SCALABLE READOUT SYSTEM

SRS
Scalable Readout System

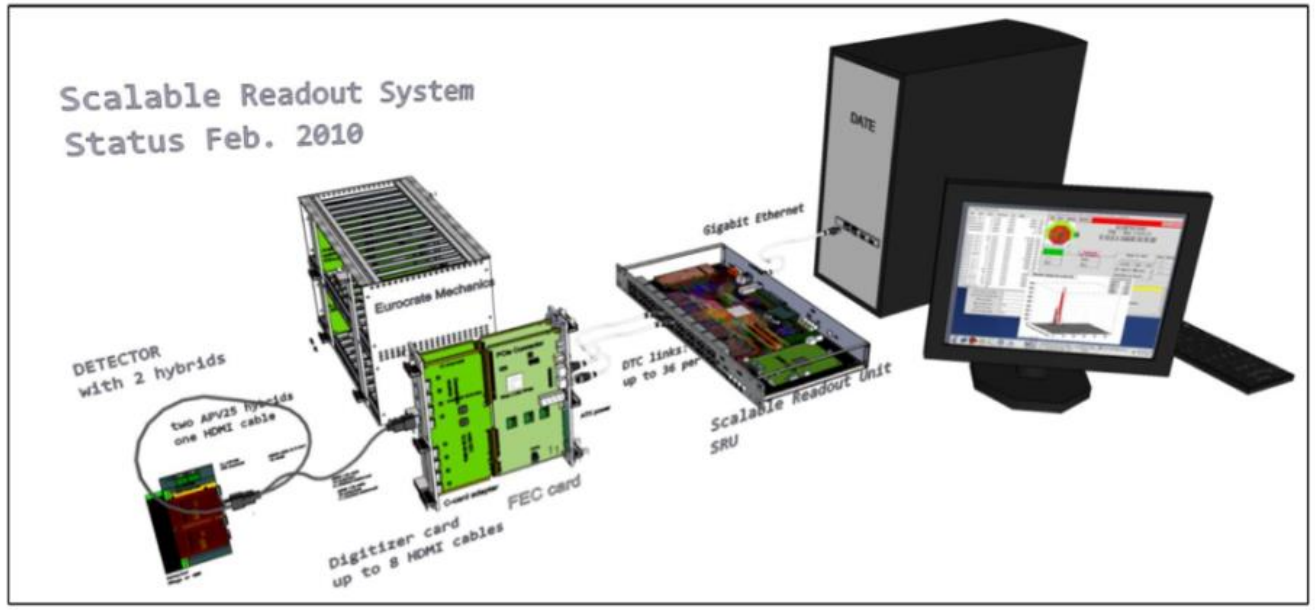
SRS was developed by RD51 collaboration for R&D on MPGD gas detectors

Collaborating SRS teams and users in 2016

MPGDs @ GDD-lab CERN, Photon detectors @ NEXT coll., Muon Tomografy @FIT, MICROMegas @ ATLAS MAMMA, DTC links and SRU@ ALICE DCAL, GEMs @ FTBF Coll., Timepix-SRS for ILC-TPC test@Bonn Univ,, GEM stack readout @BNL, GEMs@ CMS GEM collab, optical Readout@ TOTEM, GEM detectors @ PRad Coll., Neutron detectors@ ESS Brightness, Large surface MUST detector @ LSBB, VMM frontend for FOCAL E-PAD@ Univ. Tsukuba, GEMs for CP-Violation @CAPP, … and many more

SRS CONCEPT (SINCE 2009)

Scalable Readout system (SRS) of MPGD



Frontend carrier (hybrids)
ASICs, preamplifiers
on detector

FE Adapter (cards, mezzanines)
(ADC, DVM, Timepix, SiPM, PM)
+ Frontend concentrator (FEC)

DTCCP links
default HDMI

Opt. Scalable Readout Unit (SRU)
data MUX/Buffer, TTCrx, clock and
trigger source, Busy, Slow Controls

DTCC links
Default CAT7

PC / Laptop with
DAQ and Analysis SW
Slow controls

UPD/ 10GBE

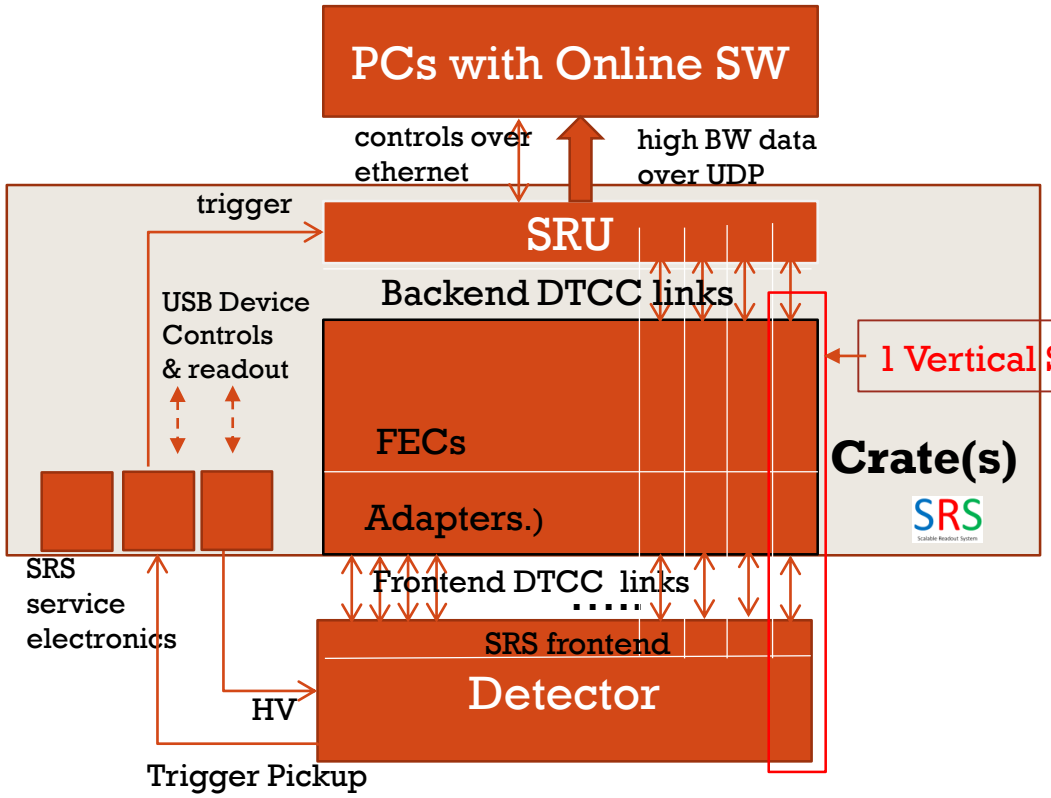
- ➔ choose the best frontend for your detector low noise, spark protection, dyn. range..
- ➔ connect X frontends to SRS backend
- ➔ scalable DTCC links instead of bus
- ➔ start with few channels (1 hybrid=128 ch.)
- ➔ get used with DAQ and Analysis software
- ➔ scale up to X channels with same software
- ➔ get support by large SRS user base RD51
- ➔ many SRS systems, much experience
- ➔ SRS services: detector-HV, amplifiers etc.
- ➔ SRS Classic: purchase via @CERN store
- ➔ Commercial SRS starting 2017 *
- ➔ New SRS frontends: request-driven R&D collaboration based

