Real Time Control for KAGRA

3km Cryogenic Gravitational Wave Detector in Japan

October 7, 2013 ICALEPCS at San Francisco, U.S.A

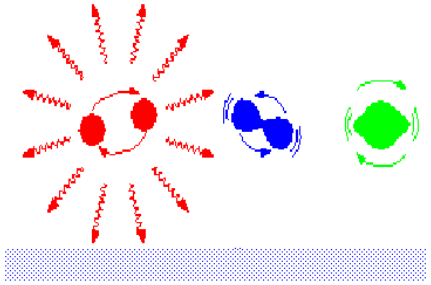
Osamu Miyakawa(ICRR, UTokyo)
and
KAGRA collaboration

Gravitational wave

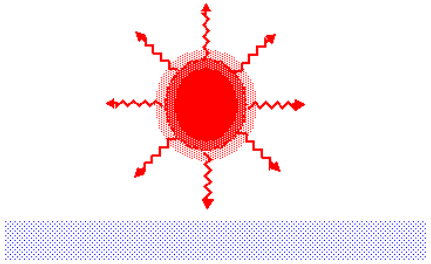
Einstein's Theory: ***information carried by gravitational radiation at the speed of light***

→ Gravitational waves!

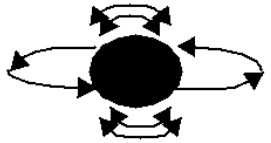
Coalescing compact binaries
(neutron stars, black holes)



Non-axi-symmetric
supernova collapse



Non-axi-symmetric pulsar (rotating,
beaming neutron star)

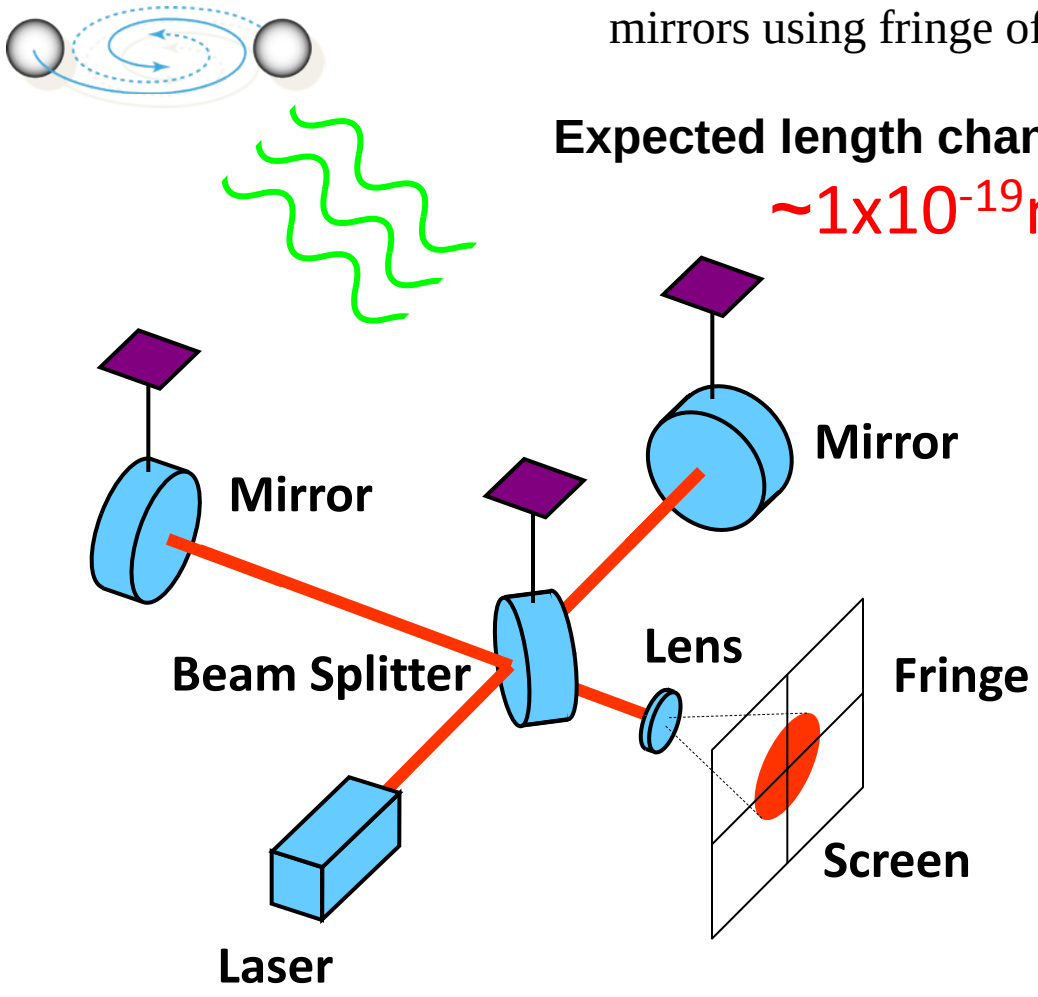


Detection of gravitational wave using laser interferometer

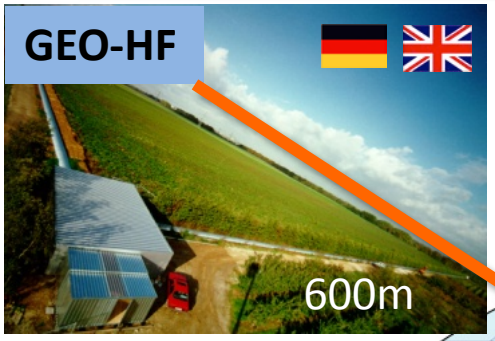
GWs move mirrors differentially.
We measure the distance between mirrors using fringe of light.

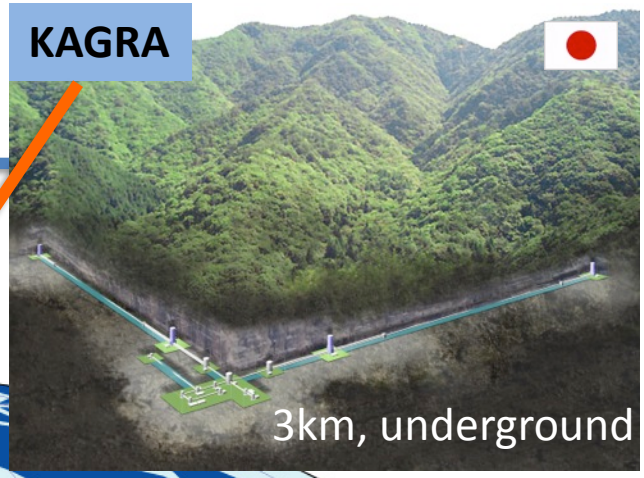
Expected length change by GW :

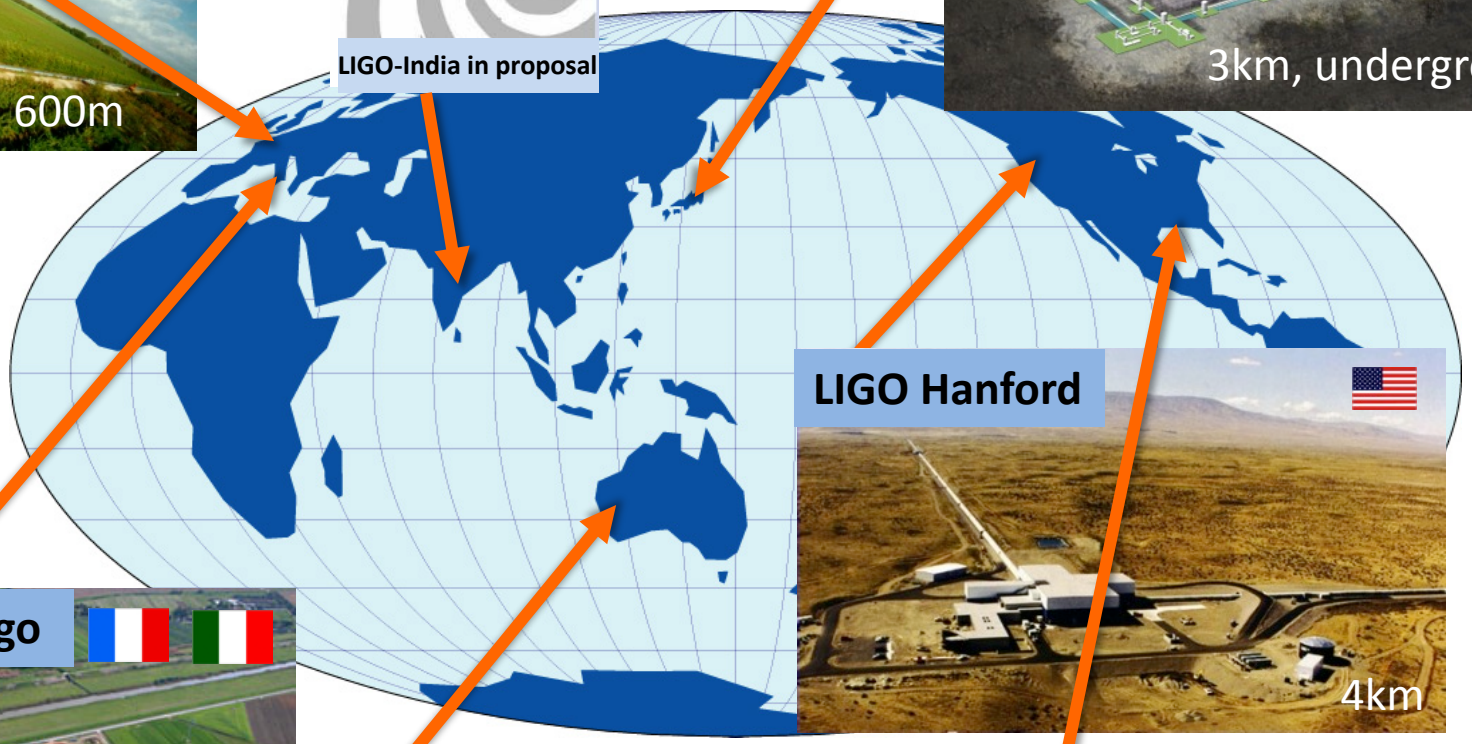
~1x10^{-19}m



Network of GW detectors

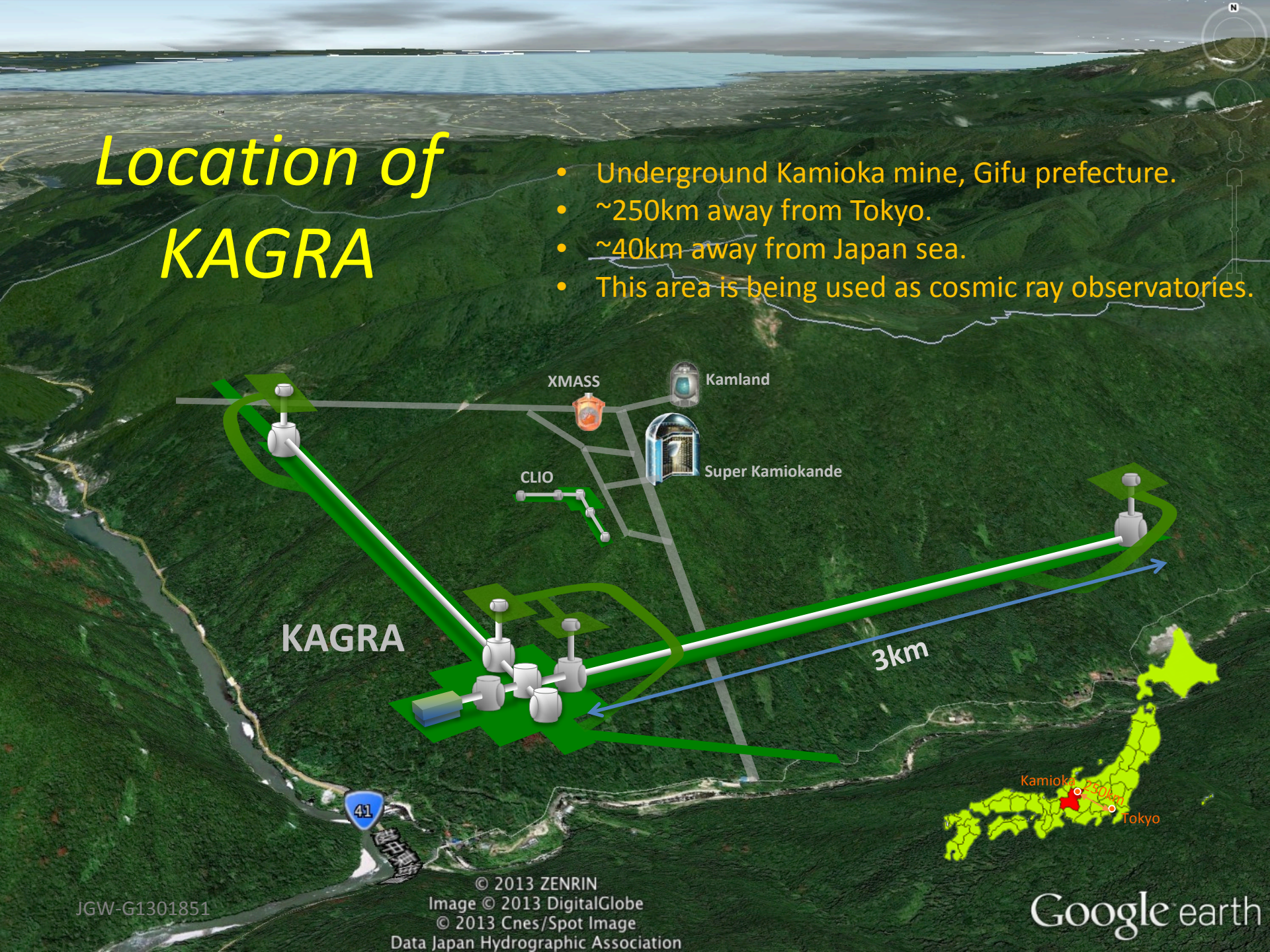






Location of KAGRA

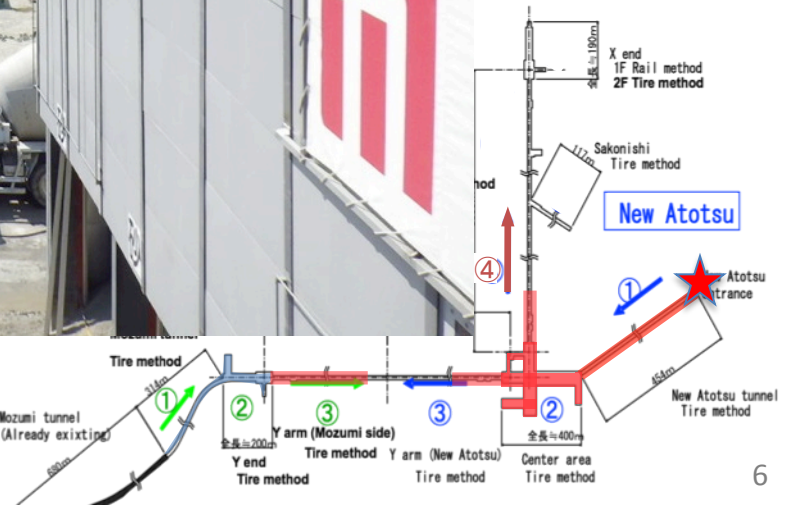
- Underground Kamioka mine, Gifu prefecture.
- ~250km away from Tokyo.
- ~40km away from Japan sea.
- This area is being used as cosmic ray observatories.



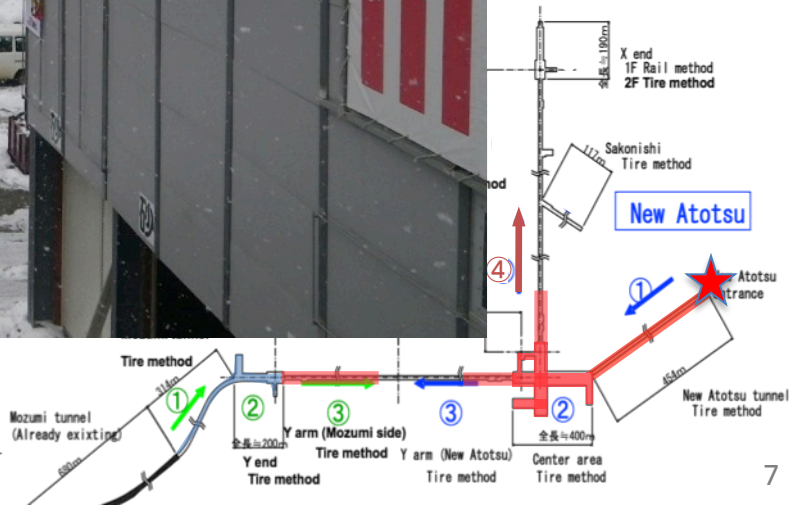
JGW-G1301851

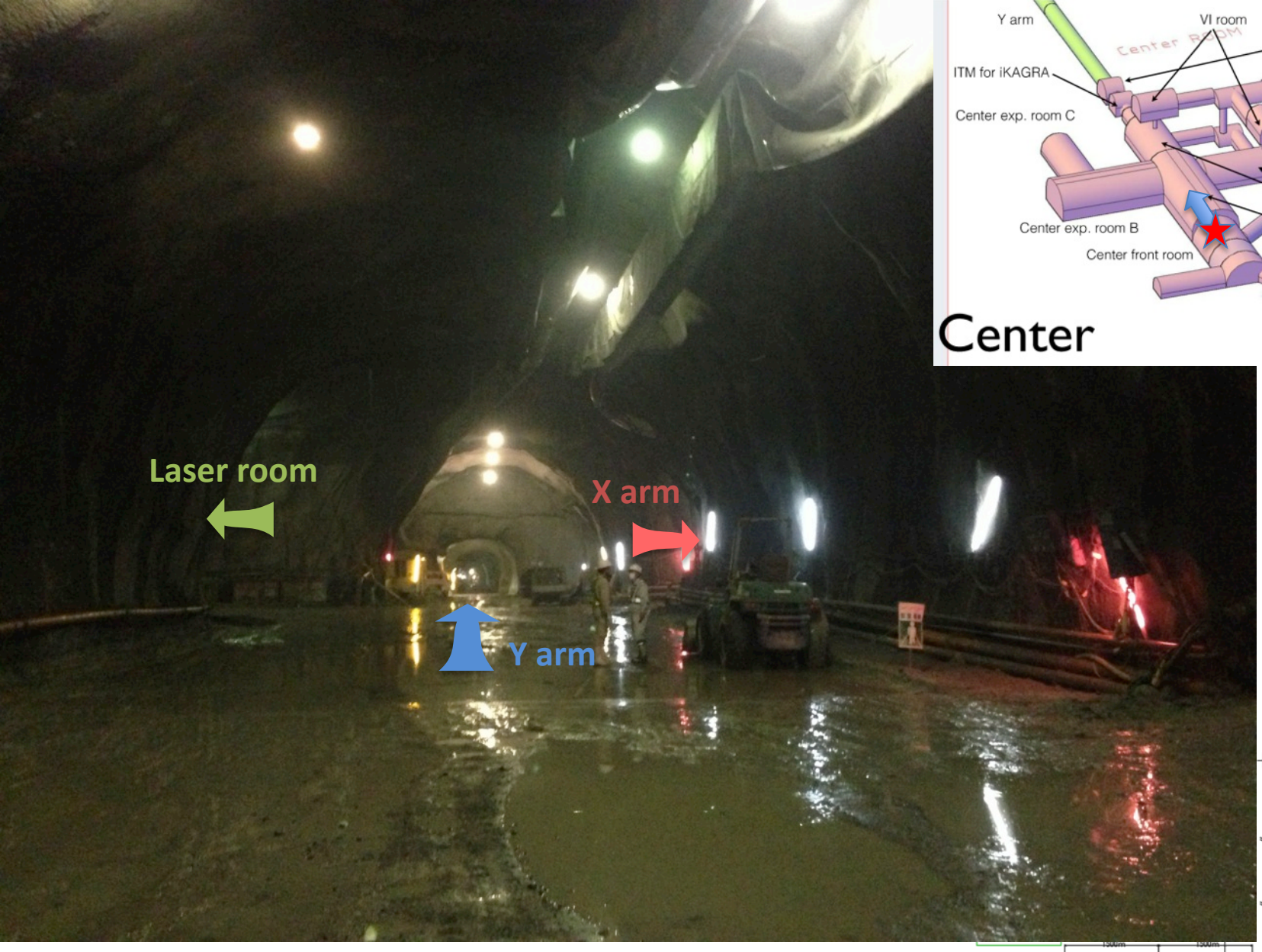
KAGRA tunnel entrance (New Atotsu)

春(Spring)



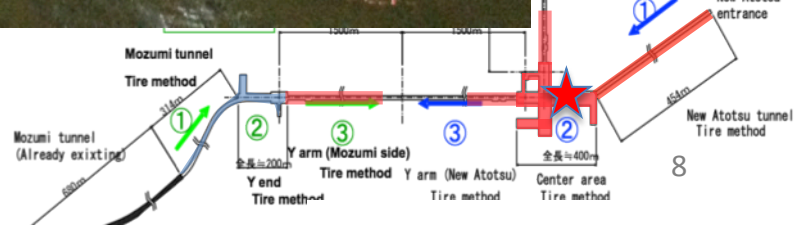
KAGRA tunnel entrance (New Atotsu)



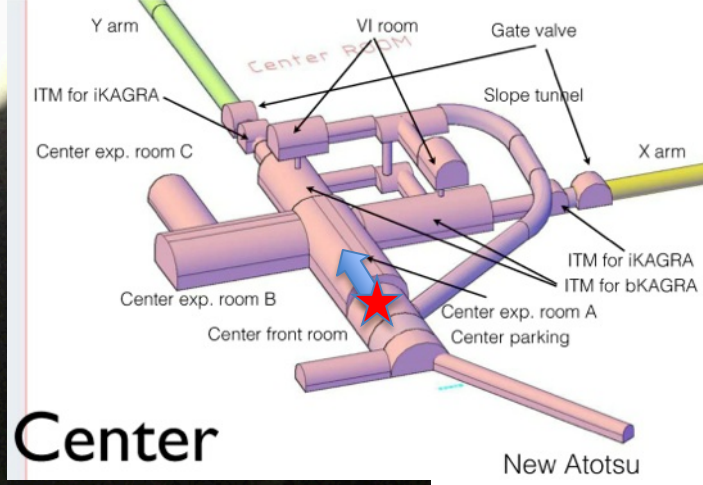

Laser room
X arm
Y arm

Y arm
VI room
Gate valve
Center ROOM
ITM for iKAGRA
Slope tunnel
Center exp. room C
X arm
ITM for iKAGRA
ITM for bKAGRA
Center exp. room B
Center exp. room A
Center front room
Center parking
Center
New Atotsu


