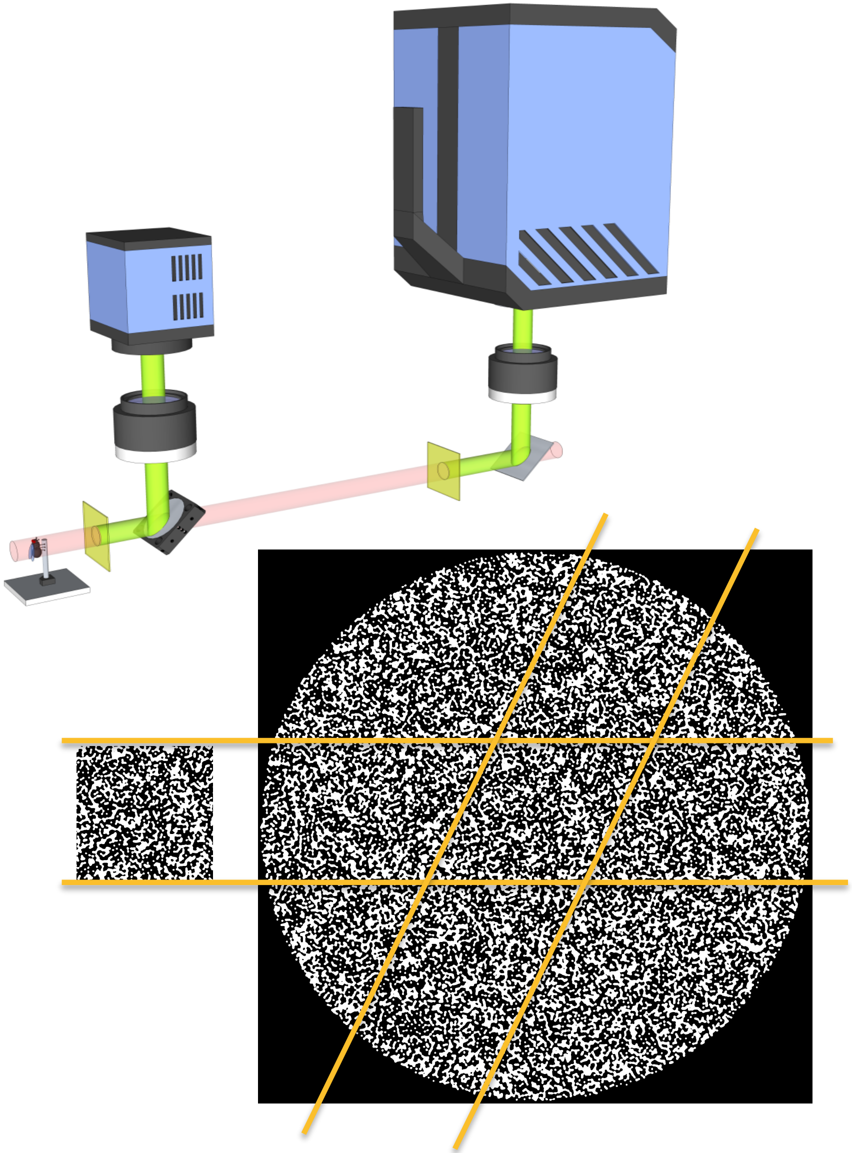
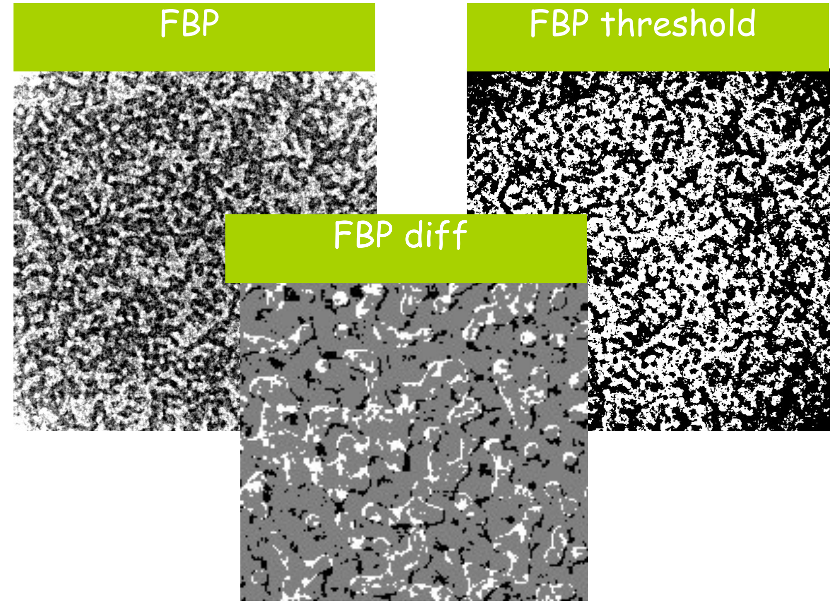
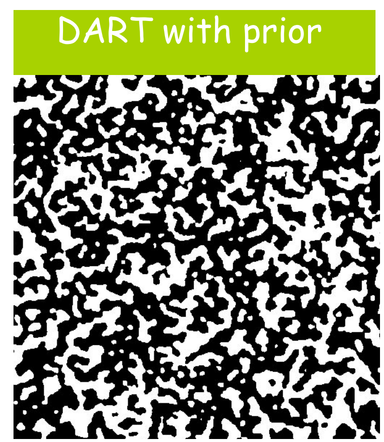
The low res. prior