*exception: APV hybrid, only available through CERN

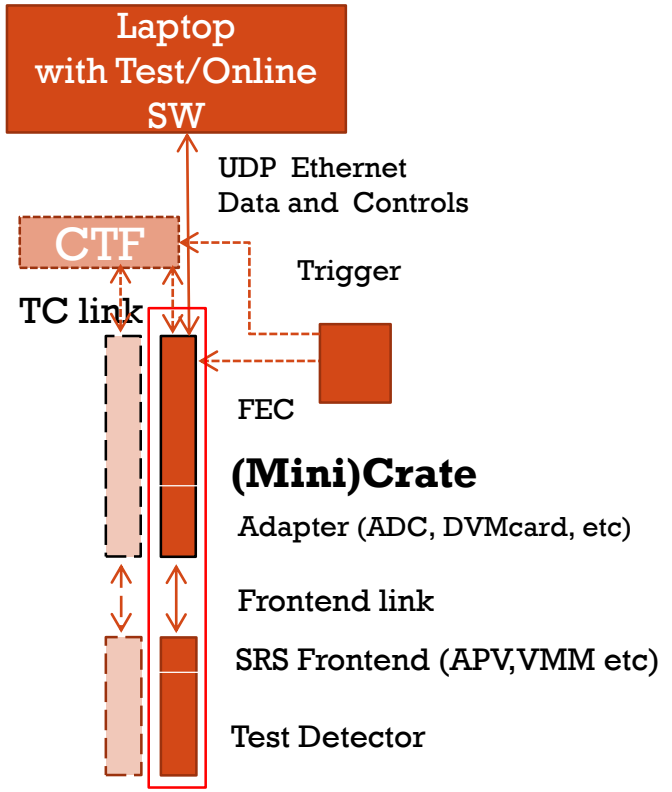
SCALABLE READOUT ARCHITECTURE

SRS
Scalable Readout System

Full SRS: stacks of vertical-slices



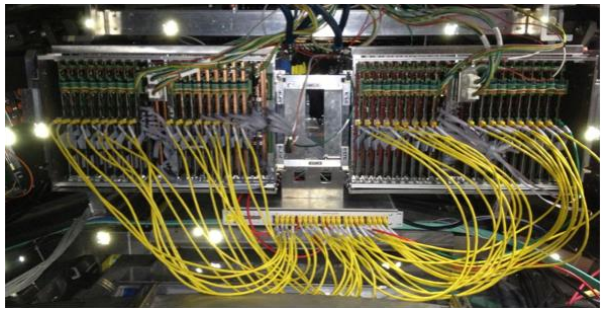
Minimal SRS: 1 or 2 vertical slices



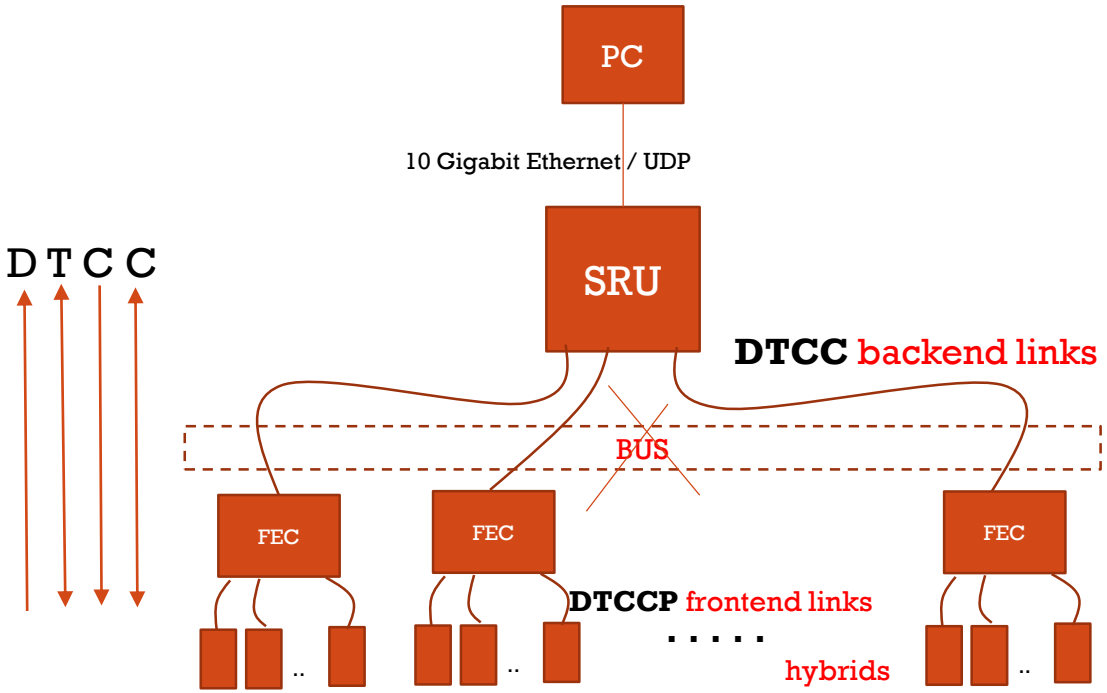
xTCx LINKS (SRS-SPECIFIC LINKS)

