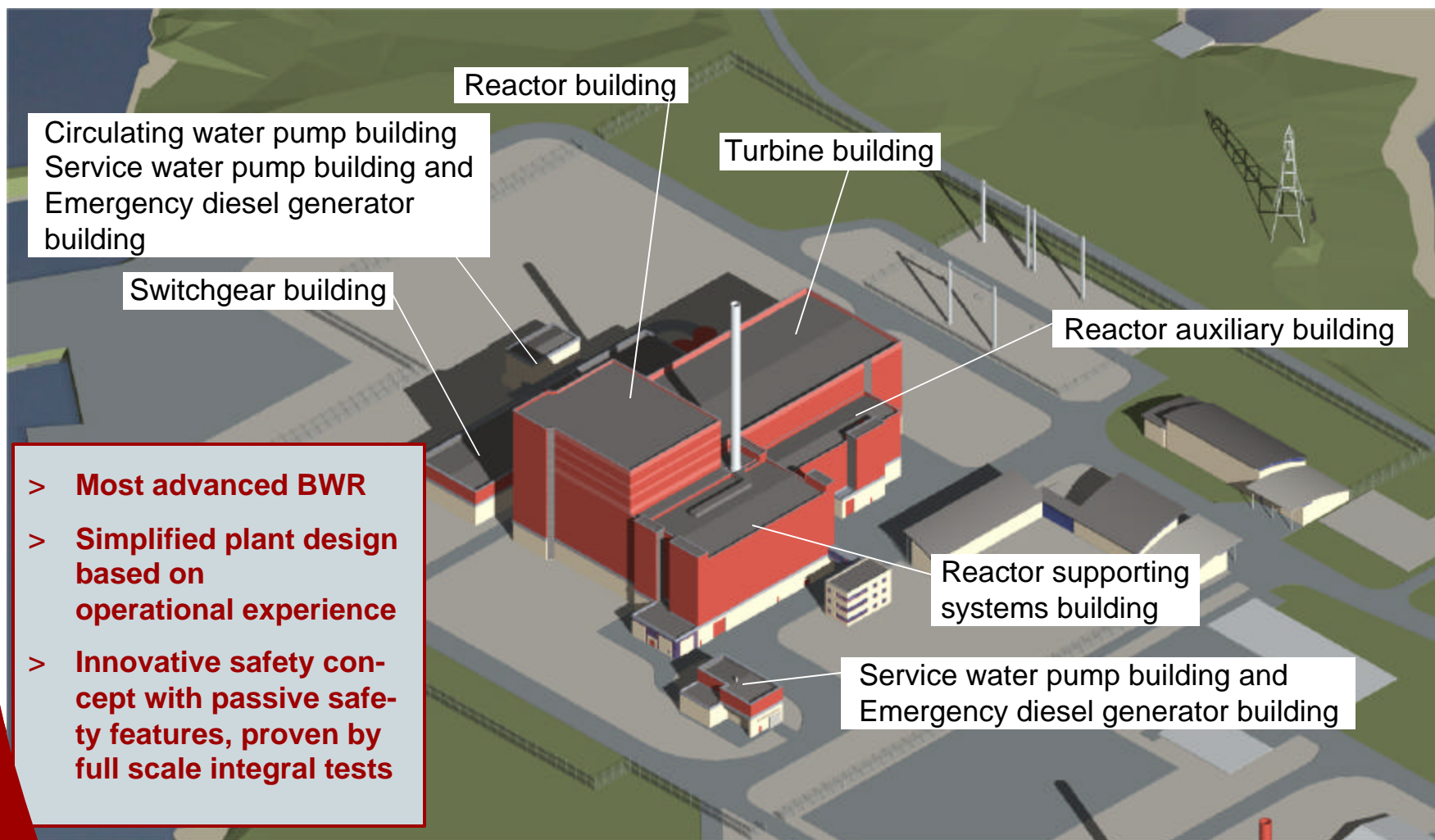


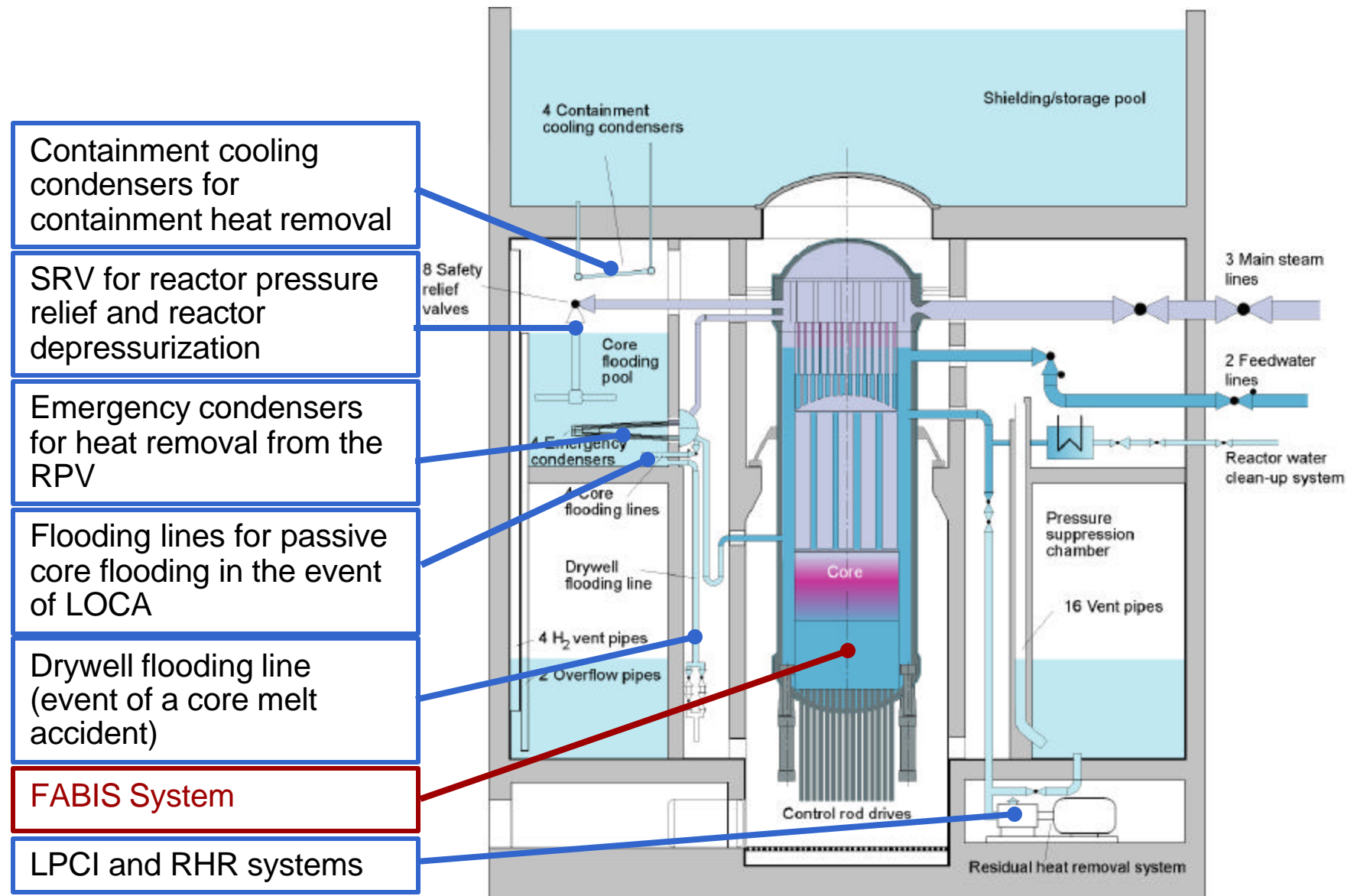
SWR-1000: NRC-Visit

FABIS East Acting Boron Injection System

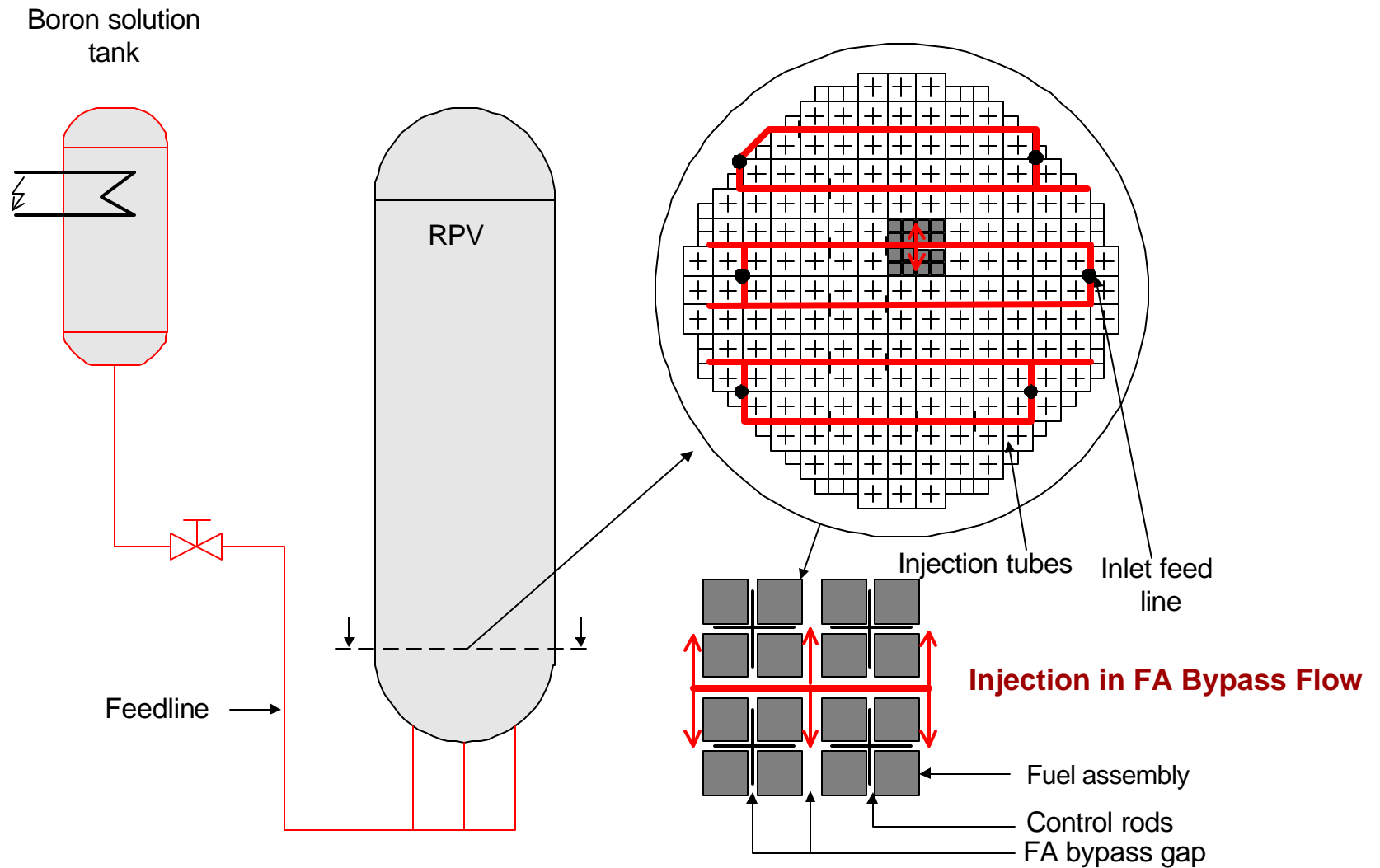
SWR 1000 – Plot Plan



SWR 1000 – Passive Safety Features



FABIS General Function



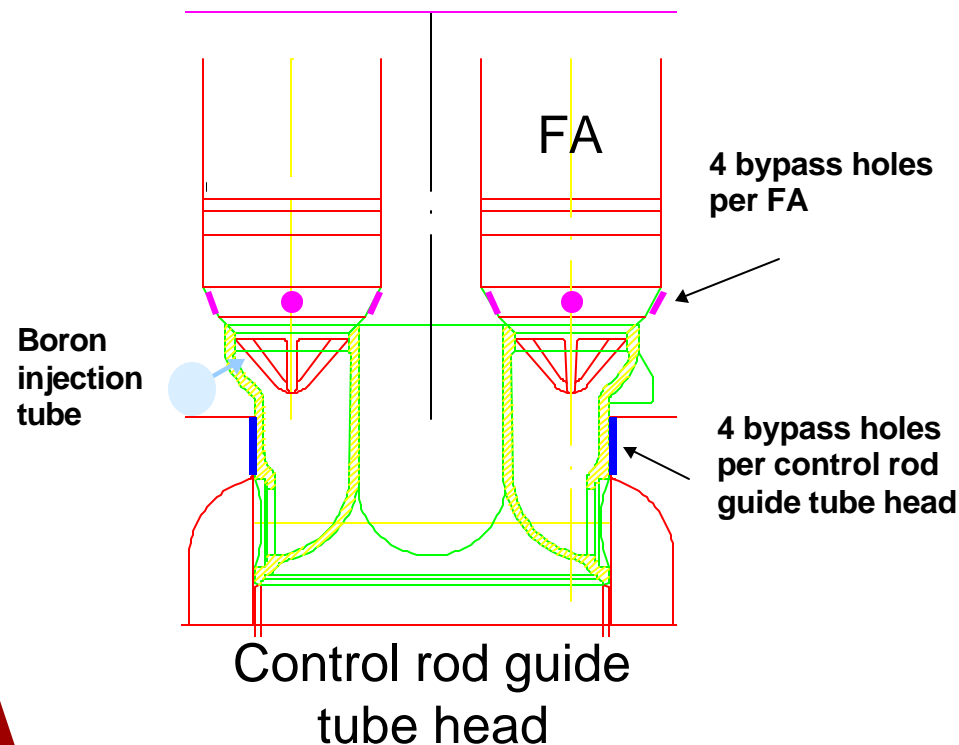
