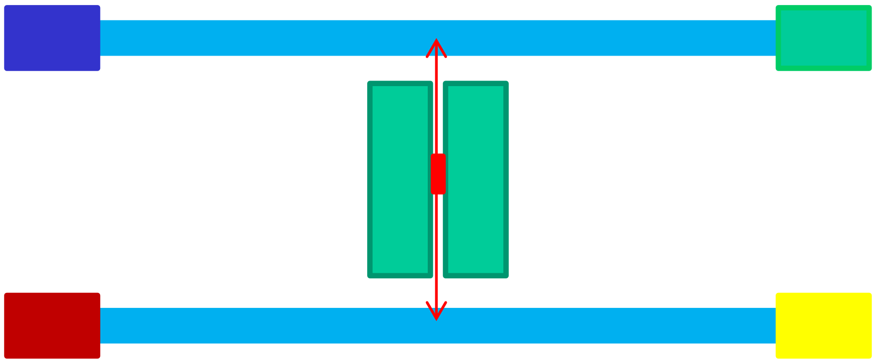
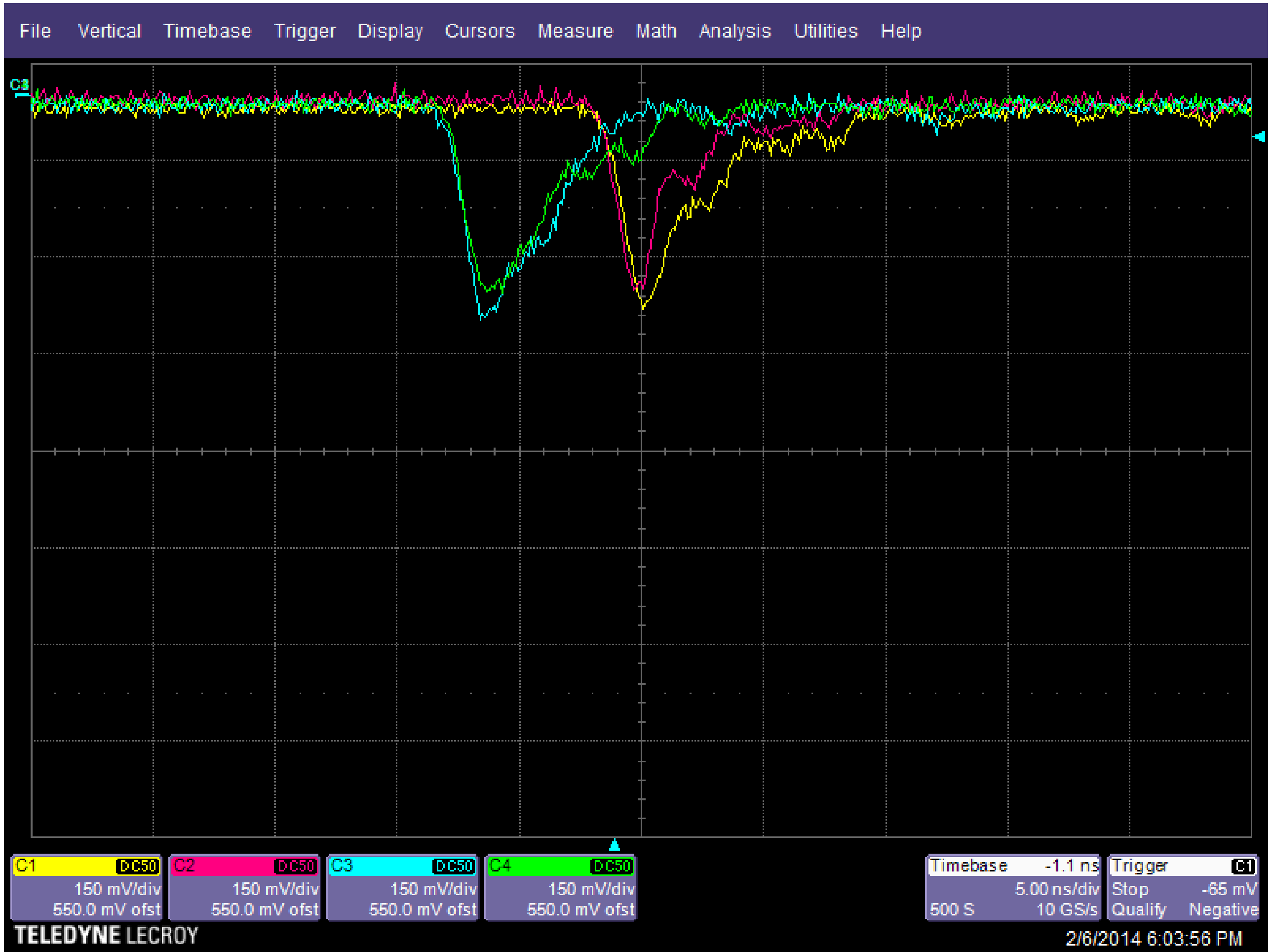
2/6/2014 5:56:15 PM





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C1 DC50
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C4 DC50
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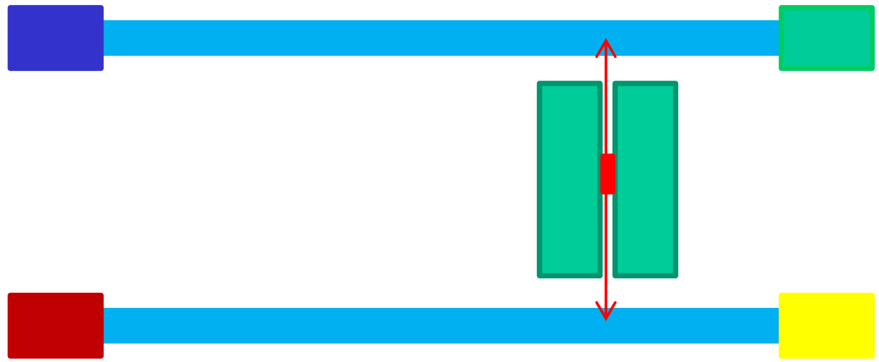