xTCx link flavors in use so far

- **DTC** Data+Trigger+Clock (over CAT7, SRU-FEE) 2009
- **DTCCP** Data+ Trigger+ Clock +Control + Power (over HMDI*, FEC-Frontend) 2010
- **TC** Trigger + Clock (over CAT7, CTF - FEC) 2010
- **DTCC** Data +Trigger+ Clock +Control (over CAT7, SRU - FEC) 2011
- **DTCCO** Data+ Trigger+ Clock+ Control over Optical fibre (planned , 2017)



ALICE DCal: DTC links over CAT7 from 40 FEE to 1 SRU



xTCx links make SRS scalable

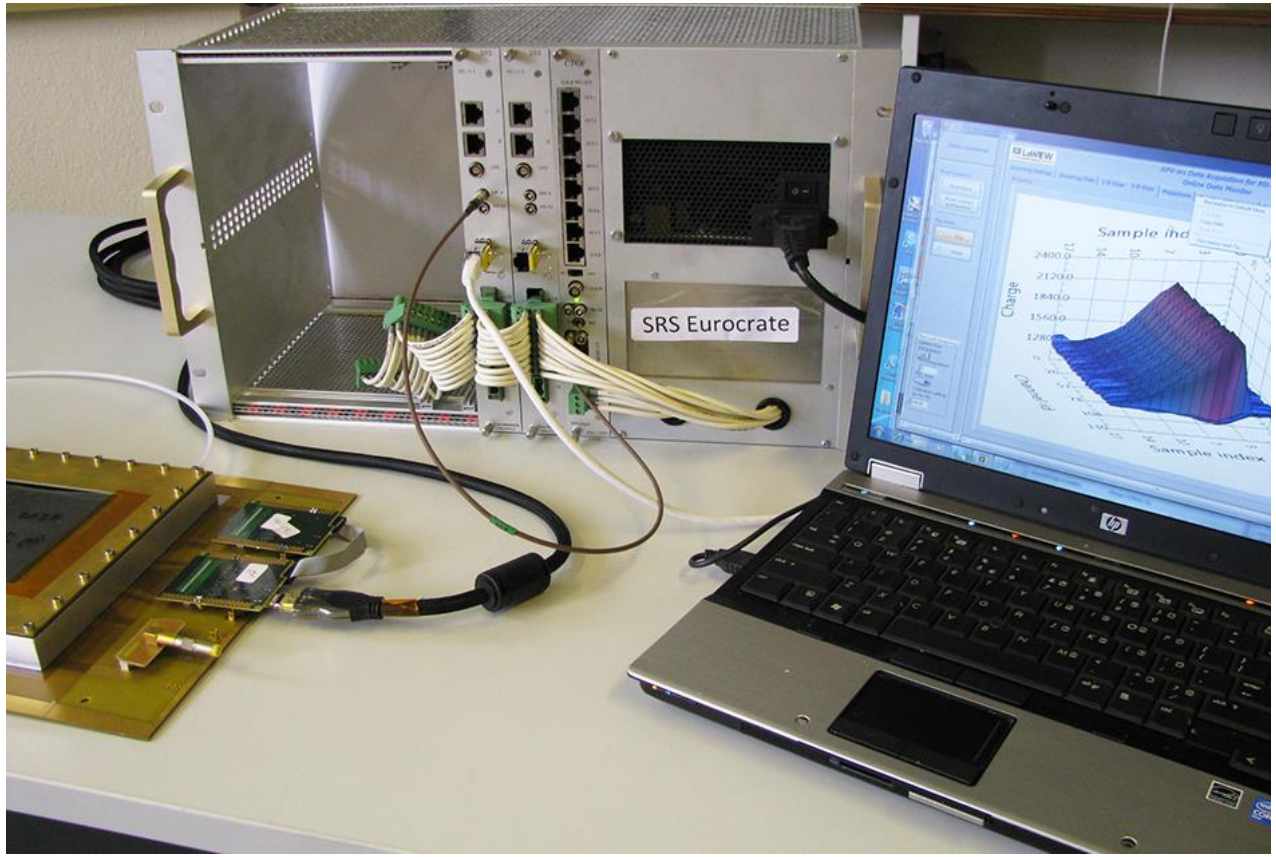
LINK scalability features vs. parallel Bus

- Data in parallel over p-p links
  =>Higher BW & Trigger rates
- point-point controlled impedance
  => very high bitrates & lower error rates
- overcome bus length limit
  => single point failures = non fatal
- less wear-out of contacts
  => more reliable, less cost