X end
1F Rail method
2F Tire method
Sakonishi
Tire method
New Atotsu

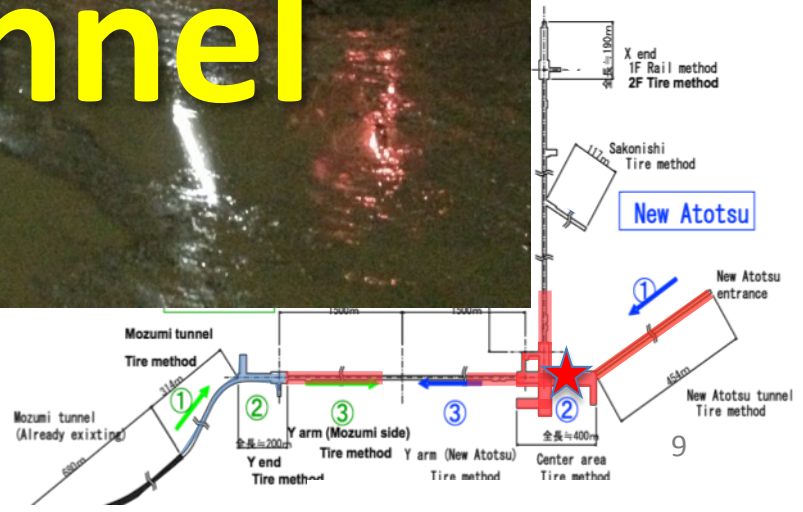

New Atotsu
entrance
Mozumi tunnel
Tire method
Mozumi tunnel
(Already exixting)
Y end
Tire method
Y arm (Mozumi side)
Tire method
Y arm (New Atotsu)
Tire method
Center area
Tire method
New Atotsu tunnel
Tire method

Center room

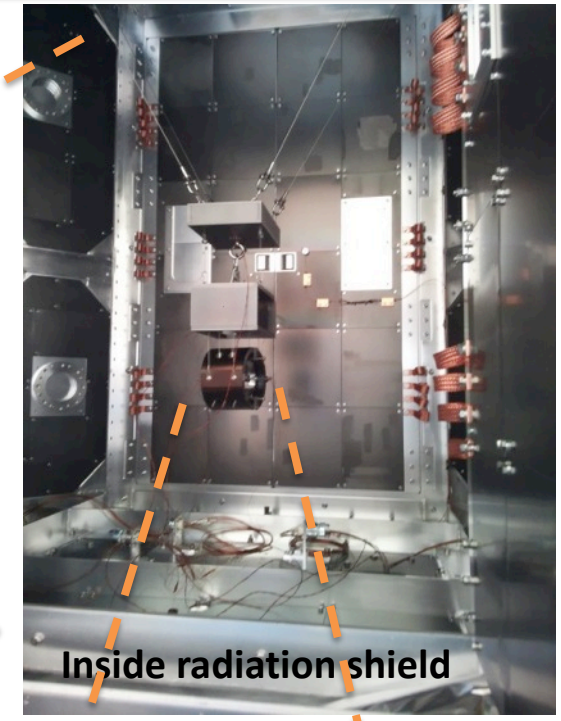


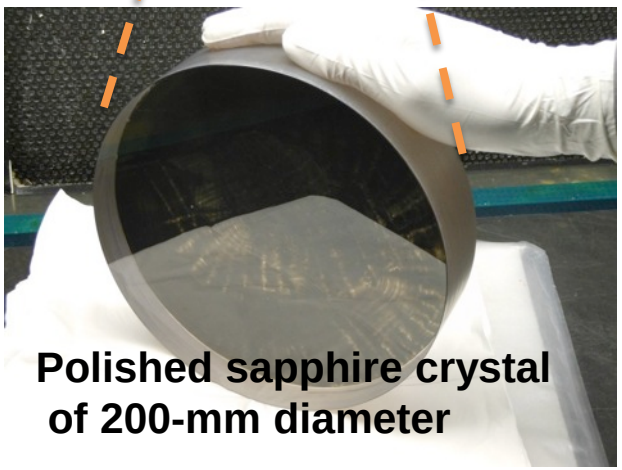
~80% of tunnel Done

Center room



Low temperature operation at KAGRA to reduce thermal distortion

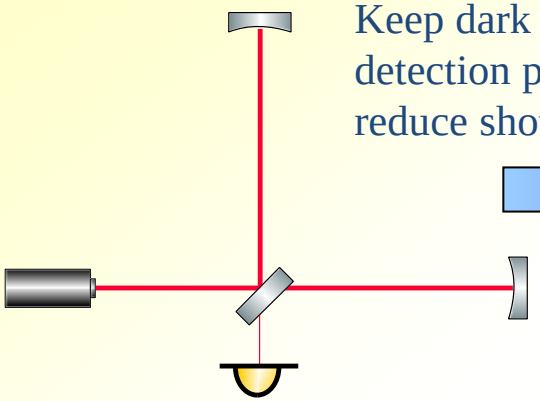




Development of optical configurations

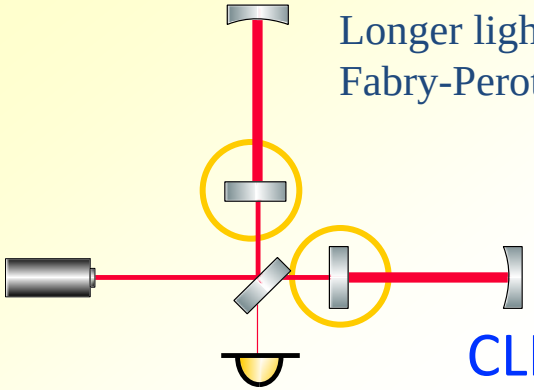
Michelson interferometer (MI)

Keep dark condition at detection port to reduce shot noise



Fabry-Perot MI (FPMI)

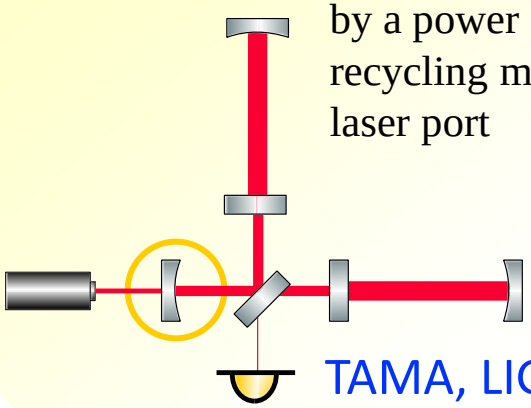
Longer light path using Fabry-Perot cavities



CLIO

Power recycling (PRFPMI)

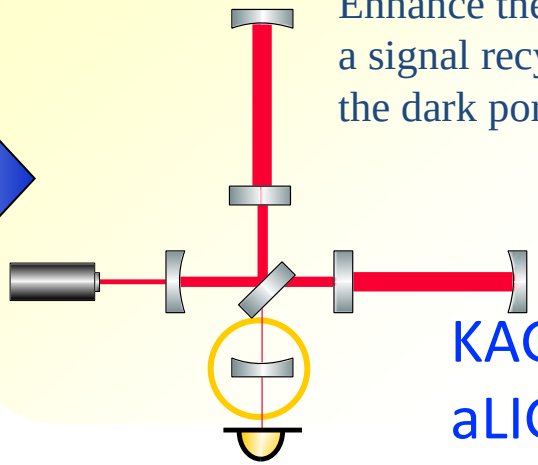
Higher laser power by a power recycling mirror at laser port



TAMA, LIGO , VIRGO

Dual recycling (DRFPMI)

Enhance the GW signals by a signal recycling mirror at the dark port



KAGRA,
aLIGO, aVIRGO

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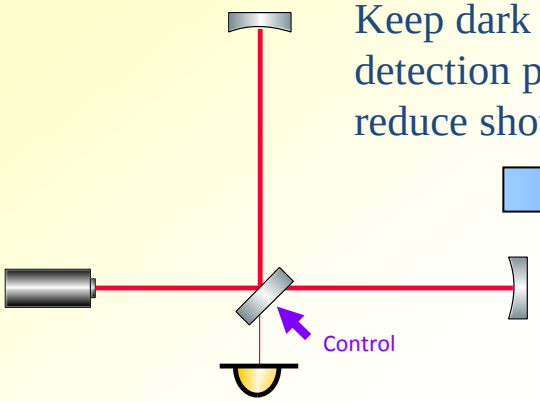

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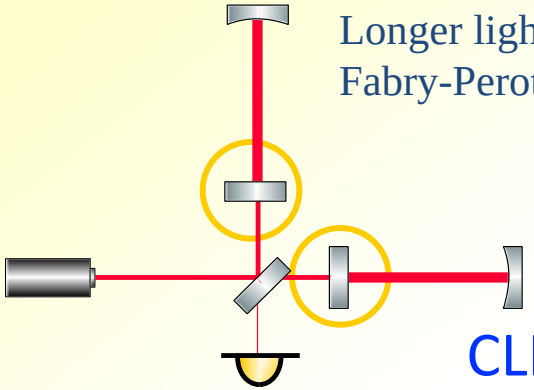

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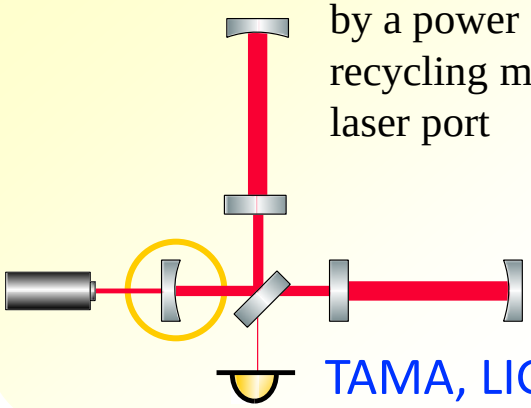

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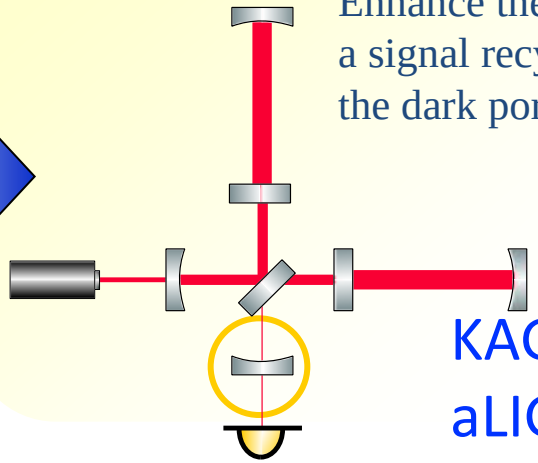

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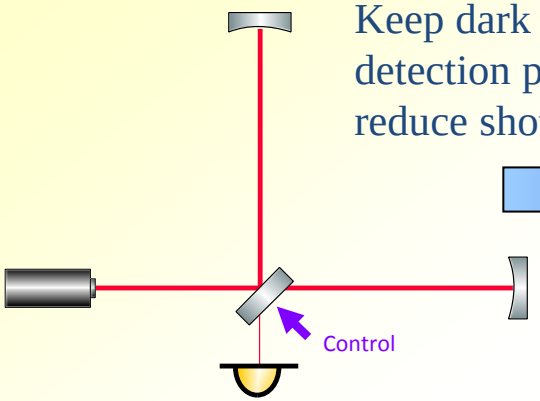

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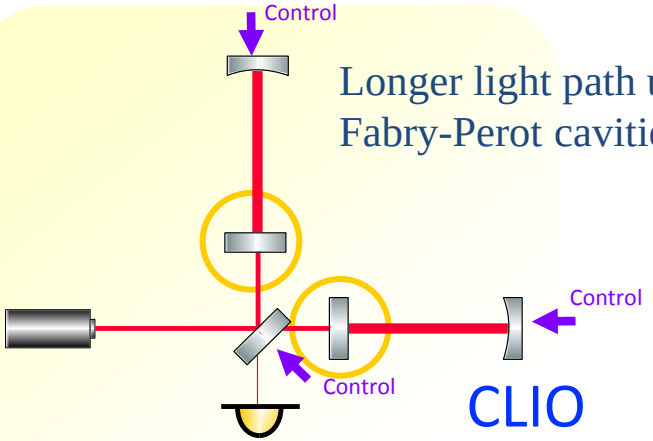

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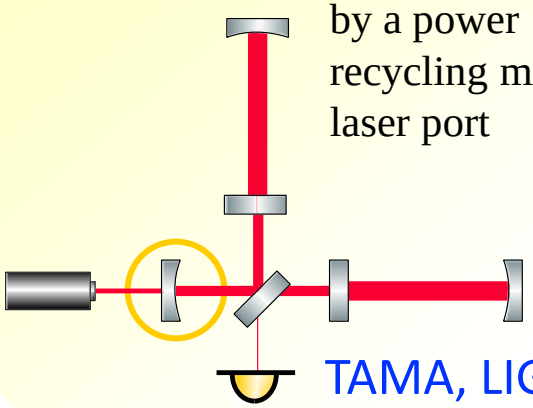
Higher laser power by a power recycling mirror at laser port



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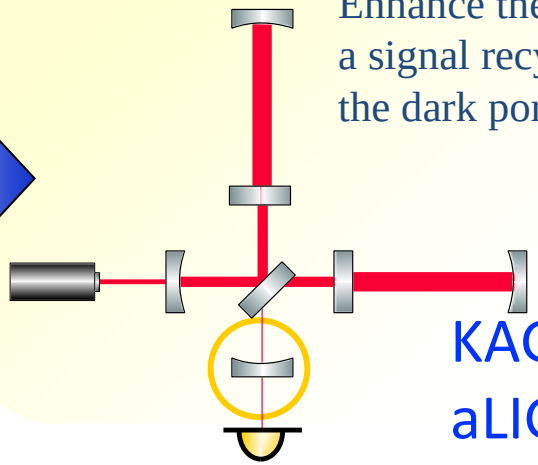

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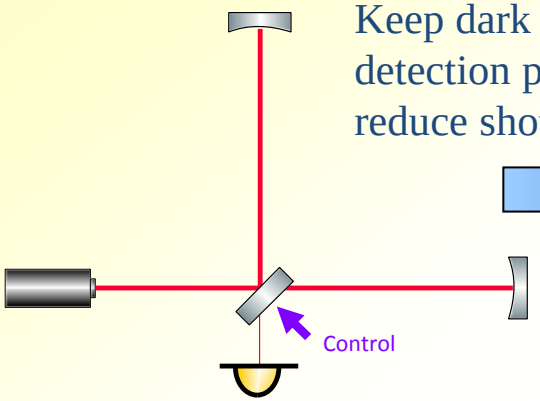

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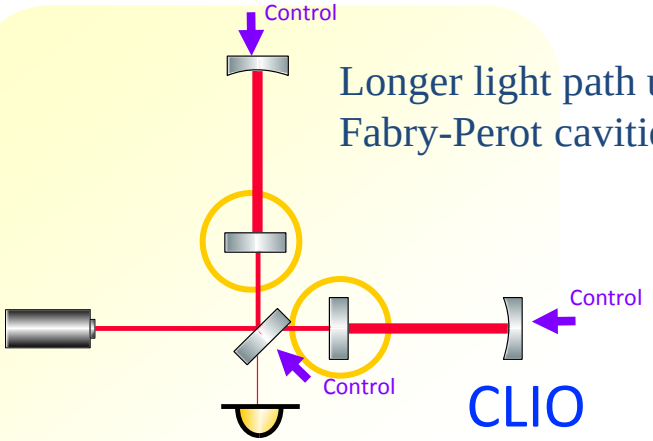

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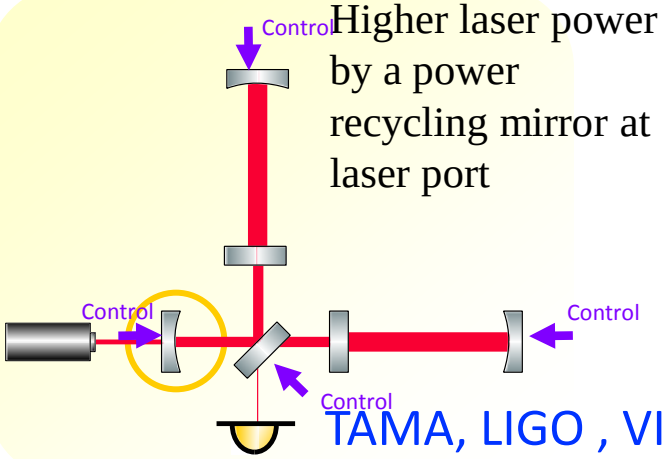
Higher laser power by a power recycling mirror at laser port



TAMA, LIGO , VIRGO

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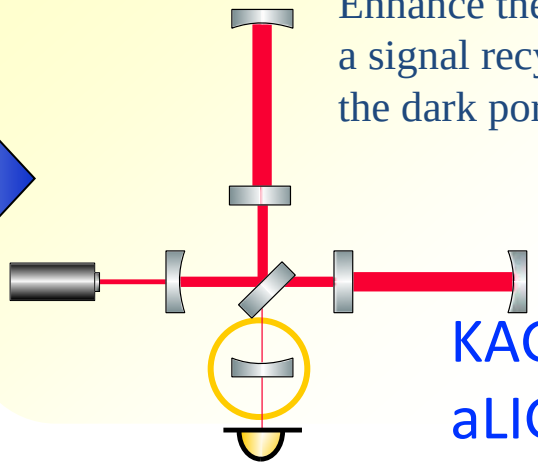

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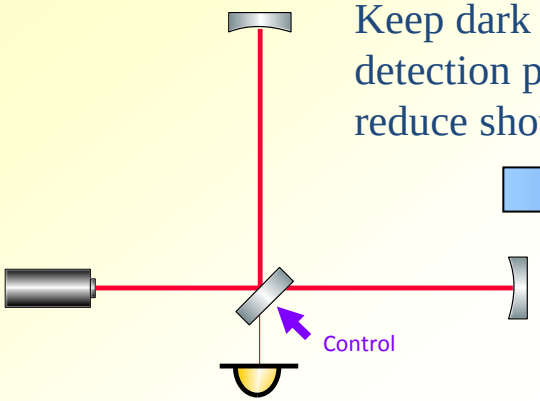

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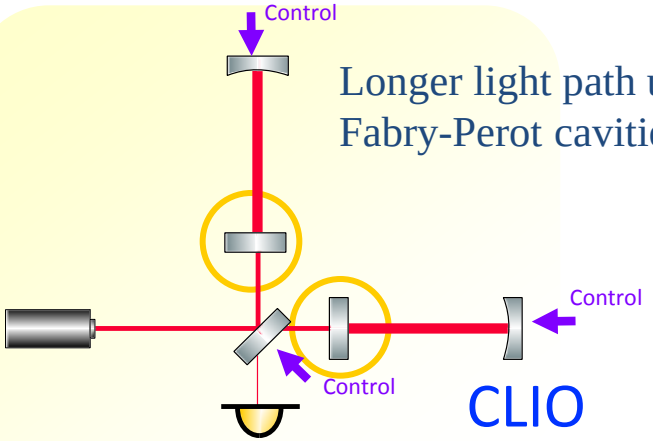

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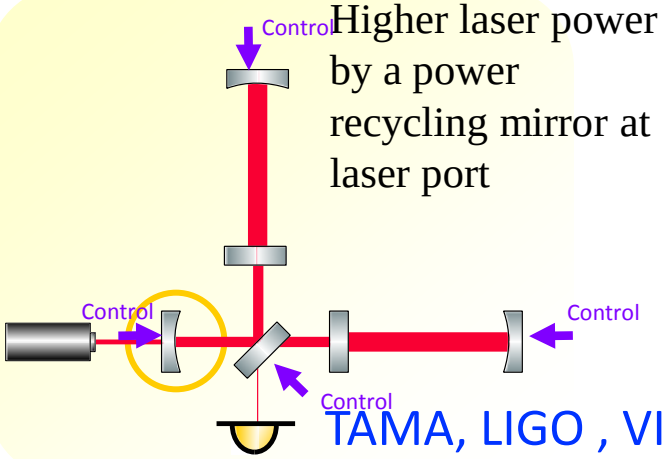

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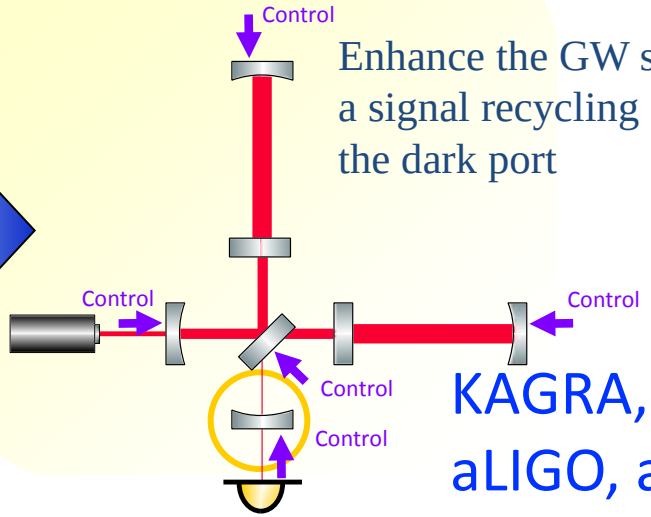


KAGRA, aLIGO, aVIRGO

Development of optical configurations

Michelson interferometer (MI)

Fabry-Perot MI (FPMI)