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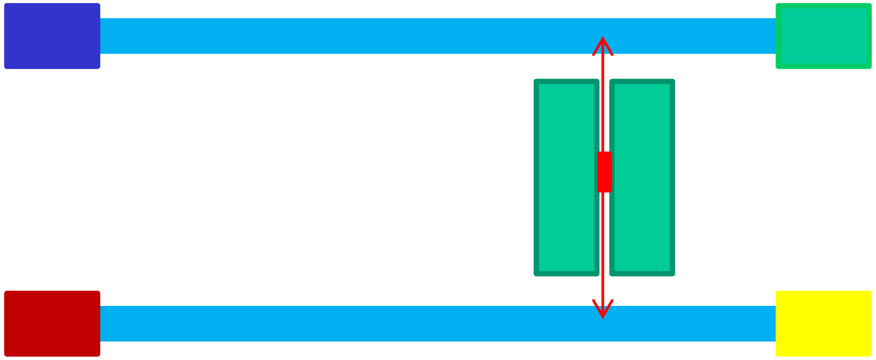

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C4 DC50
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550.0 mV ofst
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Qualify Negative
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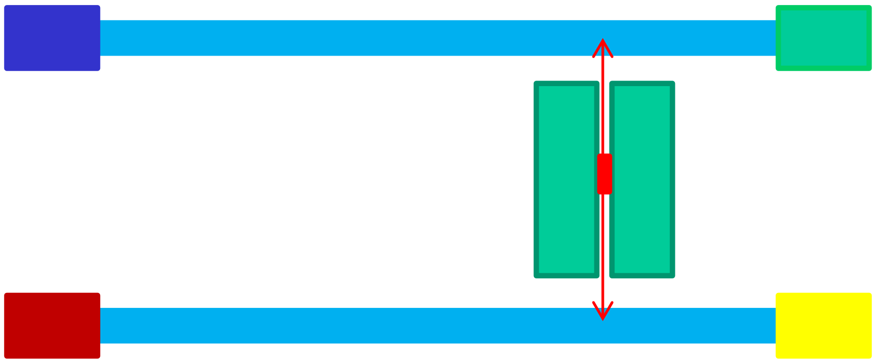

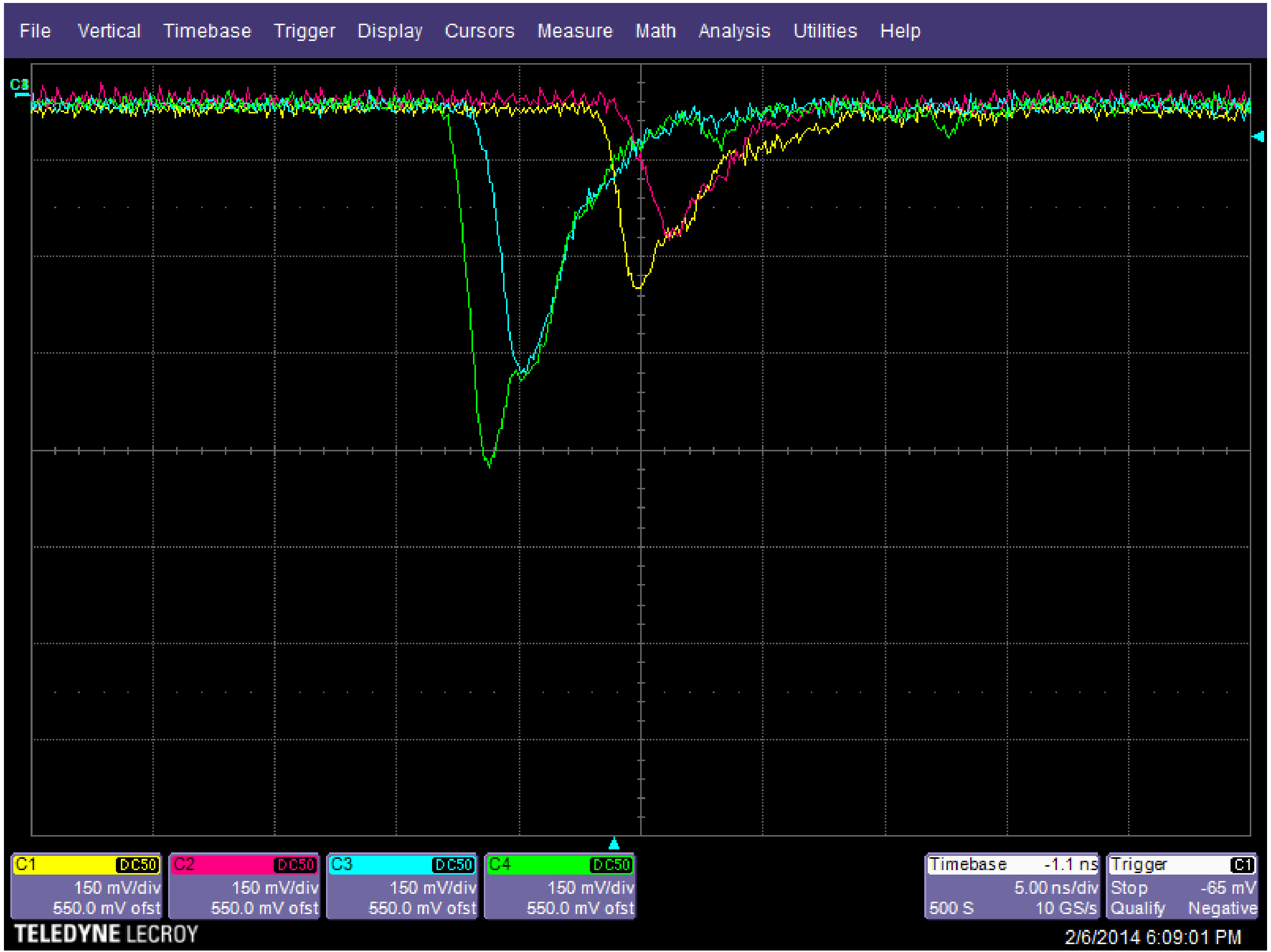

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550.0 mV ofst
C4 DC50
150 mV/div
550.0 mV ofst
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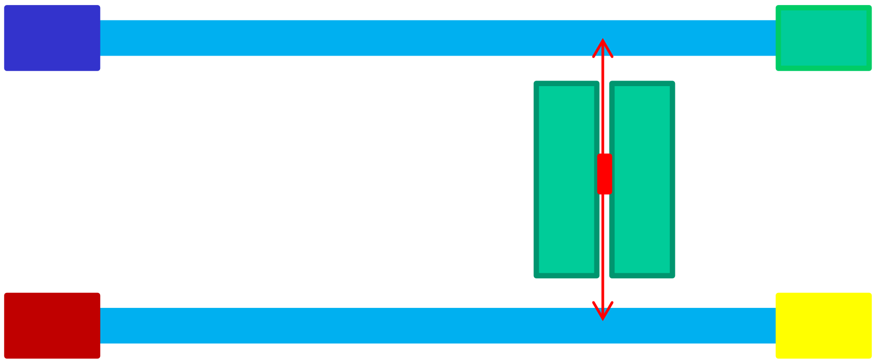