* copper or fibre

TABLE-TOP SRS

Powered SRS crate with FEC / Adapter combo



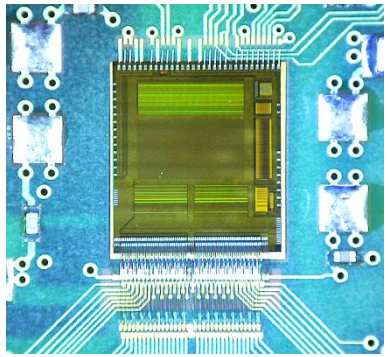
Detector
with APV hybrids

Readout & power
via HDMI link

Laptop connected via
Ethernet cable to FEC

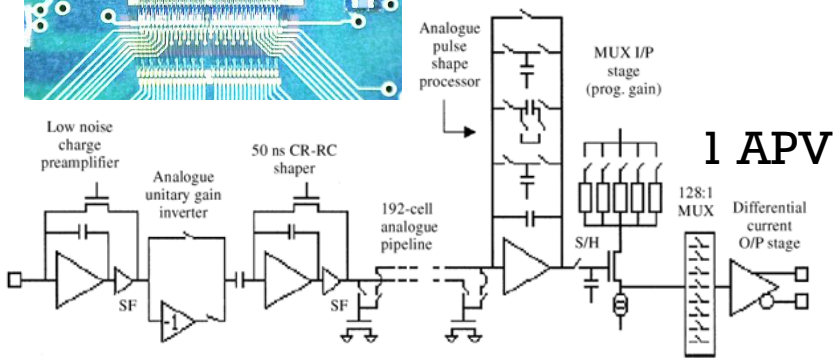
Online Readout systems
DATE, and/or Labview SRS

SCALABILITY (A. OVER TYPES OF FRONTEND)



APV wire-bonded, on SRS hybrid

1 ASIC: 128 analogue ch.



1 APV channel

-general-purpose SRS:

- APV frontend = 128 analogue ch. on hybrid
- VMM frontend= 128 digital ch. on hybrid

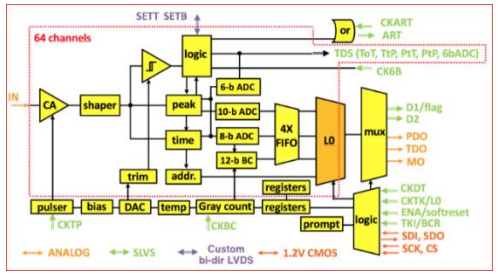
-experiment –specific SRS:

- SiPM and PM adapter (NEXT)
- Octal Timepix-2 adapter (Univ. Bonn)

Example of different frontends combined in a single RO system

2 x VMM wire bonded on SRS hybrid

1 ASIC: 64 digital ch.



1 VMM channel

SCALABILITY (B. # CHANNELS)

SRS channel unit = 1 hybrid 128 channels

DTCCP readout cable unit = 256 channels

FEC Frontend concentrator unit = 2k ch.

Multi-FEC system with SRU = 4k…16 k ch.

Multi-Crate with SRU(s) > 16k ch

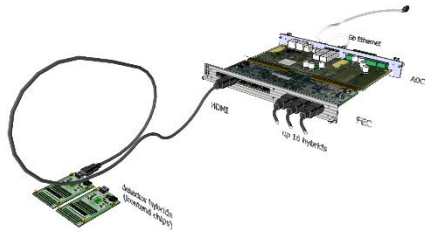
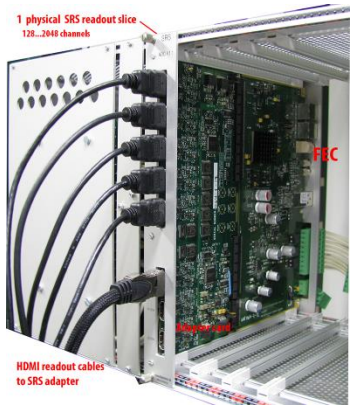
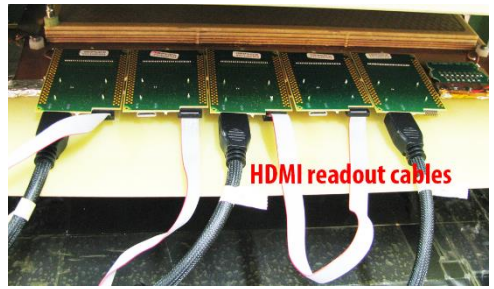


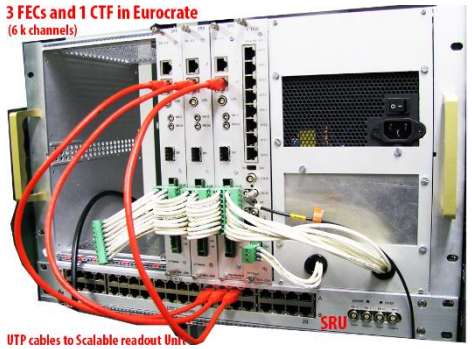
Table-top minimal SRS system



1 ADC adapter card + 1 FEC
8 HDMI ports

Frontend Hybrids
along Detctor frame

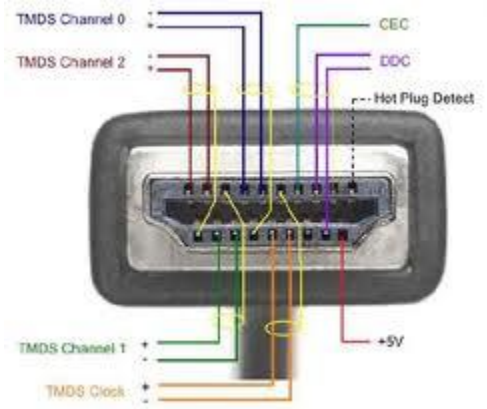




SRS slices (FEC+Adapter)
in Euocrate with SRU below

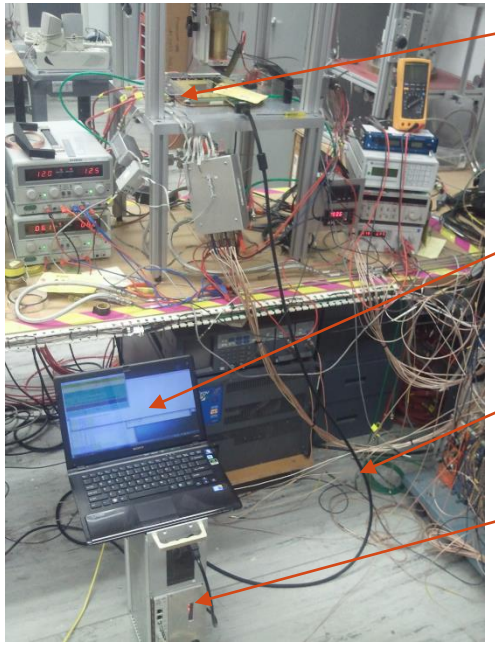
FRONTEND LINKS (DTCCP)