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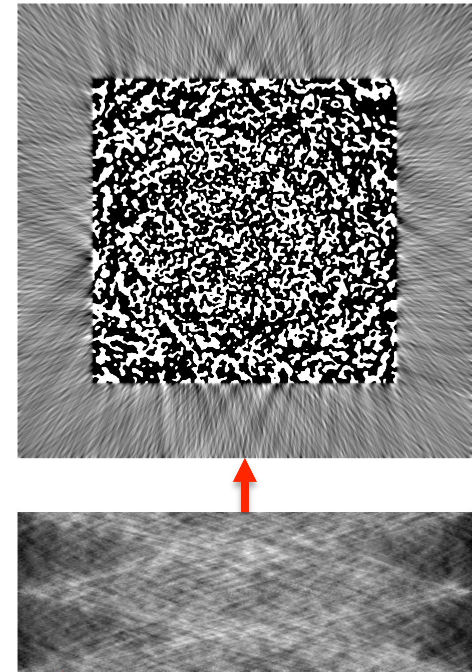
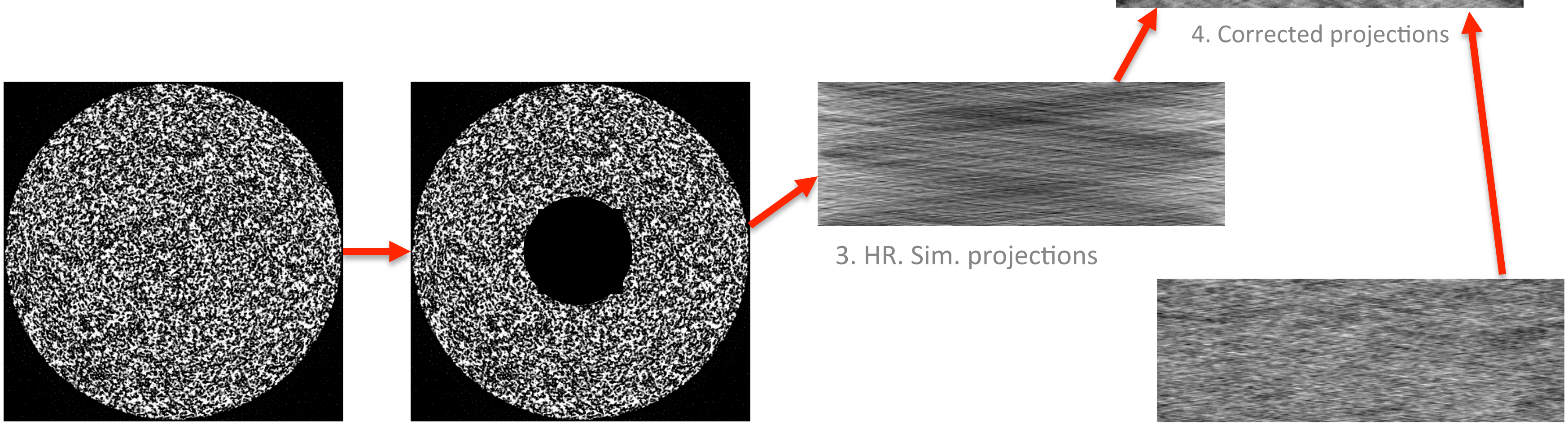
Interior-tomo: Results

Reconstruction with two geometries:

1. Performing full reconstructions with LR projections.
2. Mask out inner pixels.
3. Caclulate HR proejctions from LR reconstruction.
4. Substract it from the original HR projections.
5. Perform final reconstruction.

(Result is better if padded with non-discretized pixels.)





MAX IV

Interior-tomo

cost
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY
EXTREMA

Methods:
- Sample: porous phantom
- One low and one high resolution set of projections (LR and HR)
- Fine-tuning the HR reconstruction using info from the LR projections
- Widening the FOV of the HR reco using the LR reco and the HR projections

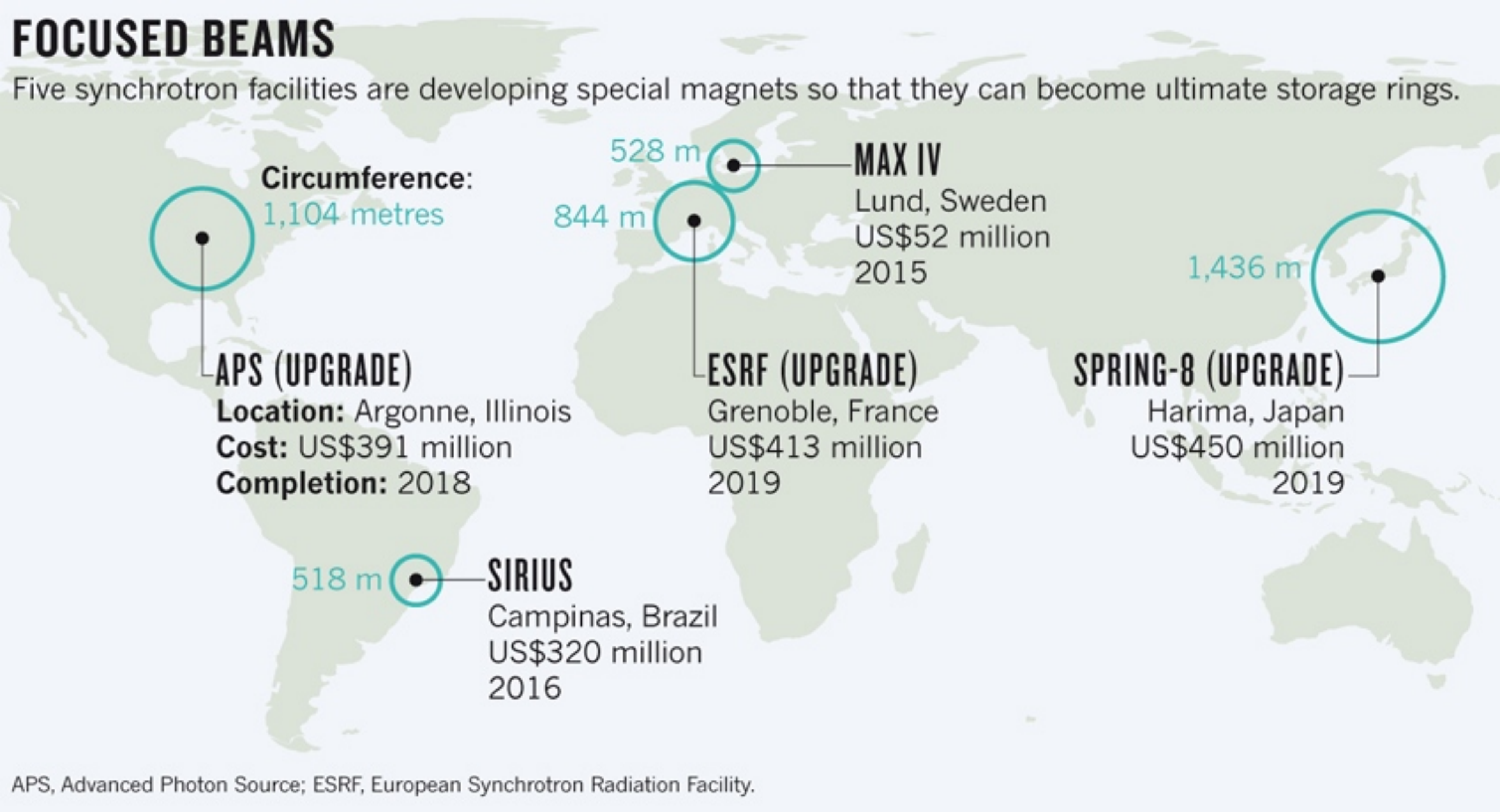
Results:
- Tomo quality improved inside the FOV (local tomo artifacts are reduced)