Investigation of FABIS Performance

- > Calculation of mixing process between boron solution and cooling agent*
- > Physical mixture tests between boron solution and cooling agent, scale 1:1*
- > Calculation of internal re-circulation*
- > Physical tests of the flow between boron solution tank and RPV, scale 1:6*

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Initial Conditions

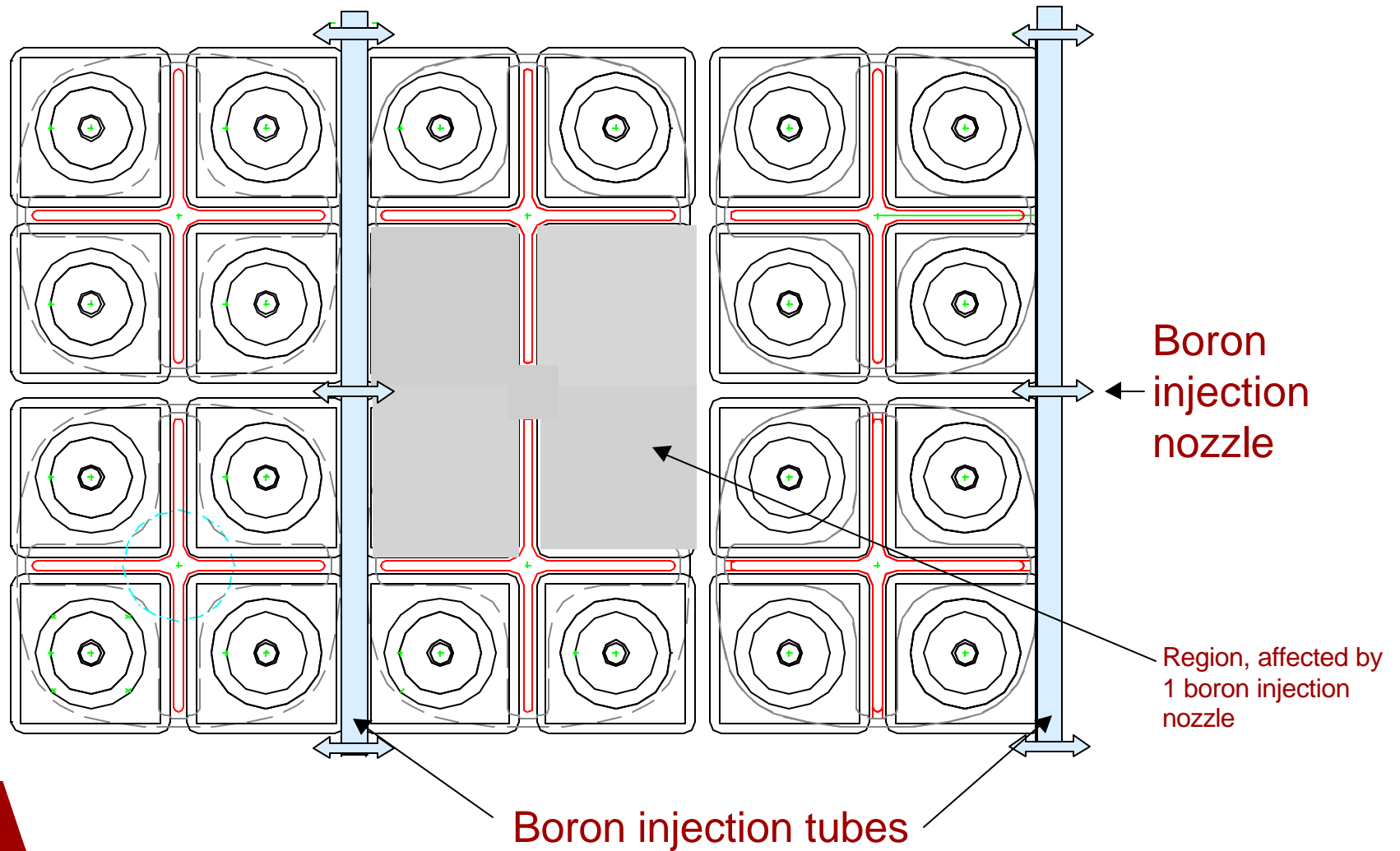
Geometrical



Hydraulic

- > Pump speed at 45% of nominal speed
- > Bypass flow 6 kg/s per guide tube
- > Bypass ratio guide tube head/FA 4:1 (@45% pump speed)
- > Boron Injection velocity ≤ 30 m/s

