Scintillation Detectors and Readout Electronics at FZJ-ZEL

March 30, 2009 | Günter Kemmerling,Ralf Engels

GSPC – Launch Meeting, PSI Villingen

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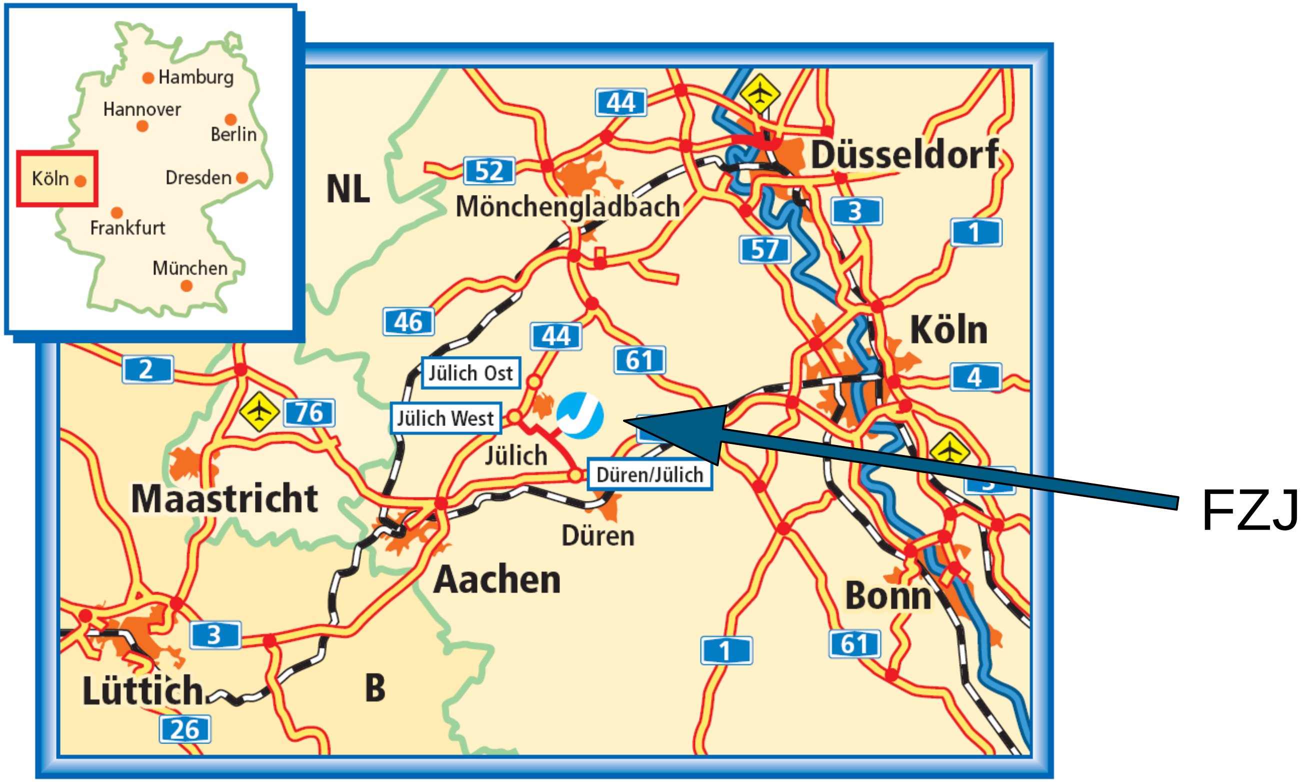
Forschungszentrum Jülich GmbH (FZJ)

- Location:

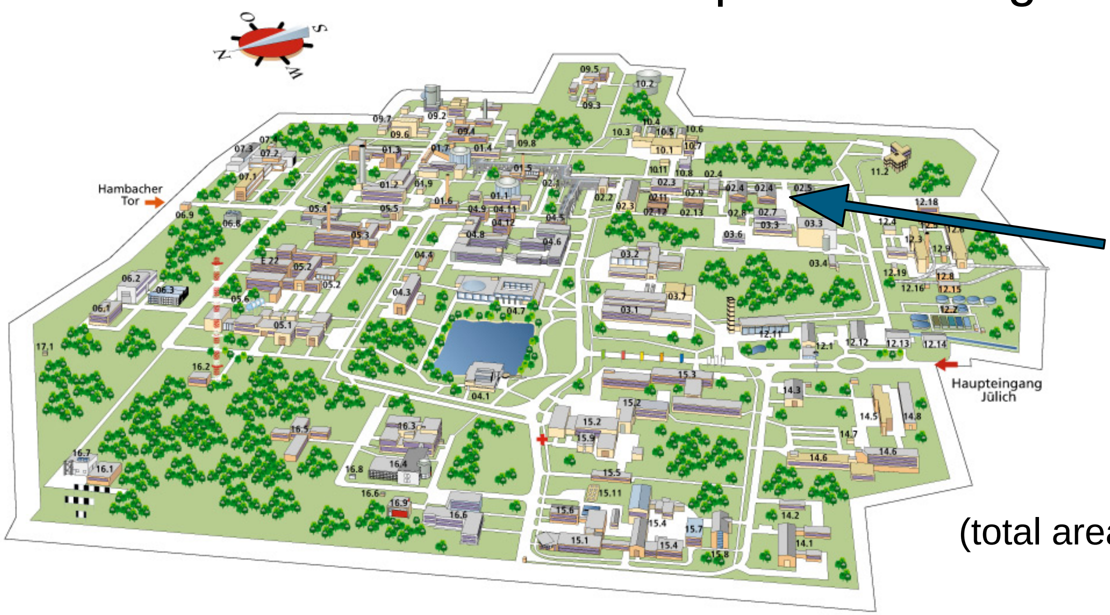


FZJ – Basic facts & figures

- Founded:
  - December 1956, originally as “atomic research centre“
- Partners:
  - Federal Republic of Germany (90%)
  - Federal State of North Rhine-Westphalia (10%)
- Budget:
  - € 436 million (2007)
- Staff: total ~ 4400, including
  - Scientists: ~ 1250
  - PhD students & fellows: ~ 330
  - Technical staff: ~ 1630
  - Trainees: ~ 350

FZJ – Campus

- Research:
  - Health, energy & environment, information, key technologies
  - 9 institutes & 3 scientific-technical joint facilities
  - Large instruments: e.g. COSY, TEXTOR, SAPHIR
  - High performance supercomputing centre
  - Virtual institutes for research cooperations: e.g. CNI, JCNS



ZEL

(total area: ~2.2 sq. km)

Zentralinstitut für Elektronik (ZEL)

- Scientific-technical joint institute of FZJ
  - R&D projects in scientific instrumentation in close collaboration with other FZJ institutes
  - Synergy effects through similar system solutions in different research areas

ZEL – Basic data

- Key competencies:
  - Analog and digital signal processing
  - Detector, sensor and imaging technologies
  - Control and measurement systems
  - Scientific and technical informatics
  - Intranet communication (JuNET)
  - Lab for prototyping of electronical equipment (e.g. SMD)
- Staff: total ~ 90, including
  - Scientists & Engineers: ~ 33
  - Technicians: ~ 26
  - Trainees: ~ 20
- Work organized in 4 divisions

Detector Systems Division at ZEL

- Group: Detector Development & Nuclear Pulse Processing
  - Discrete analog/digital detector electronics
  - Neutron and gamma scintillation detectors
- Group: Micro-Structure Detectors
  - Si-pad and microstrip detector systems
  - Fast readout electronics for pnCCD-detectors
- Group: Interfacing and fast Digital Technology
  - FPGA based readout electronics
  - Fast homemade bus systems and optical links