HDMI* cables A-D (micro) up 5m
HDMI cables A-A coupled to A-D up 25m



5m HDMI standard A to micro (D)

Photo: SRS test with RCDAQ at BNL



GEM detector with SRS APV hybrid, powered over HDMI

Laptop with RCDAQ

DTCC link HDMI A-A

SRS Minicrate

NEW (tests in preparation)

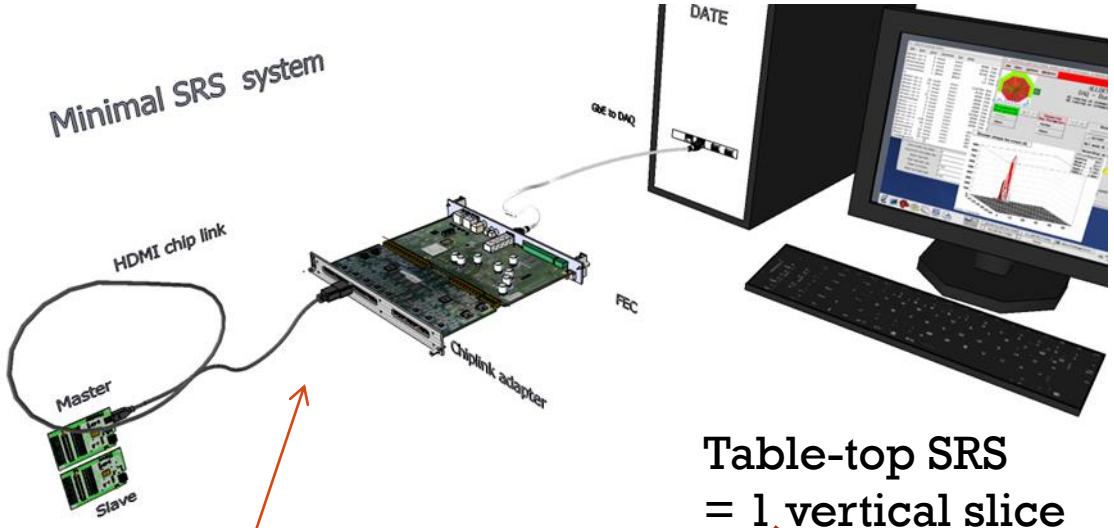
- active HDMI copper A-A + A-D max 50 m

- active HMDI fibre A-A + A-D max 150 m

Commercial
100m active, optical
HDMI cable

* we do NOT use HDMI protocols

SMALL SYSTEMS



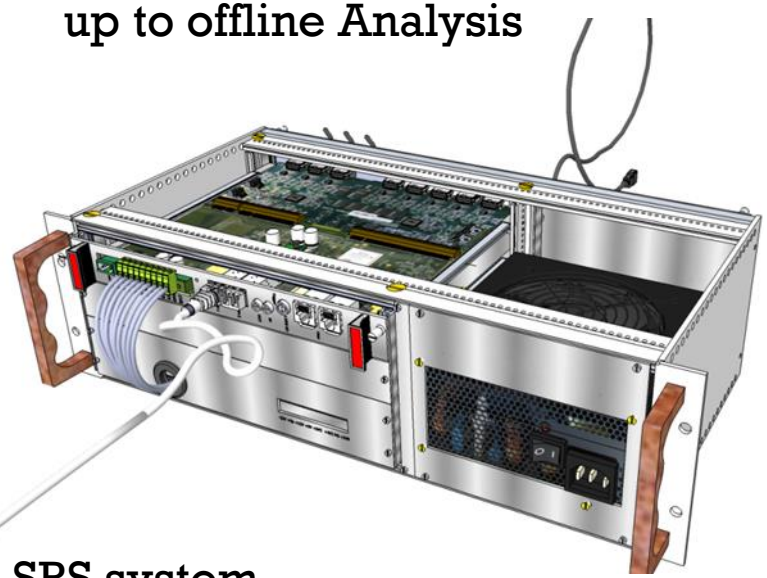
HDMI cables max 25 m
(active HDMI up 150m)

Table-top SRS
= 1 vertical slice

- Hardware available via CERN store
- Firmware included
- Software via RD51 database
- 2017+ commercial SRS sales licences

"SRS Classic"

Complete
readout system from detector
up to offline Analysis

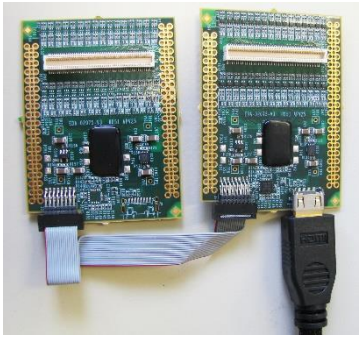


Crate –based SRS

Mini-crate SRS system

> 100 crate systems in use worldwide
mainly by members of the RD51 collaboration

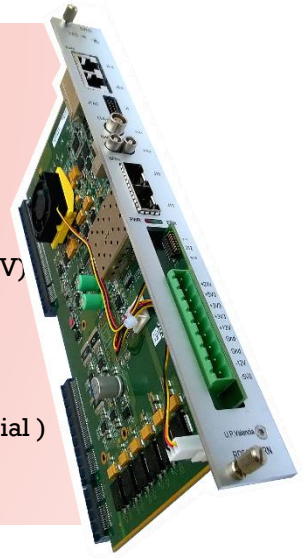
SRS FRONTENDS



- APV25 (128 ch, analog) @ CERN store, standard FE for RD51
- VFAT (64 ch, digital) CMS/Totem -> prototype only
- Beetle (128 ch, anal +digital) -> prototype only
- SiPM and PM frontend @ UPV Valencia for NEXT
- VMM (128 ch, digital+ ZS) @CERN -> testing RD51/ESS
- GEMROC (64 ch , digital) in prep @ AGH and EicSys
- Timepix R&D for ILC TPC @ Bonn Univ. Proto system