To keep interferometer being operated, we need

Very Low Noise Control all the time

Position: ~10DOFs

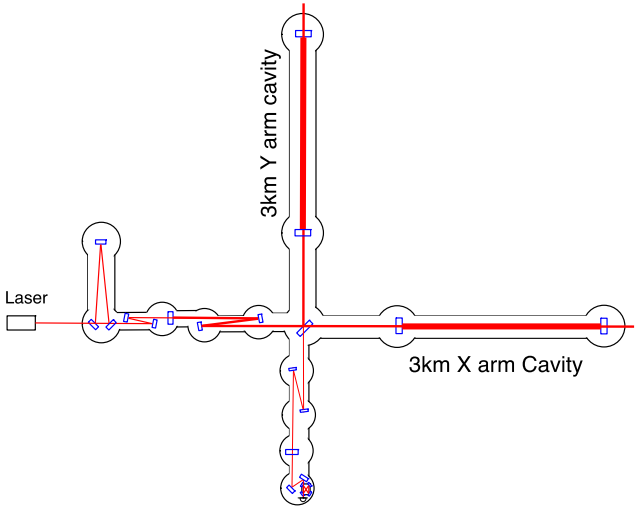
Angle: ~20DOFs

Others: ~100DOFs

TAMA, LIGO , VIRGO

KAGRA,
aLIGO, aVIRGO

KAGRA control network design



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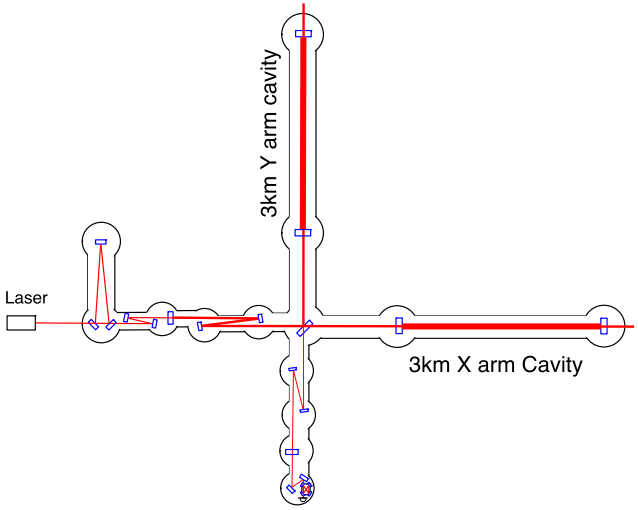

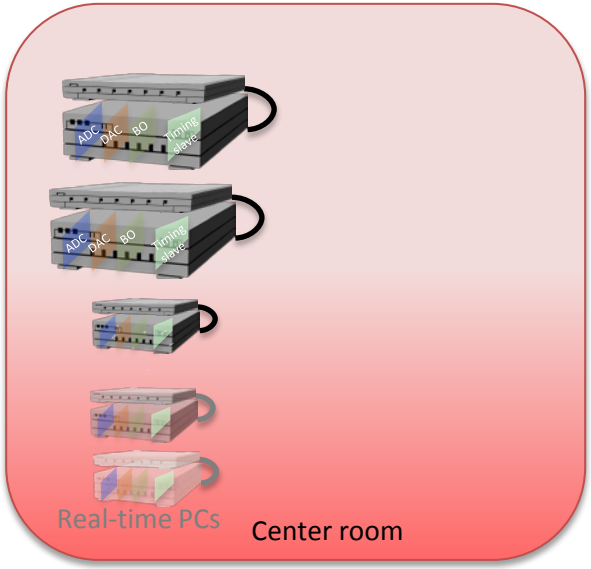

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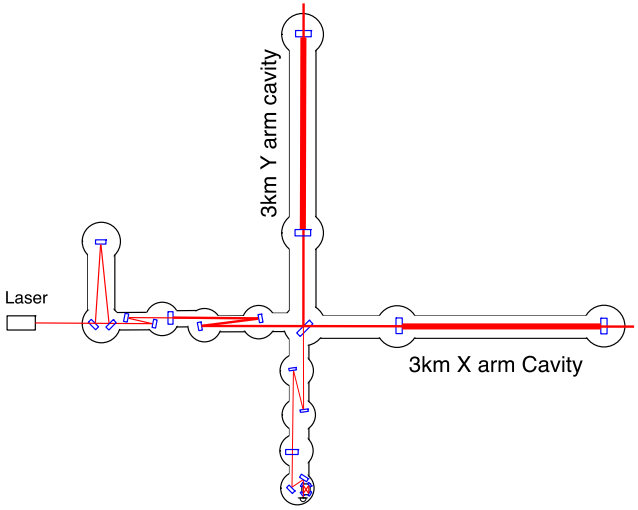

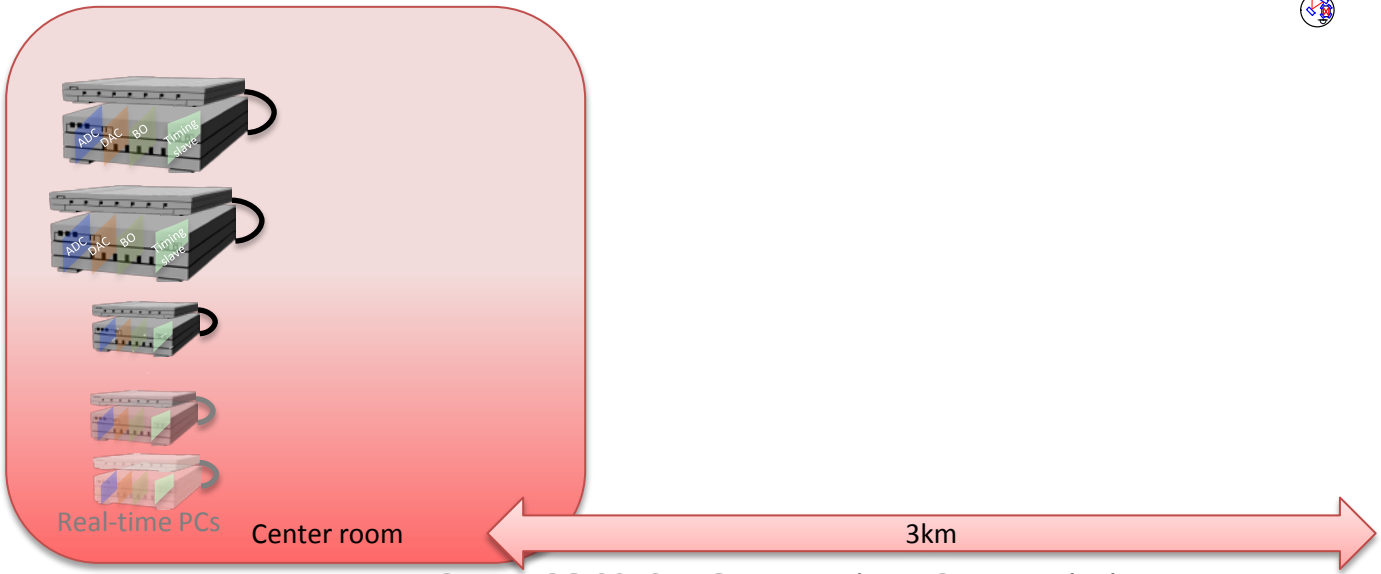

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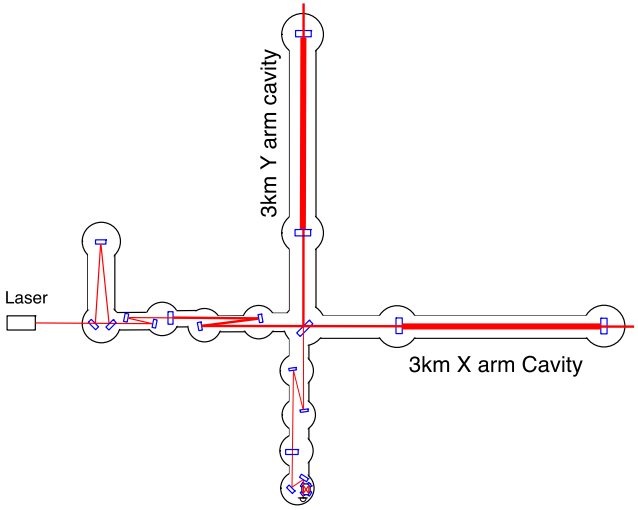
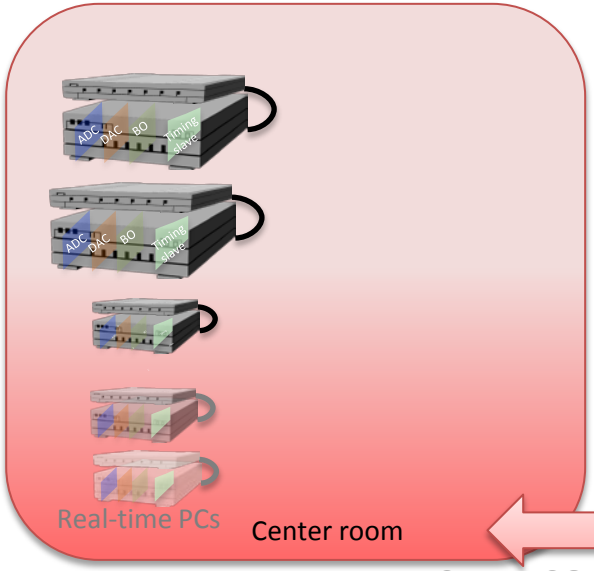
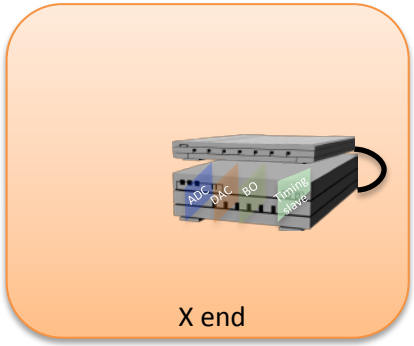
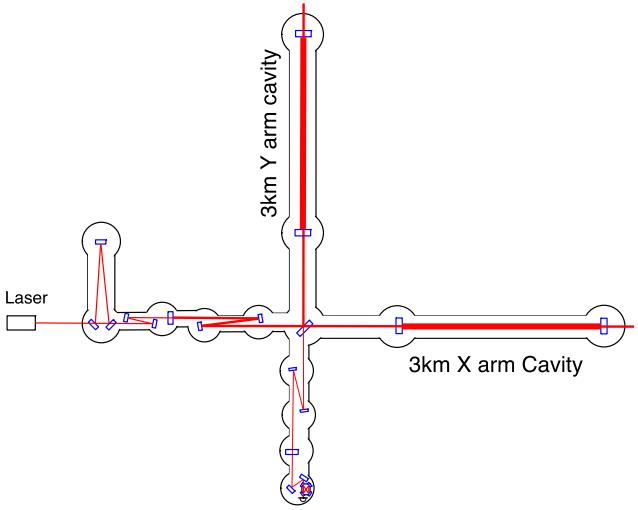


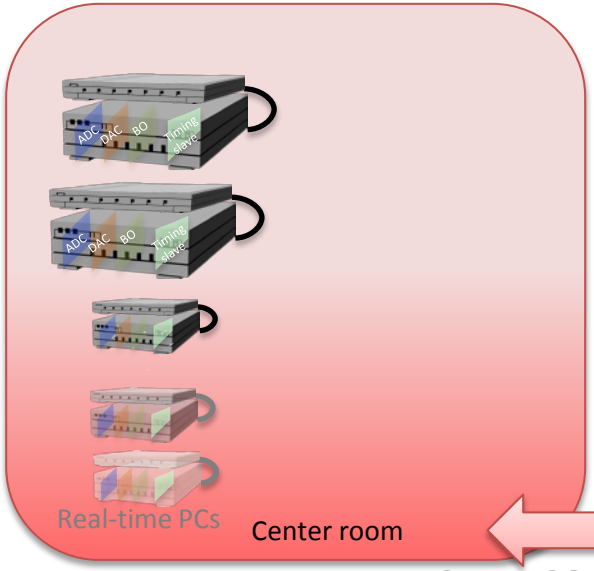


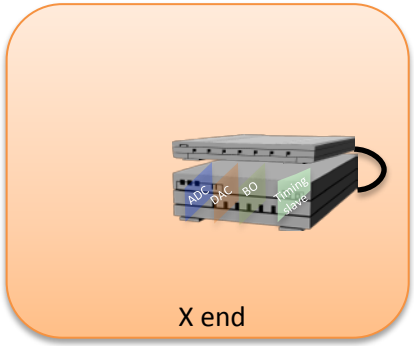


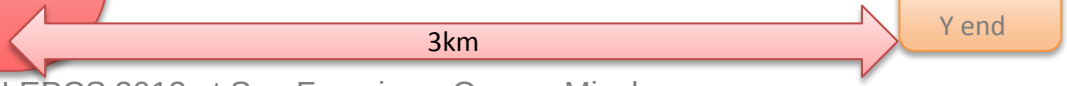
3km

KAGRA control network design









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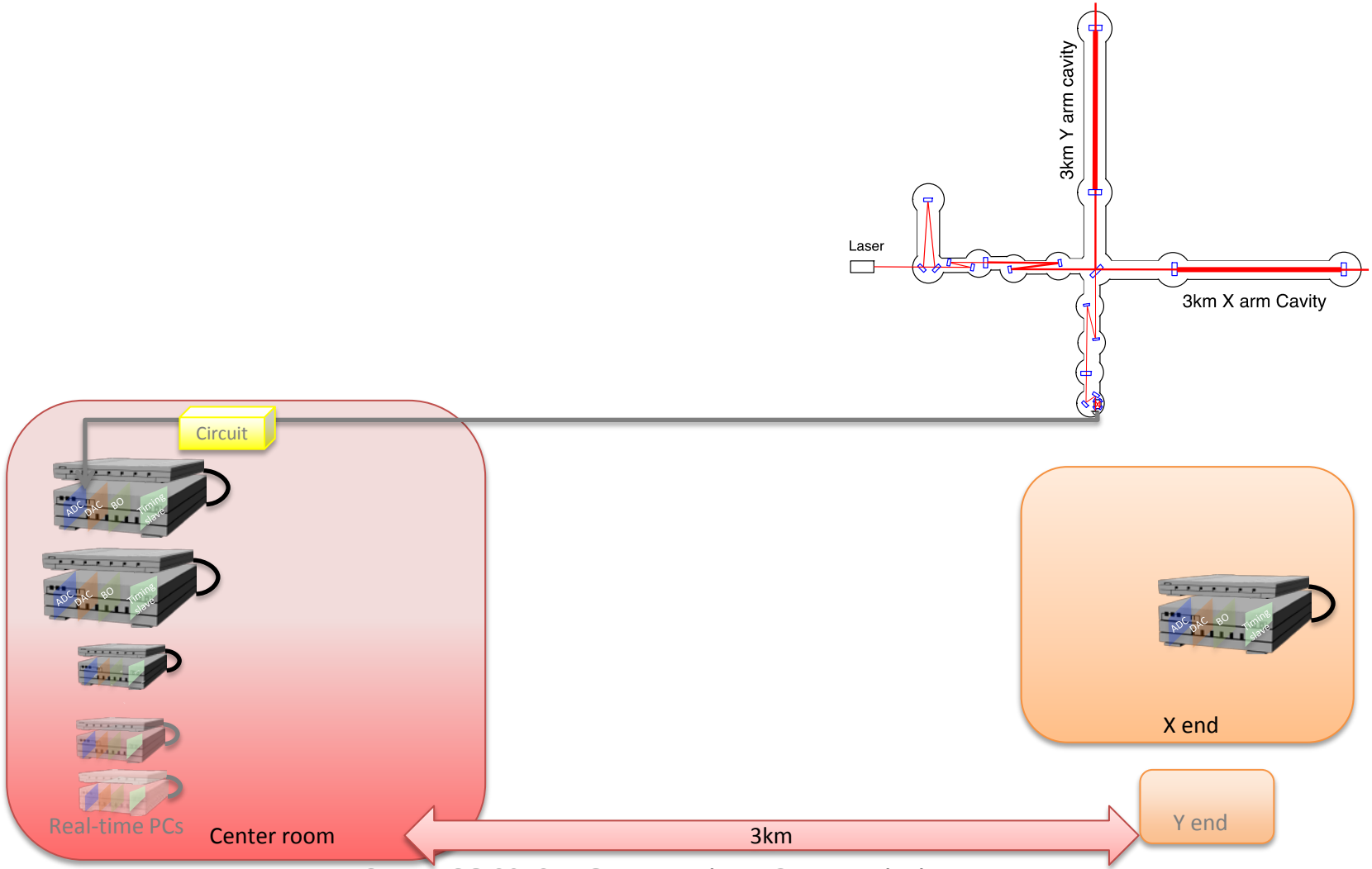

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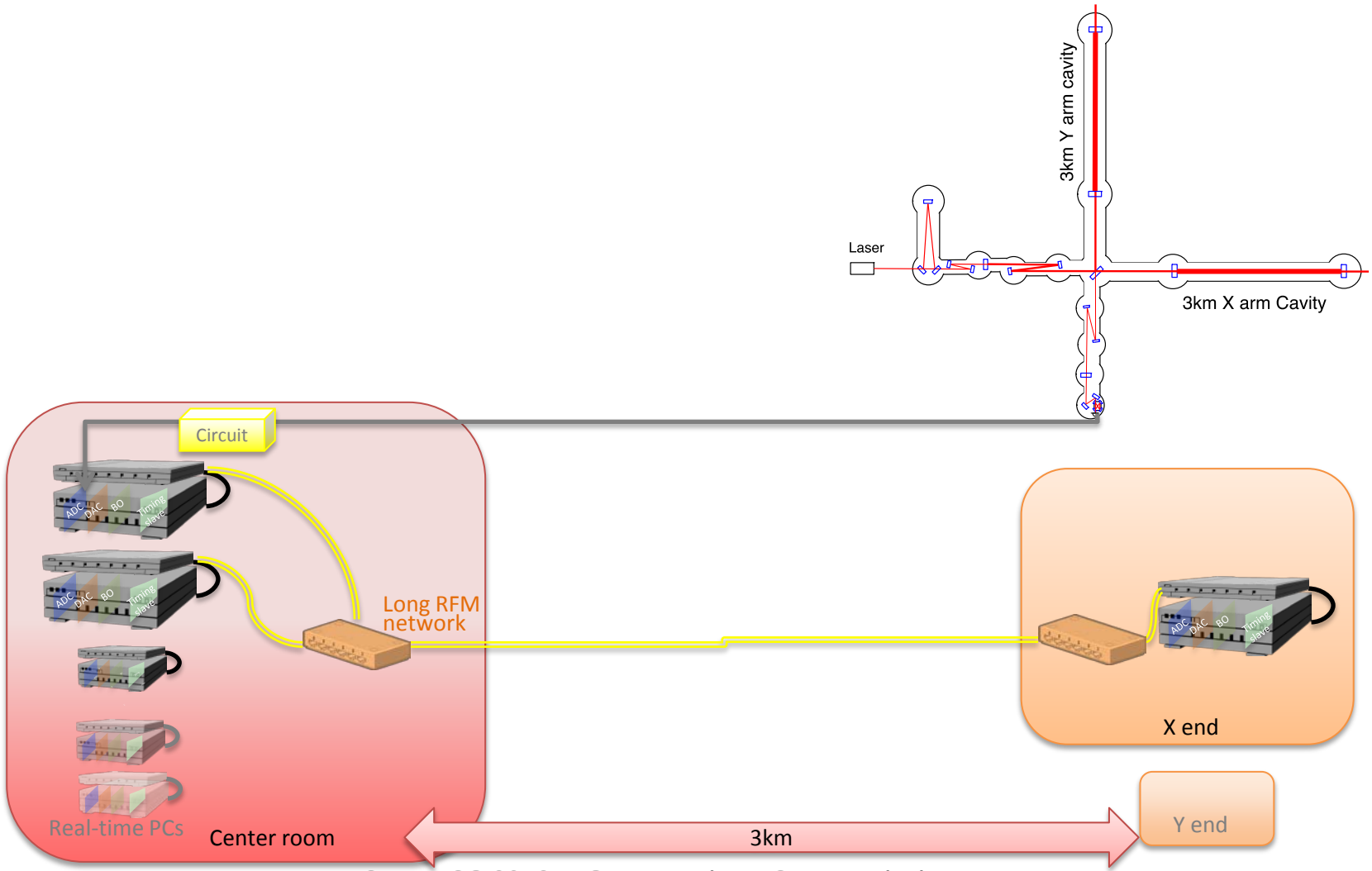

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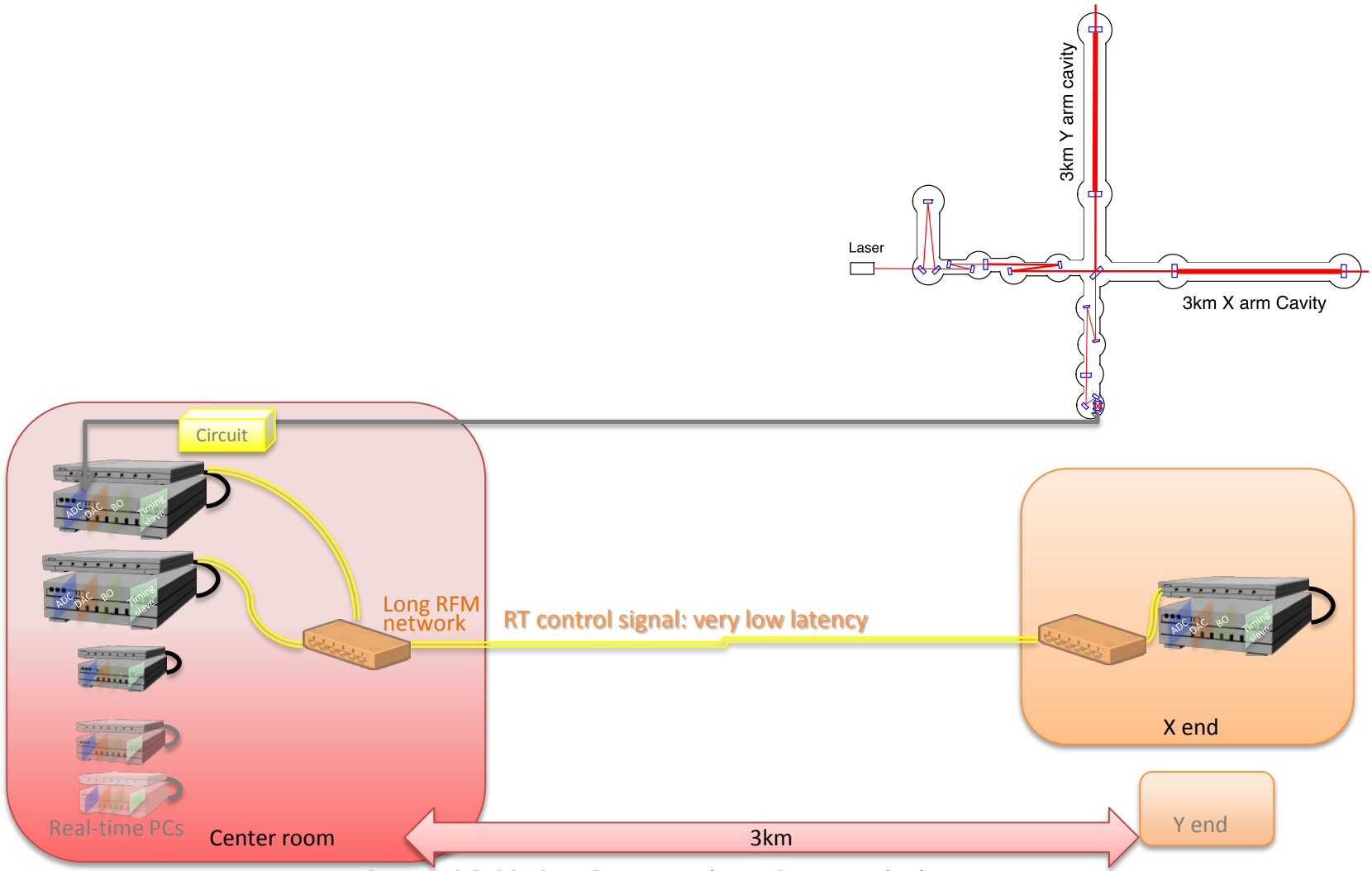