Neutron Detector Developments at ZEL

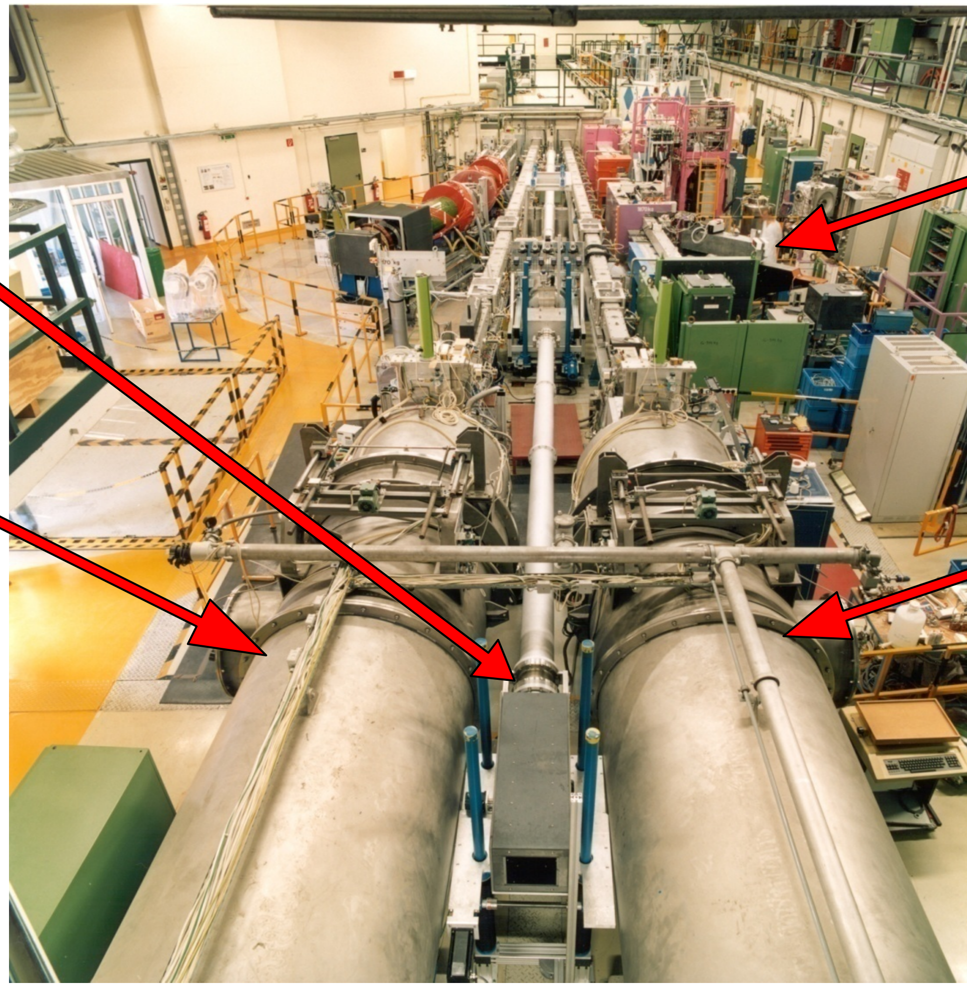
- Group established in 1969
- Early 70's:
  - Developments based on ^{3}BF, later ^{3}He Detectors
- End 70's early 80's:
  - Neutron scintillation detector prototype developments for SNQ
- Mid 80's:
  - Development of neutron detectors for renewed FRJ-2
- Beginning 90's:
  - Prototype developments for ESS
- Since end 90's:
  - Focus on high-rate detectors for FRM-2 & SNS

Instruments with ZEL - Position Sensitive Detectors

FRJ-2 Neutron Guide Hall (until May ’06)

KWS 3

HADAS



KWS 2

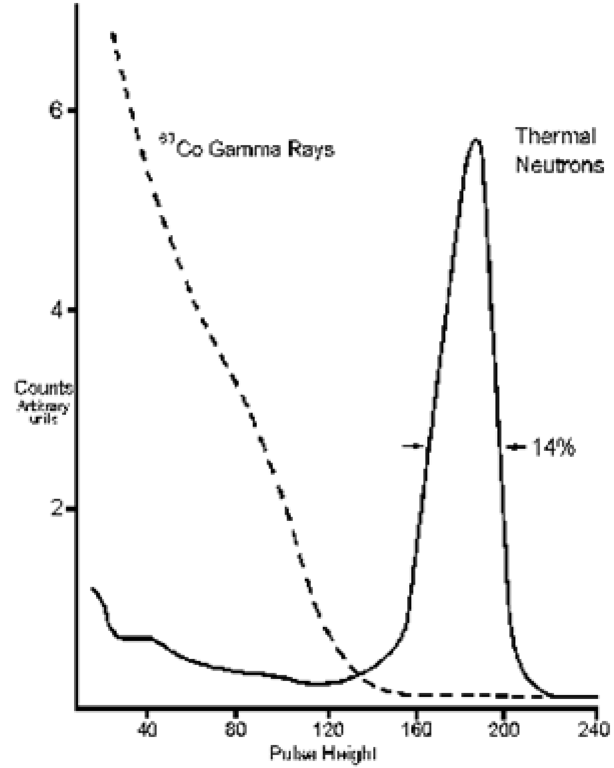
KWS 1

Standard Neutron Scintillator: GS20-^{6}Li-glass

- Neutron capture reaction:

$$n + {}^{6}\mathrm{Li} \rightarrow {}^{4}\mathrm{He} + {}^{3}\mathrm{H} + 4.79\,\mathrm{MeV}$$