Scripts, algorithms:
- FBP, SIRT, DART, Szeged EM-DTR

OUTLINE
The ingredients of fast tomography

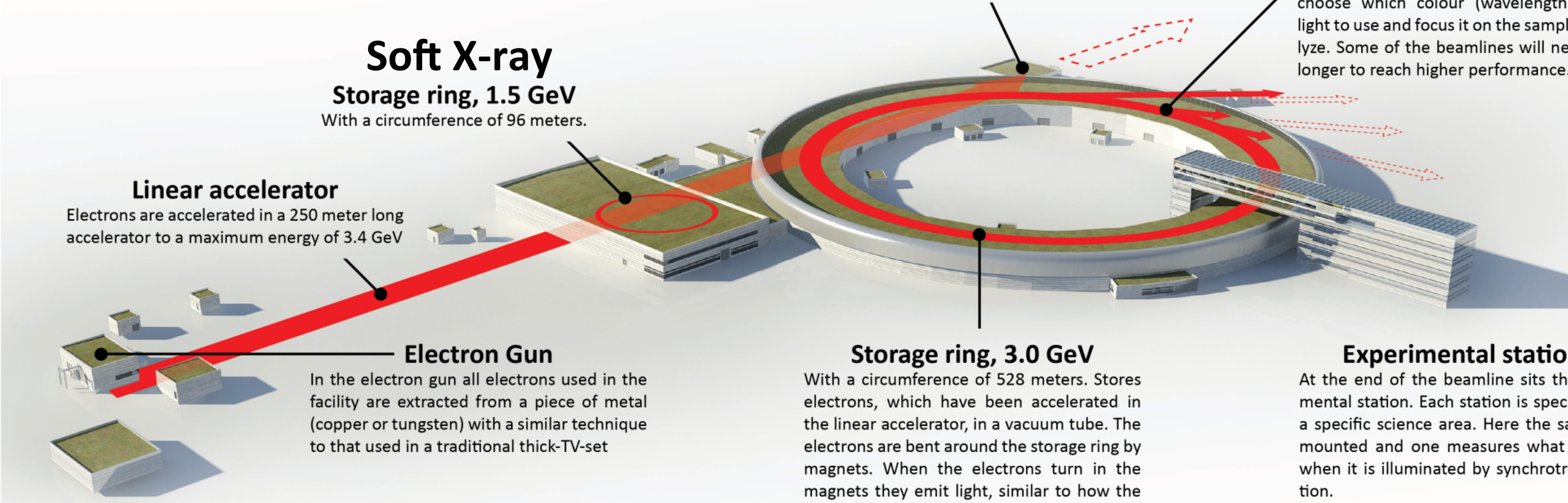
- Sensing the phase
- Fast detectors
- Advanced tomographic reconstruction algorithms
- **The brilliance of the synchrotron sources**
- Image analysis with physical priors

Ultimate storage rings



MAX IV

Investment in accelerator ~1150 MSEK
13 beamlines ~900 MSEK
Operations ~350 MSEK/year (2016)
Secured until 2019 (VR + LU)



Soft X-ray

Storage ring, 1.5 GeV
With a circumference of 96 meters.

Linear accelerator
Electrons are accelerated in a 250 meter long accelerator to a maximum energy of 3.4 GeV

Electron Gun
In the electron gun all electrons used in the facility are extracted from a piece of metal (copper or tungsten) with a similar technique to that used in a traditional thick-TV-set

Radiation
The electrons in the accelerator create a small amount of background radiation when the machine is operated. When the machine is switched off there is no remaining radiation as no radioactive material is produced. The accelerator itself is built into concrete and thus one can work freely in all other areas of the laboratory. If someone would enter the accelerator area the machine will stop automatically.

Short pulse facility
Extremely short light flashes can be produced here by using the electrons directly from the linear accelerator.

Beamline
The light that is produced by the electrons shines through the beamline to the experimental station. In the beamline one can choose which colour (wavelength) of the light to use and focus it on the sample to analyze. Some of the beamlines will need to be longer to reach higher performance.

Storage ring, 3.0 GeV
With a circumference of 528 meters. Stores electrons, which have been accelerated in the linear accelerator, in a vacuum tube. The electrons are bent around the storage ring by magnets. When the electrons turn in the magnets they emit light, similar to how the current in an antenna emits radio waves. Since the electrons travel with close to the speed of light, the light is called synchrotron radiation and has very special properties.