Boron Injection

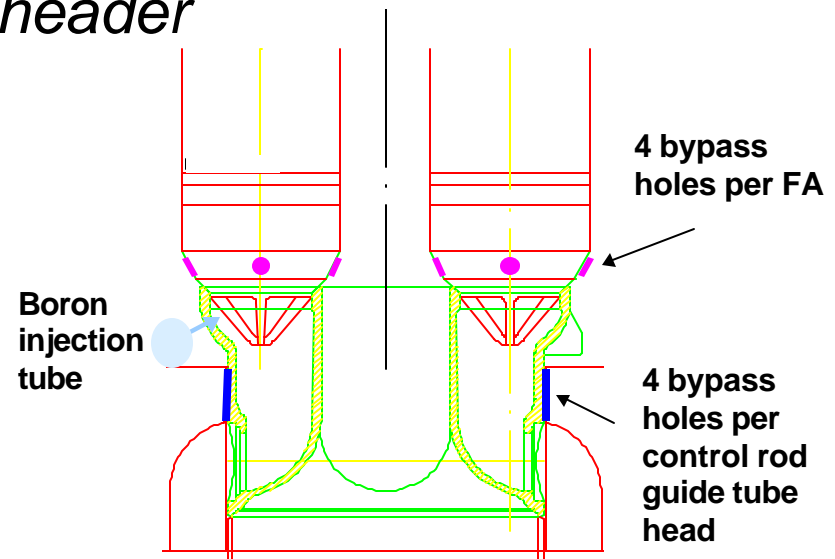


CFD General

- > *Use of PHOENICS code, virtual reality option*
- > *Aim: Provide evidence of sufficient homogeneous Boron mixing in the core*
- > *Different models: 1 jet, 2 jets*
- > *Parameters varied:*
 - *jet rate and direction*
 - *bypass rate, position, number and opening area*
- > *Steady state and transient calculations*

CFD Modeling Design Details

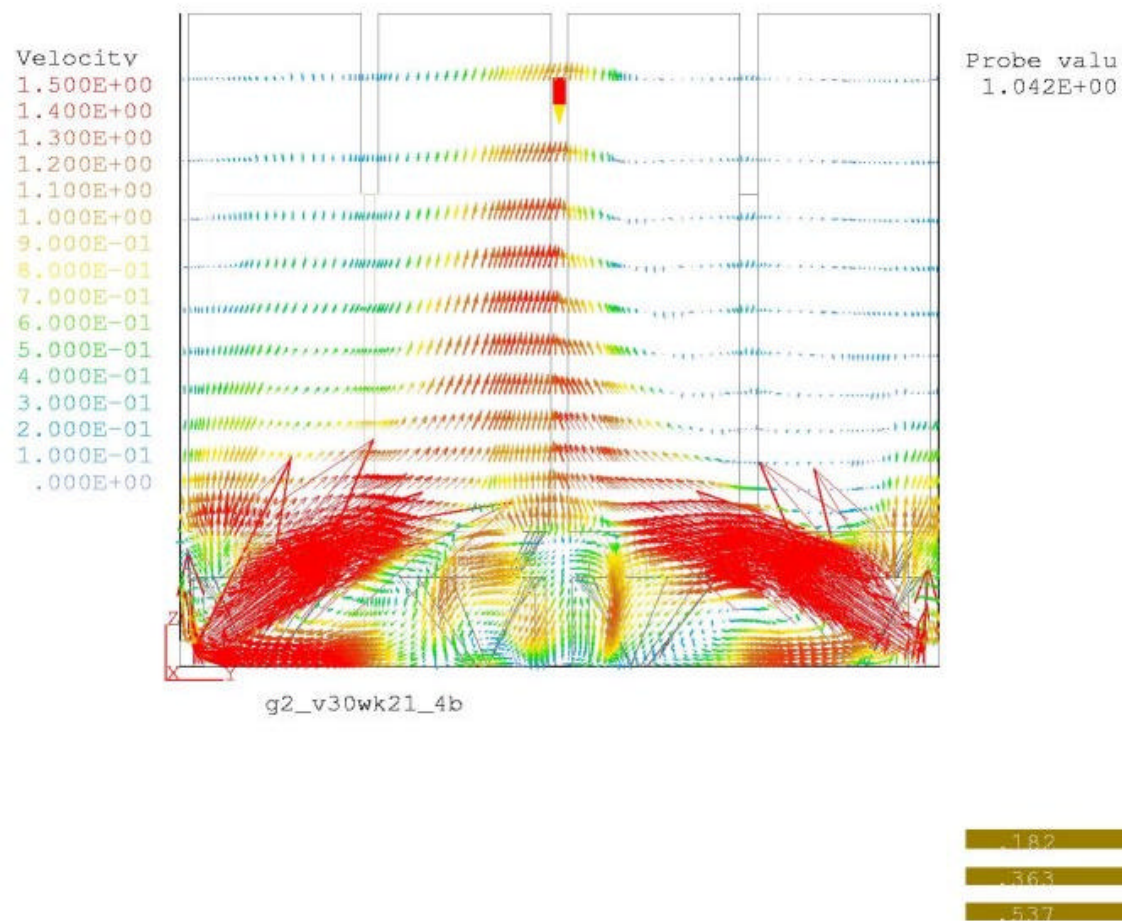
- > Arrangement of the jet distribution system
- > Control rods, control rod guide tubes
- > Arrangement of fuel assemblies
- > Dimensions of guide tube header
- > Bypass possibilities



CFD Modeling and Grid

- > Basic cell units with symmetry boundaries clipped for modeling*
- > Modeling with fixtures (inserted structures)*
- > Cartesian coordinates*
- > Grid up to 350000 mesh nodes*
- > Turbulence model: Standard k-e*
- > PHOENICS option „virtual reality“ used*