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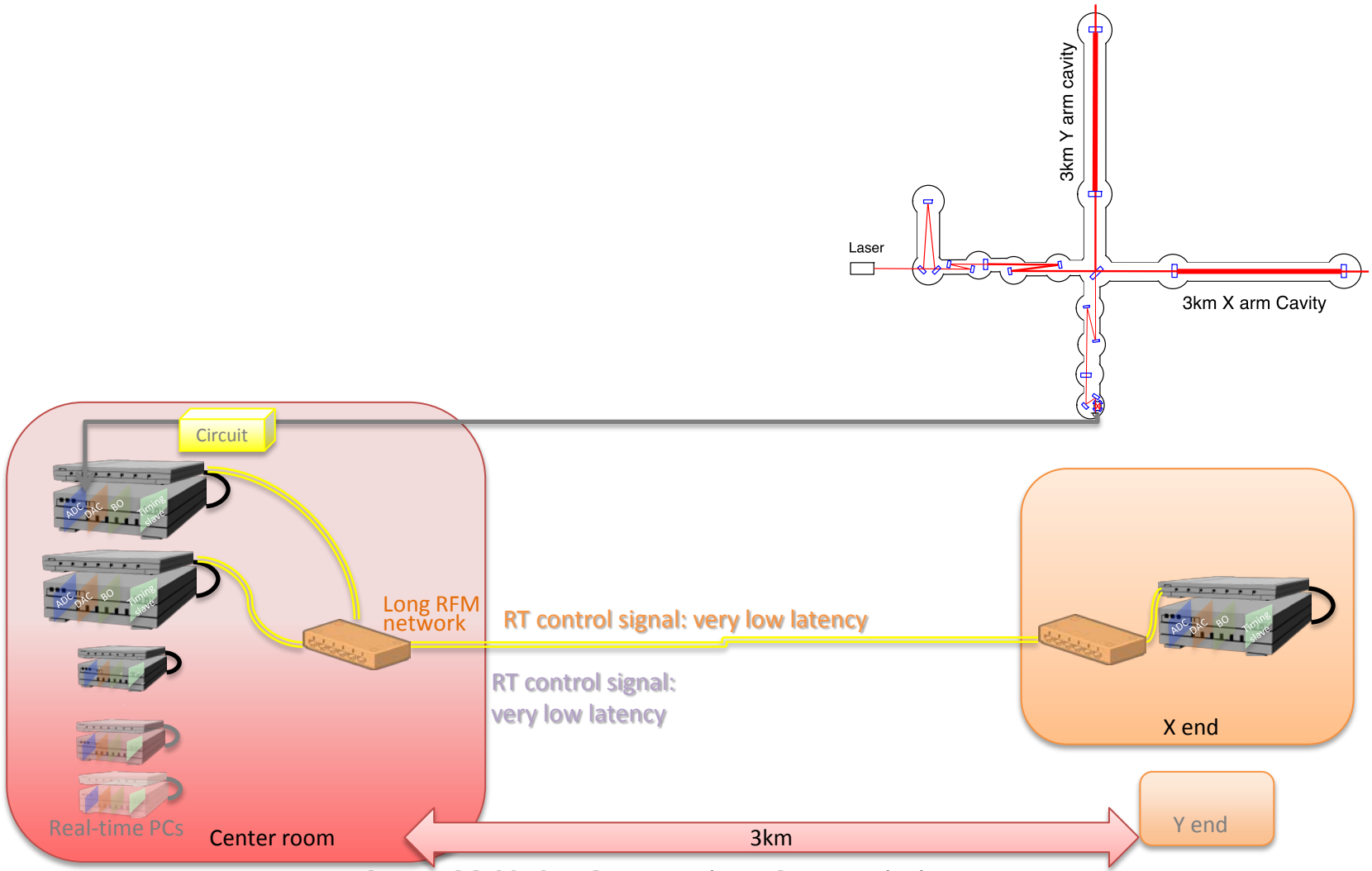
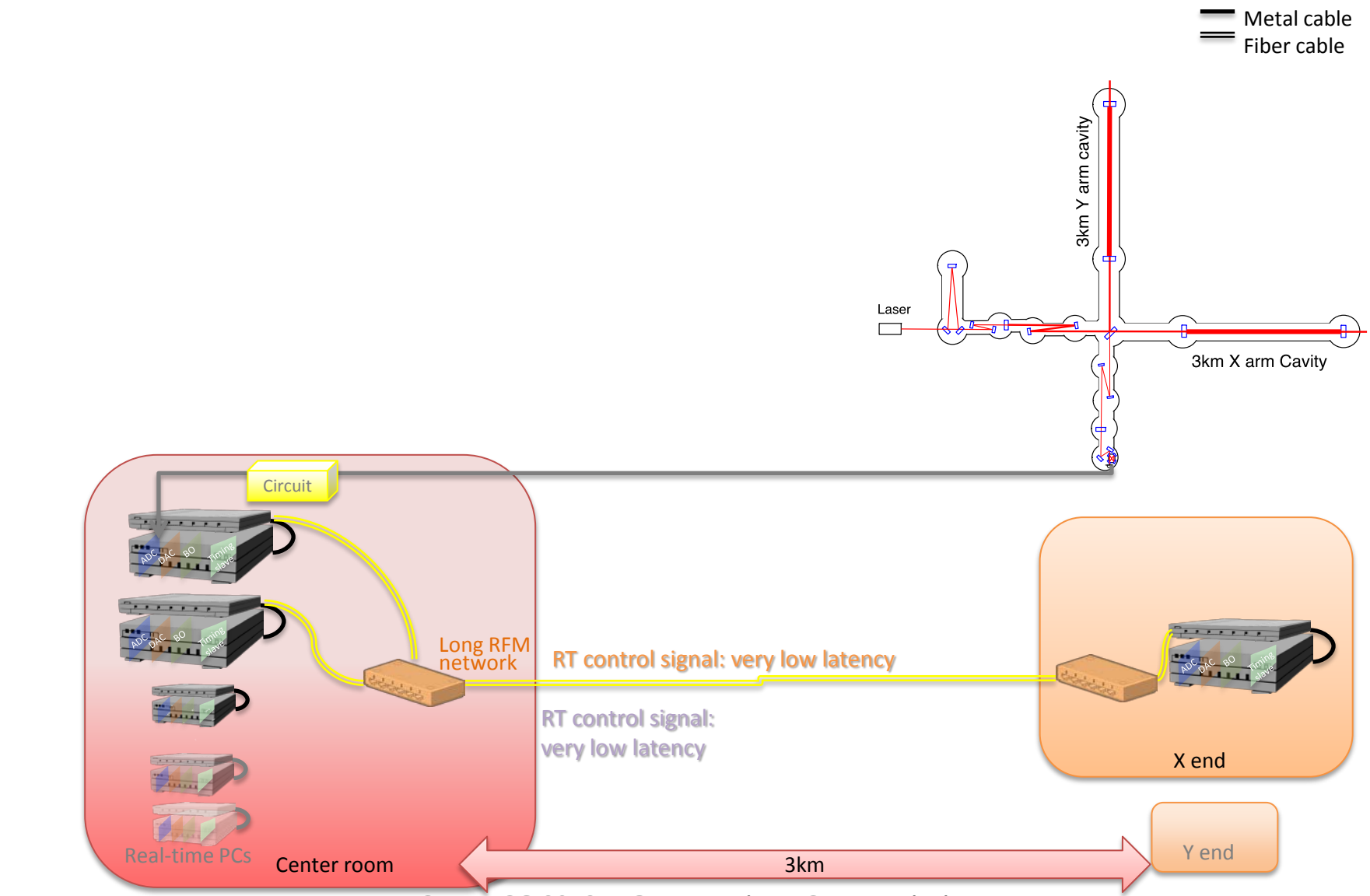
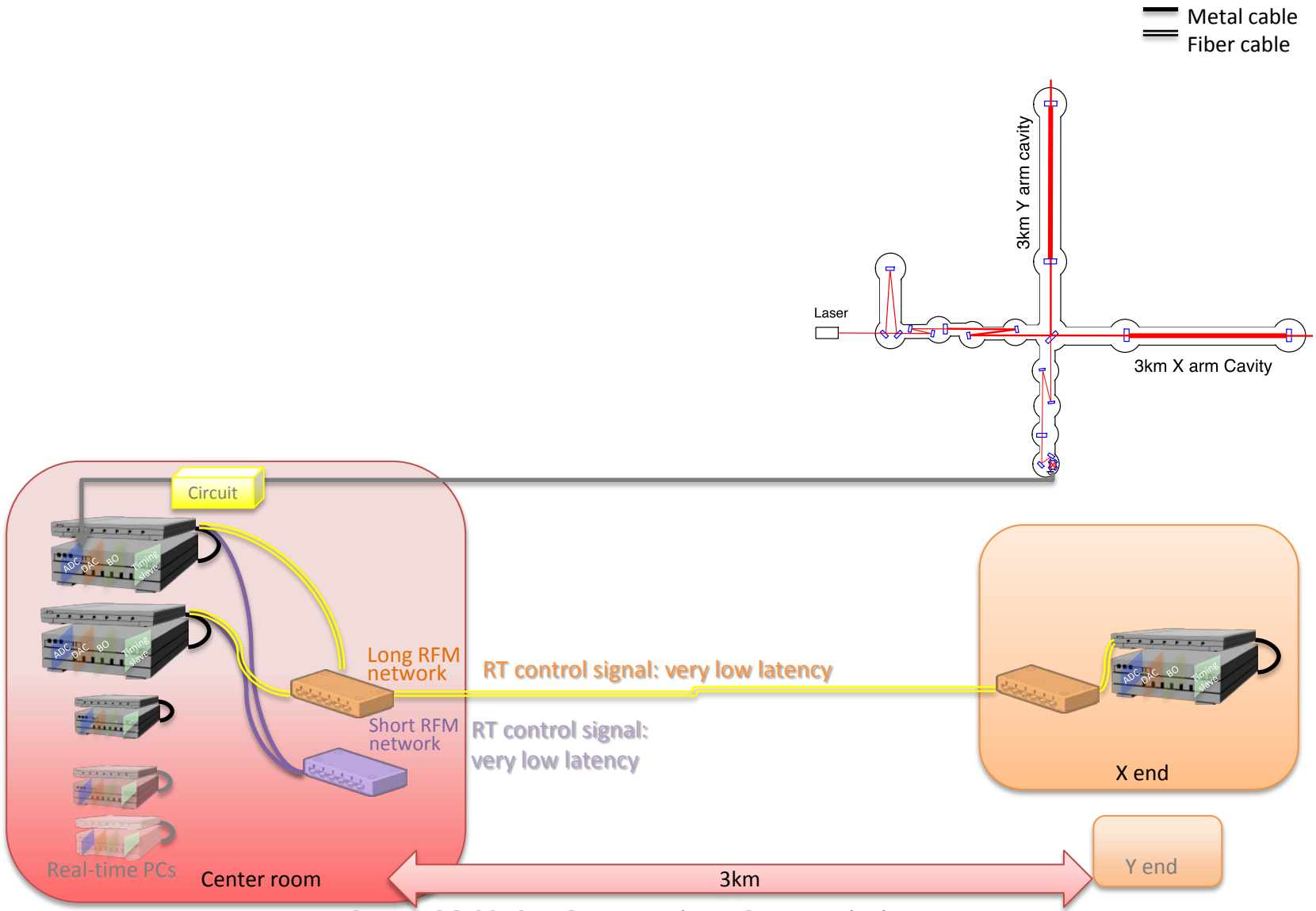