Experimental stations
At the end of the beamline sits the experimental station. Each station is specialised to a specific science area. Here the samples is mounted and one measures what happens when it is illuminated by synchrotron radiation.

Hard X-ray

~26 beamlines in 2026 is the plan

The Max IV imaging beamlines

SoftiMAX
Soft X-rays
(in construction -> 2018)

MedMAX
The biomedical imaging beamline
(preparing CDR)

NanoMAX
The nanofocus beamline
(users in 2017)

DanMAX
Imaging & diffraction
(in construction -> 2018)

2016 2017 2018 2019-20

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Imaging at new generation storage rings

- High flux density:

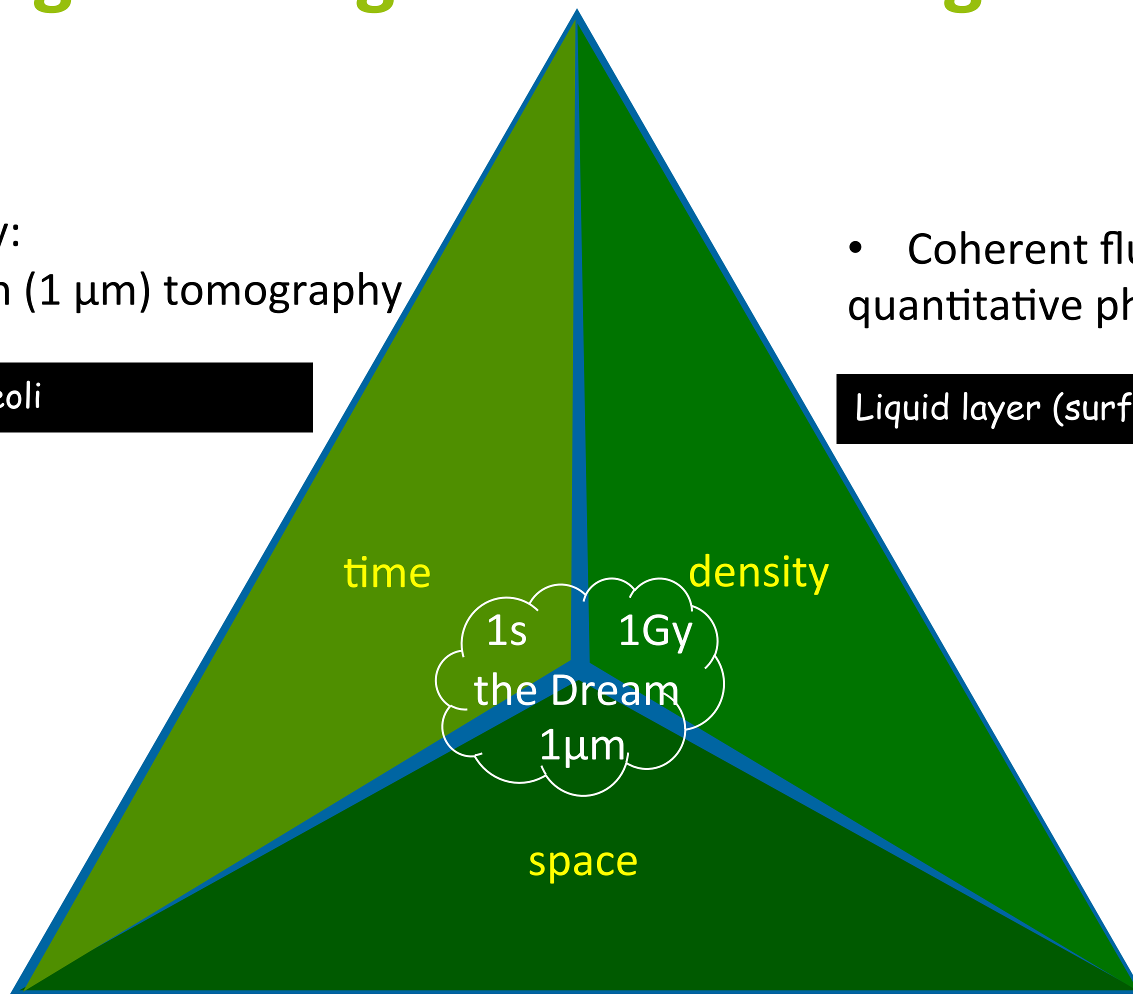
fast high resolution (1 µm) tomography

alveoli

- Coherent flux:

quantitative phase imaging

Liquid layer (surfactant distribution)



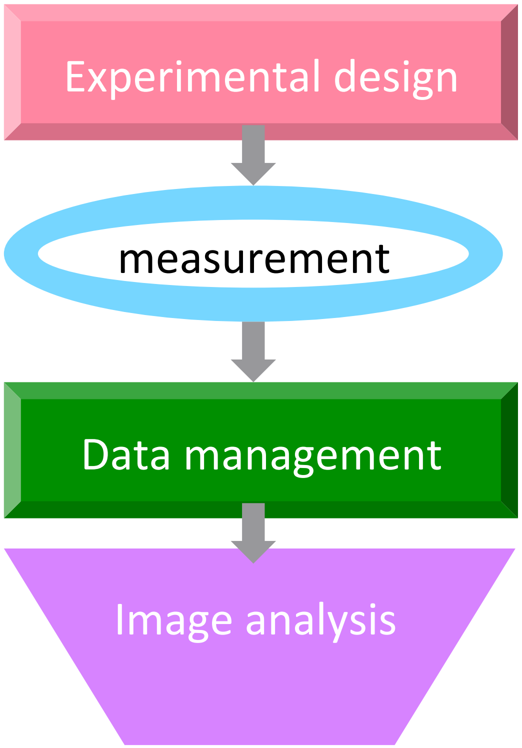
- Brilliant beam: Small spot size for zoom tomography

