Validation and parameter selection for *GREIT*

GREIT: Graz Consensus Reconstruction Algorithm for EIT

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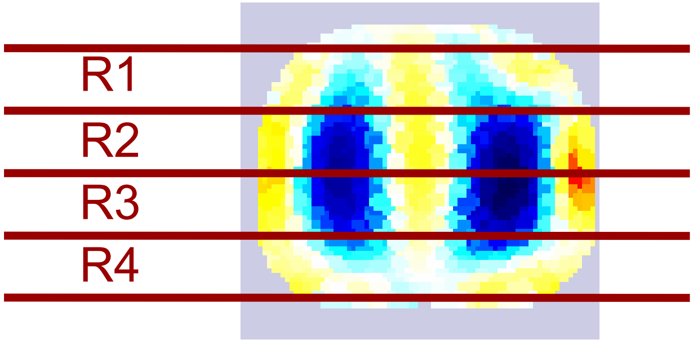
What problem are we trying to solve?

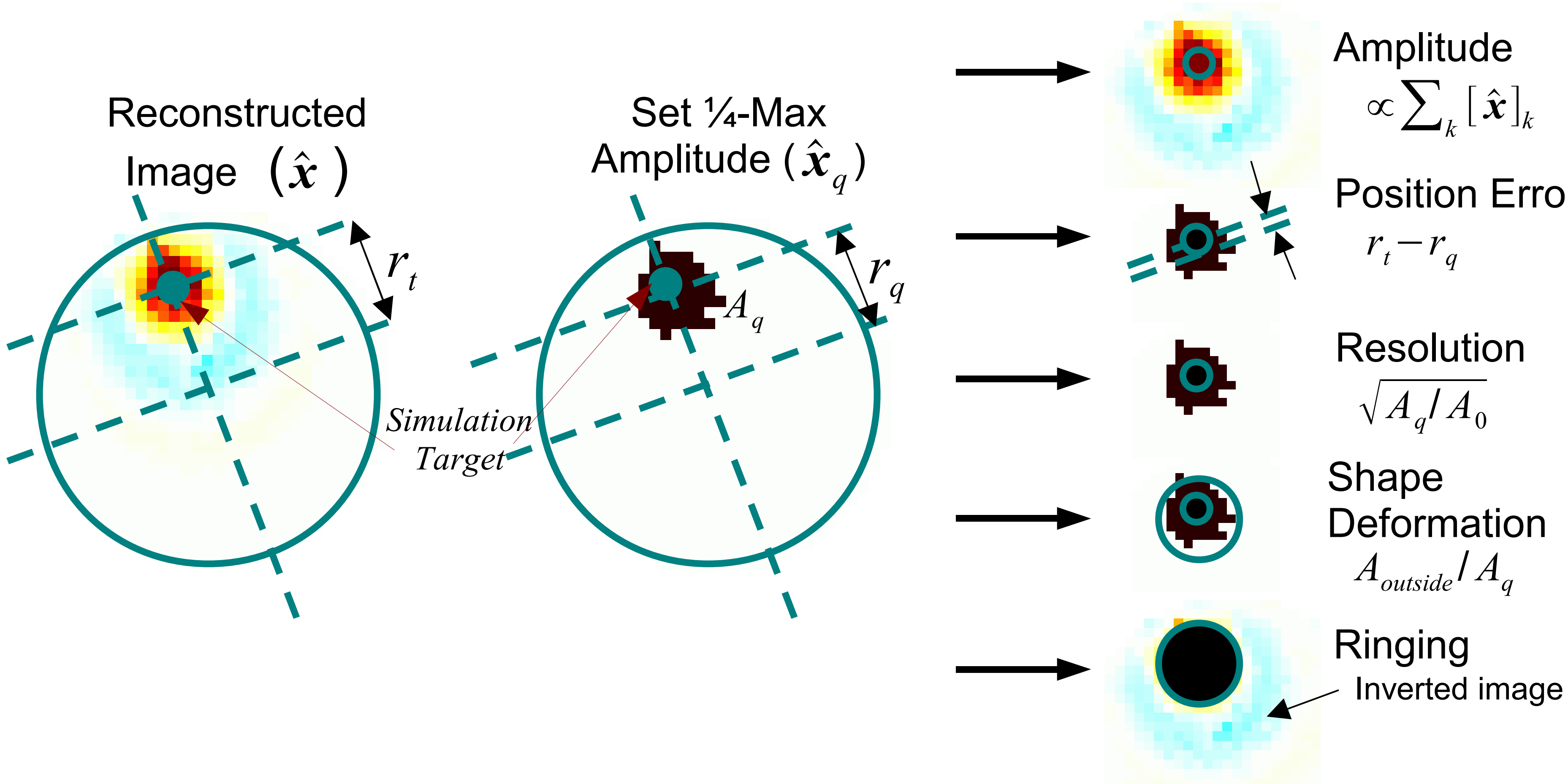
EIT useful to image regional lung air flow. But, we can't compare regions unless