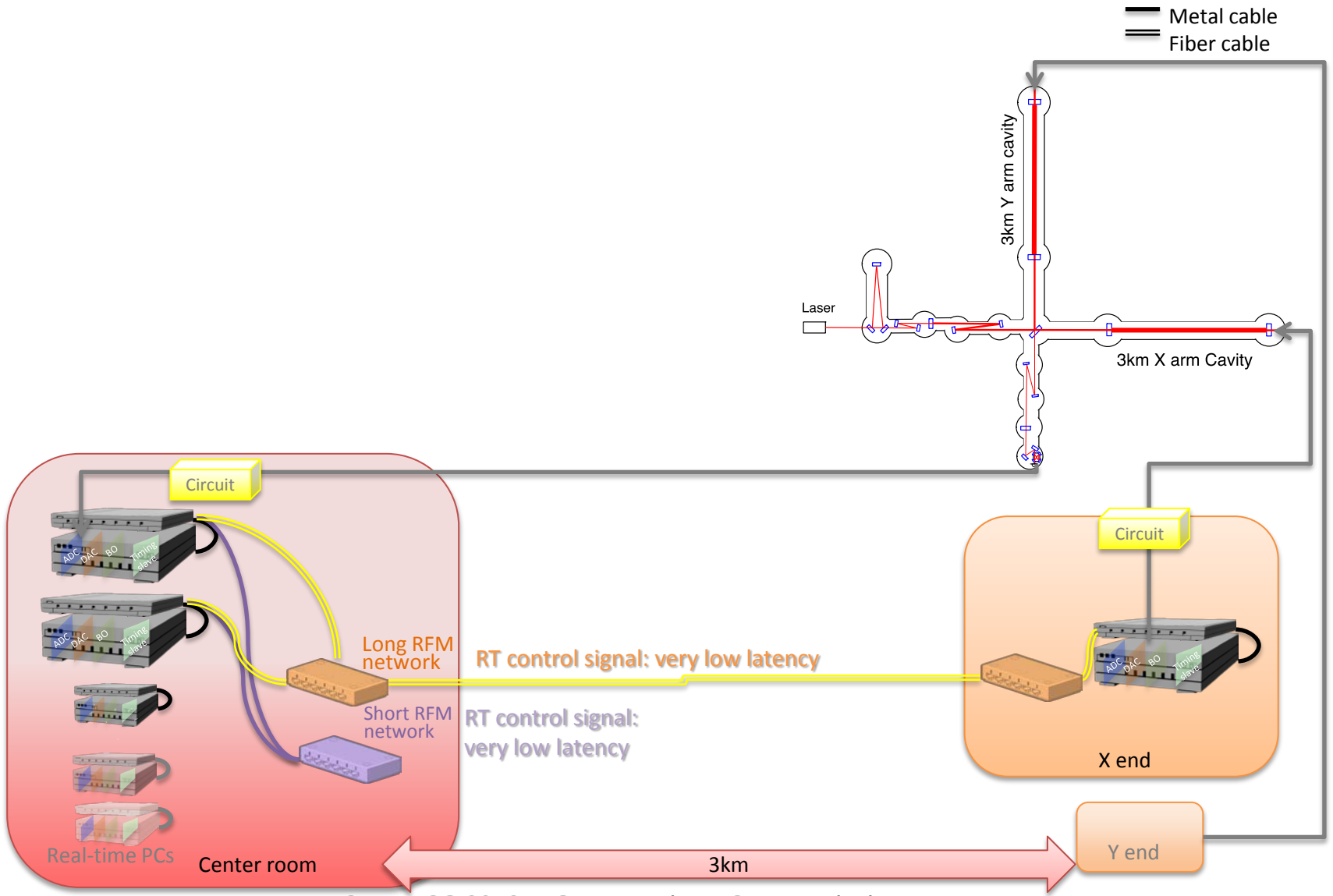
KAGRA control network design



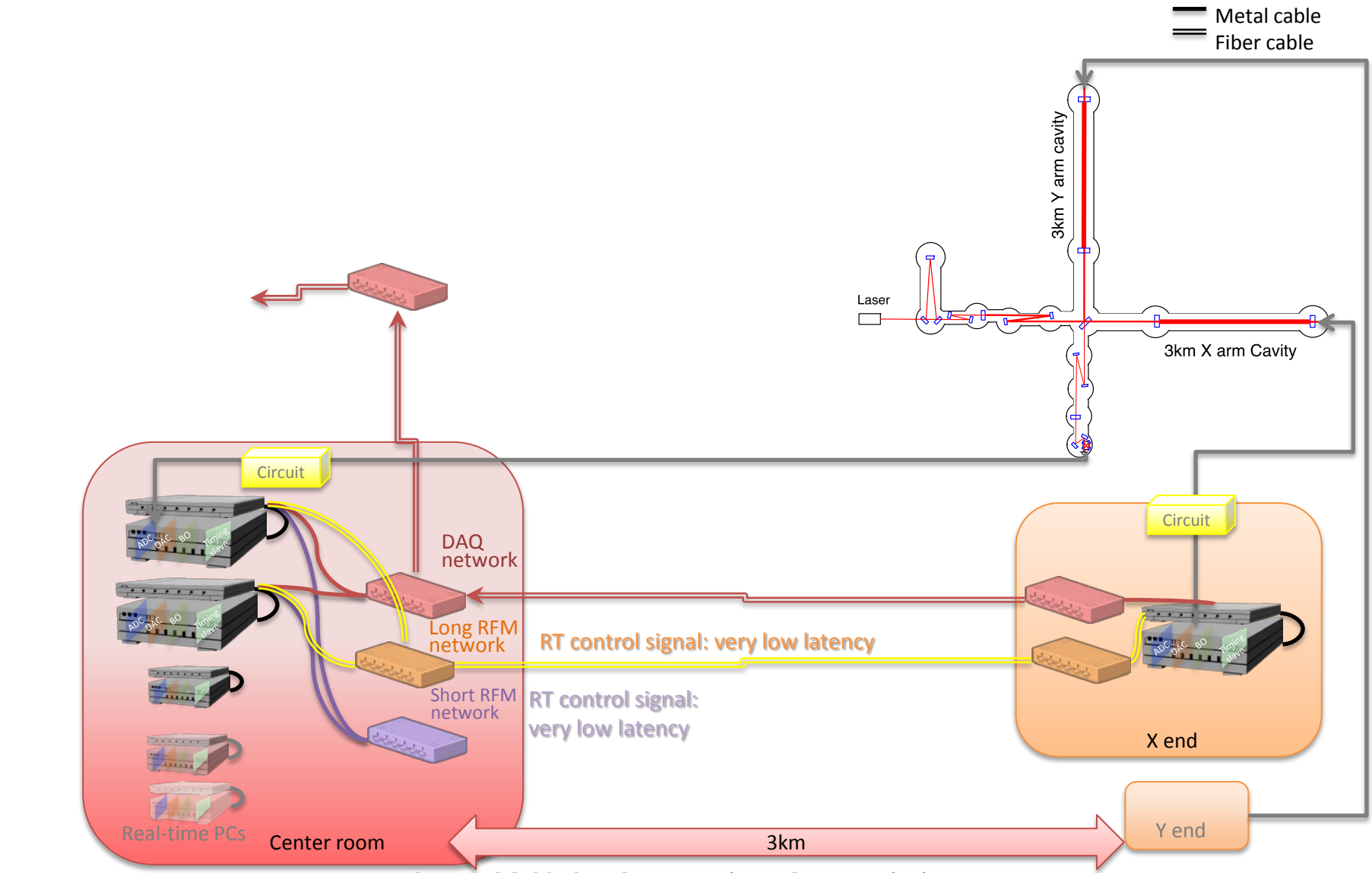
KAGRA control network design



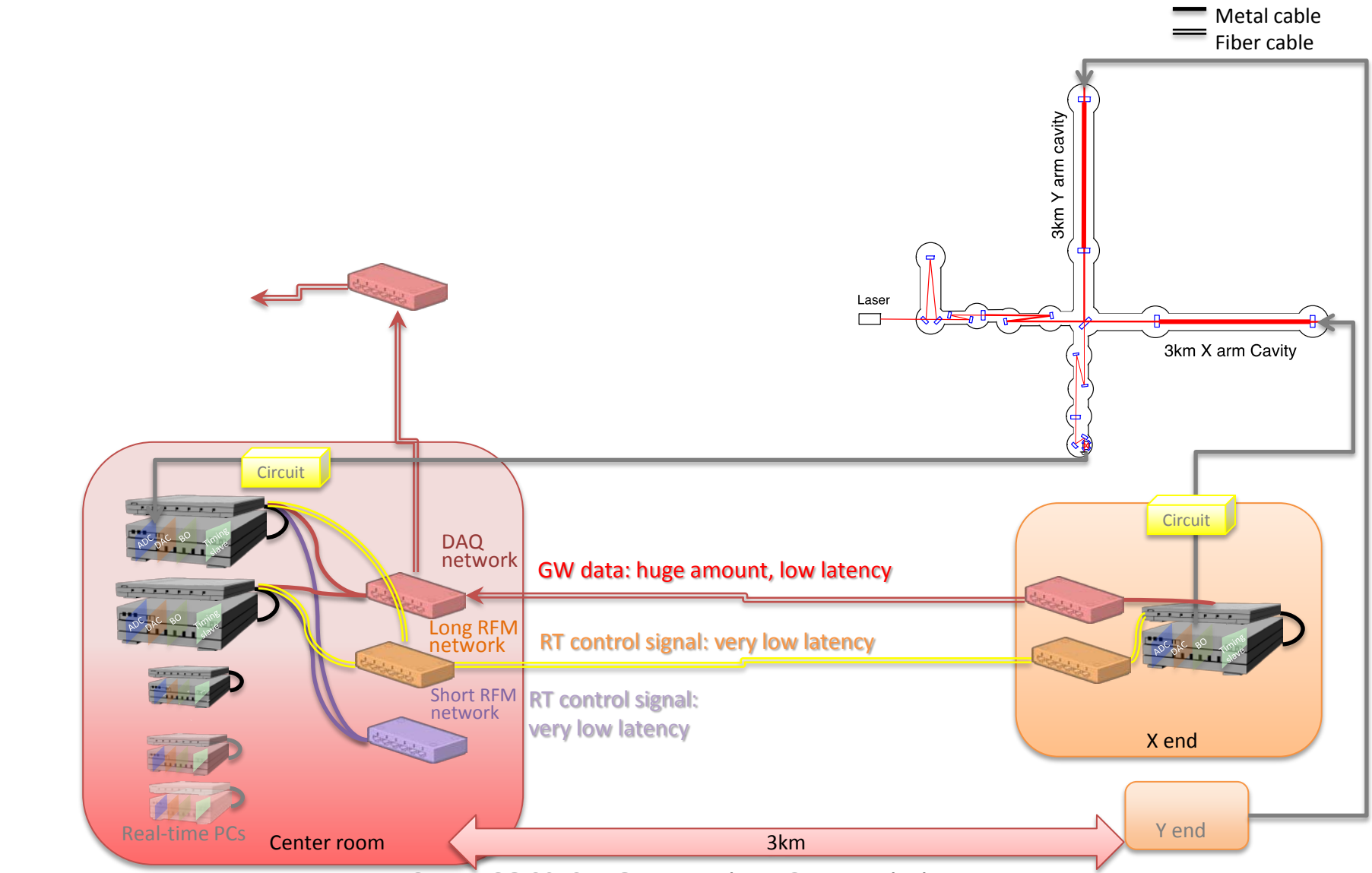
KAGRA control network design



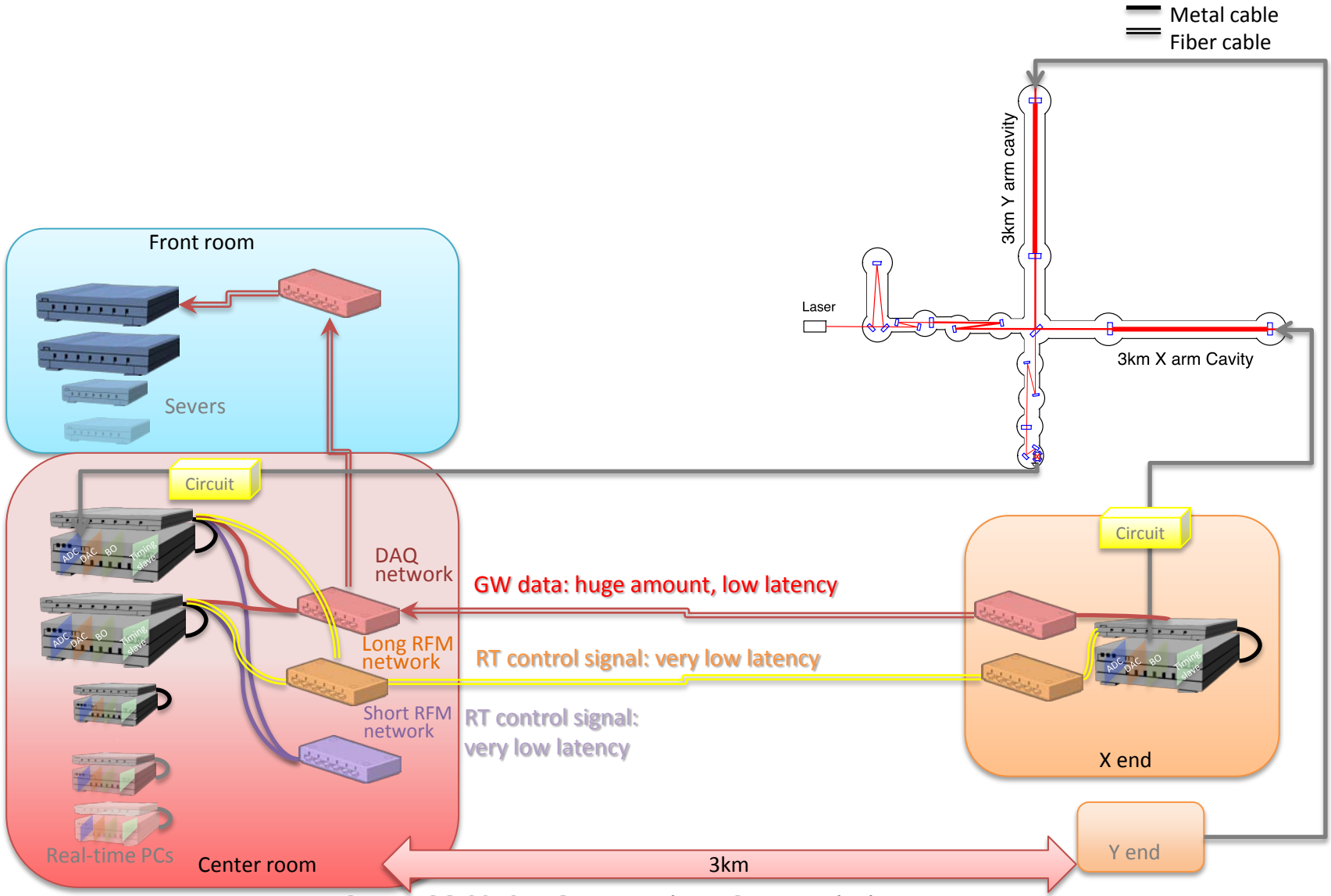
KAGRA control network design



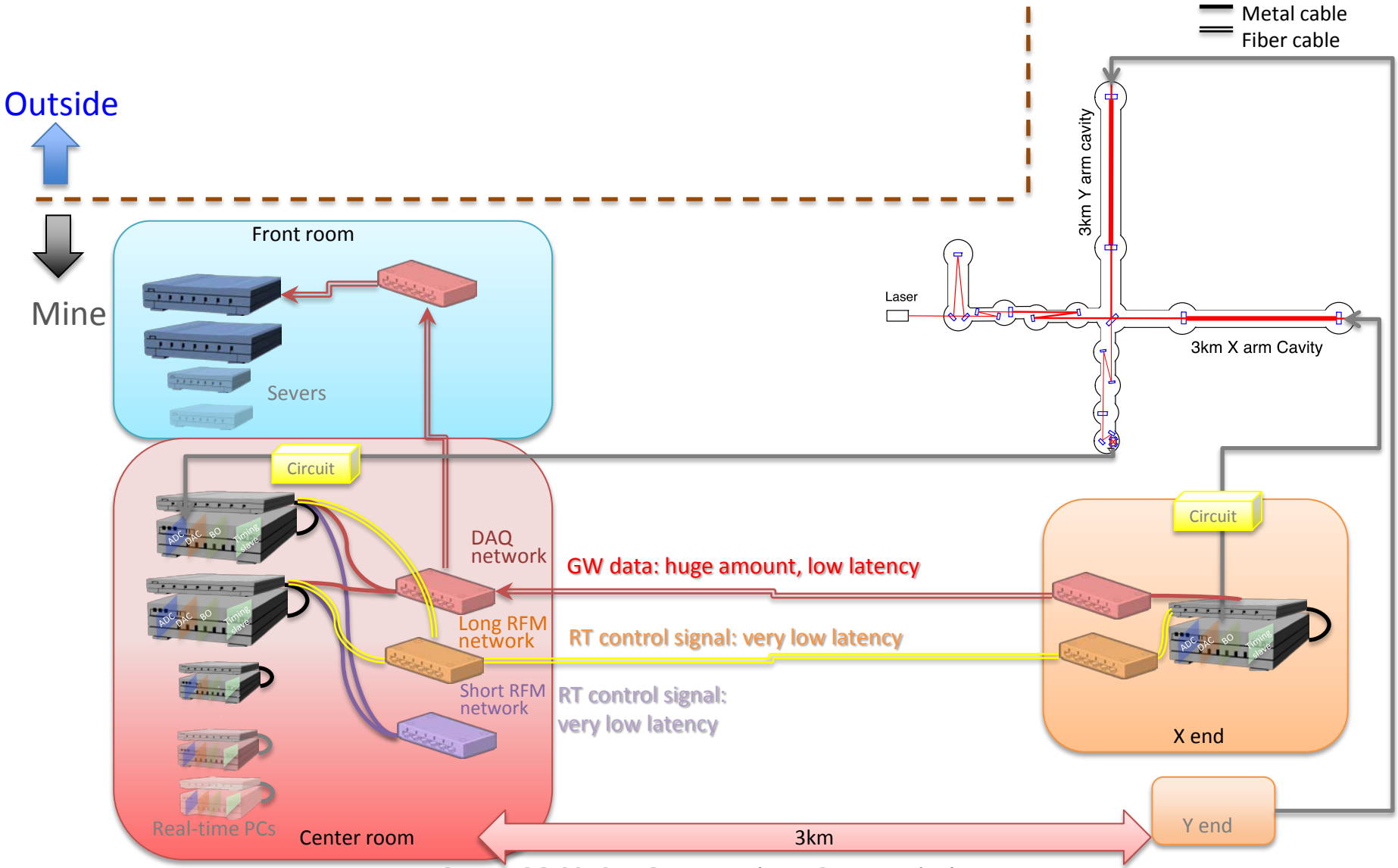
KAGRA control network design



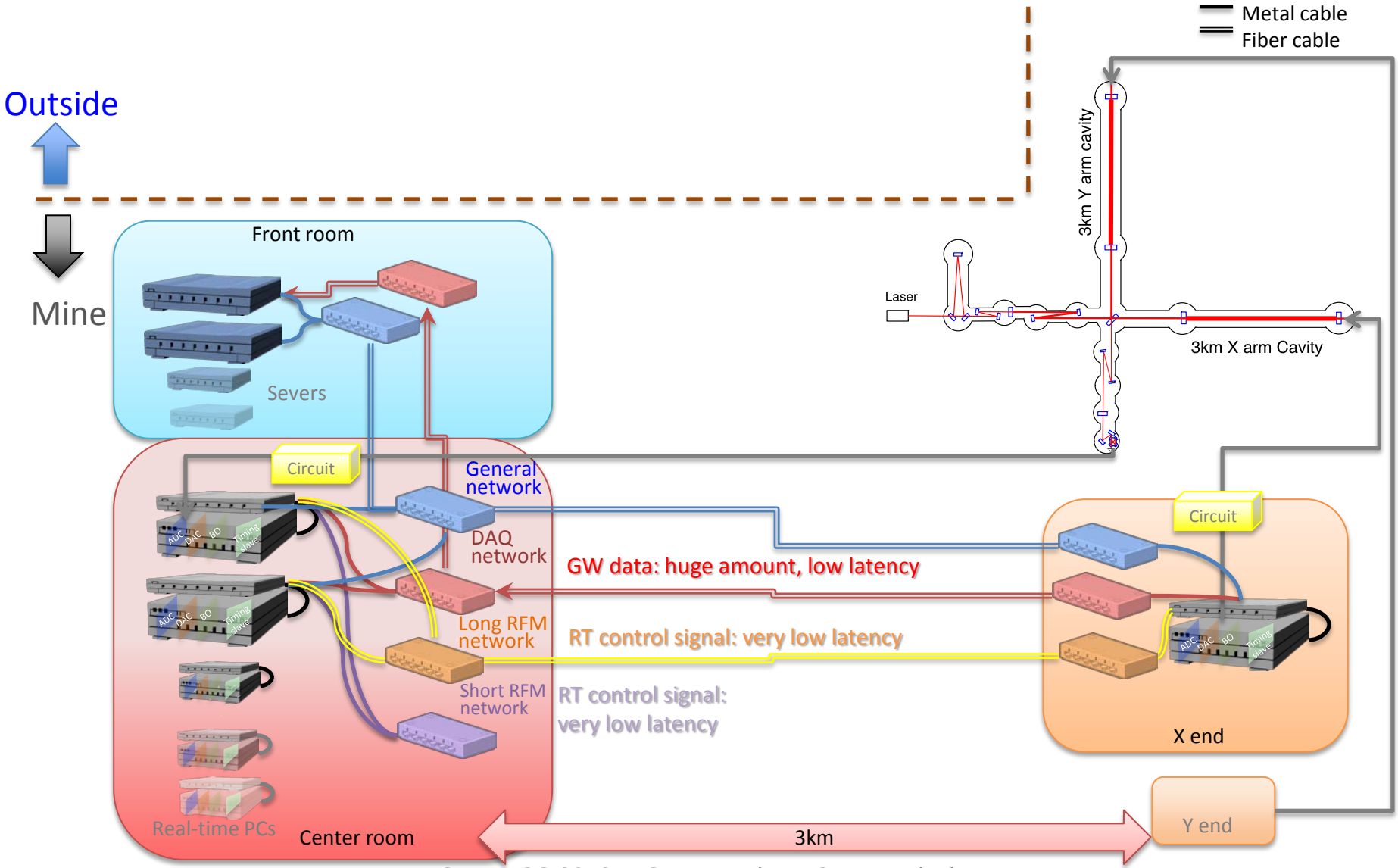