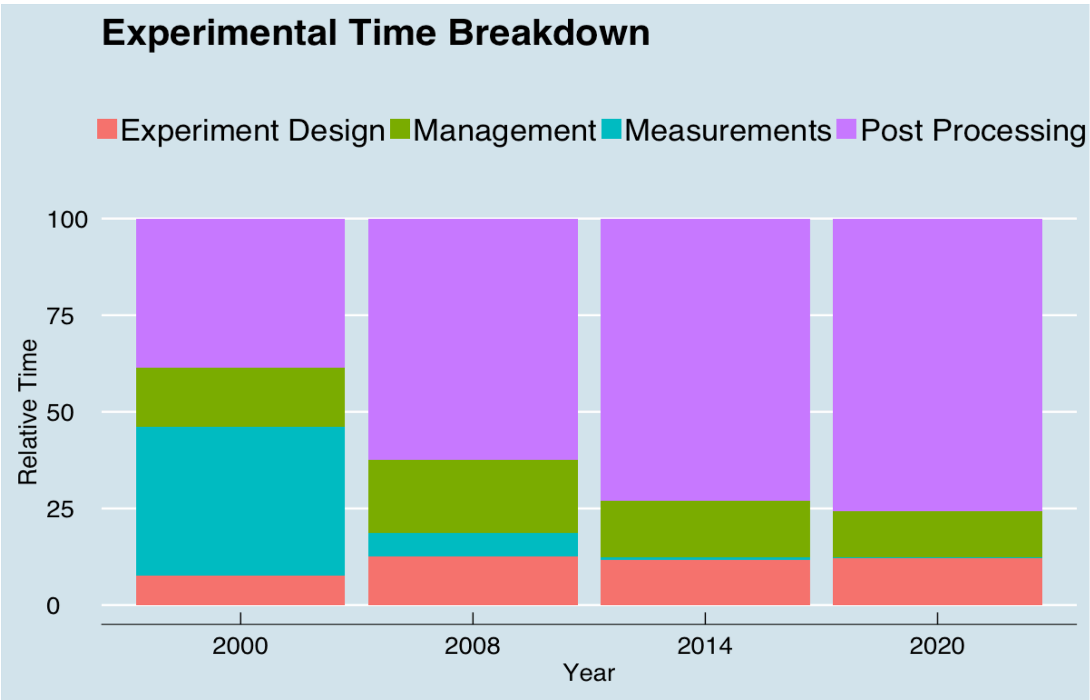
Nanoparticle tracking in the airways

OUTLINE
The ingredients of fast tomography

- Sensing the phase
- Fast detectors
- Advanced tomographic reconstruction algorithms
- The brilliance of the synchrotron sources
- Image analysis with physical priors

From design to results





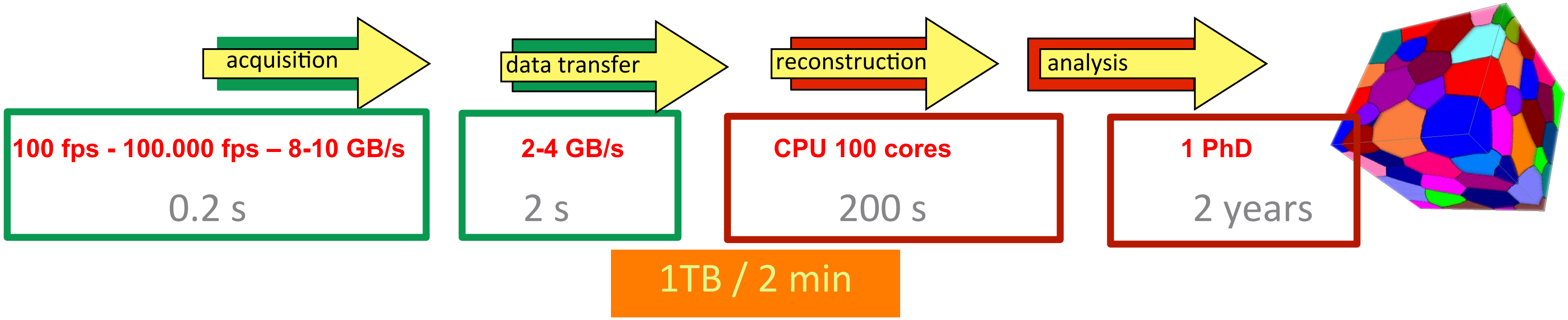


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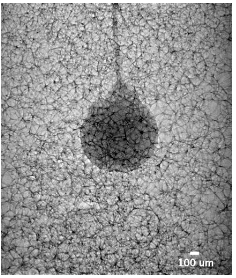
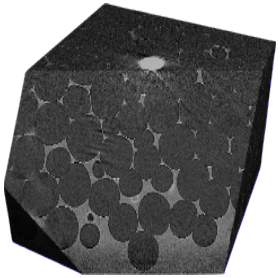
Image-based quantitative information retrieval