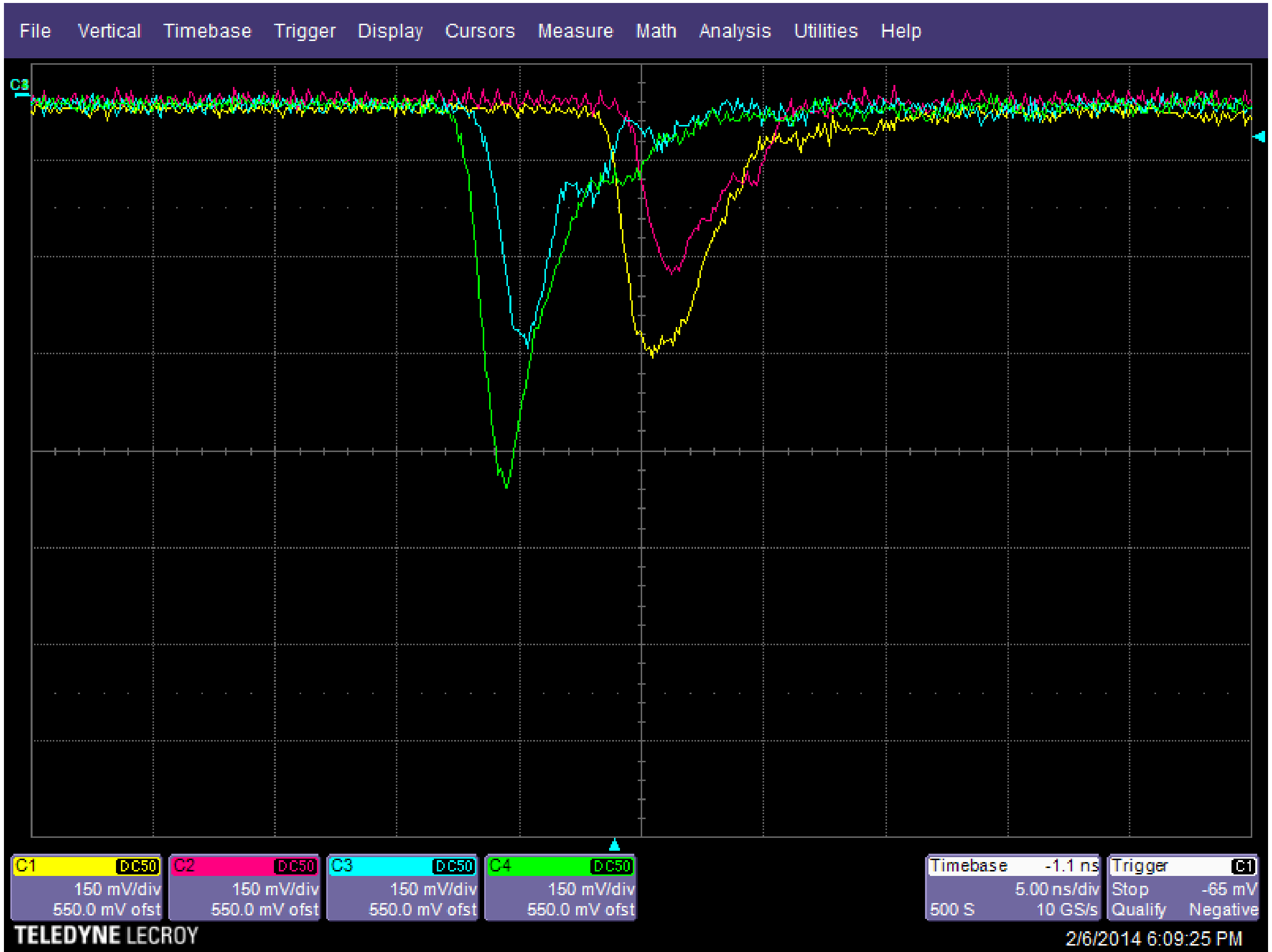

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550.0 mV ofst
C4 DC50
150 mV/div
550.0 mV ofst
Timebase -1.1 ns
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Qualify Negative
