Detector development in the ESRF Upgrade Programme

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General guidelines

- **Intensify R&D on X-ray detectors**
  - Aim is to reduce the “detector handicap”:
    - Use all the available photons (efficiency, active area, deadtime, …)
    - Obtain the desired information (resolution, time domain, …)
  - Identify the main development lines
- **Collaborative approach across Europe and worldwide**
  - Coordination with other SR facilities
  - Involvement of detector development labs and manufacturers
- **Maintain a good level of in-house expertise and involvement**
  - Proper adaptation and integration of the new detectors
  - Guarantee support and evolution

Main development lines

Improvement of current 2D detectors

- High sensitivity large-area detectors
- High efficiency sensors
  - → high energy experiments
  - → high spatial resolution

Access to shorter time domains

- Fast imaging cameras
- Time resolved 2D counting detectors

Exploration of new features:

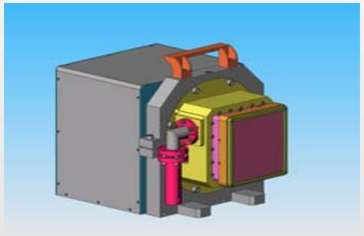
- Extended dynamic range
- Energy resolving 2D detectors

Detector development programmes

Indirect detection	High sensitivity integrating detectors (CCD, MAPS, CMOS panels)
	Very fast imaging cameras
	High resolution scintillators
Hybrid pixel detectors	Diversification of pixel detector technology
	Small-pixel detectors
	Detectors with microsecond time resolution
	APD-based 2D detectors
	Detectors with extended dynamic range
	High-Z semiconductor sensors
Energy resolution	Energy resolving 2D/multielement detectors

➢ High sensitivity integrating 2D detectors

CCD cameras are workhorse detectors for SR

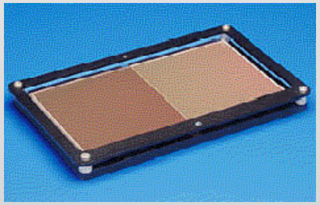


Last developments approach single photon sensitivity

- i.e. FReLoN 4M : RMS noise ≈ 1 photon (@17.4 keV)

CCD technology is very mature but there is room for improvement

- buttable devices
- speed (multiport, parallel readout)



60 x 120 mm
4k x 8k pixels

To be compared with other sensors:

- Particularly important in the longer term
- MAPS, CMOS panels

➢ Very fast imaging cameras

High speed X-ray cameras with sub-ms framing time

- Benefit from advances in fast imaging (scientific & military)
  - A few commercial fast cameras are in the market
    i.e. fast tomography experiments at ESRF
  - Effort should be put in increasing the dynamic range.
    - Good matching to X-ray scintillators
- Optimised X-ray detectors may require new sensors.
  - CCD or CMOS sensors with fast parallel readout

➢ High resolution scintillators

Development of screens with optimum combination of

- detection efficiency (challenging at high energy)
- spatial resolution (in the μm range)

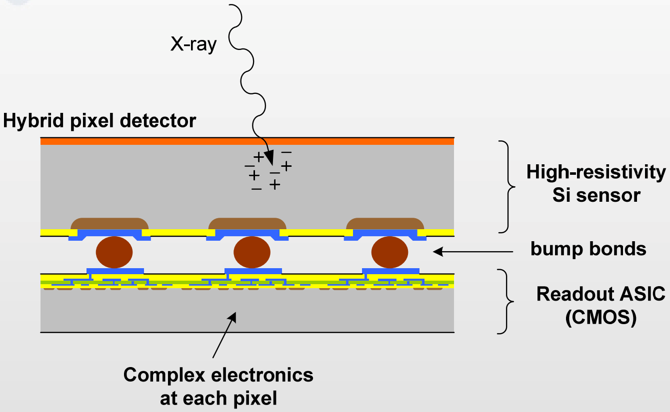
Specific to synchrotron radiation (1 μm resolution @ 20 keV)

- the ESRF is leading this field
- progress of ×10 during the last 8 years
- substantial room for further improvements:
  - screen material and thickness, substrates, optical quality, activator ions …
  - structured screens

➢ Hybrid pixel technology

Improvement of technological aspects

- Radiation tolerance (a major concern)
- Interconnection issues
  - Module tiling
  - Reduction of dead areas (edgeless sensors)
- Fast data readout
- Lower cost



A common development platform for SR applications

- Needs coordination with ongoing projects (PILATUS, XPAD, XFEL)
- Aiming a certain level of “standardisation”
- Ease the development of application specific pixel detectors (diversification)

➢ High-Z semiconductor sensors

Development of high-Z sensors (GaAs, Cd(Zn)Te, ...) for pixel detectors

- Extend the usability of the detectors to higher energy
- Enhance the radiation tolerance

Extremely important but difficult issue. Needs improvements in:

- Sensor size
- Quality and uniformity (charge collection efficiency)

Push the sensor development from the application side

- Collaborate with material research labs and manufacturers
- Select and characterise the most appropriate materials
- Fabricate sensors and evaluate them with existing readout chips

Hybrid pixel detectors

➢ Small-pixel detector

Photon counting 2D detector:

- Pixel size: ~50 μm
- Radiation tolerant design

Will combine features found in existing chips

Consider supporting/joining ongoing projects

➢ Pixel detectors with microsecond resolution

Readout architecture optimised for time resolved experiments down to 1 μs resolution

- Possible readout schemes:
  - Multiframe storage
  - Event-by-event readout
  - Mixed mode (combination of both)