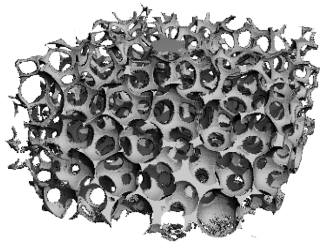
300 GB



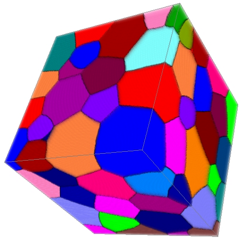
+ 300 GB



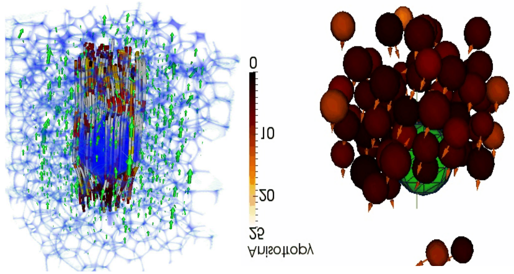
+ 100 GB



1 GB



1 MB



acquisition

Scanning
Sample conditioning

reconstruction

segmentation

feedback

labeling

quantification

visualization

1TB / 2 min

robust, simple & universal

Customized & flexible

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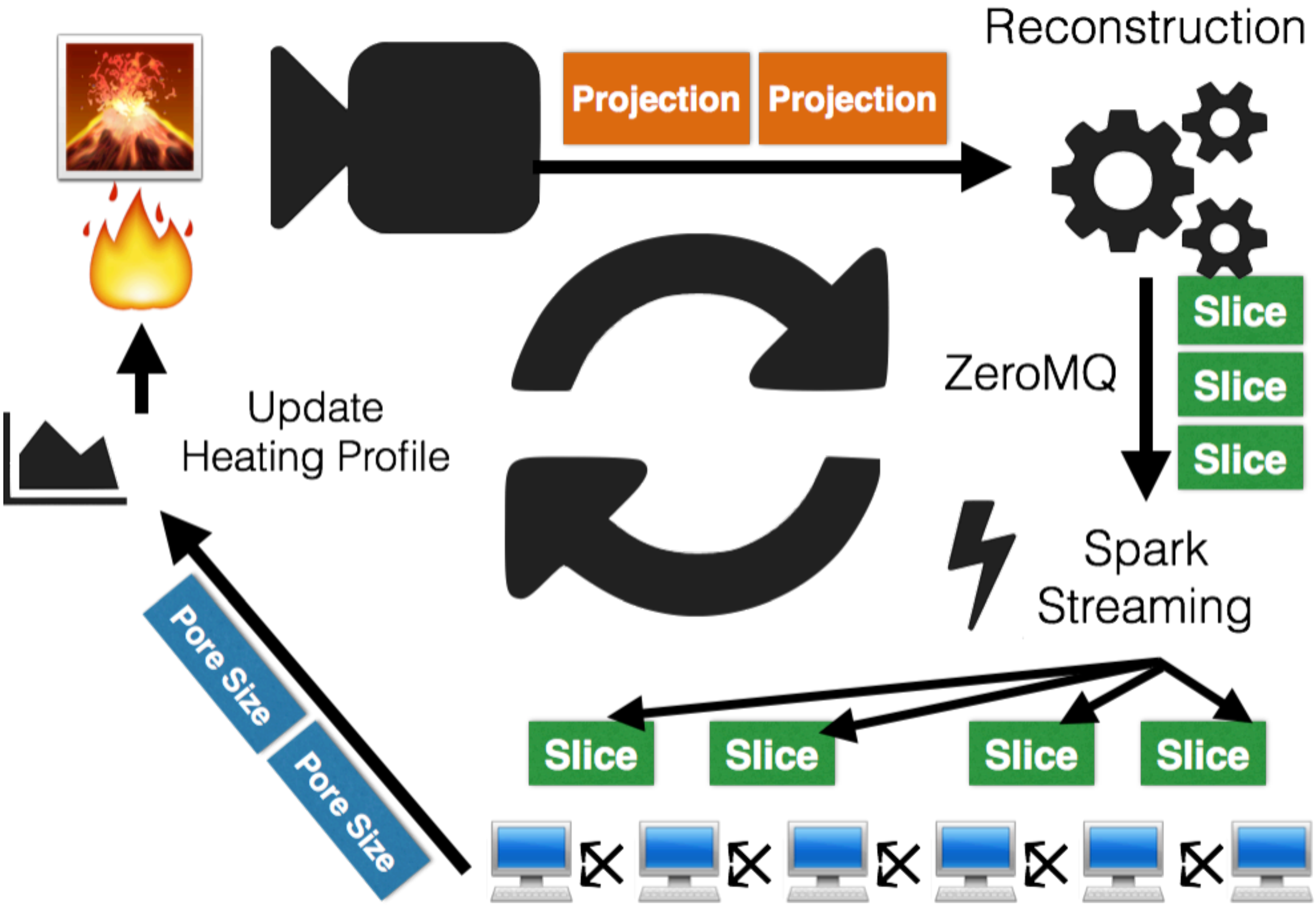
Real time QA feedback



Courtesy: Kevin Mader

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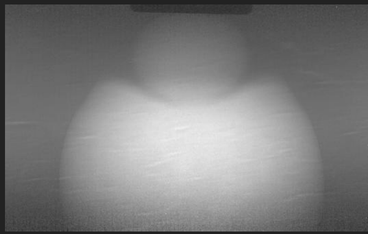
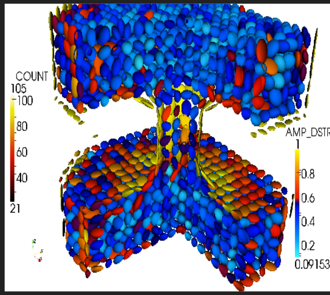
Outline

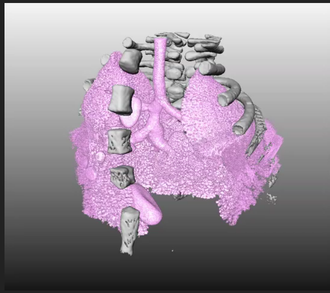
I. Ultrafast 2D imaging
   I. Dynamic processes

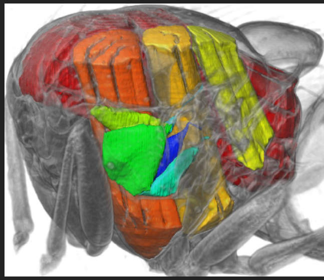
II. Fast 3D imaging
   I. The ingredients

III. Examples
   I. Lungs, fly, foams









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The challenges of fast tomography

Imaging matter:

- Many angles
- Noisy data (short exposure)

Imaging life:

- Few angles (gated)
- Noisy data (dose)
- Interior / local tomo

periodic

moderately fast (s)