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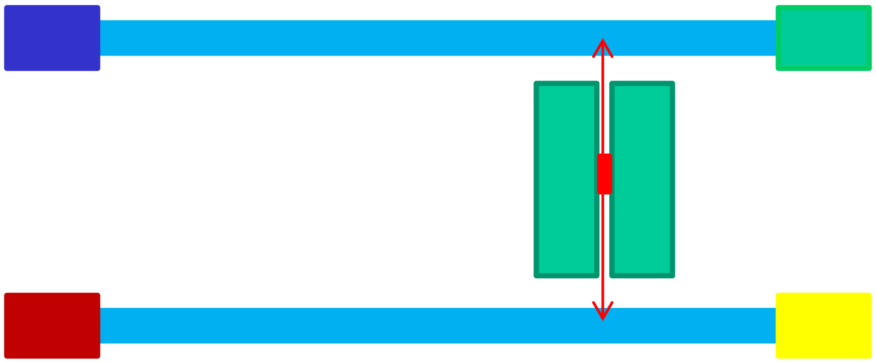
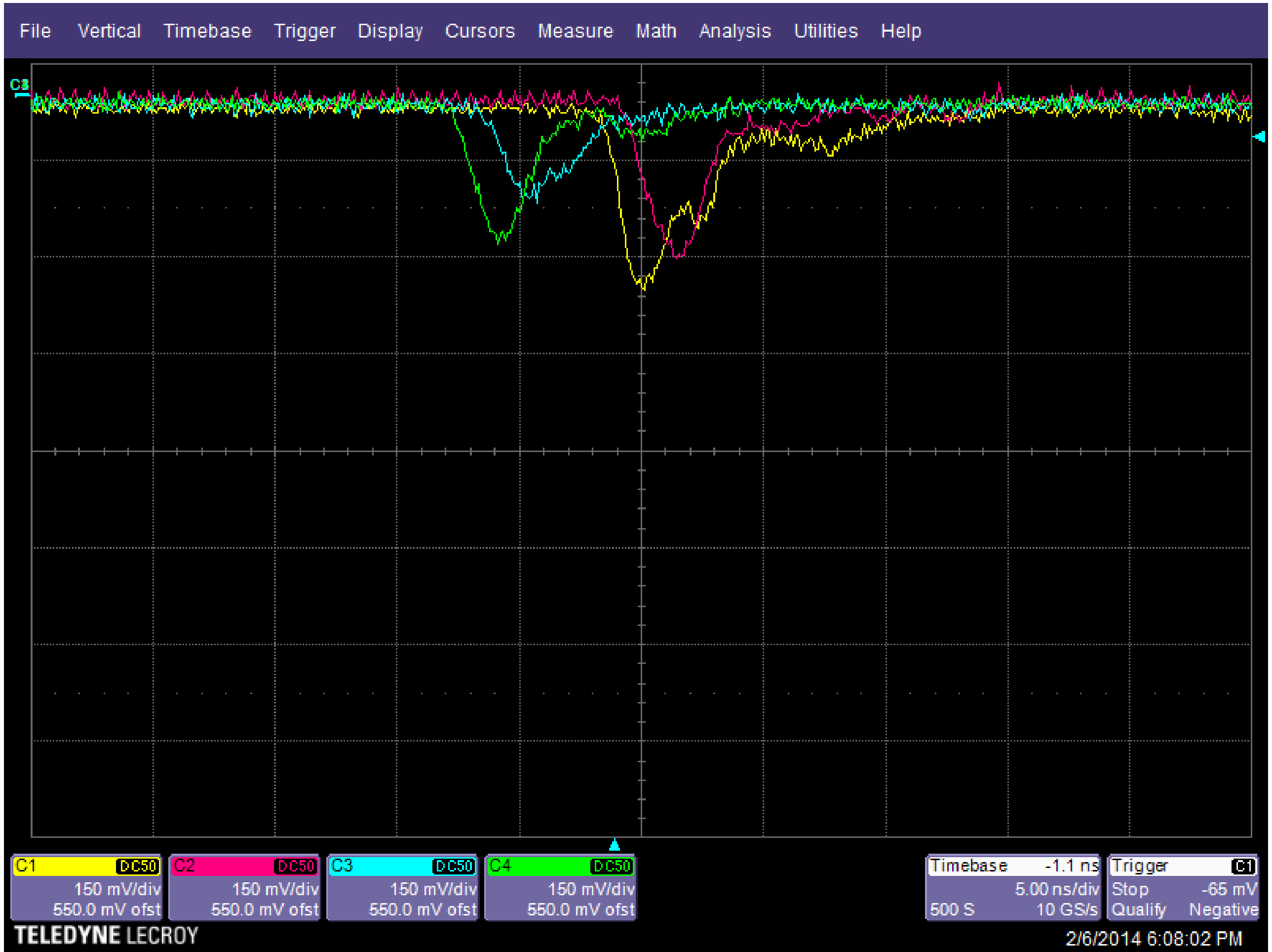
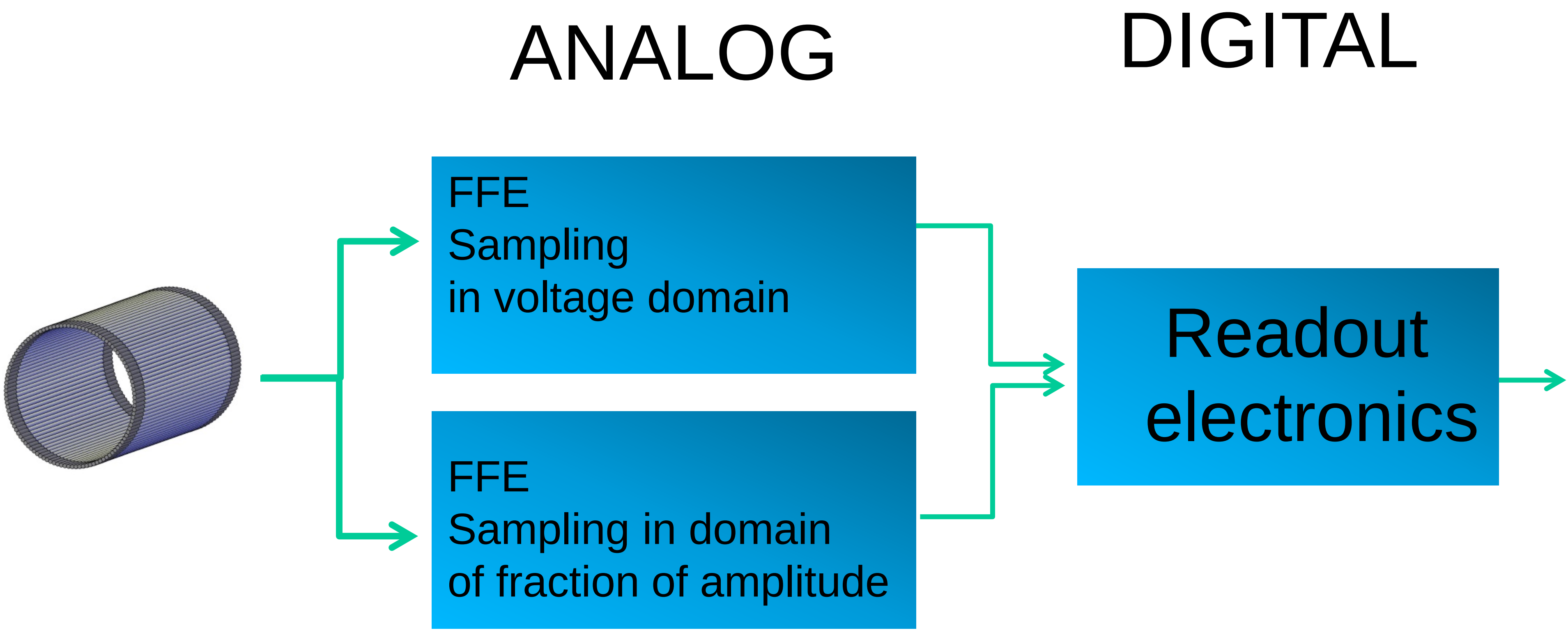
2/6/2014 6:09:25 PM