- Consistent response:
  - Air volume in two places must show the same image
- Accurate positions
- No strange shapes

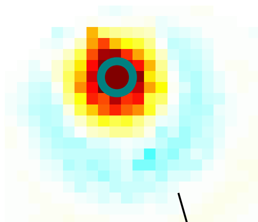


Our main goal is *consistency*

Requirements



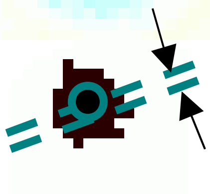
Consensus Ranking



Amplitude

$\propto \sum_k [\hat{\boldsymbol{x}}]_k$

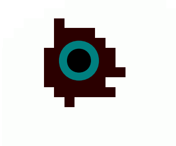
#1. Requirement: *uniform*



Position Error

$r_t - r_q$

#2. Requirement*: uniform and small*

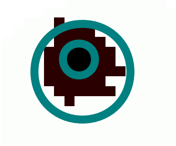


Resolution

$\sqrt{A_q / A_0}$

#4. Requirement: *uniform*

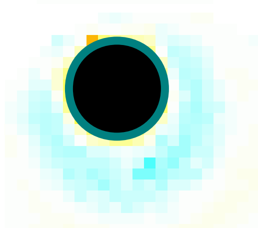
*#*6. Requirement: *small*



Shape Deformation

$A_{outside} / A_q$

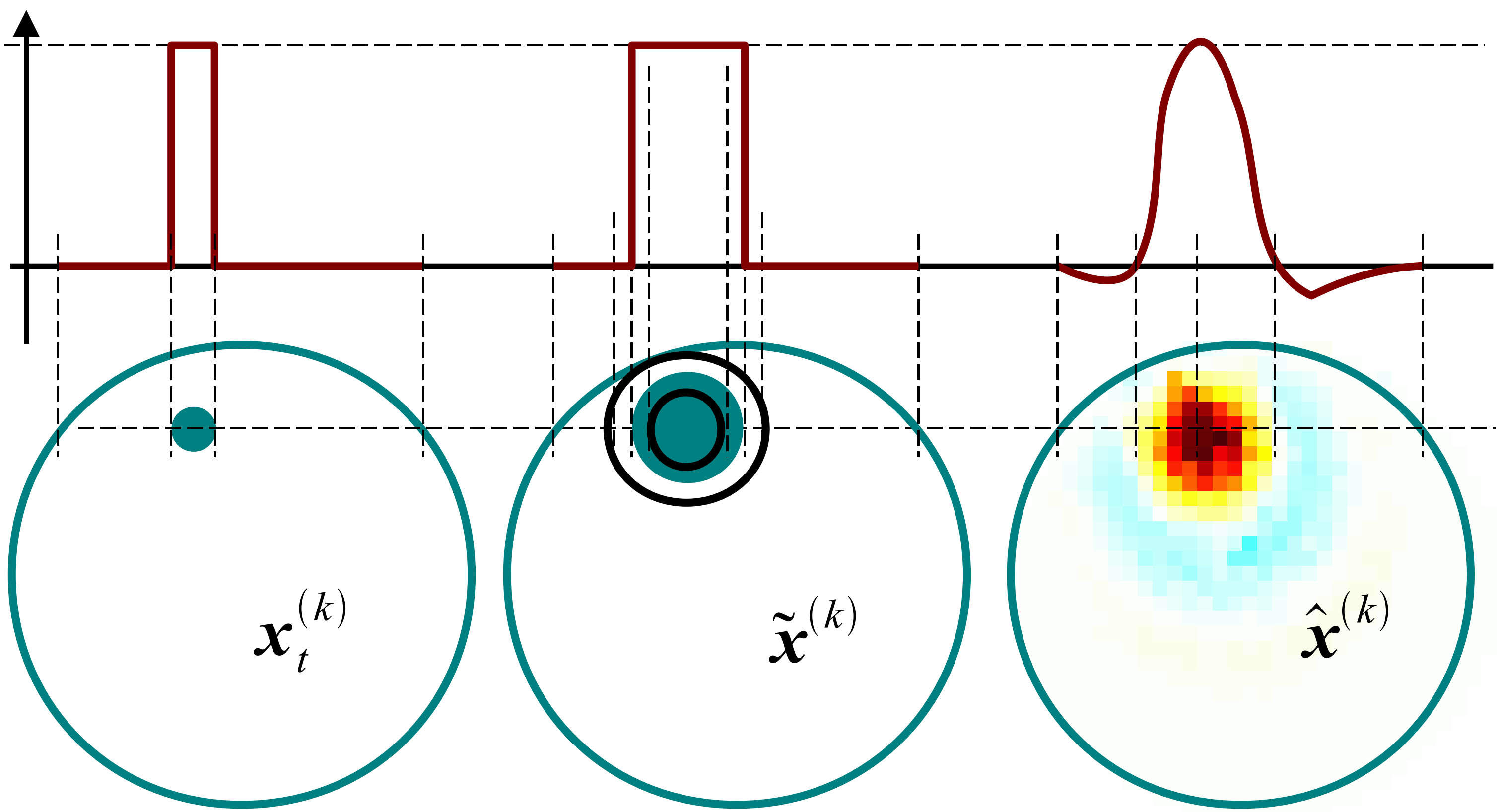
#5. Requirement: *small*



Ringing

#3. Requirement: *small*

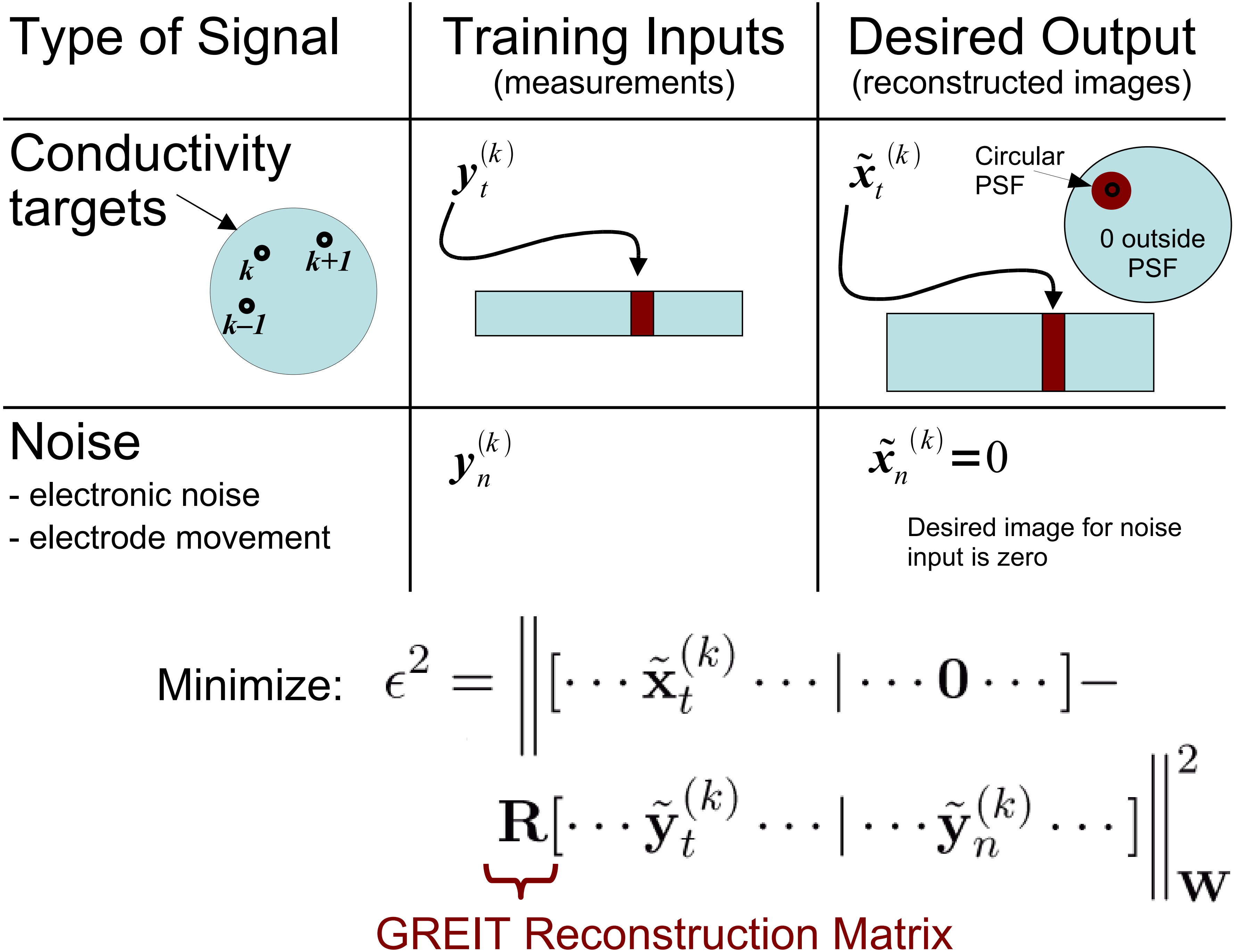
Formulation: *Training data*



Simulation Target

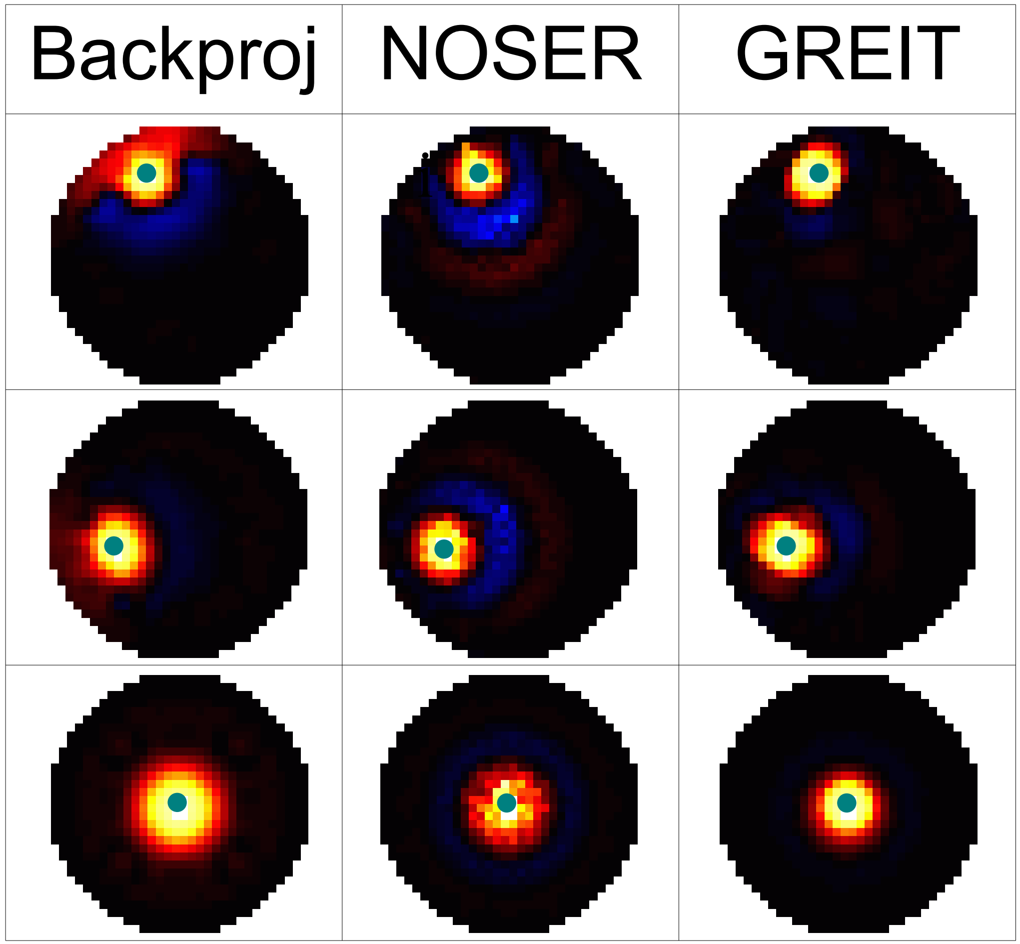
Desired image
- based on requirements

Reconstructed image
- to be optimized

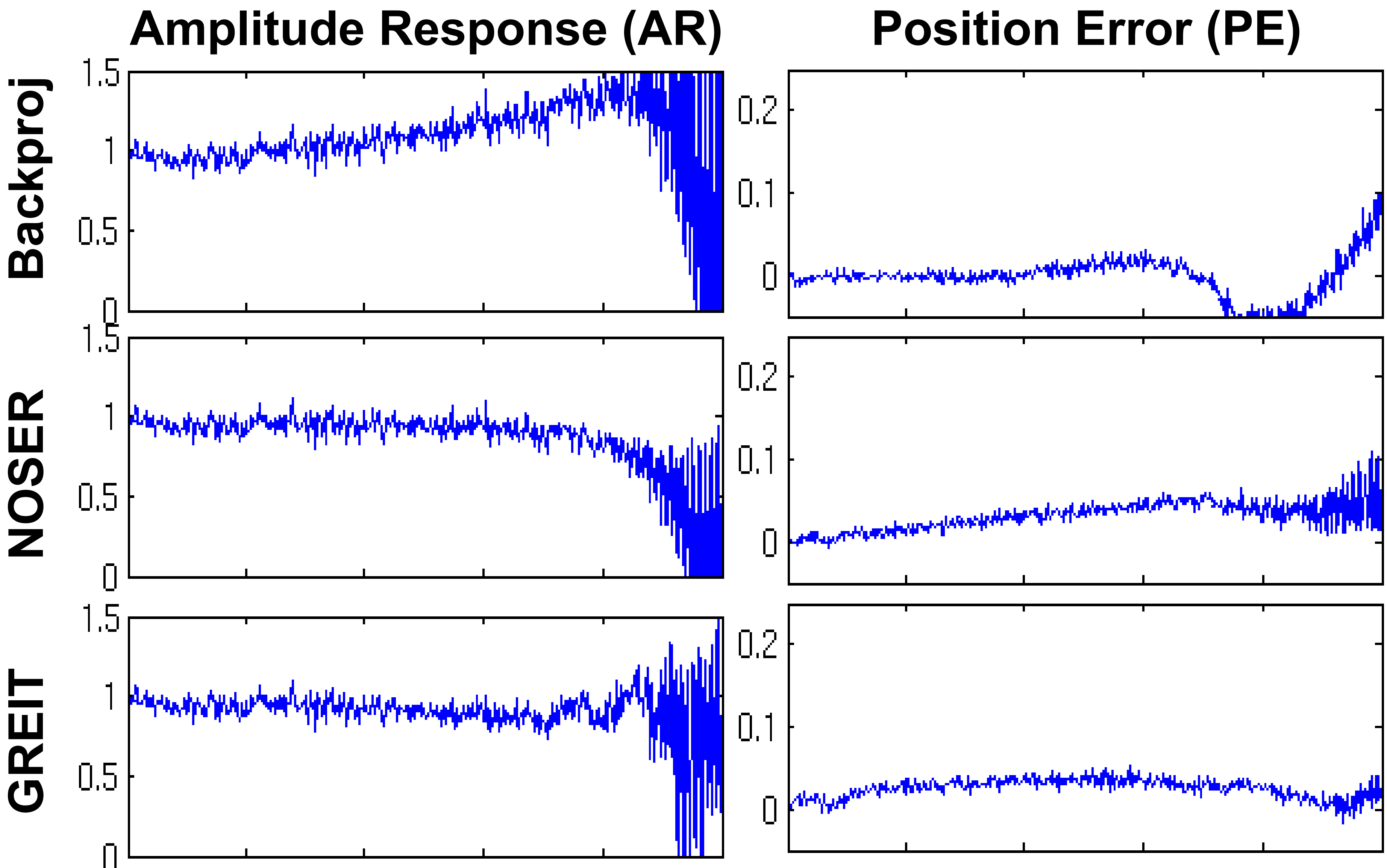


Type of Signal
Training Inputs
(measurements)
Desired Output
(reconstructed images)
Conductivity targets
k
$k+1$
$k-1$
$y_t^{(k)}$
$\tilde{x}_t^{(k)}$
Circular PSF
0 outside PSF
Noise
- electronic noise
- electrode movement
$y_n^{(k)}$
$\tilde{x}_n^{(k)} = 0$
Desired image for noise input is zero
Minimize: $\epsilon^2 = \left\| \left[\cdots \tilde{\mathbf{x}}_t^{(k)} \cdots \middle| \cdots \mathbf{0} \cdots \right] - \underbrace{\mathbf{R}}_{\text{GREIT Reconstruction Matrix}} \left[\cdots \tilde{\mathbf{y}}_t^{(k)} \cdots \middle| \cdots \tilde{\mathbf{y}}_n^{(k)} \cdots \right] \right\|_{\mathbf{W}}^2$
GREIT Reconstruction Matrix