CFD Examples 1/2

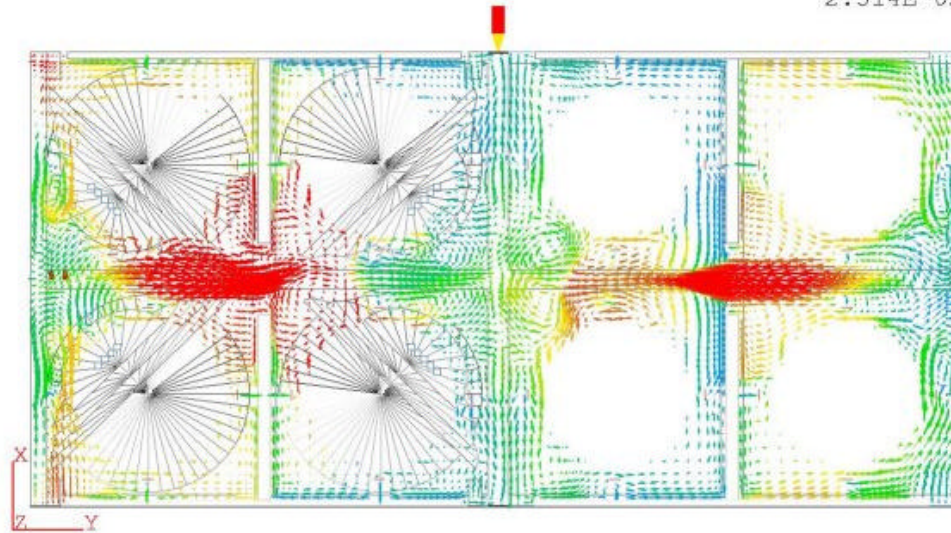


CFD Examples 2/2

BOR

1.100E-01
1.027E-01
9.533E-02
8.800E-02
8.067E-02
7.333E-02
6.600E-02
5.867E-02
5.133E-02
4.400E-02
3.667E-02
2.933E-02
2.200E-02
1.467E-02
7.333E-03
.000E+00

Probe valu
2.314E-02

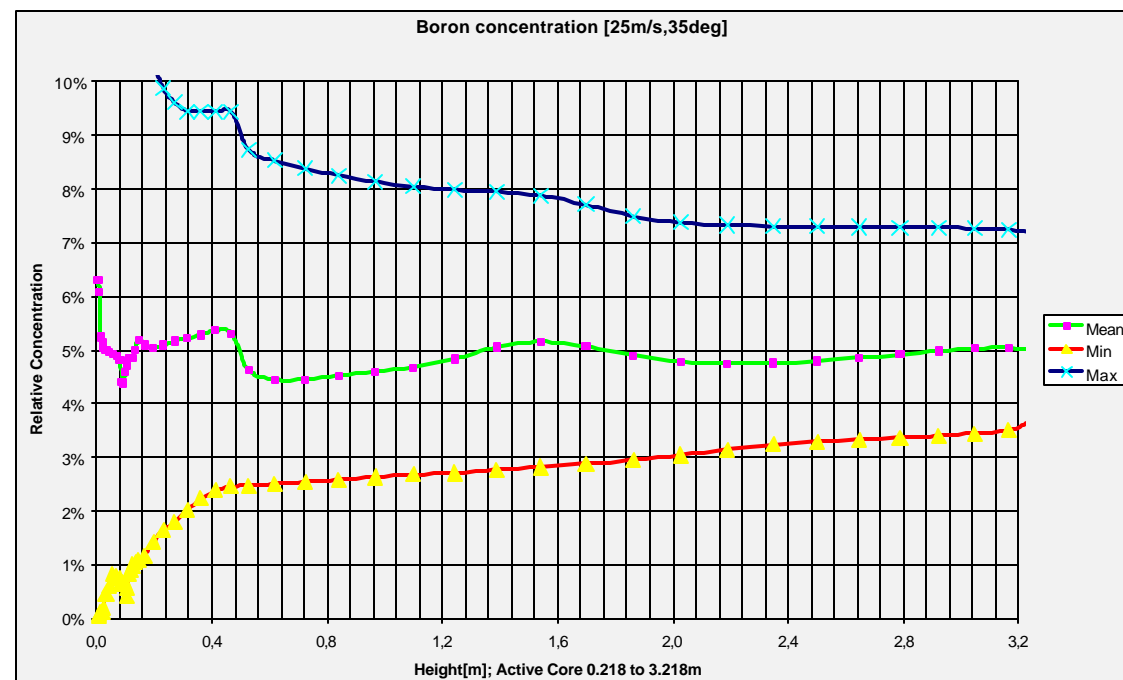


.363
.363
.100

CFD Results 1/2

> *Most effective mixing with Boron concentrations between 2% and 8% along the active zone of FE achieved by*

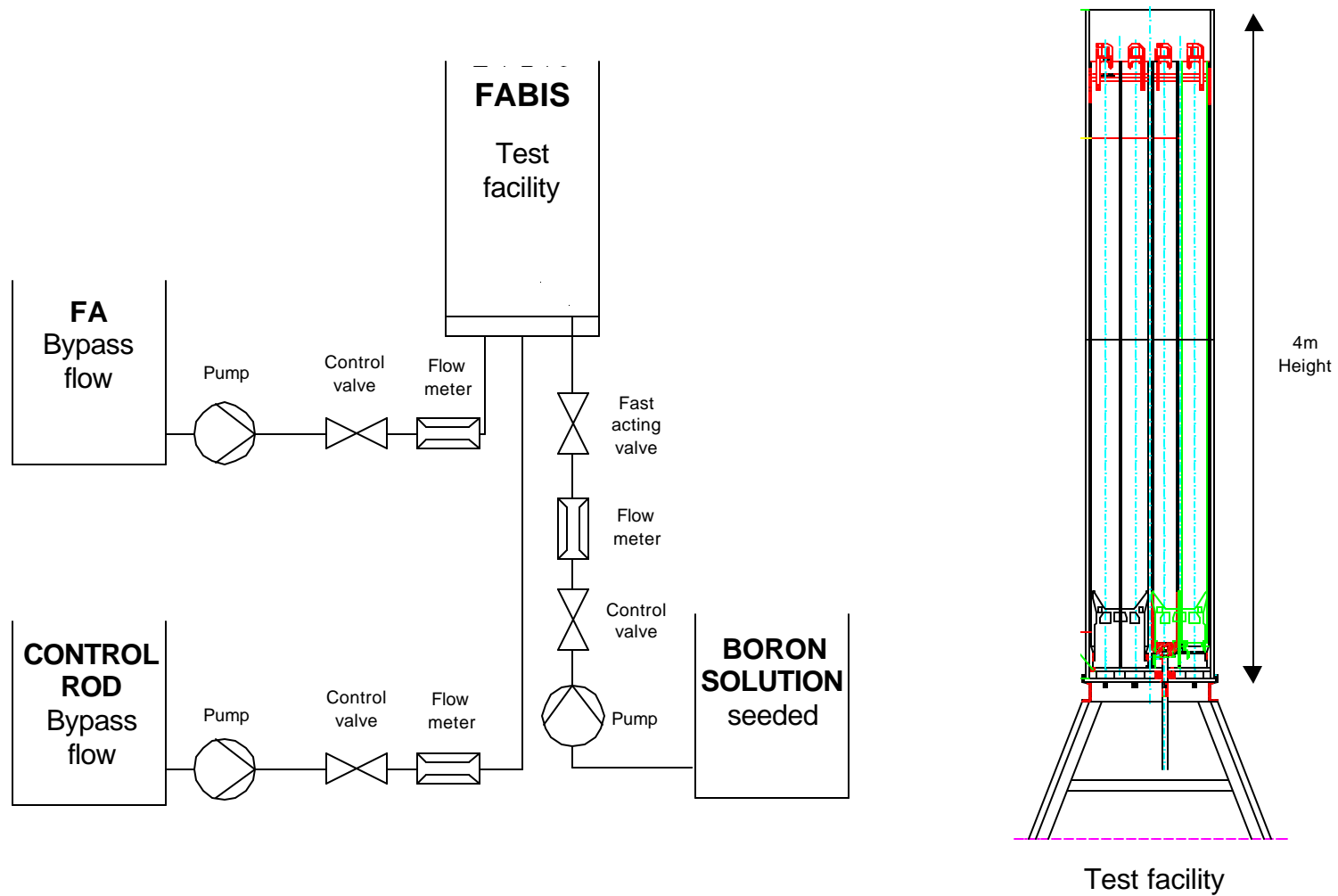
- *injection flow rates of 25m/s and 30m/s*
- *injection flow directions between 30° and 40°*