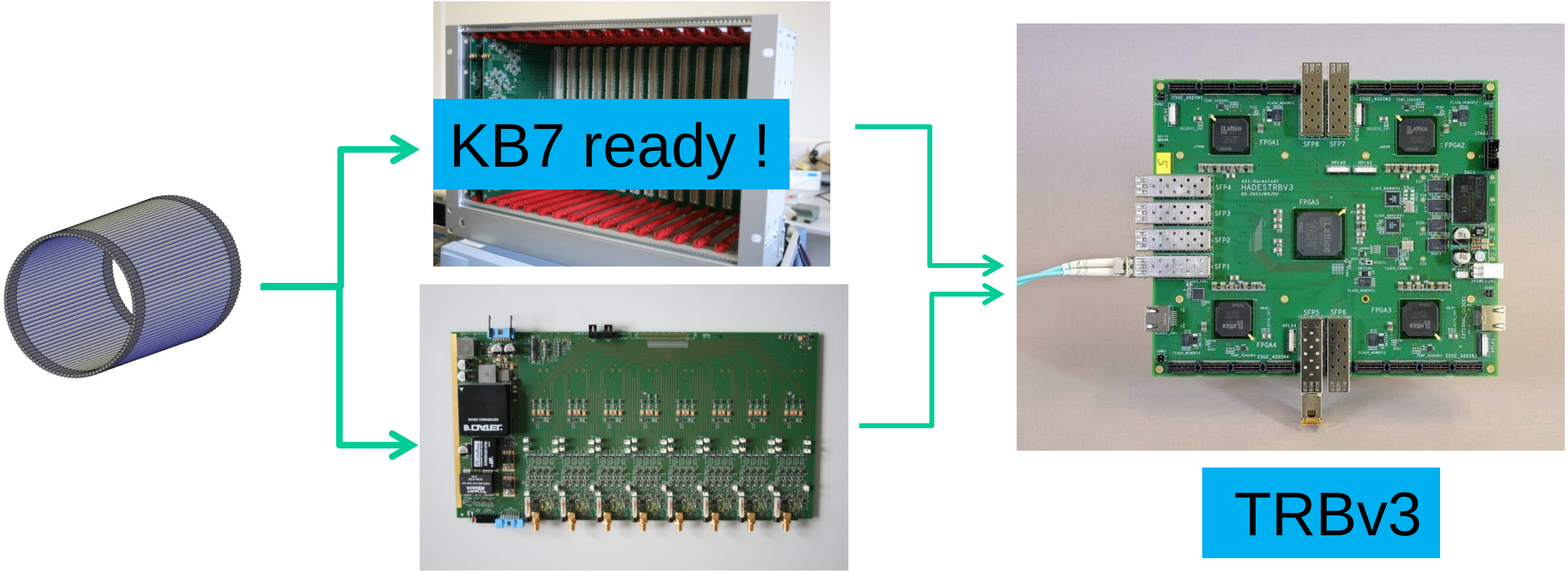


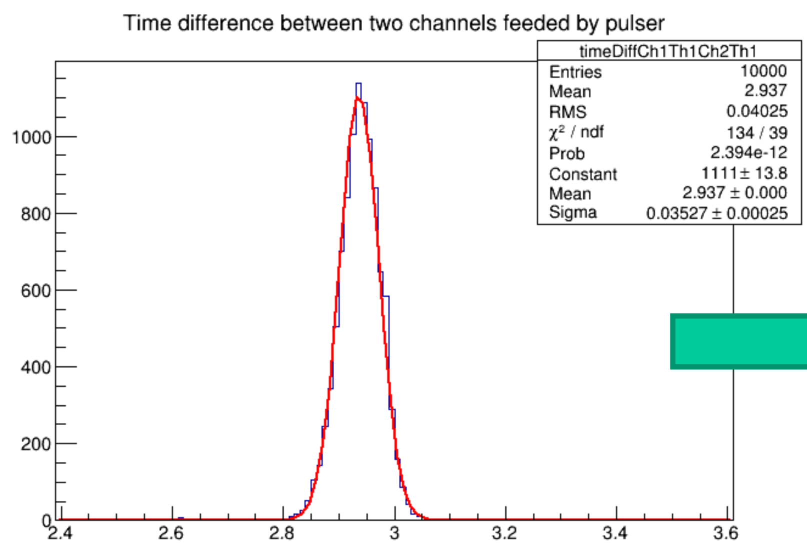


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
C1 DC50 150 mV/div 550.0 mV ofst
C2 DC50 150 mV/div 550.0 mV ofst
C3 DC50 150 mV/div 550.0 mV ofst
C4 DC50 150 mV/div 550.0 mV ofst
Timebase -1.1 ns 5.00 ns/div 500 S 10 GS/s
Trigger C1 Stop -65 mV Qualify Negative
TELEDYNE LECROY
2/6/2014 6:08:02 PM

First challange is to develope FFE electronics with sampling precision better than 50 ps



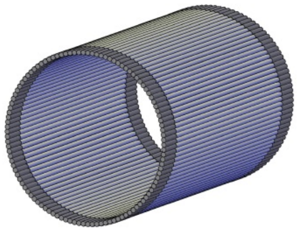




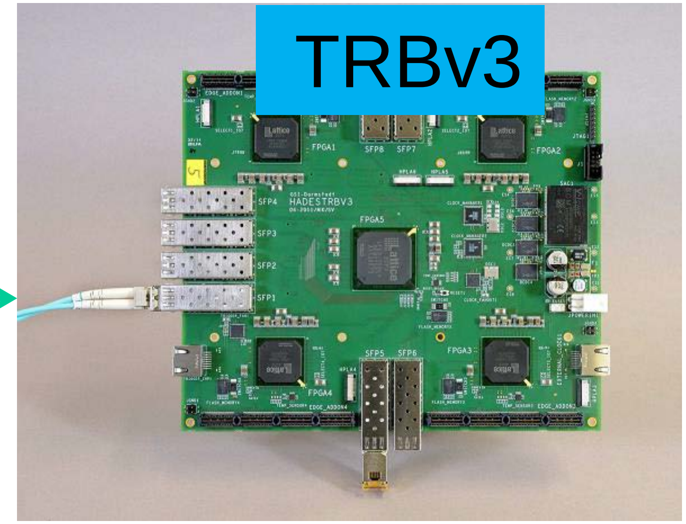
Si-Ge and As-Ge

KB7 + TRBv3 together

sigma(t) = 25 ps



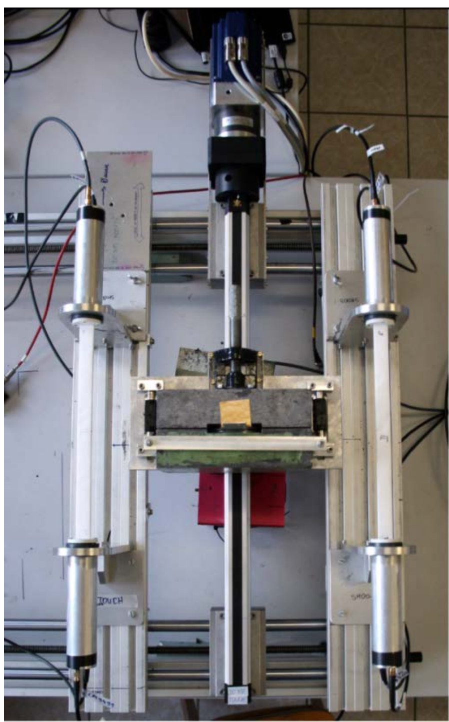
KB7 ready !