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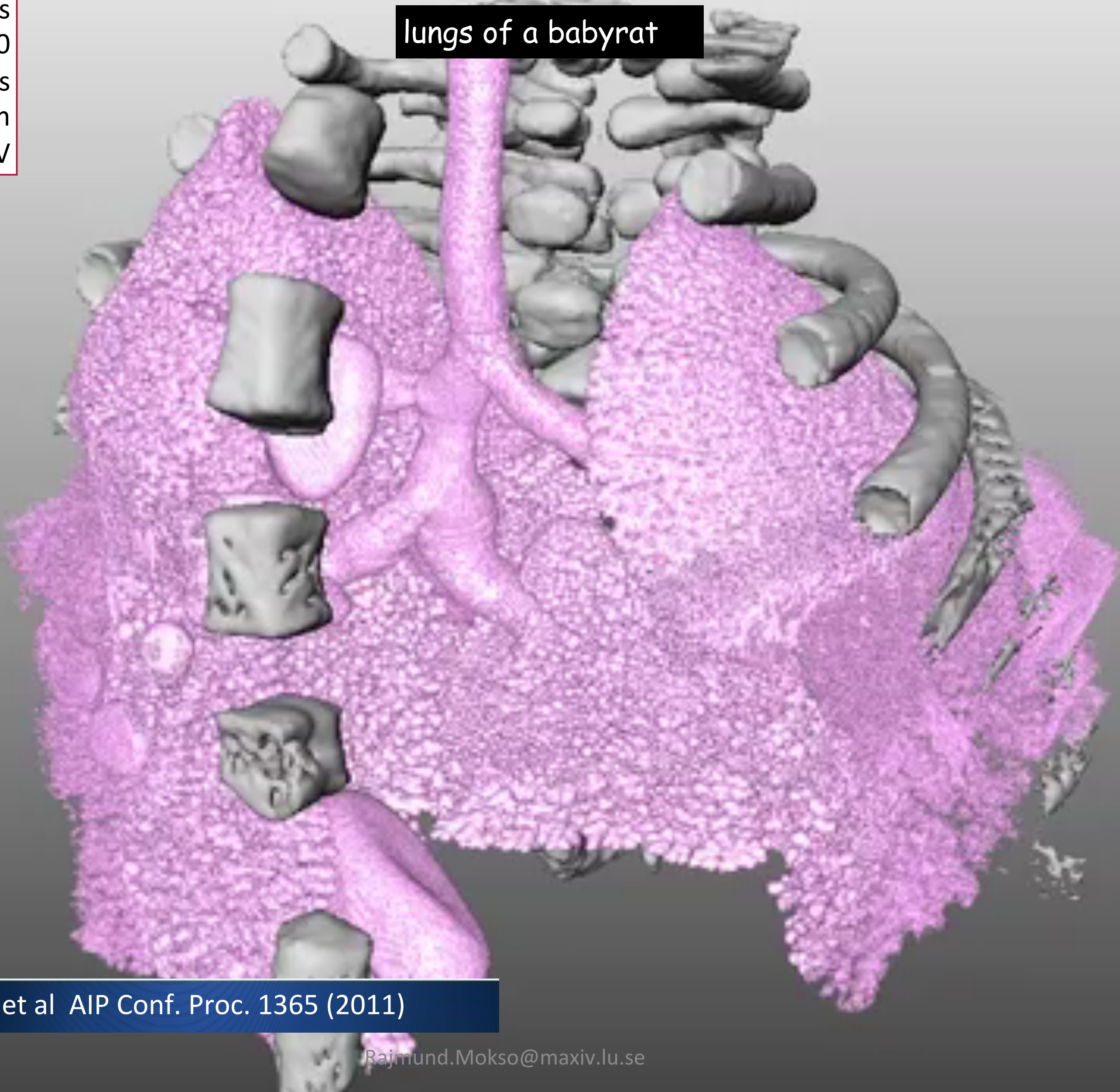
The lung imaging project

Goran Lovric, PhD thesis at PSI
Johannes Schittny, anatomy institute, Bern University
Matthias Roth-Kleiner, head of neonatal intensive care unit, University Hospital Lausanne

In-vivo lung imaging

exposure time= 1.1 ms
projections= 500
total scan time= 0.57 s
voxel size= 11 um
E= 20 keV