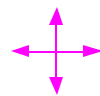
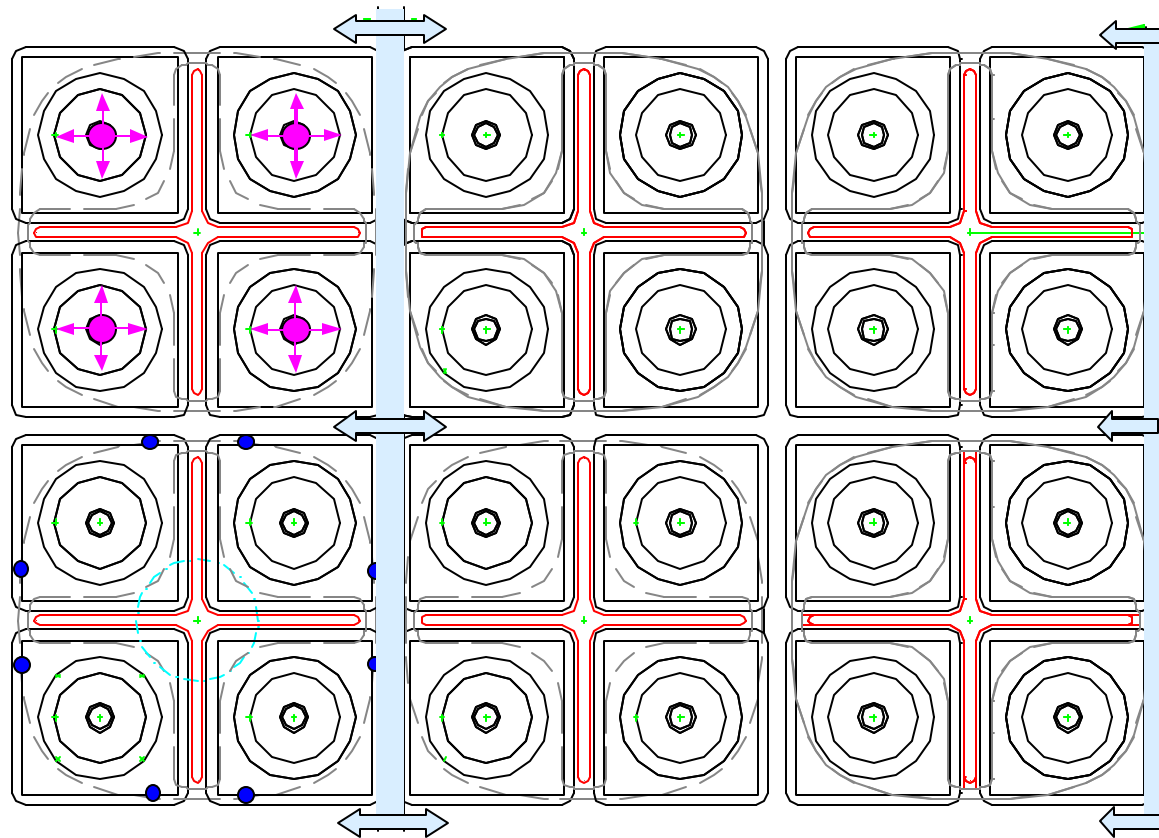
CFD Results 2/2

- > *Main mixing zone: up to 133mm (bottom of FA)*
- > *Bypass distribution is important for this result:*
 - *main mixing effect must take place below casings of FA*
- > *Transient calculations confirm that the required boron concentration is established within 20s after start*