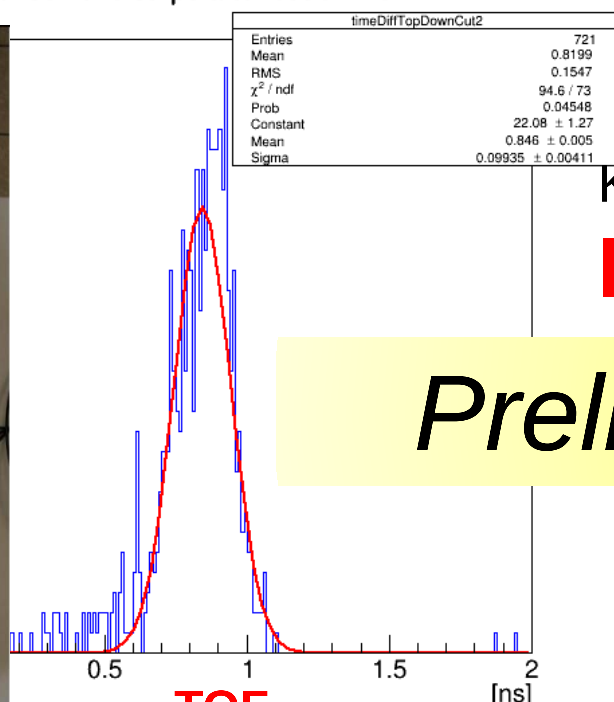
TRBv3

Triggerless mode !