Example Images



Performance Measures



GREIT Variants

Body shape

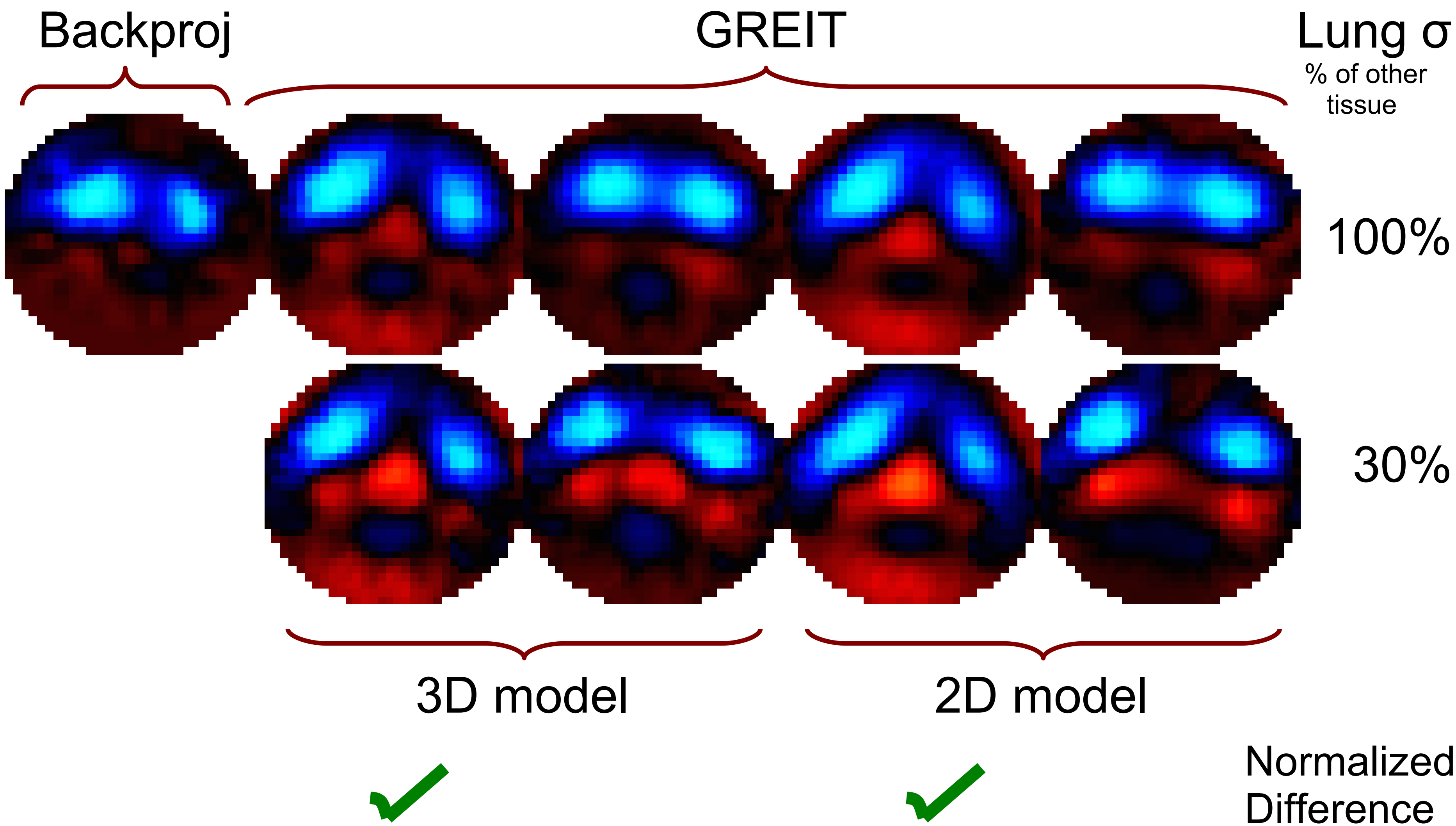
Lung conductivity

Fat thickness

Image from 6-7th intercostal space: male visual human

How important?
How many models?

Example: reference conductivity



Lung injured piglet at 10cmH_2O. Data from Frerichs *et al* (2003)

“Roadmap”

Step 1: Agree on “ingredients” and “requirements”