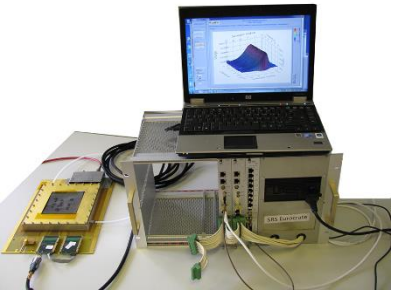
SRS system Hardware

- FEC cards (CERN store + commercial)
- analogue adapter (16 x ADC 12 bit) (CERN store + commercial)
- digital adapter for VMM frontend (commercial)
- Mini-crates up 4k channels (CERN store)
- Eurocrates (REV2) up 16 k channels (commercial)
- ATCA crates, RTM cards 10 GBE, SFP (commercial)
- ATCA blades (2x LX240) (commercial)
- ATCA mezzanines (ADC, 6x12fibre ribbon) commercial, CDT (UPV)
- CTF clock-trigger fanout (inhouse-> commercial)
- Timepix adapter 6U card (Bonn Univ, prototype)
- Optocard VFAT 6U card (Totem)
- High Voltage for MPGD's AVD NIM (in prep. -> commercial)
- SRU LX240, 40xDTCC, NIM, 10GBE, 4x SFP (inhouse-> commercial)
- APIC preamp-shaper , battery box (finalized -> commercial)
- Femto online current measurement over 10 decades (in prepar.)



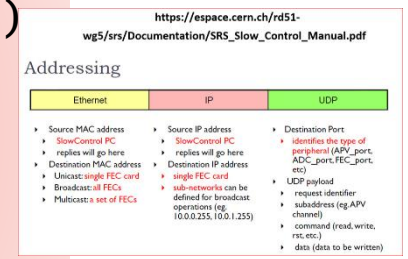
SRS Online SW (via UDP)

- DATE (= default RD51)
- MMDAQ (ATLAS MM)
- CODA (PRad)
- RCDAQ (BNL/RHIC)
- Labview SRS (test systems)

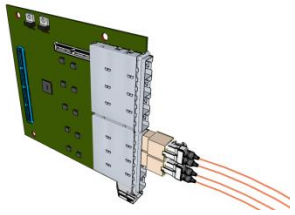


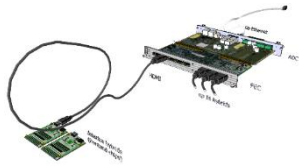
Slow controls (via IP)

- SDC (Scalable Detector Controls)
- scripts via Linux/DATE
- Labview (for testing)



FRONTEND LINK ADAPTERS





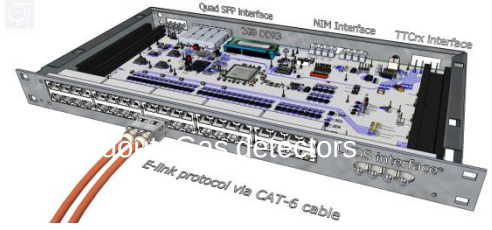
- ADC and DVM cards with HDMI ports
- HDMI and SFP mezzanines (ATCA)
- Optical ribbon mezzanines (ATCA)

Crate environment

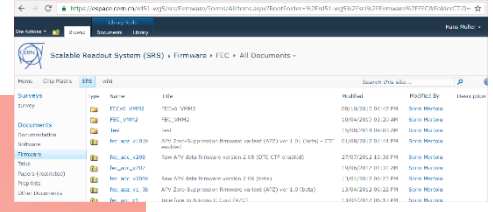
- Minicrate 19” 3U (CERN store)
- Eurocrate 19” 6U (CERN store)
- ATCA Minicrate (EicSys)
- ATCA 14 slot full crate (EicSys)

Readout Units

- Network switch (small systems)
- SRU (default, large systems)
- SRU-ATCA (planned)

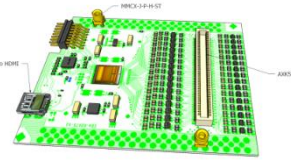


SRS firmware



- FEC -APV frontend
- FEC -VMM frontend
- analogue module APV readout
- common mode/pedestal correction
- Zero Suppression APV
- 10 Gbit core Virtex6 XAUI (SRU)
- DDL core ALICE
- Slink core ATLAS
- TTC rx module Virtex-6 (SRU)

APV 128 HYBRID SRS (CERN STORE SCEM 07.89.00.005.9)



SRS
Scalable Readout System

Master-Slave cable connector

Low noise LDO's

Wire –bonded, APV 25 chip, analogue 128 channels (below globtop)

PLL for clock/trigger separation

Micro HDMI-D readout plug = SRS chiplink

Standard connector RD51 Detectors (128 channels)