- 6.6 weight% Li, 95% ^{6}Li-enriched
- Emission peak at ~390 nm (Ce doped)
- Light yield ~ 6000 photons/n (corresponds ~1.5 MeV gamma)



APPLIED SCINTILLATION TECHNOLOGIES

(www.appscintech.com)

GS20-^{6}Li-glass Efficiency

$$\varepsilon = \frac{I_0 - I(x)}{I_0} = 1 - e^{-n\sigma x}$$

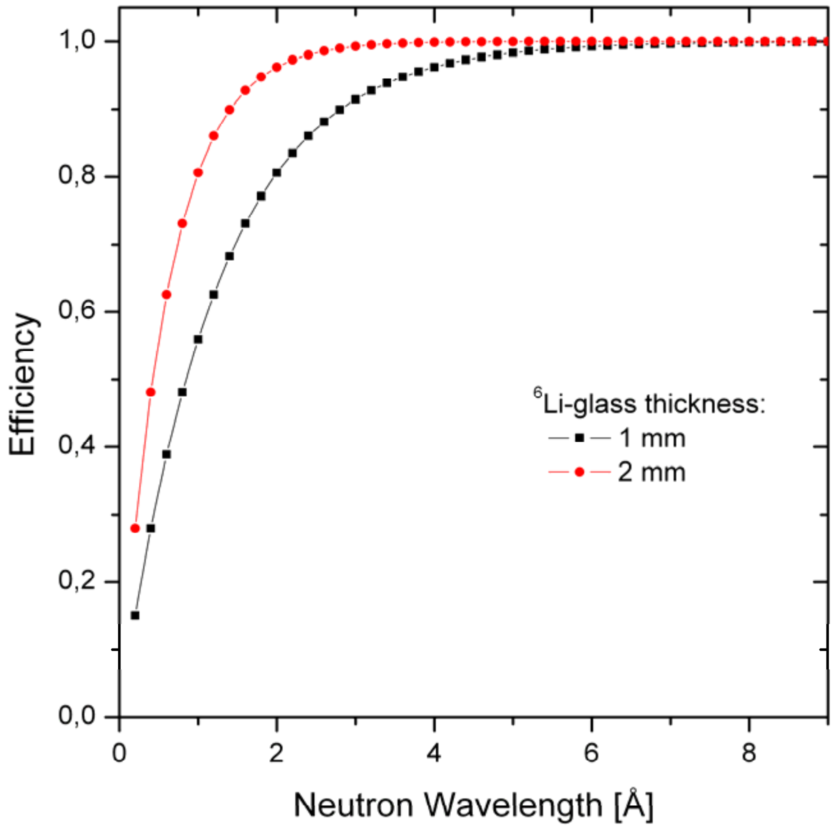
$$n = \rho_{Li-glass} \cdot W_{eff} \cdot \frac{N_A}{A}$$

$$\rho_{Li-glass} = 2.5\,g \cdot cm^{-3}$$

$$W_{eff} = 6.6\% \cdot 0.95 = 6.27\%$$

$$A_{^6Li} = 6.015\,g \cdot mol^{-1}$$

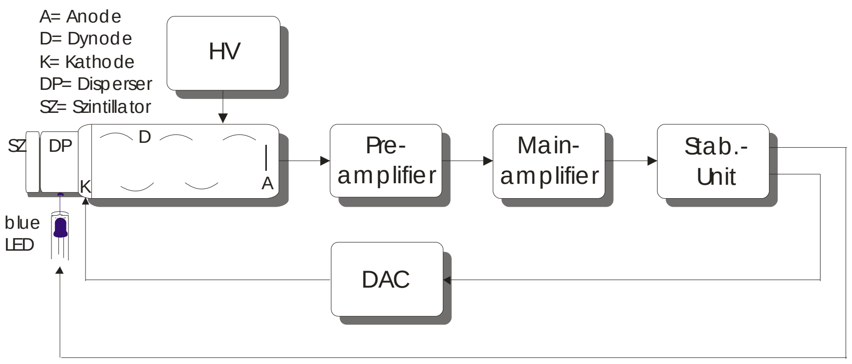
$$\sigma = \frac{\lambda}{1.8\,A} \cdot \sigma_{1.8A} = \frac{\lambda}{1.8\,A} \cdot 940 \cdot 10^{-24}\,cm^2$$