Step 2: Develop an algorithm framework

- Physiol. Meas. 30:S35-S55, 2009

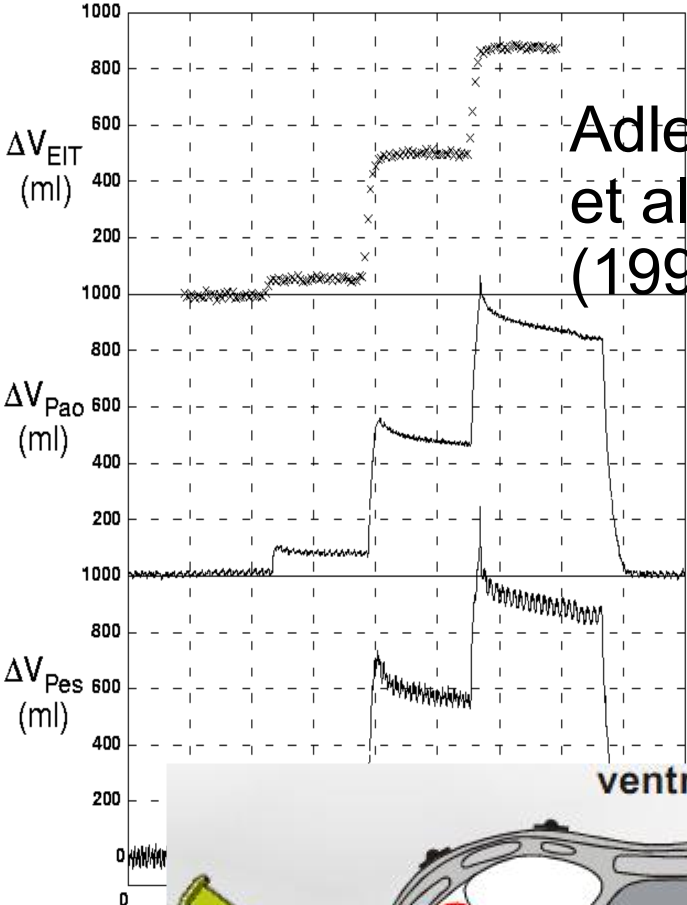
Step 3: Distribute tools

- Publish software (EIDORS 3.4) June 09
- Analysis tools (including online)