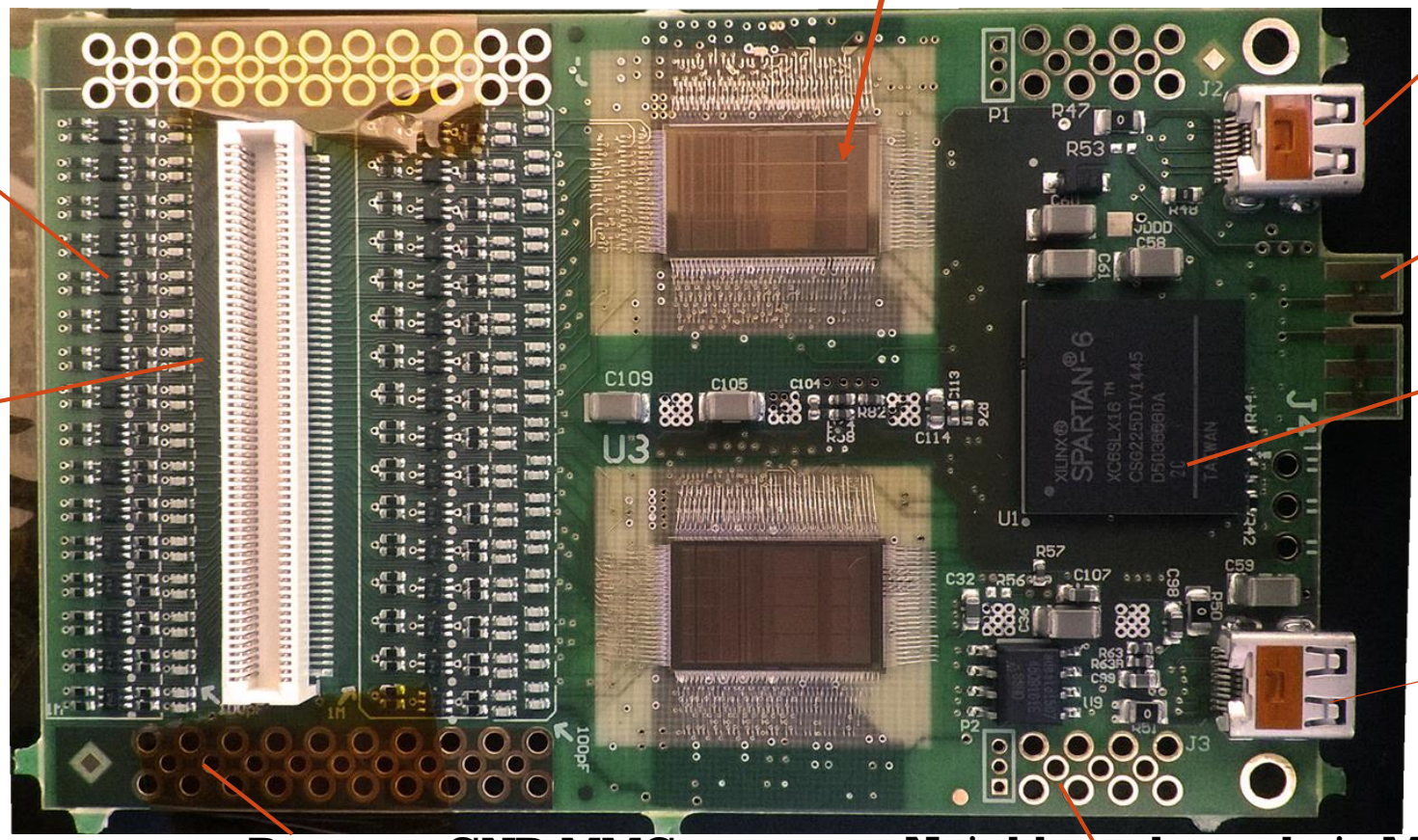
IEC-61000 Level-4 spark protection

Discrete AC coupling and grounding

MMCX connector array for GND/click-in

VMM HYBRID SRS (NEW DIGITAL SRS FRONTEND UNDER TEST)

Photo: 2 x wire-bonded VMM2 chips, VMM3 under work)



APV (ANALOGUE)

APV (250 nm CMOS)

- Pipeline depth: max. 192 clocks
- Trigger latency: max. 3 us
- Noise: < 500 e- intrinsic >750..1400 e- on detector
- dynamic range: 25 fC
- Detector capacity: 18… < 60pf
- ADC ext. 4096/1000 [counts/baseline]
- Gain: fixed CSA gain 100uA/mip, 5 output signal gains (in step of 20%)
- Timing jitter : ½ (1/fc) [+- 12ns]
- Shaping times: 50 ns adjustable to 80 ns
- max readout rate: 7 kHz

VMM (DIGITAL)

SRS
Scalable Readout System

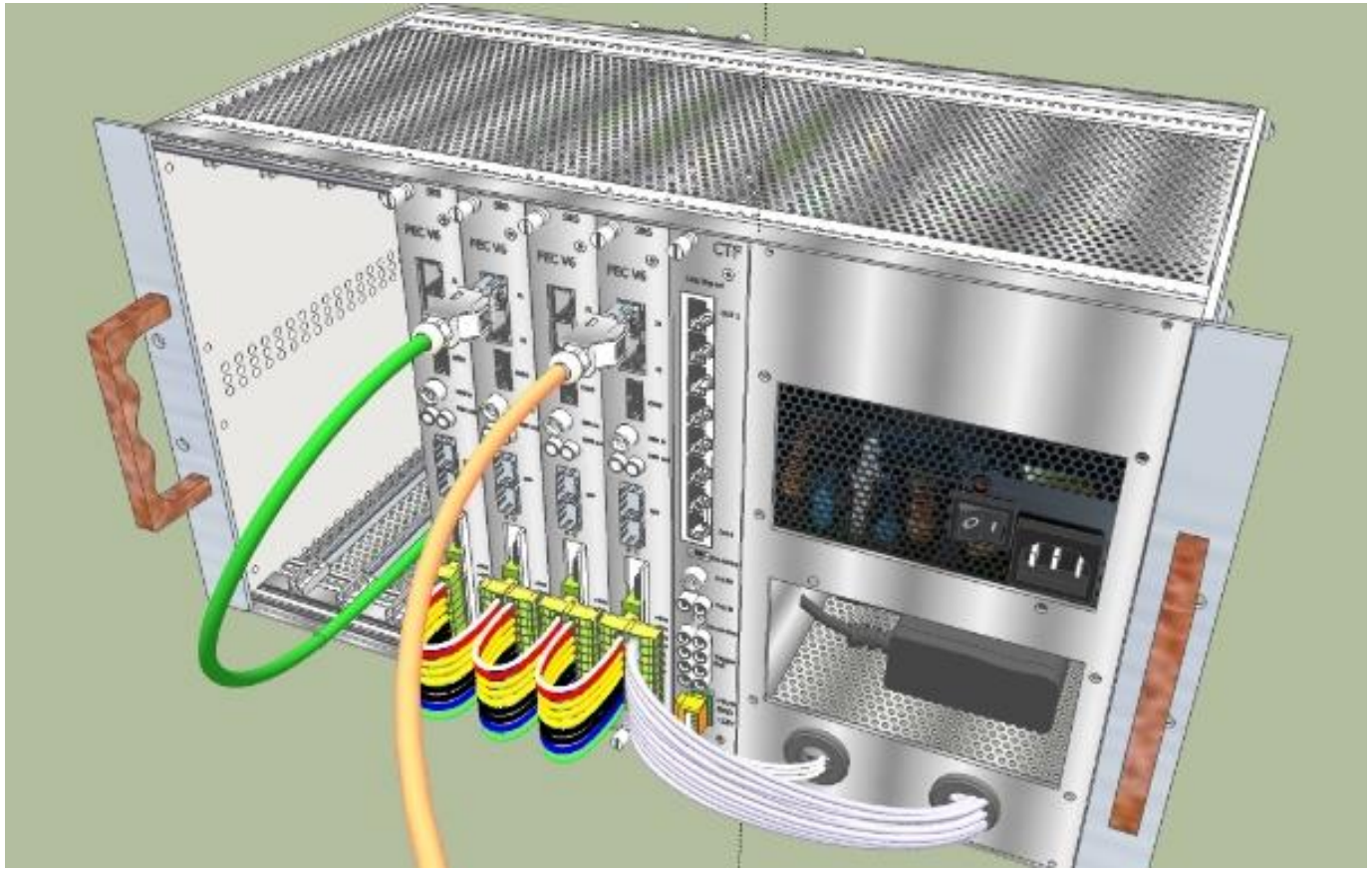
VMM (130nm CMOS)