R. Mokso et al AIP Conf. Proc. 1365 (2011)

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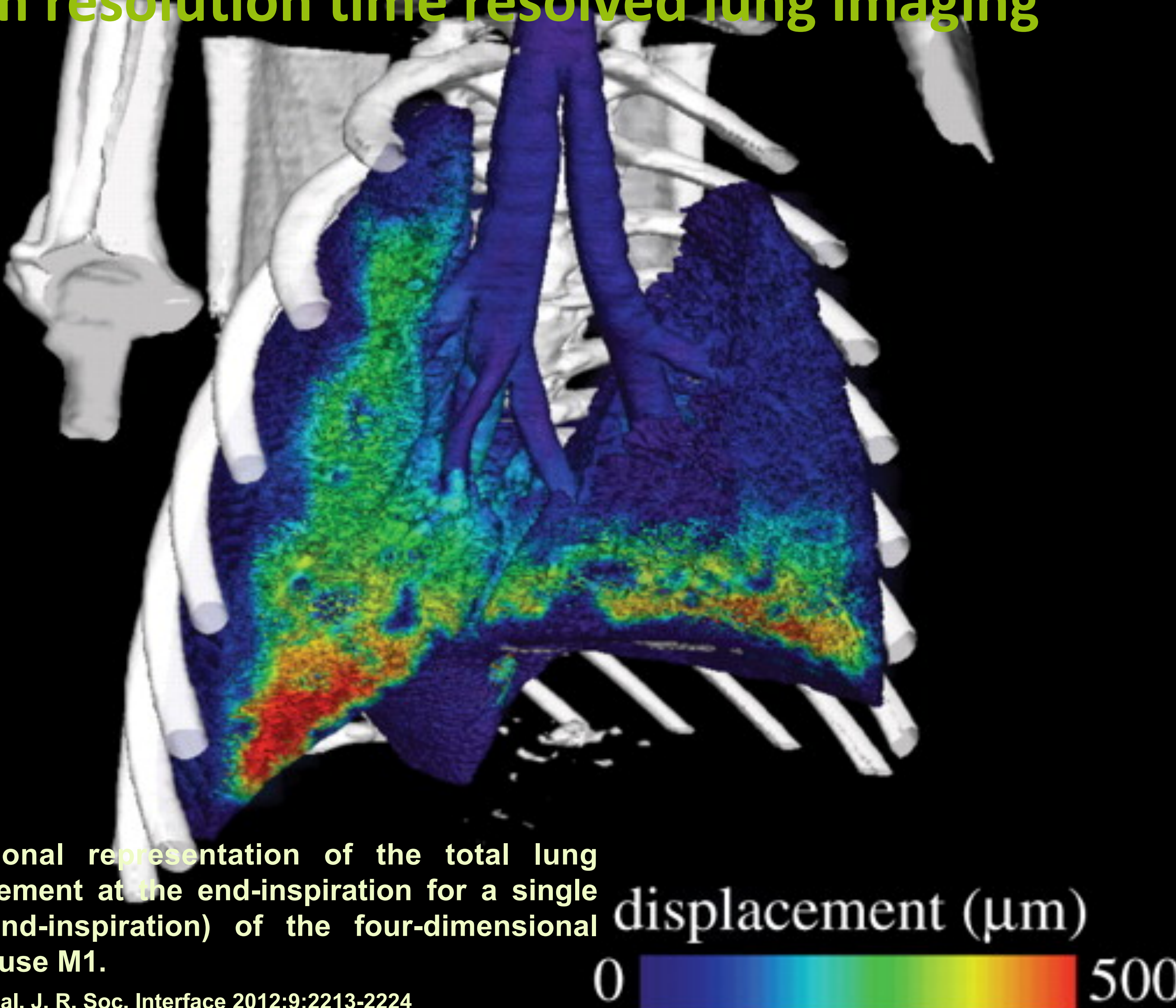
Medium resolution time resolved lung imaging



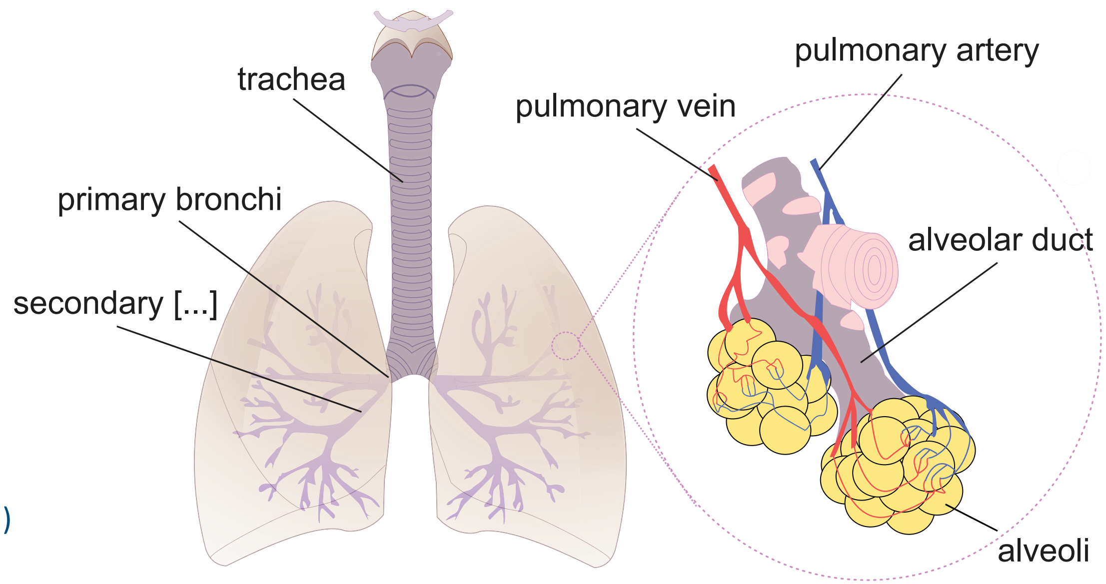
Three-dimensional representation of the total lung tissue displacement at the end-inspiration for a single time point (end-inspiration) of the four-dimensional dataset for mouse M1.

Stephen Dubsky et al. J. R. Soc. Interface 2012;9:2213-2224

Dynamic imaging of lungs at the micrometer scale: motivation

Ventilator-induced lung injury (VILI)

- Overextension of lung tissue in certain lung regions (mechanical damage, biotrauma)
- Still unclear how ventilation induces its deleterious effect [4]
- Hypothesis: local strains in the alveolar wall cause hotspots (overstretching regions)



- Human lungs (Source: Wikipedia)

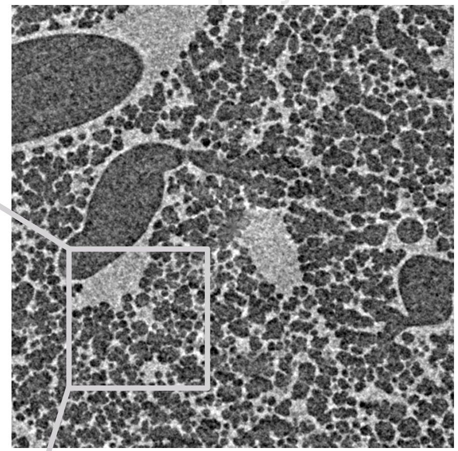
[4] Rausch, S. M. K., Haberthür, D., Stampanoni *et al.*, Ann Biomed Eng **39** (11), 2835 (2011).

Image quality vs. radiation damage

G. Lovric et al., J. Appl. Cryst. 46 (4) 2013

2.9 µm pixel-size optics

901 projections | 901 projections | 901 projections | 361 projections



	901 projections	361 projections
Scan time	0.24 s	0.17 s
CNR	2.3	1.5
Entrance dose	12 Gy	9 Gy

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