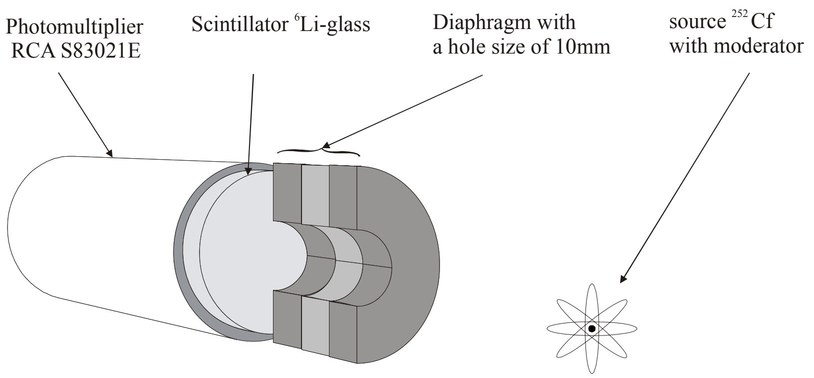


Test of Neutron Scintillator Characteristics

- Light yield:
  - gamma discrimination, position resolution
- Decay Time:
  - pulse processing electronics, dead time
- Neutron Capture Efficiency

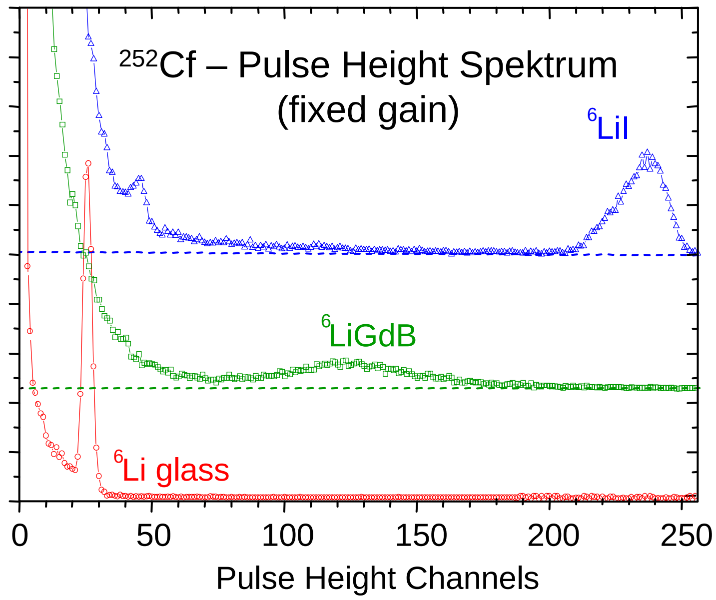
Test Setup:





Comparison of some neutron scintillators

- GS20-^{6}Li-glass
  - gamma sensitive at ~1.2 MeV
  - fast decay time (~75 ns)
- ^{6}LiI-scintillator:
  - light yield: ~9x Li-glass
  - decay time ~1.5 µs
  - hygroscopic, no longer produced
- ^{6}Li^{158}GdB with binder
  - light yield: ~5x Li-glass
  - homogenity problems!
  - decay time: ~1µs



Neutron Anger camera detectors

- Neutron capture creates light in scintillator (e.g. GS20)
- Disperse light cone on PMT array
  - Total reflection at air gap limits angle of light propagation
- Derive position of neutron capture from PMT signals
  - e.g. by Center-of-gravity, Right-left asymmetry etc.
  - Position resolution: $R \sim D/\sqrt{n}$

Right-left asymmetry

$$q_k = \frac{S_{k+1} - S_{k-1}}{S_{k-1} + S_k + S_{k+1}}$$