Physical Tests General Set Up



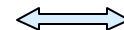
Physical Tests Fluid Path



FA foot bypass

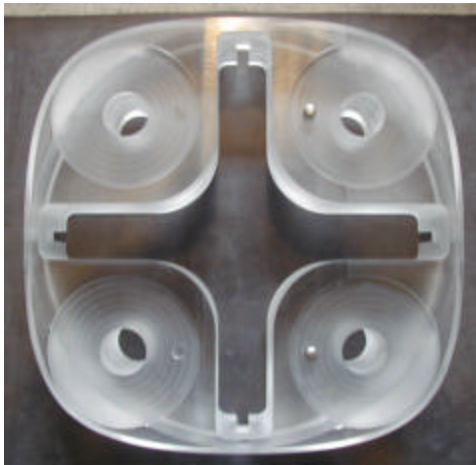


Guide tube bypass

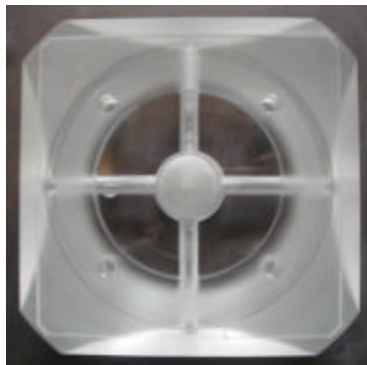


Boron injection nozzle

Test Facility Details



Control rod guide tube head



FA foot



Test facility

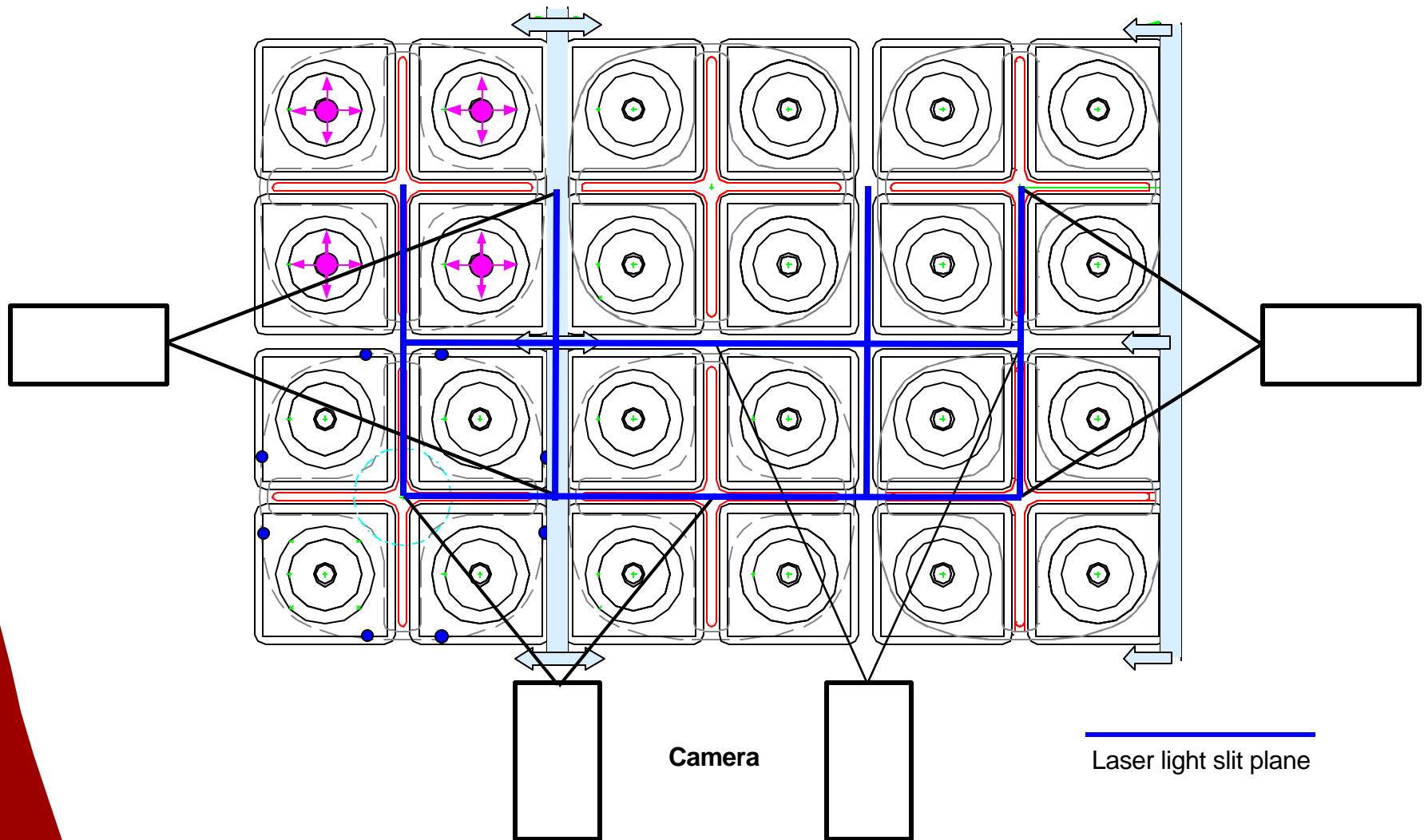


Control rod guide tube bypass

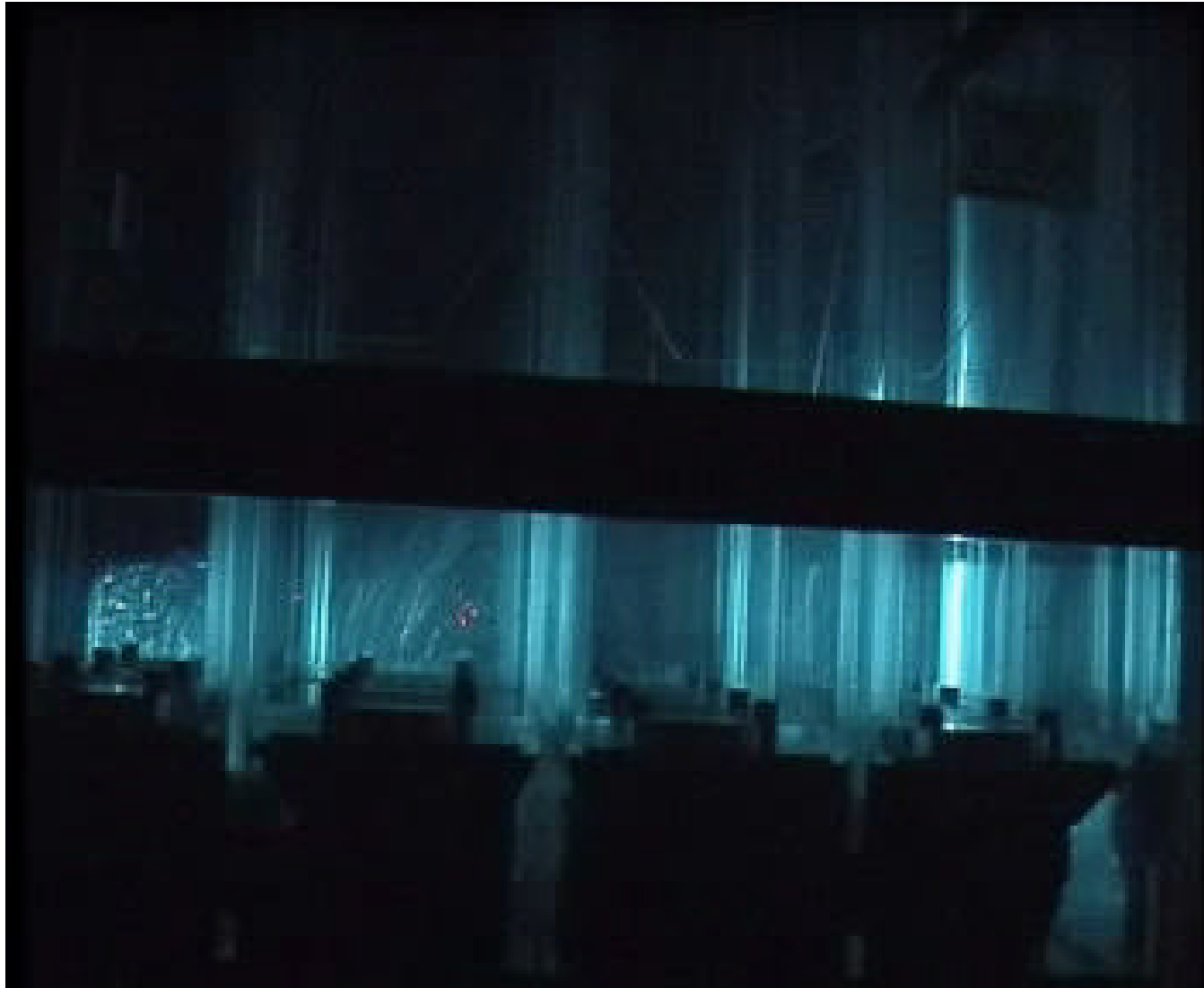


Control rod head and FA feet

Laser Light Slit Tests