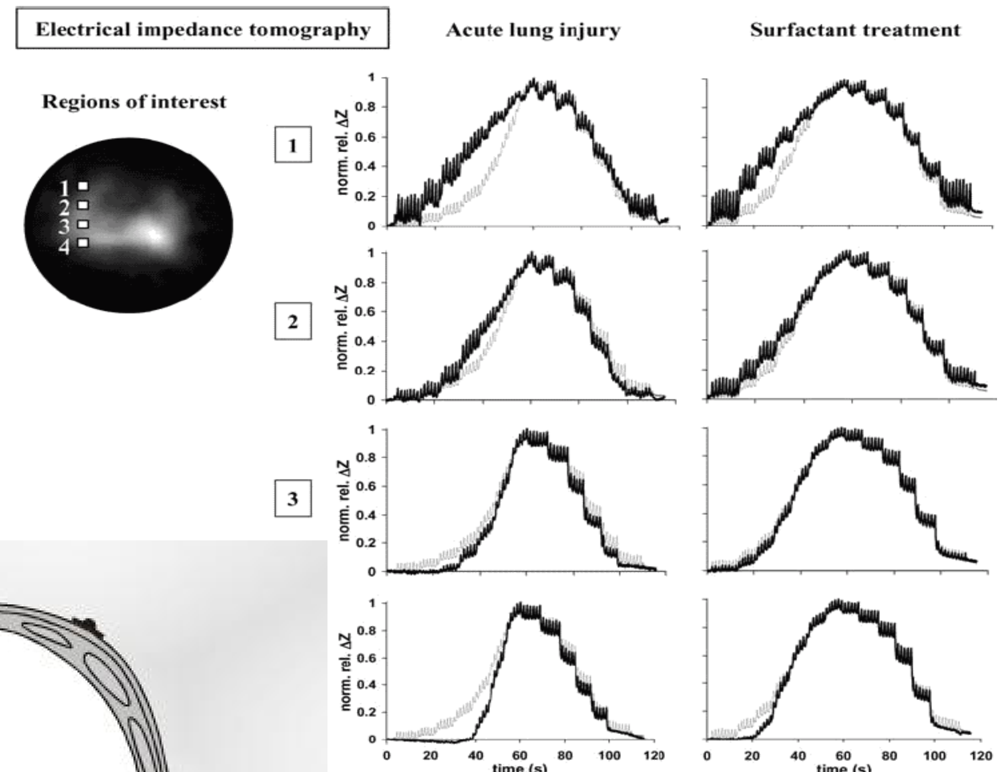
Step 4: Validate Oct. 09

- Experience using GREIT
- Systematic evaluation with “real” data

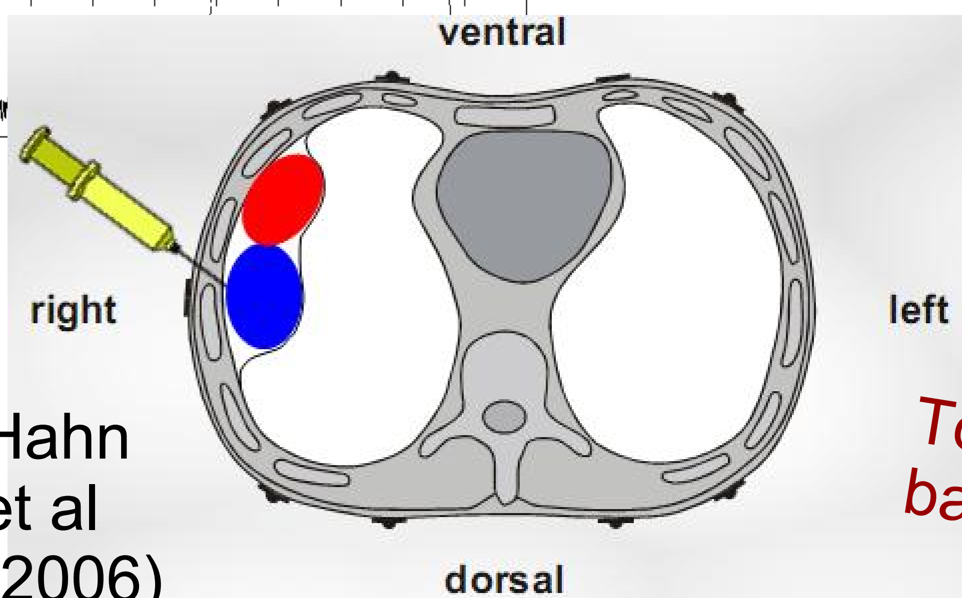
Calibrated animal tests



Adler et al (1996)



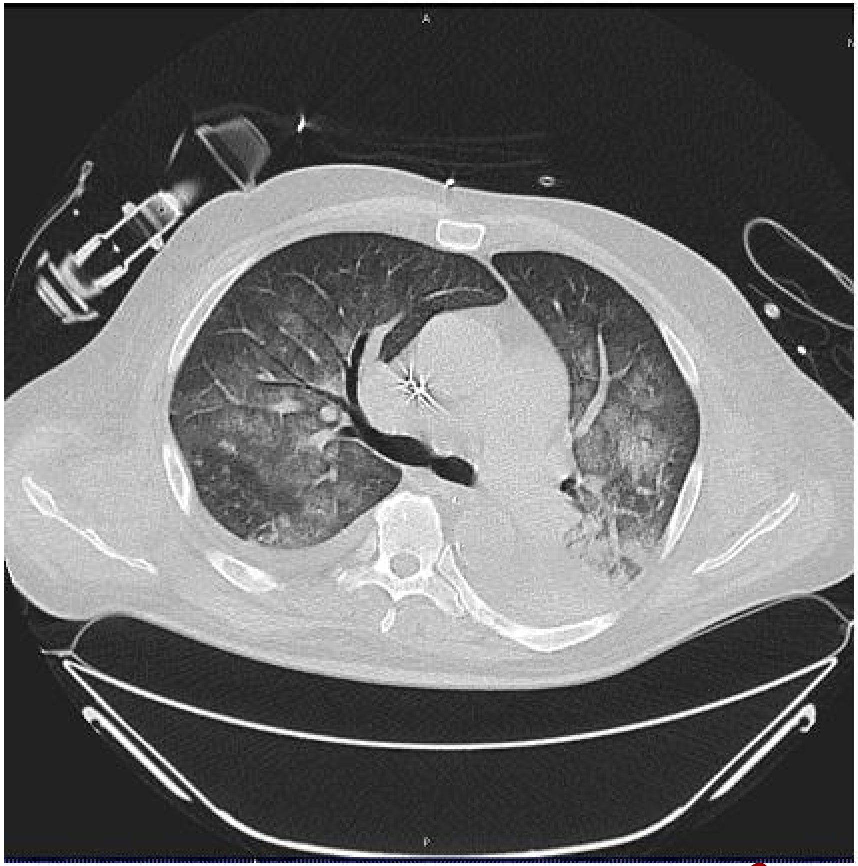
Frerichs et al (2003)



Hahn et al (2006)

To Do: Design tests based on these data

Clinical data



- **Patient data** male 59 yrs 188 cm 120 kg
- **Current diagnosis** Sepsis with acute lung injury Acute renal failure (continuous dialysis) Atelectasis left lower lung lobe
- **Medical history** Implantation of cardiac pacemaker Arterial hypertension
- EIT measurements performed in the ICU
- **Mode** Continuous positive airway pressure ventilation with assisted spontaneous breathing (CPAP/ASB)
- $\mathbf{F_IO_2}$ 0.5 **PEEP** 9 cmH2O **Frequency** 25 breaths/min **Minute ventilation** 15.1 l/min
- During the EIT measurement of 180 s duration approx. after 60 s PEEP was reduced from 9 to 5 cmH2O and after 120 s increased to 13 cmH2O.
- $\mathbf{P_{peak}}$ 20 cmH_2O $\mathbf{P_{mean}}$ 13 cmH_2O at **PEEP** 9 cmH_2O $\mathbf{SO_2}$ 97 %
- $\mathbf{P_{peak}}$ 16 cmH_2O $\mathbf{P_{mean}}$ 9 cmH_2O at **PEEP** 5 cmH_2O $\mathbf{SO_2}$ 92 %
- $\mathbf{P_{peak}}$ 24 cmH_2O $\mathbf{P_{mean}}$ 16 cmH_2O at **PEEP**13 cmH_2O $\mathbf{SO_2}$ 97 %

To Do: Design tests based on these and other clinical data