PCT/EP2014/068352



Time difference between two strips after cut on TOT



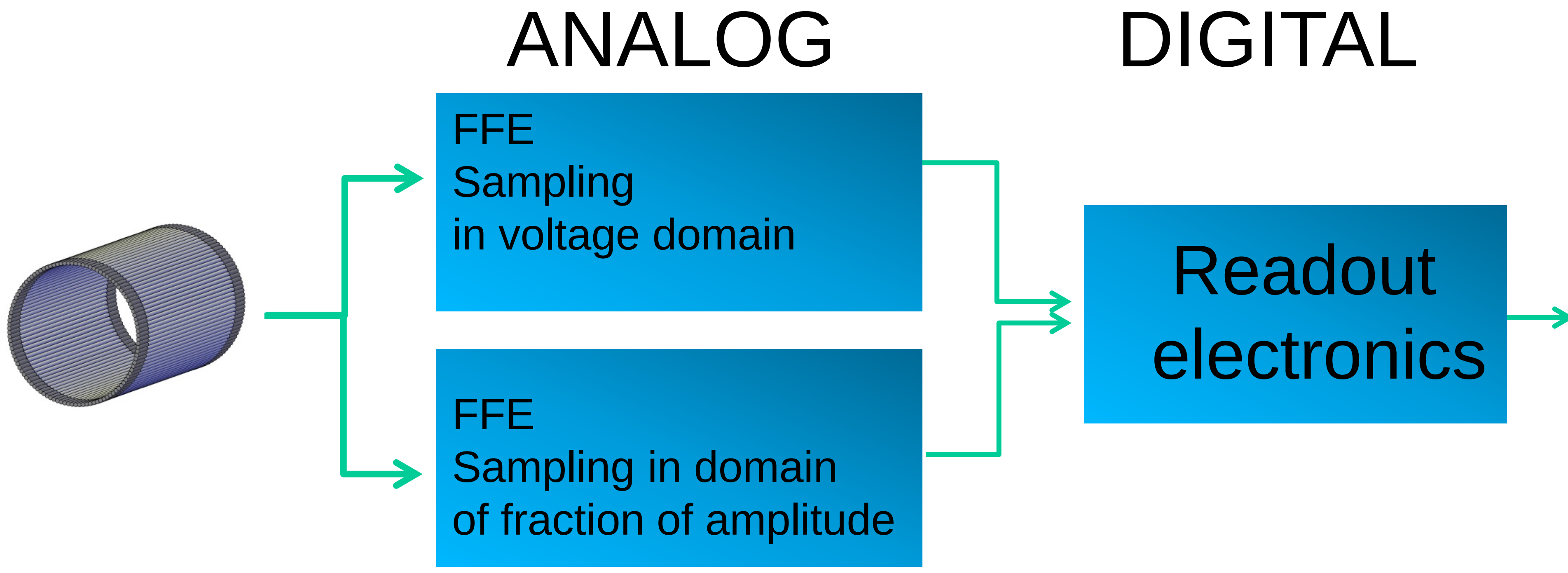
TOF

KB7 + TRBv3 with single threshold

FWHM(TOF) < 220 ps

Preliminary

Comapred to ~ 600 ps of current TOF-PET

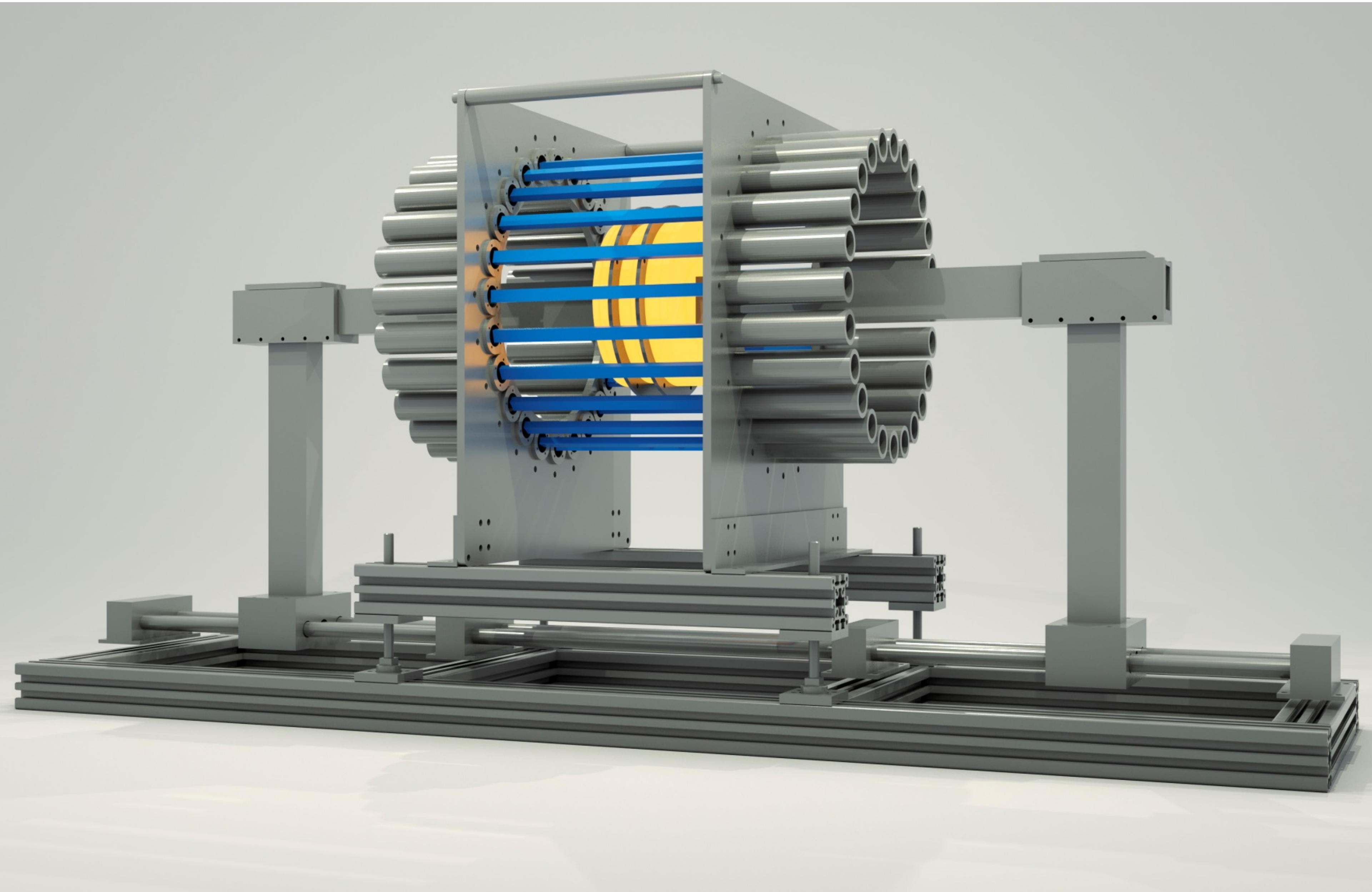


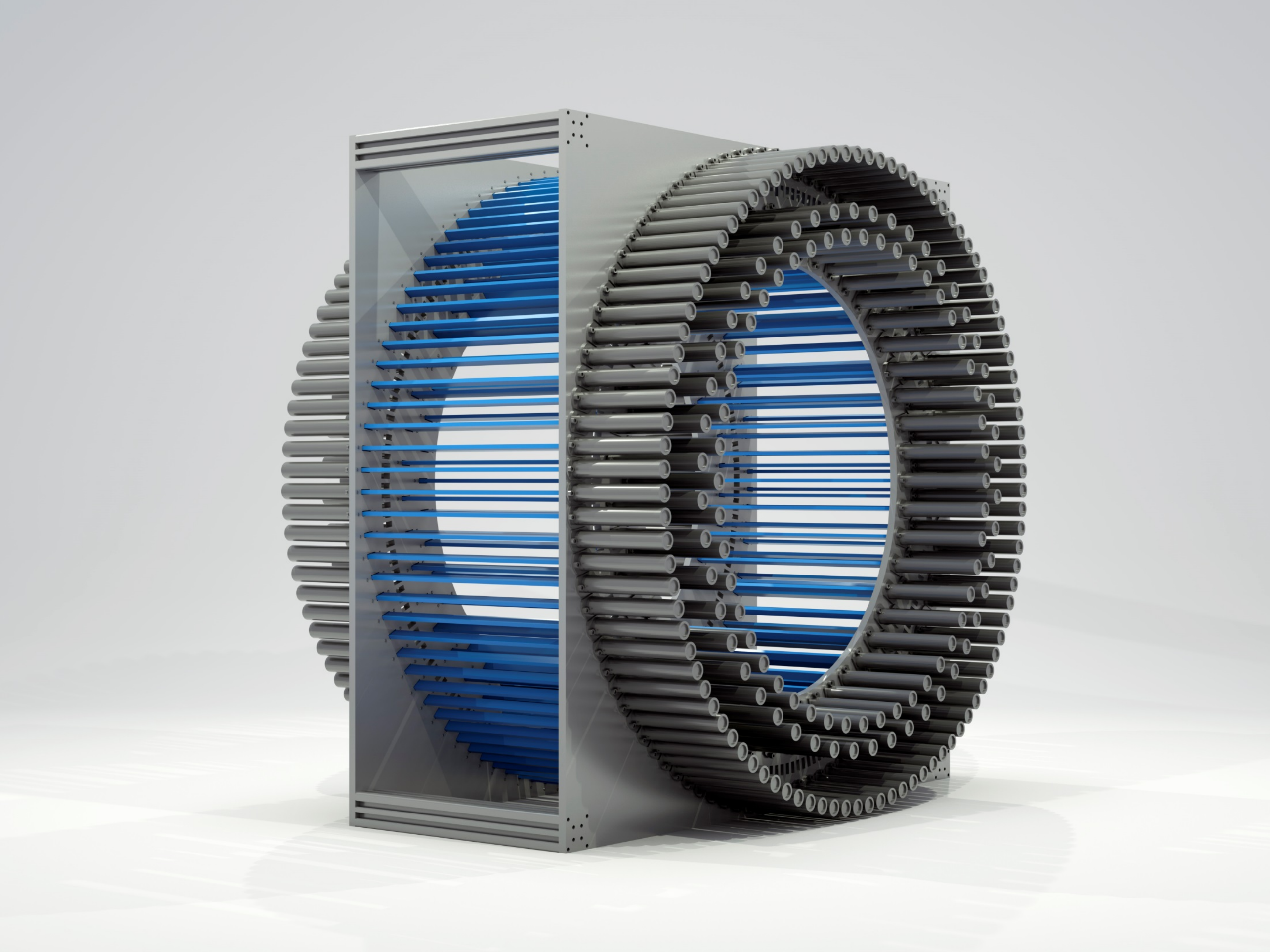
New idea… BREAK THROUGH

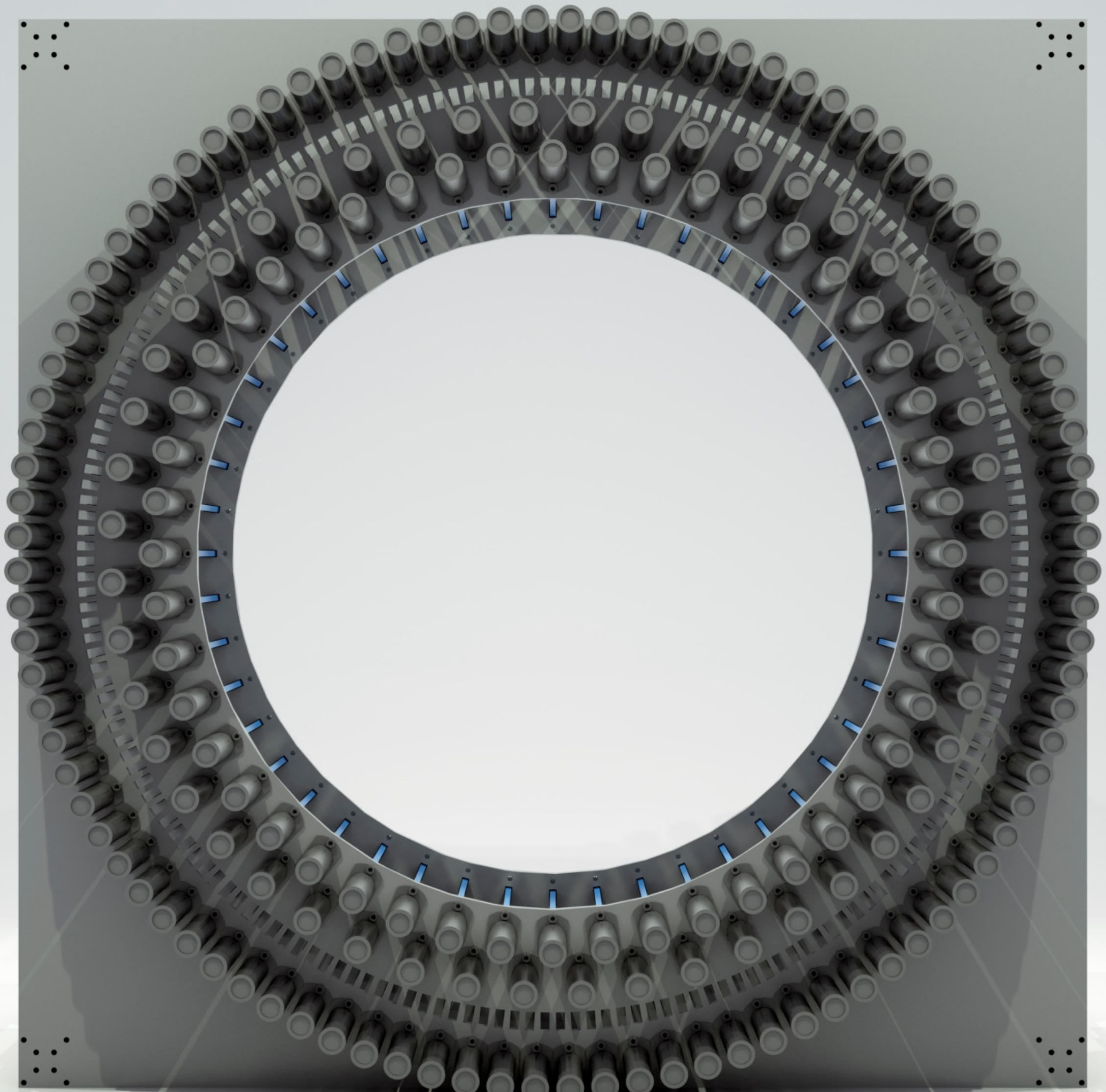
simultaneous PET-CT scan: **PCT/EP2014/068363**
and
simultaneous PET-MRI scan: **PCT/EP2014/068373**

petct_animation41_loop.mp4

Z³o¿enie_PET_MRI.avi







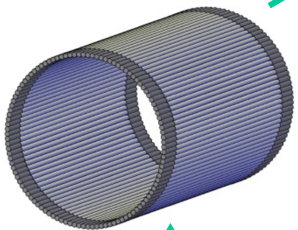
INSTYTUT FOTONOWY COMPANY

ELECTRONICS

P. Salabura, T. Kozik,
M. Pałka, P. Strzempek

Nowoczesna Elektronika COMPANY

DAQ TRIGGERLESS
G. Korcyl, M. Kajetanowicz



SIMULATIONS
P. Kowalski, W. Wiślicki
(Świerk Computing Centre)
D. Kamińska, O. Rundel

EXPERIMENTS, CALIBRATIONS
D. Alfs, T. Bednarski, E. Czerwinski,
J. Smyrski, E. Kubicz,
Sz. Niedźwiecki, M. Silarski,
M. Zieliński

Analysis framework
W.Krzemień, T. Gruntowski,
A.Gruntowski

SYNTHESIS OF SCINTILLATORS
Ł. Kapłon,
A. Wieczorek,
A. Kochanowski,
M. Molenda,
A. Danel (AU)

TIME and HIT-POSITION RECONSRUCTION
L. Raczyński, N. Sharma, N.Zoń

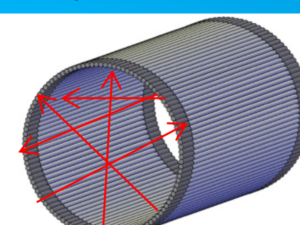


IMAGE RECONSTRUCTION
P. Białas, J. Kowal, Z. Rudy,
A. Słomski, A. Strzelecki

IMAGE VISUALISATION

SILVERMEDIA IT COMPANY


THANK YOU
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