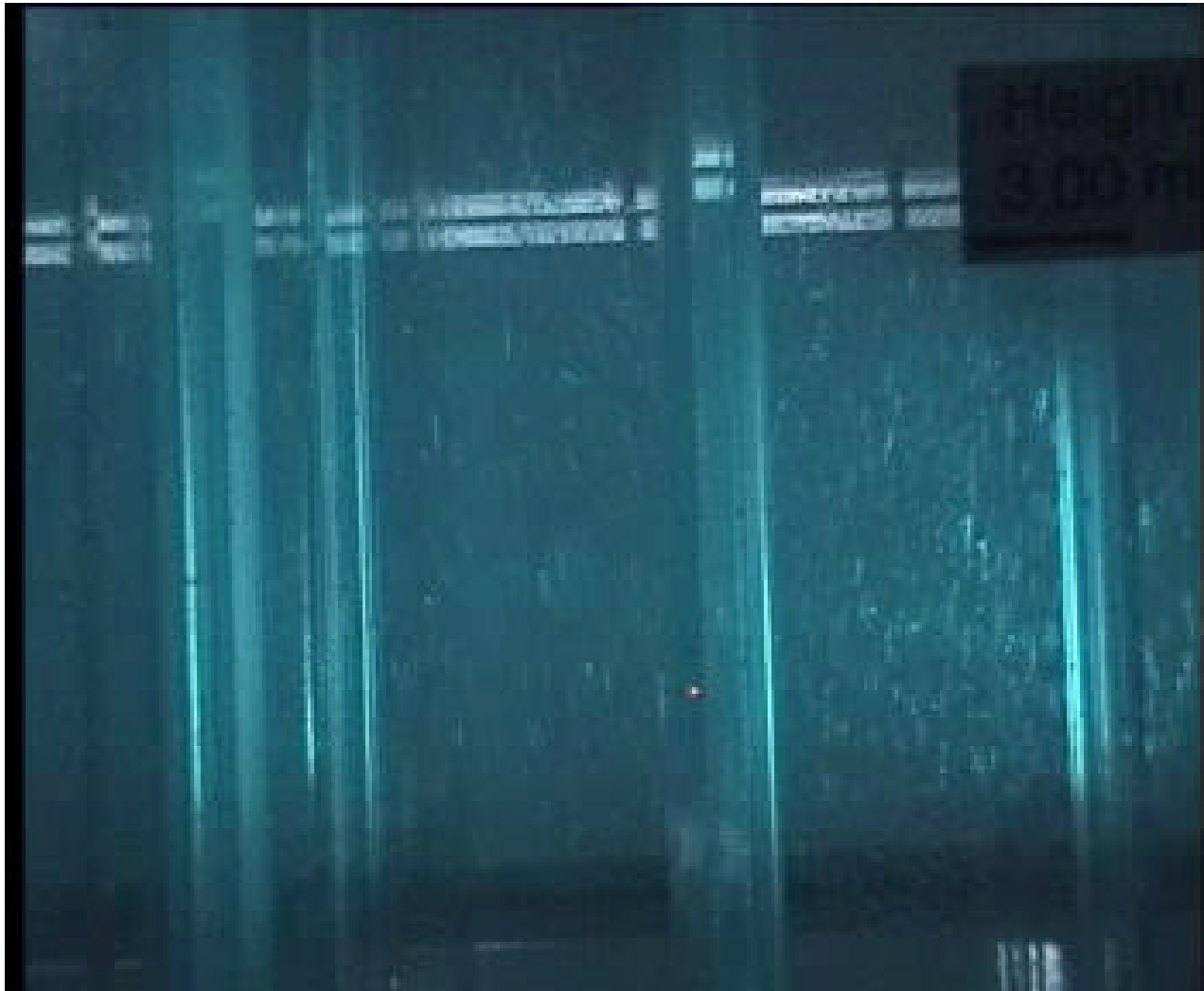


Laser Light Slit Tests Examples 1/2



FA foot region

Laser Light Slit Tests Examples 2/2



FA top region

Integral Color Test Example



Test facility

Results

- > Results of CFD calculations and physical tests show good qualitative agreement***
- > Necessary boron concentration is reached from beginning of active zone of FAs over the whole FA height***
- > FABIS is a new passive safety feature for SWR 1000 proven by full scale integral tests***