KAGRA control network design



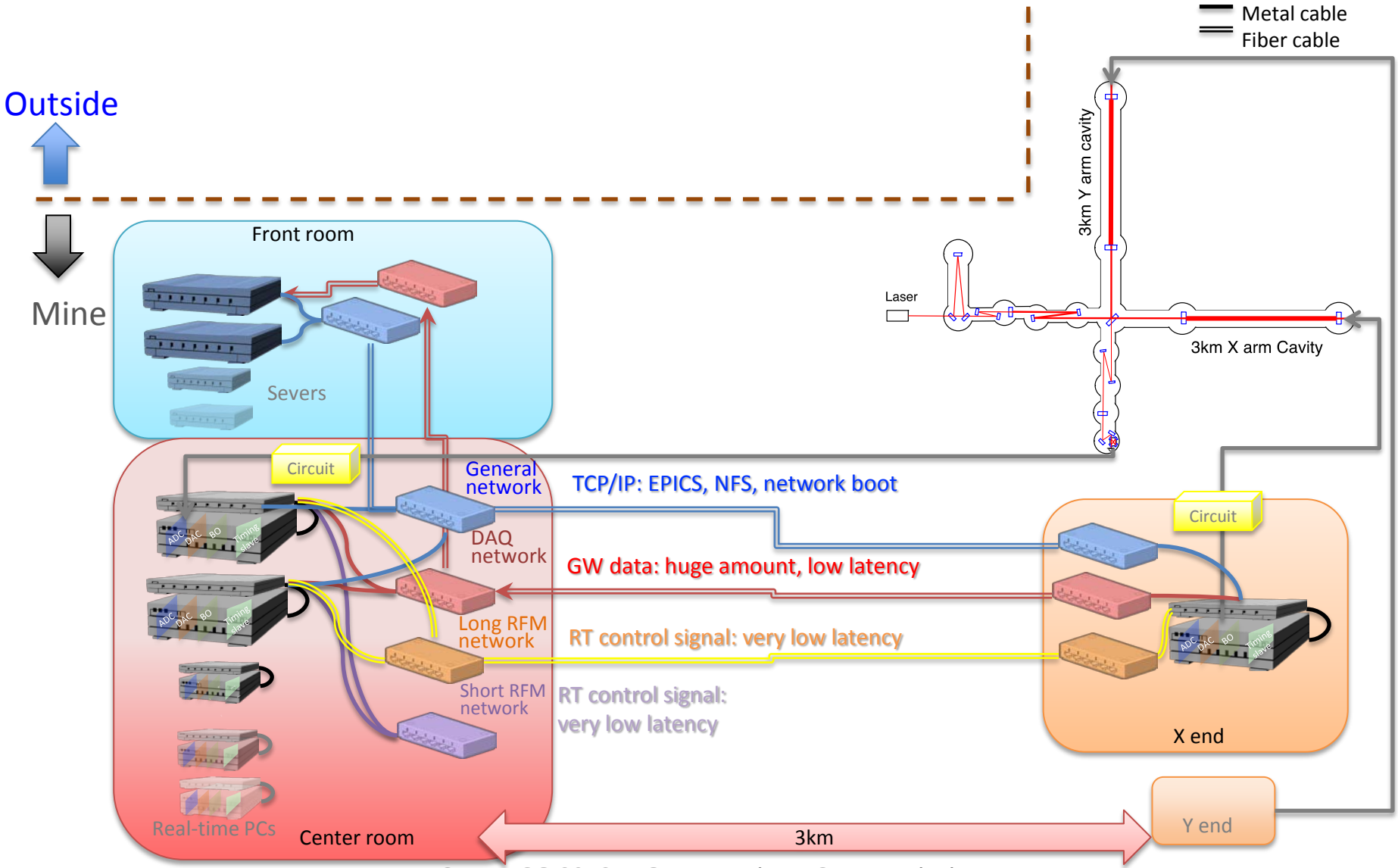
KAGRA control network design



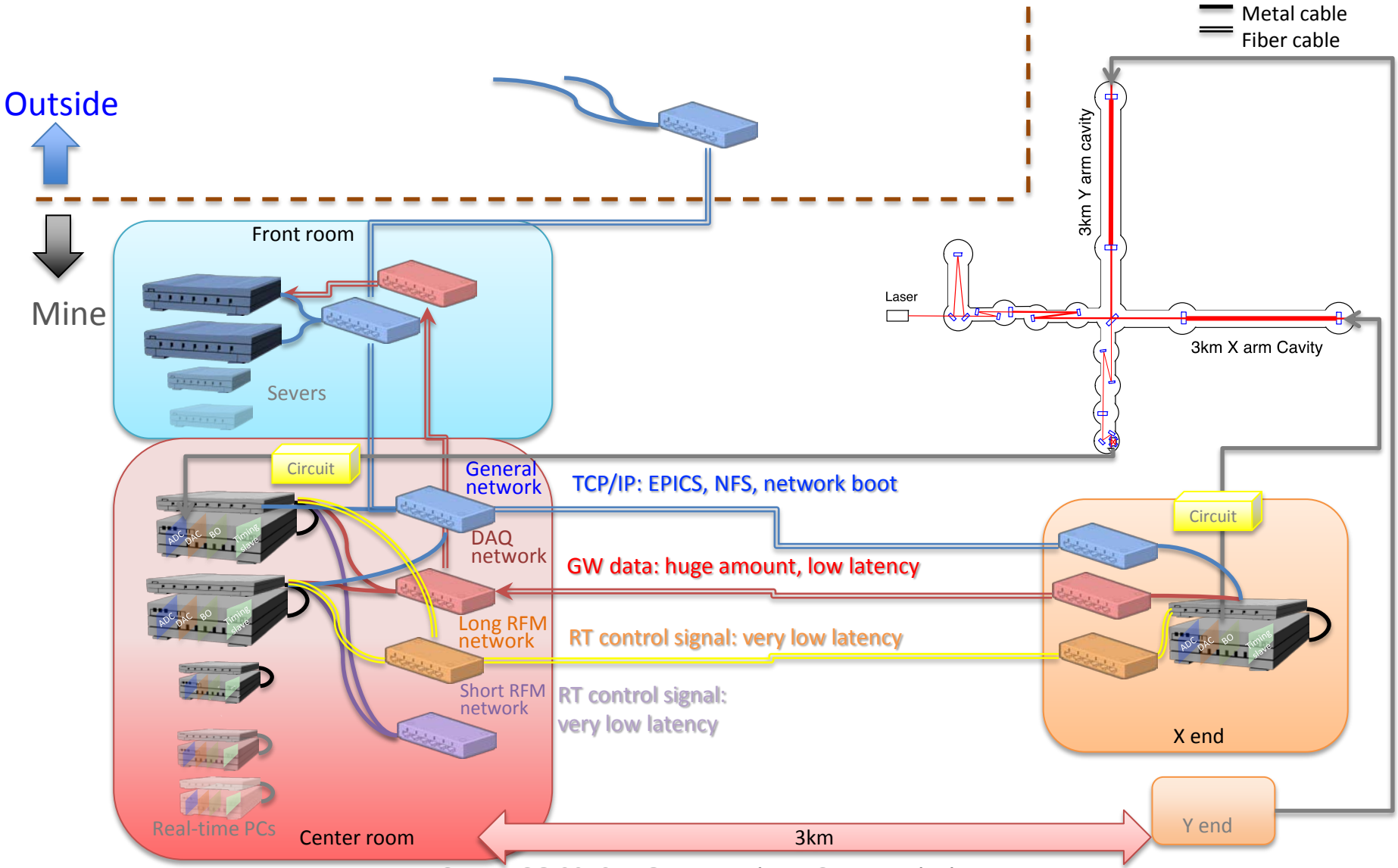
KAGRA control network design



KAGRA control network design



KAGRA control network design



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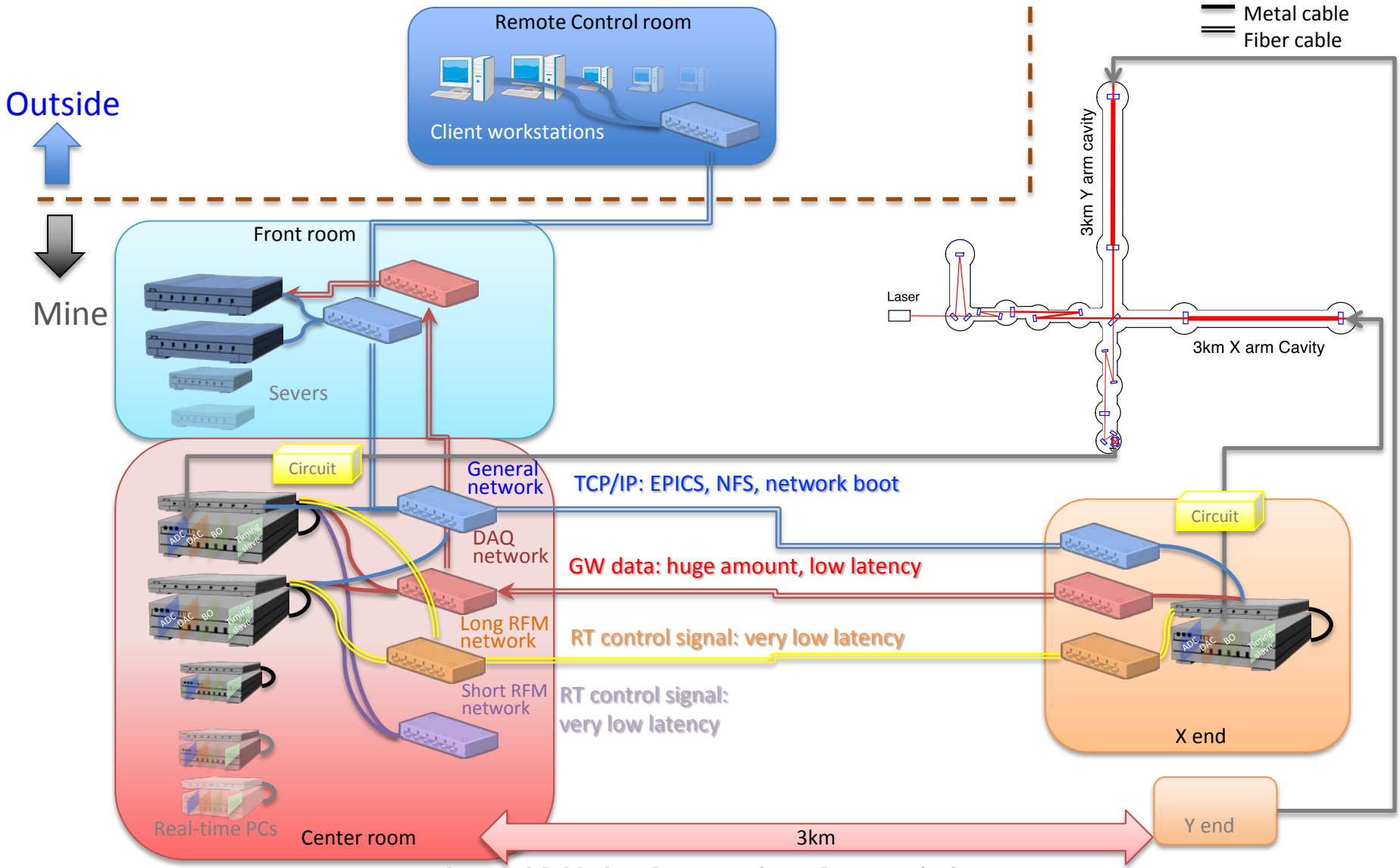
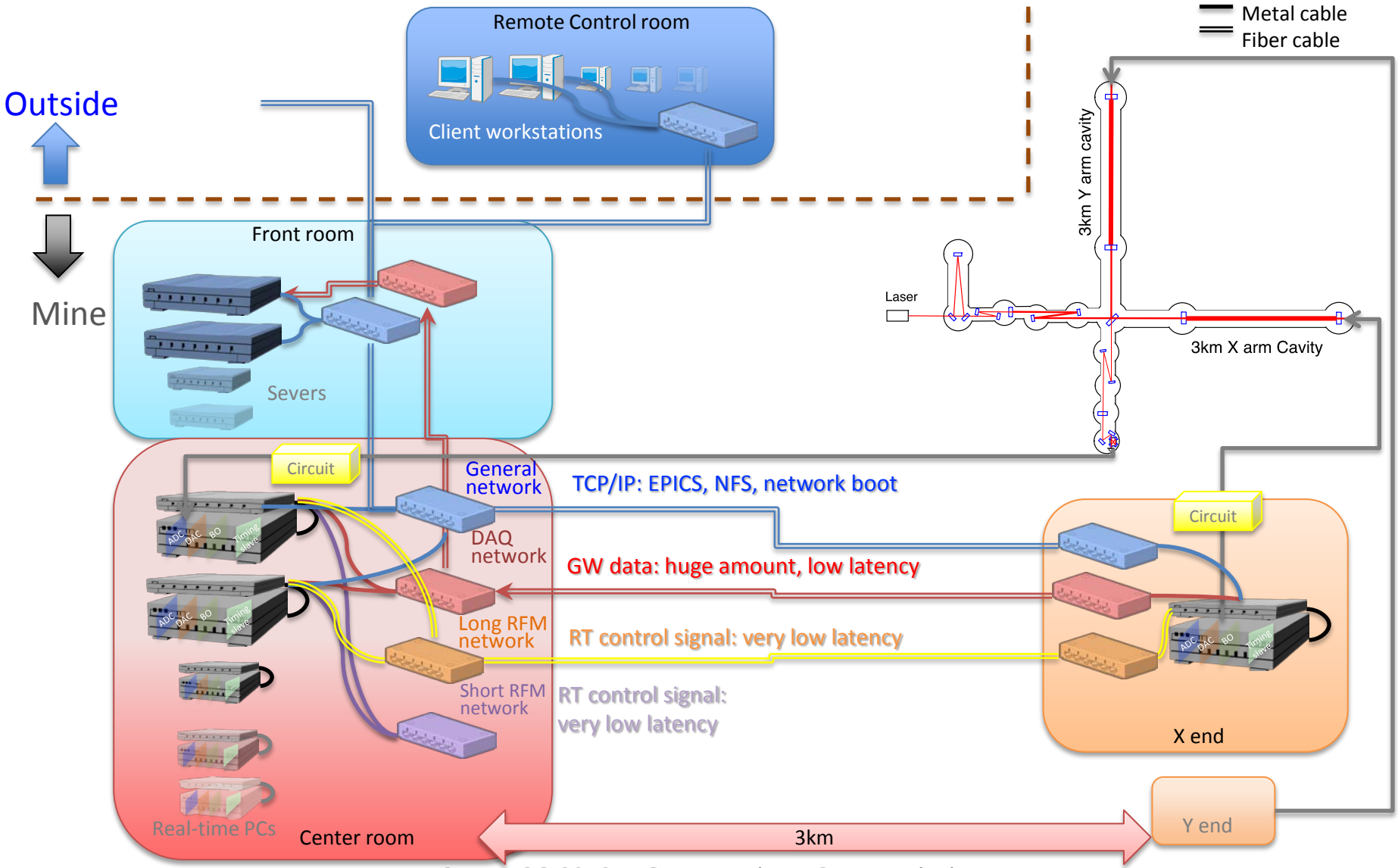
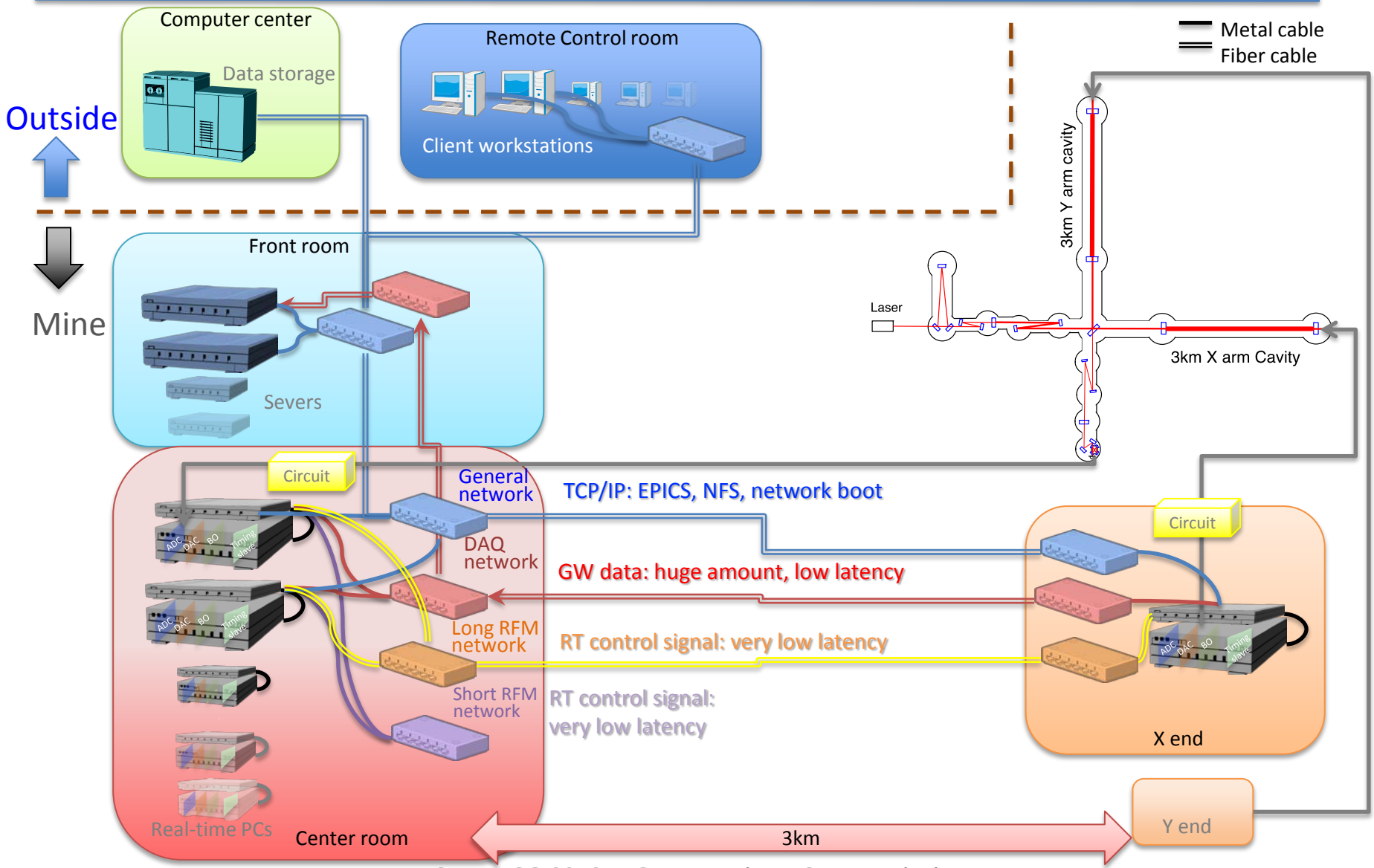