APD-based pixellated detectors

Development of counting pixel detectors based on pixellated avalanche photodiodes (APD)

- Time resolution pushed down to ~1ns
- Higher counting rate (>10^8 ph/s/pixel)

Challenging

- Very fast readout electronics, power dissipation issues
- APD sensors larger than 1cm x 1 cm will need R&D

A pilot project (SNAP) is starting now

- Collaboration ESRF, DESY, Spring8 and University of Heidelberg
- Sensor development by an industrial partner

Exploratory programmes

➢ Pixel detectors with extended dynamic range

- Select sensitivity on a pixel by pixel basis (integrating mode)
- Combining photon counting and integrating modes

Goal: combine in the same image very weak signals with strong diffraction features

➢ Energy resolving 2D/multielement detectors

Evaluate emerging detectors technologies like:

- Solid state devices (DEPFET arrays)
- Cryogenic detectors (microcalorimeters, tunnel junctions)

Study their current status and their projection into the future

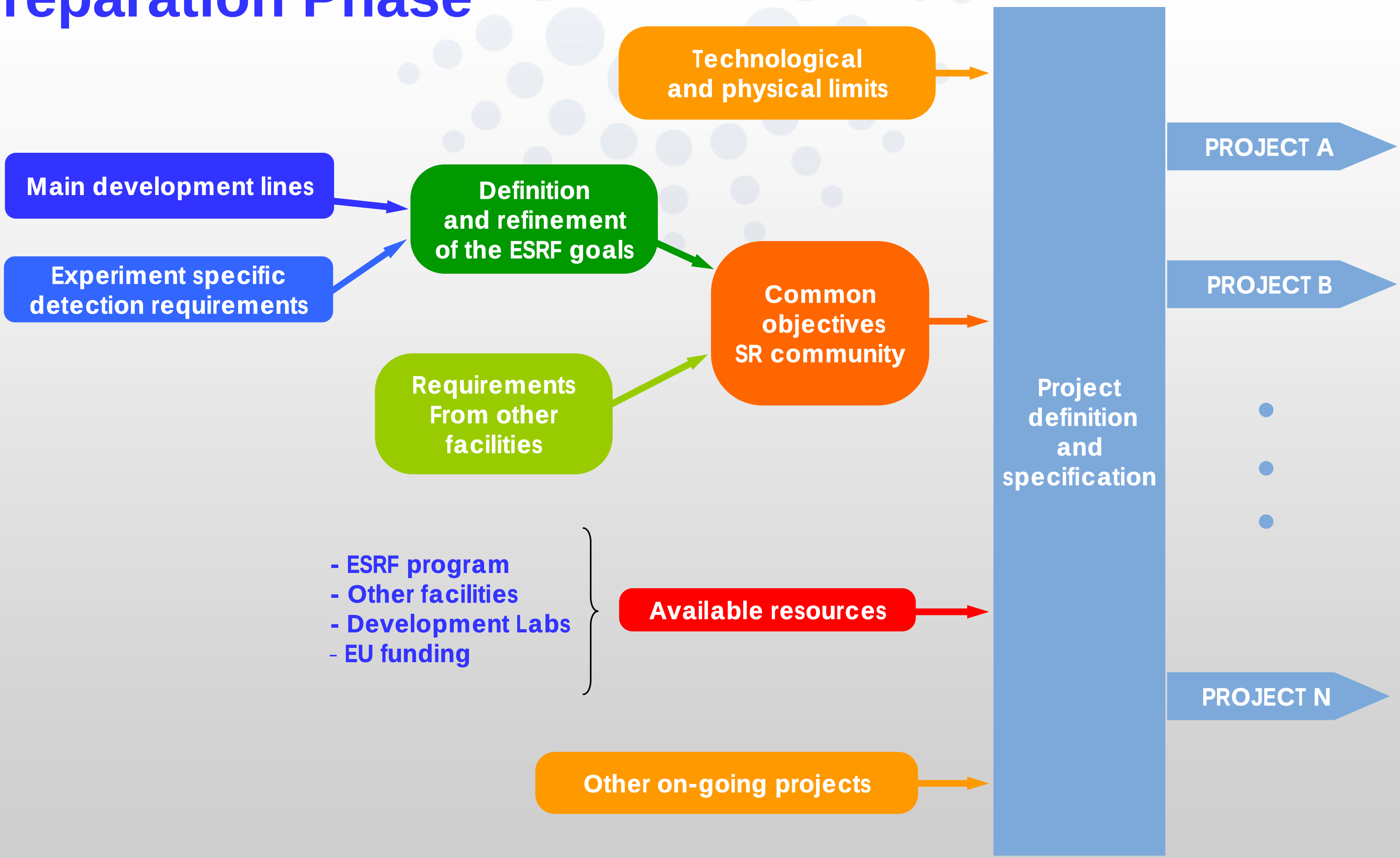
Preparation of the Detector Programme

Among the actions started or foreseen during 2008 are:

- Continue the technical studies (technology choices, feasibility)
- More detailed identification and specification of the ESRF needs
- Identify other SR facilities and labs able and ready to invest resurces and know-how in common development programmes.

The preparation of the development program is crucial as well as the total final effective available resources.

Preparation Phase



Summary:

- This programme aims to make an special effort to overcome the "detector handicap".

- The preparation phase is crucial (and not easy!). Maximum input from the experiments side is needed.

- The participation of other facilities and development labs is fundamental to achieve ambitious goals.

- A number of development lines have been identified but the actual number of projects and detectors to be developed will be very much dependent on the final effective resources.