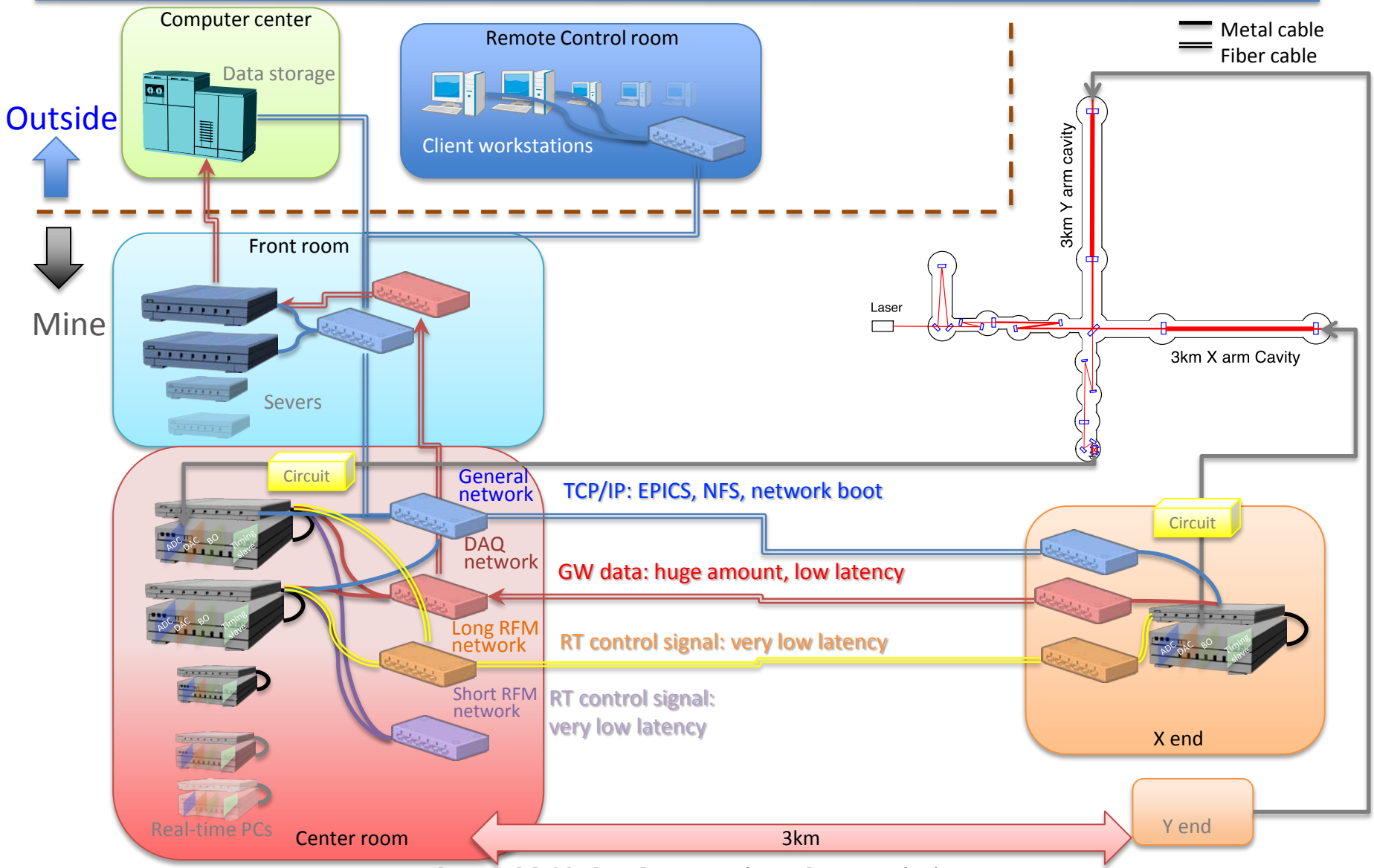
KAGRA control network design



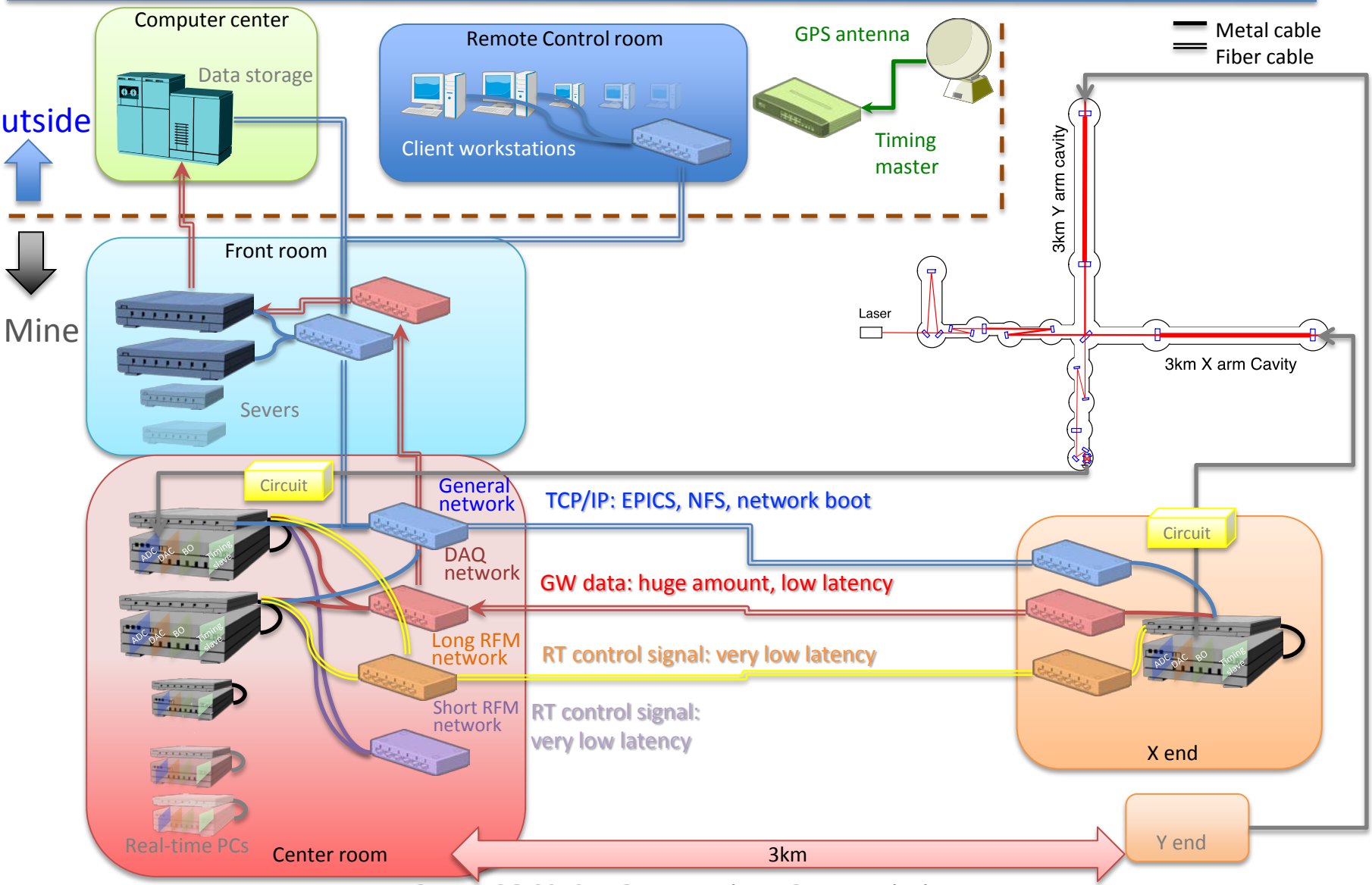
KAGRA control network design



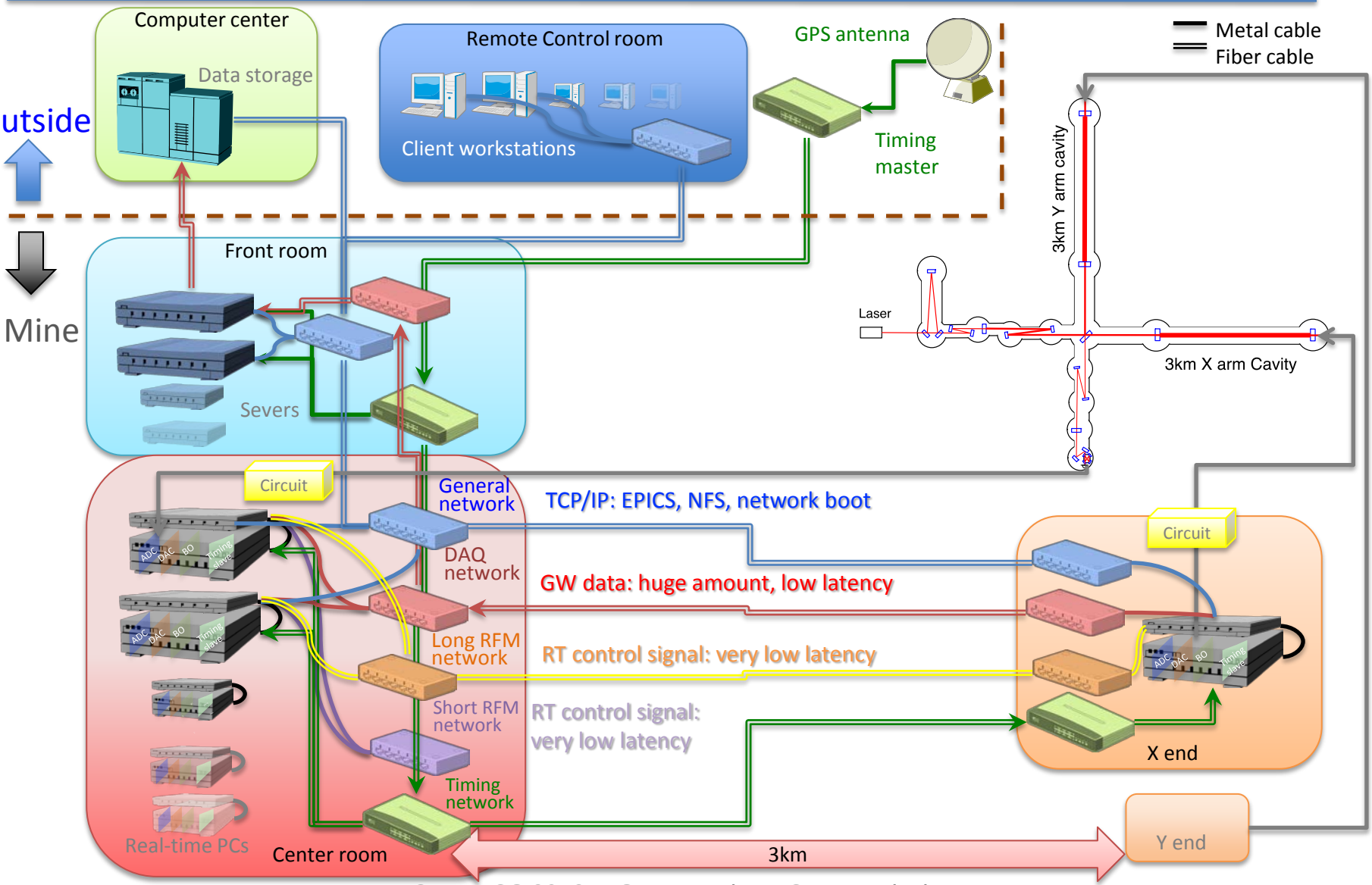
KAGRA control network design



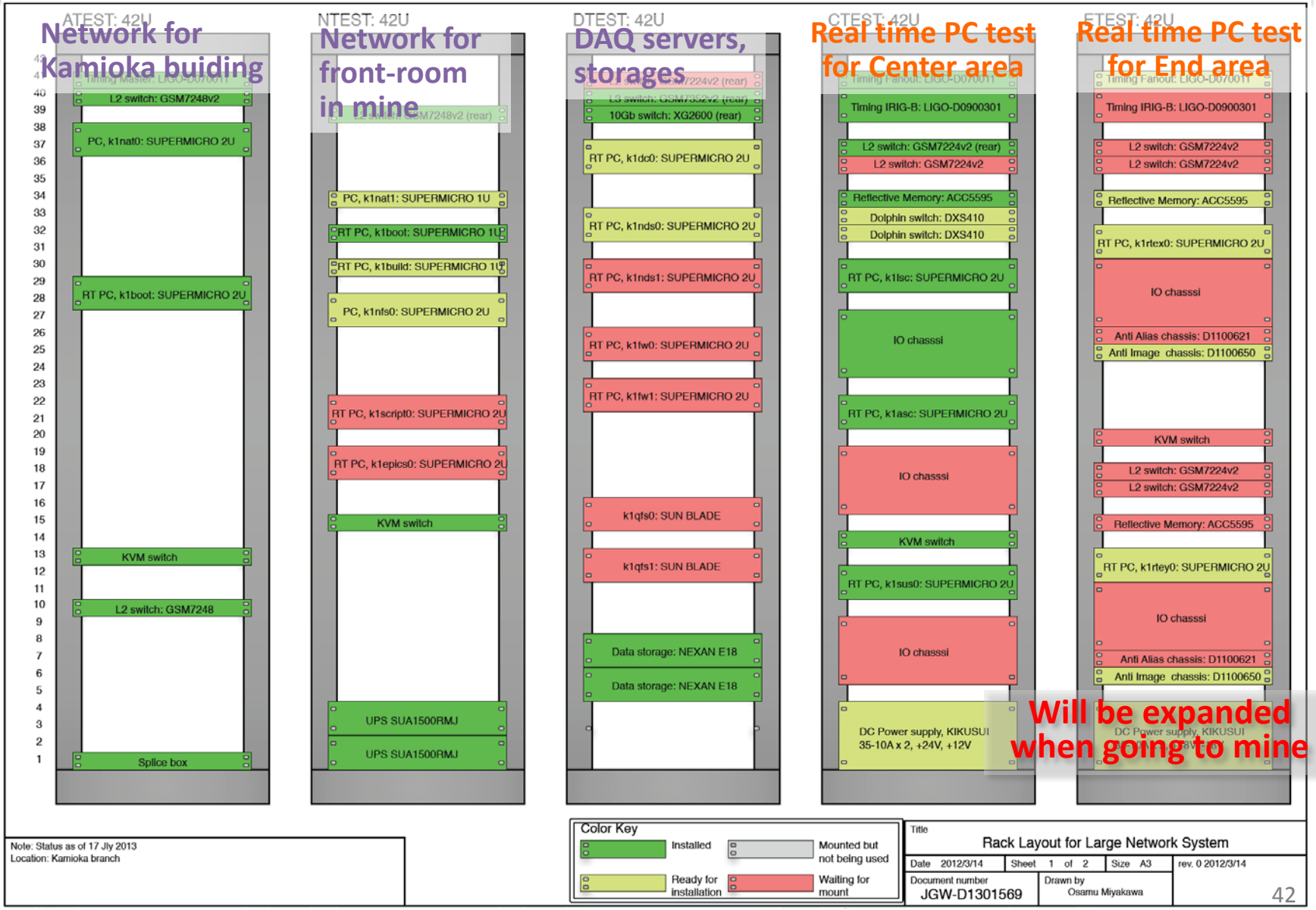
KAGRA control network design



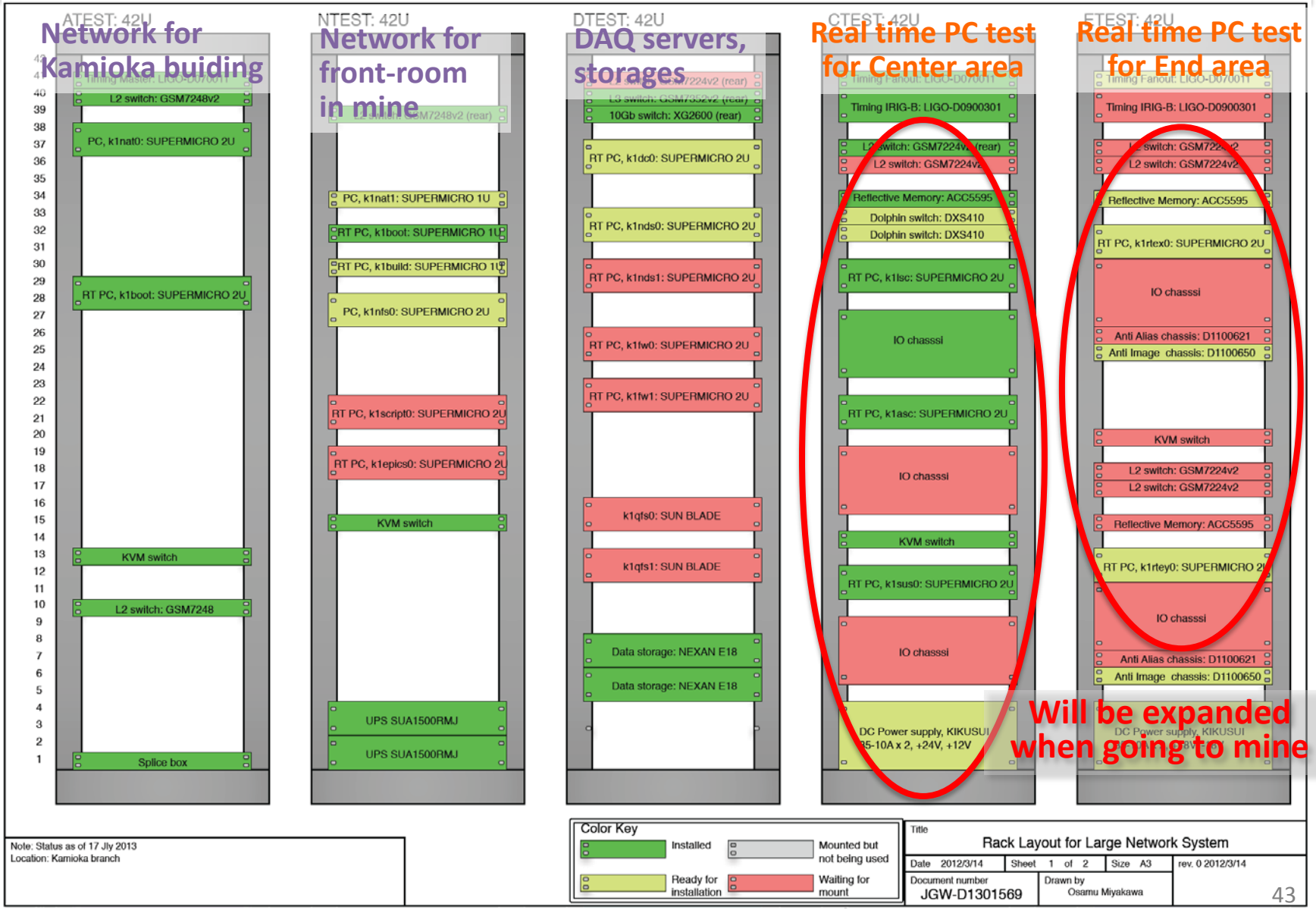
KAGRA control network design



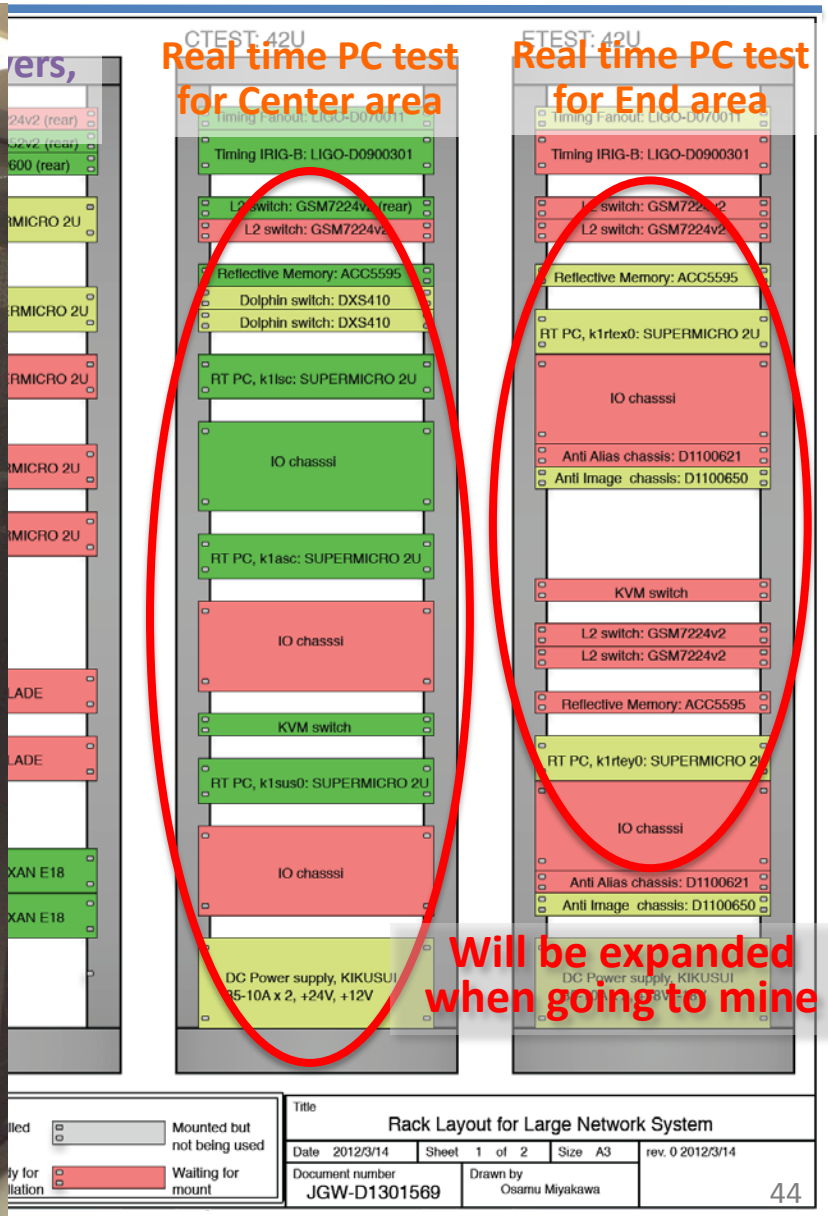
Rack layout for initial setup



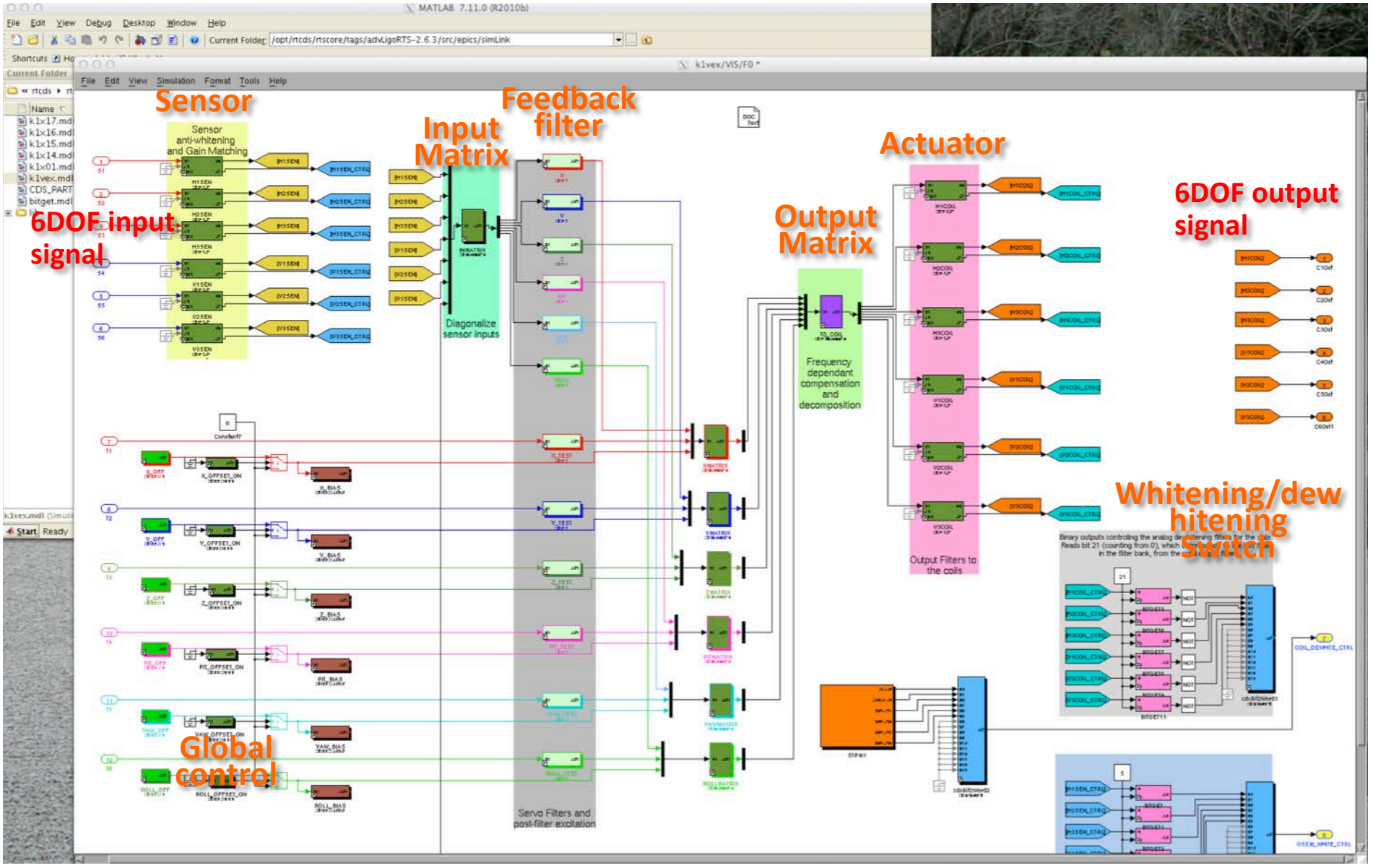
Rack layout for initial setup



Rack layout for initial setup



Real time model on Matlab, Simulink



Generated C source of Real Time code from GUI

Actual control signals（filter bank, matrix, trigger, linearization etc.）will be generated automatically when building real time modules.

```
 .
 .
//Start of subsystem LSC ************************************************
// FILTER MODULE
lsc_pox = filterModuleD(dsp_ptr,dspCoeff,LSC_POX,dWord[0][0],0);

// FILTER MODULE
lsc_poxfb = filterModuleD(dsp_ptr,dspCoeff,LSC_POXFB,dWord[0][1],0);
.
.
for(ii=0;ii<1;ii++)
{
    lsc_nxmtrx[1][ii] =
    pLocalEpics->ctr.LSC_NXMTRX[ii][0] * lsc_trx + pLocalEpics->ctr.LSC_NXMTRX[ii][1] * lsc_poxdc;
}

// Relational Operator
lsc_operator = ((pLocalEpics->ctr.LSC_XTHRESH) <= (lsc_trx));

// DIVIDE
if(lsc_nxmtrx[1][0] != 0.0)
{
    lsc_divide = lsc_pox / lsc_nxmtrx[1][0];
}
else{
    lsc_divide = 0.0;
}
```

Generated C source of Real Time code from GUI

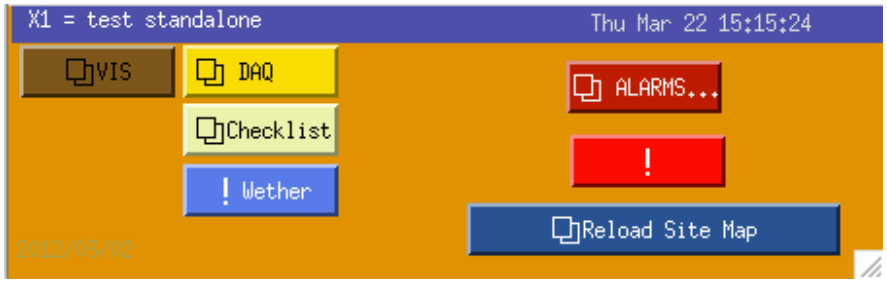
Actual control signals（filter bank, matrix, trigger, linearization etc.）will be generated automatically when building real time modules.

```
 .
 .
//Start of subsystem LSC ************************************************
// FILTER MODULE
lsc_pox = filterModuleD(dsp_ptr,dspCoeff,LSC_POX,dWord[0][0],0);

// FILTER MODULE
lsc_poxfb = filterModuleD(dsp_
.
.
for(ii=0;ii<1;ii++)
{
    lsc_nxmtrx[1][ii] =
    pLocalEpics->ctr.LSC_NXM
}

// Relational Operator
lsc_operator = ((pLocalEpics->c

// DIVIDE
if(lsc_nxmtrx[1][0] != 0.0)
{
    lsc_divide = lsc_pox / lsc_nx
}
```

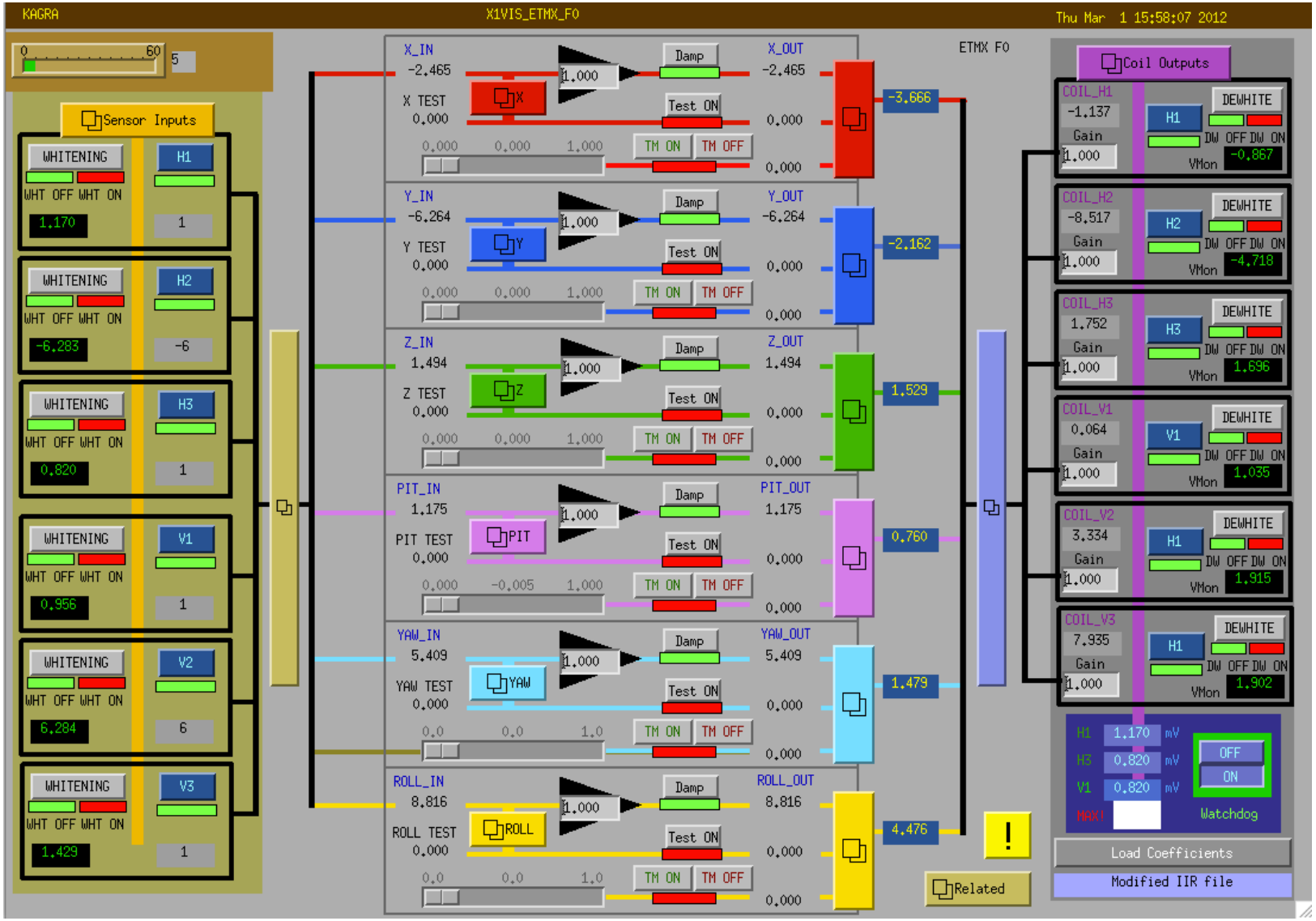
Running as kernel modules of Linux

```
tftpboot — controls@standalone:~ — ssh — 92×28
miyakawa@192.168.11.110's password:

MAC5:tftpboot miyakawa$ ssh -Y controls@192.168.11.110
controls@192.168.11.110's password:
Linux desktop1 2.6.35-32-server #67-Ubuntu SMP Mon Mar 5 21:13:25 UTC 2012 x86_64 GNU/Linux
Ubuntu 10.10

Welcome to the Ubuntu Server!
 * Documentation:  http://www.ubuntu.com/server/doc

4 packages can be updated.
0 updates are security updates.

New release 'natty' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Fri Jul  5 03:06:10 2013 from 172.16.176.182
desktop1:~>matlab &
[1] 9513
desktop1:~>ssh 192.168.11.100
Password:
Last login: Wed Sep 11 00:21:12 PDT 2013 from 192.168.11.4 on pts/1
controls@standalone ~ $ lsmod
Module                  Size  Used by
k1vex                9456277  0
k1x01                9198940  1 k1vex
mbuf                    7317  7 k1vex,k1x01
controls@standalone ~ $
```

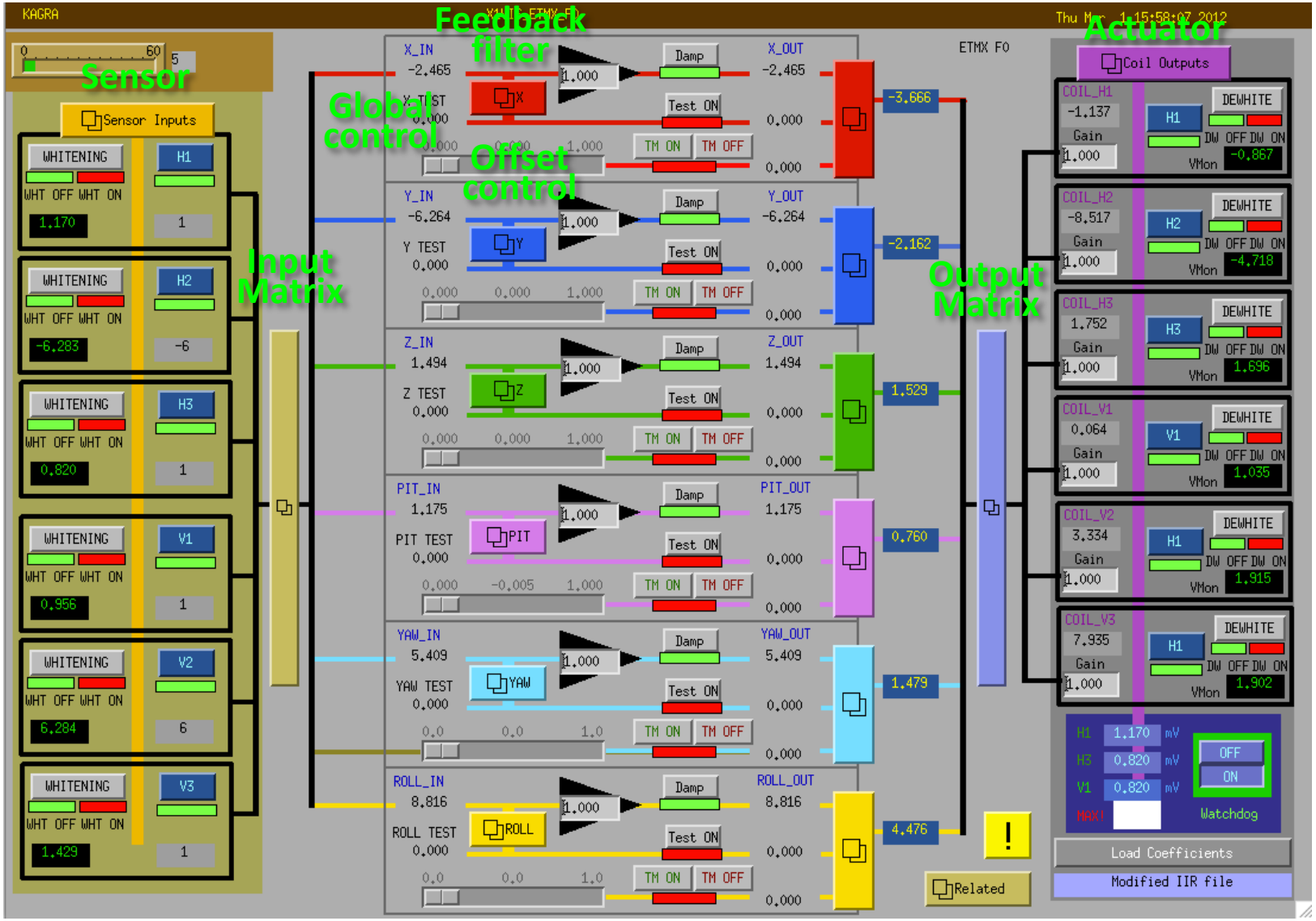
MEMD screen -- GUI for EPICS --



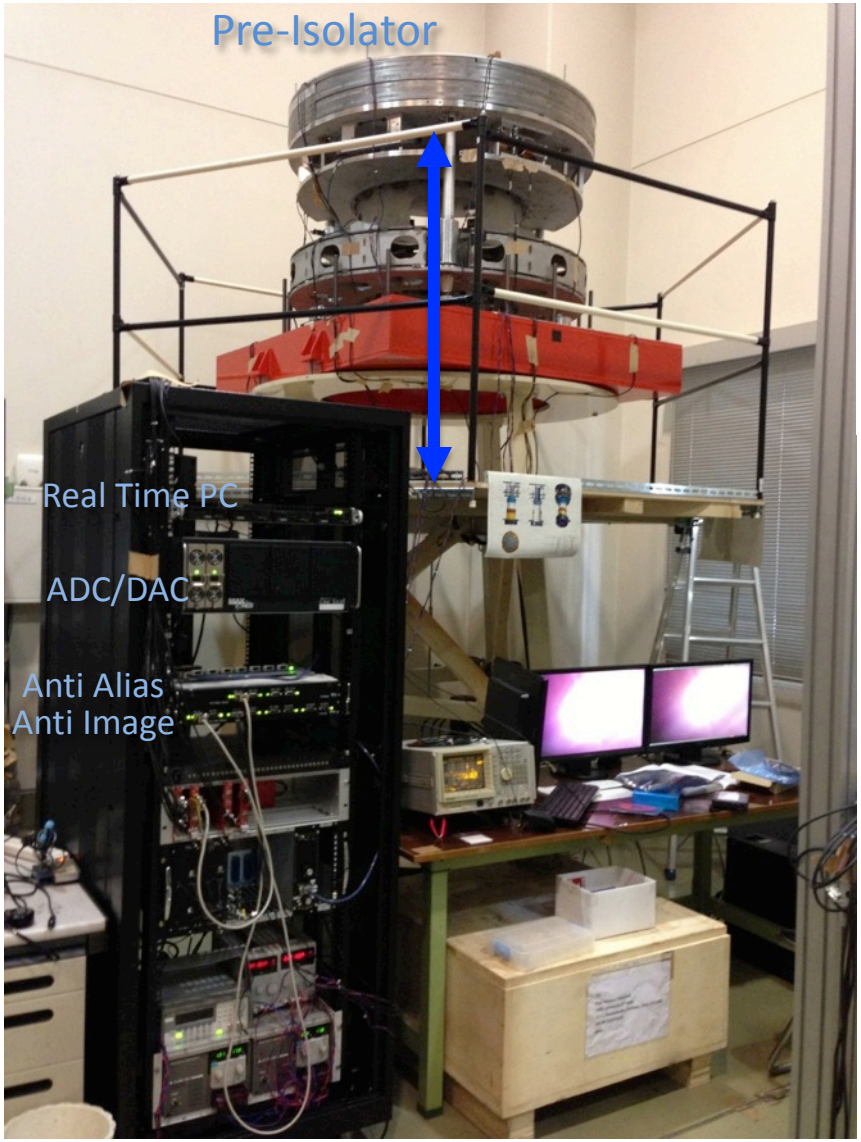
MEMD screen -- GUI for EPICS --

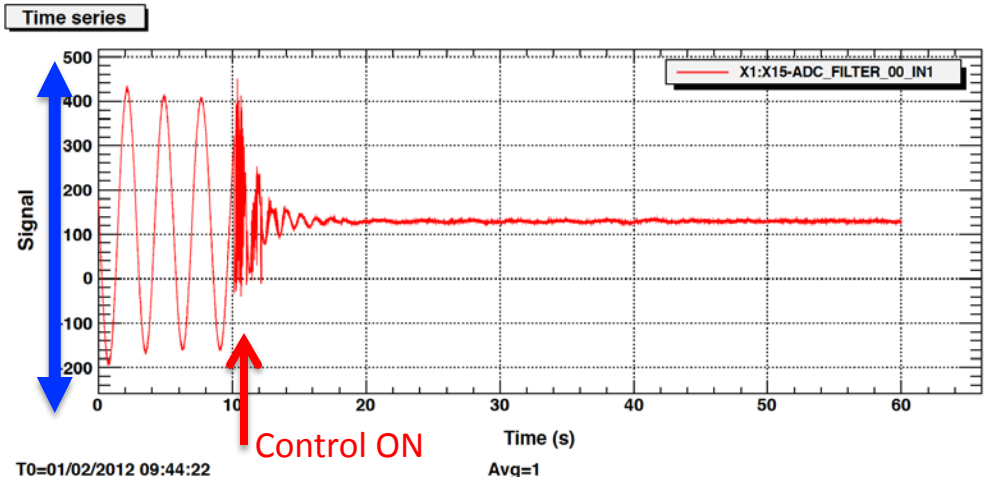


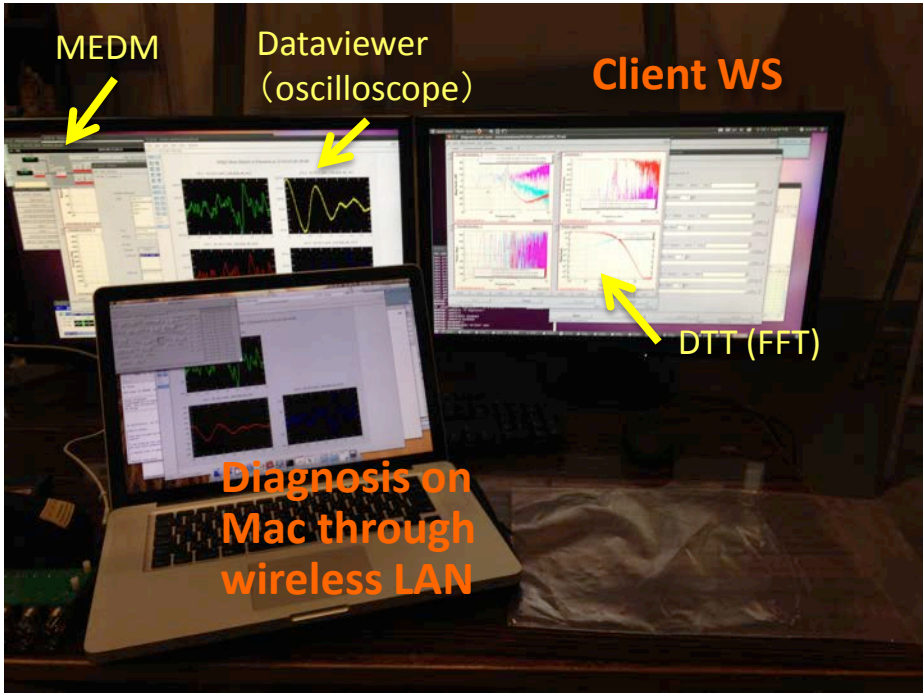
MEMD screen -- GUI for EPICS --



Local control for Pre-Isolator

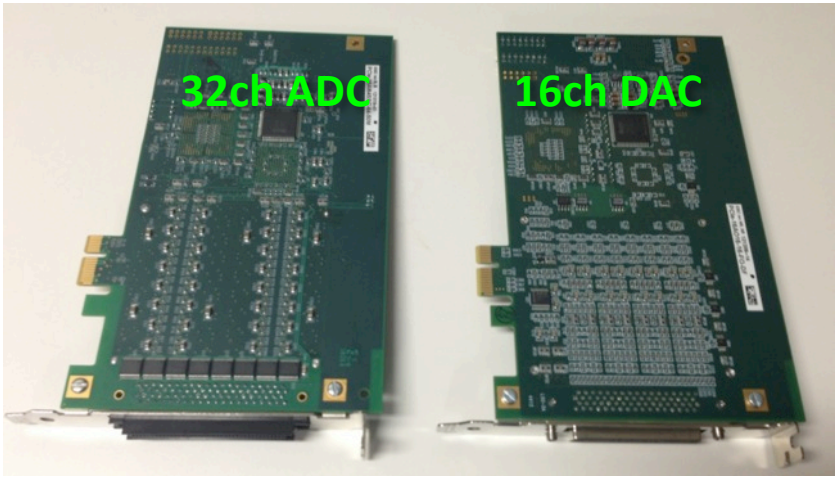


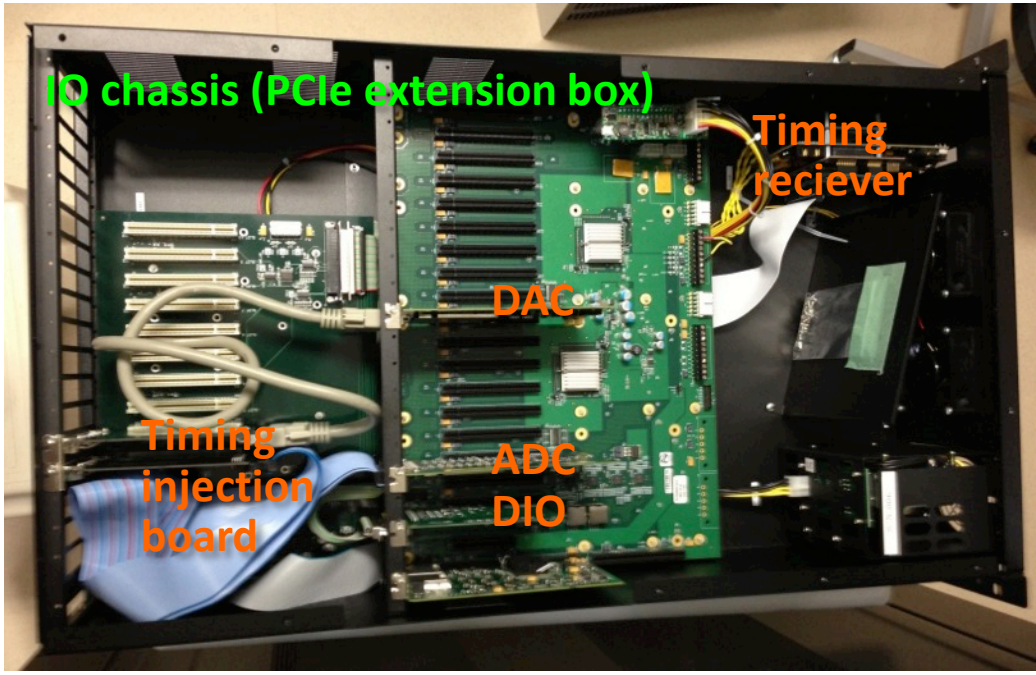


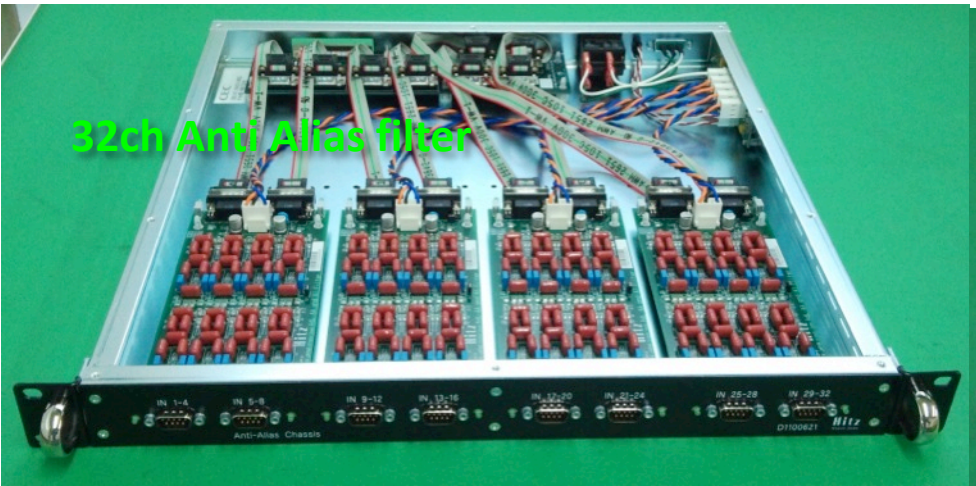


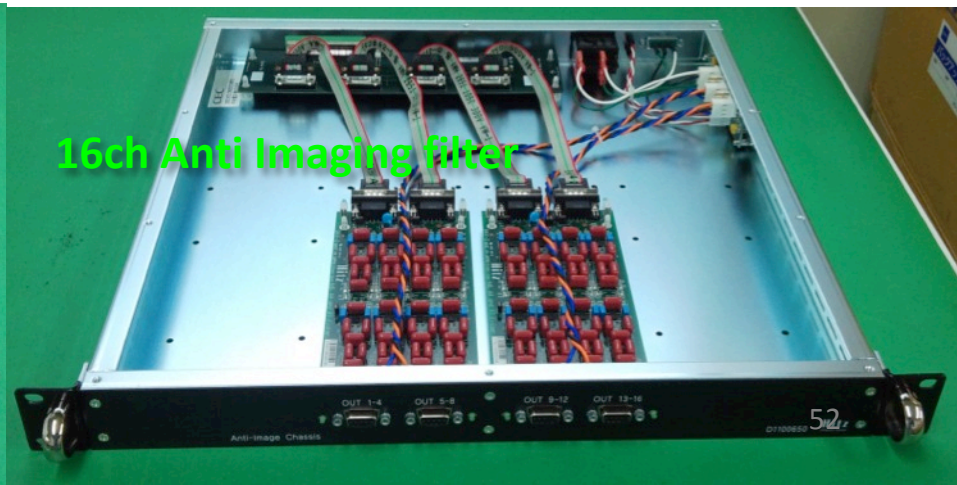
DAQ items

- ~30 RT front-end PC
- ~30 Fiber connected PCIE extension chassis
- ~60 ADC (x32ch) : total ~2000ch
- ~40 DAC(x16ch): total ~500ch
- ~80 DO (x32ch): total ~2000ch

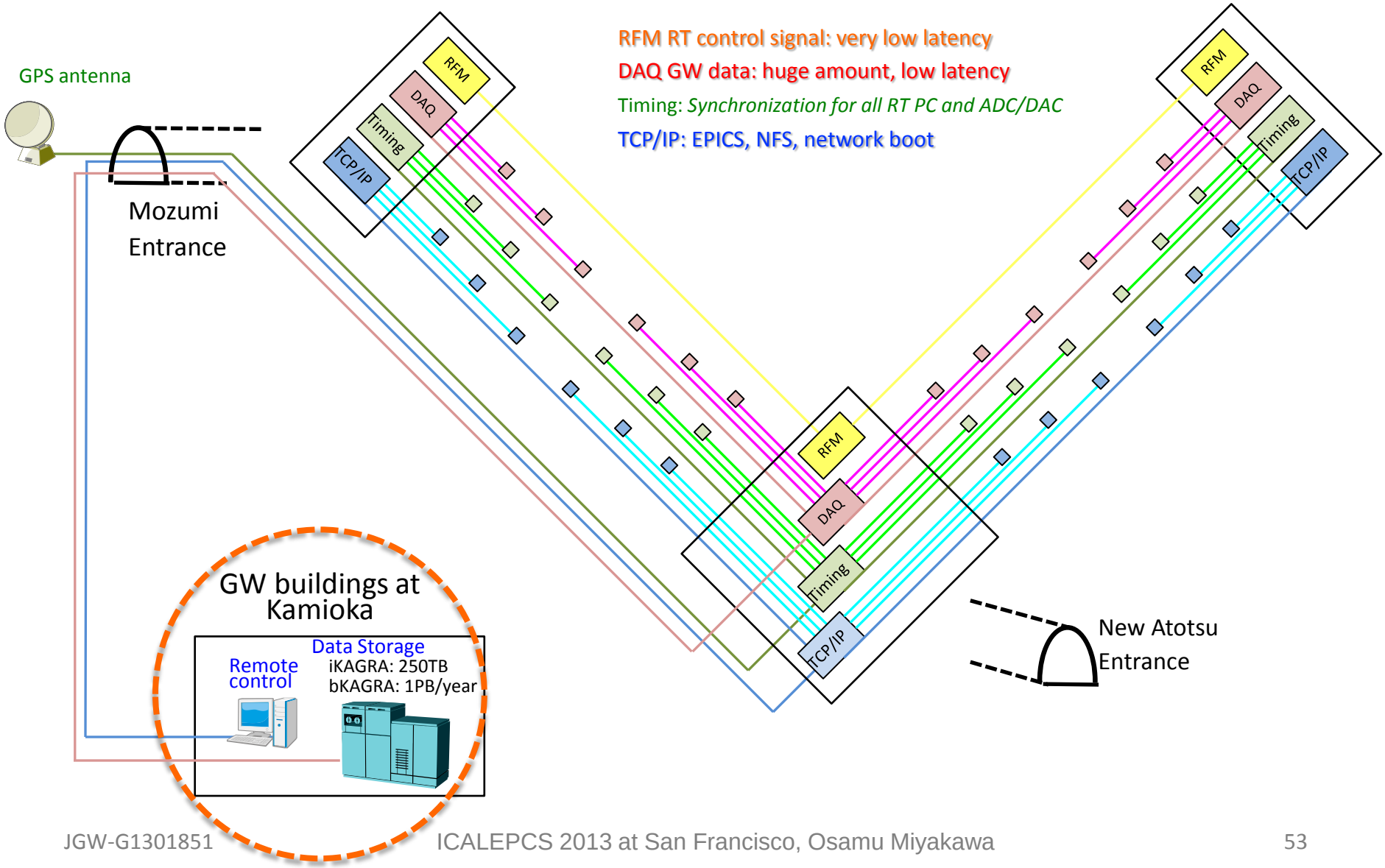




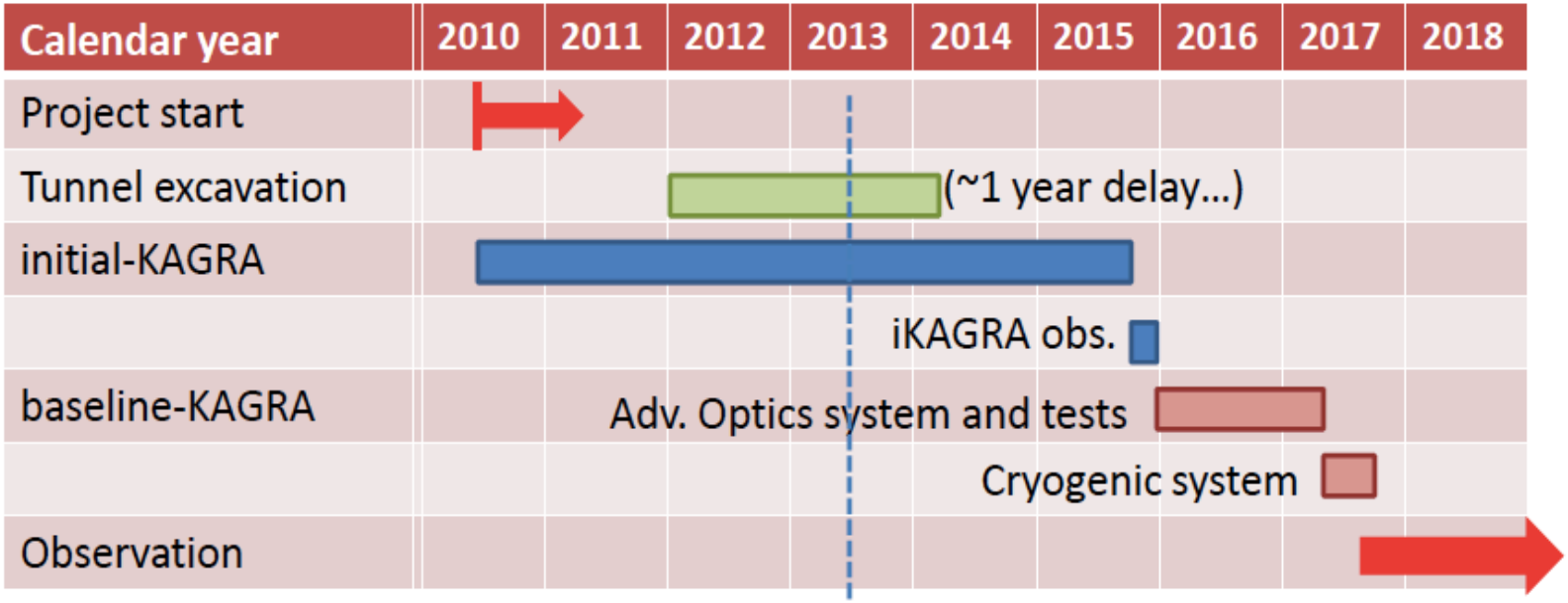




Network design for controls and DAQ



Schedule



initial KAGRA

- Room-temp. FPMI
- Low laser power (10W)
- Simple seismic isolation
- 10kg silica TM

baseline KAGRA

- Cryogenic RSE
- High laser power (180W)
- Low frequency seismic isolation
- 23kg sapphire TM

- The project started in 2010
- Due to the March 11 earthquake (2011), budget implementation was delayed and whole the schedule shifted 1 year behind.
- KAGRA will be in 2 stages: iKAGRA and bKAGRA