- Pipeline depth: 64 digital frames (peak)
- Trigger latency: (self triggered) or L0 (12.8us)
- noise : < 400 e- on 10x10 detector reported
- dynamic range: expect >> 25 fC
- Detector capacity: 30pF .. .. < 1nF
- ADC: embedded, 10 bit
- Gains: 8 CSA gains [0.5..16mV/fC]
- Timing jitter: 20 bit t-stamp, 1ns resolution
- Shaping times: 4 [25… 200ns]
- max readout rates: estimated 4 MHz/ch

SRS
Scalable Readout System

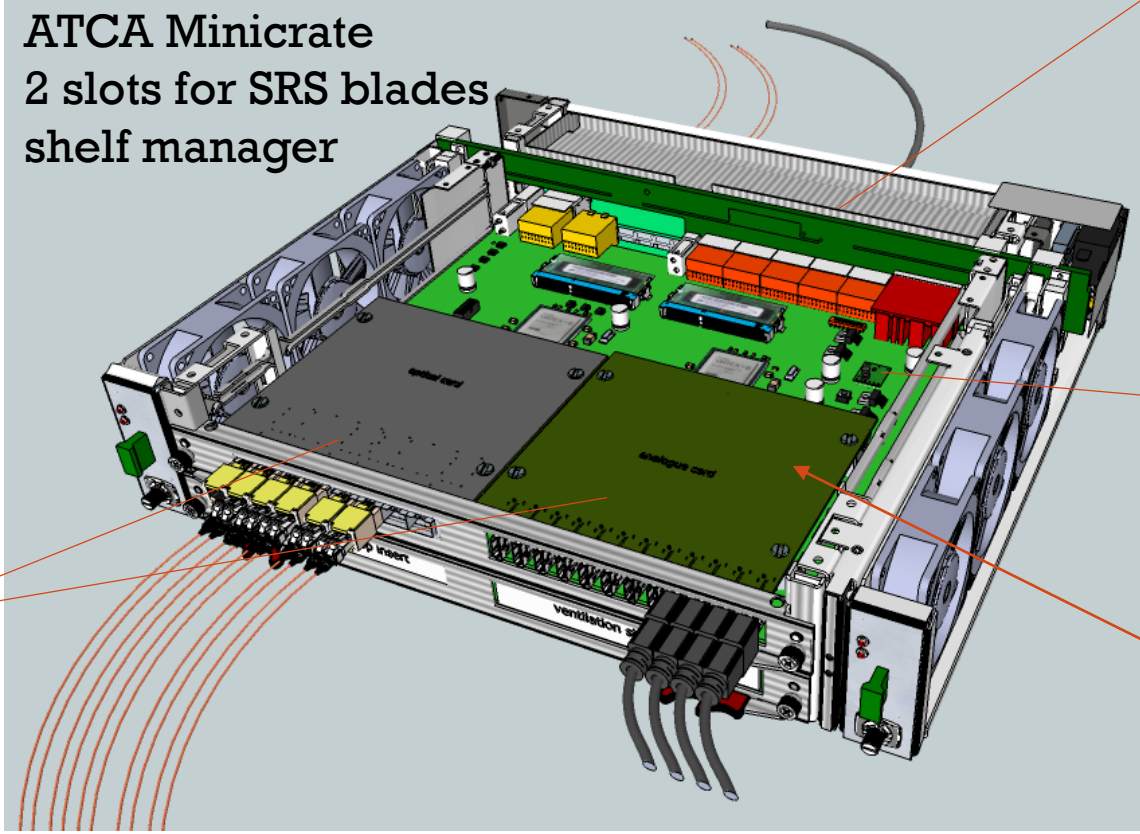
EUROCRATES FOR LARGER SYSTEMS

- Stacking "of vertical slices"
- up to 8K channels per crate
- CTF card for common clock and Trigger (TC link)
- HDMI frontend links connected on rear side
- Power for APV or VMM via HDMI



SRS ATCA

ATCA Minicrate
2 slots for SRS blades
shelf manager



Meshed backplane
(6 Gbps, 100Ω links)

RTM (rear Transition Module)
10 GB Ethernet, 3 GB SFP

SRS ATCA blade
2x FPGA LX240, 2 mezzanine slots

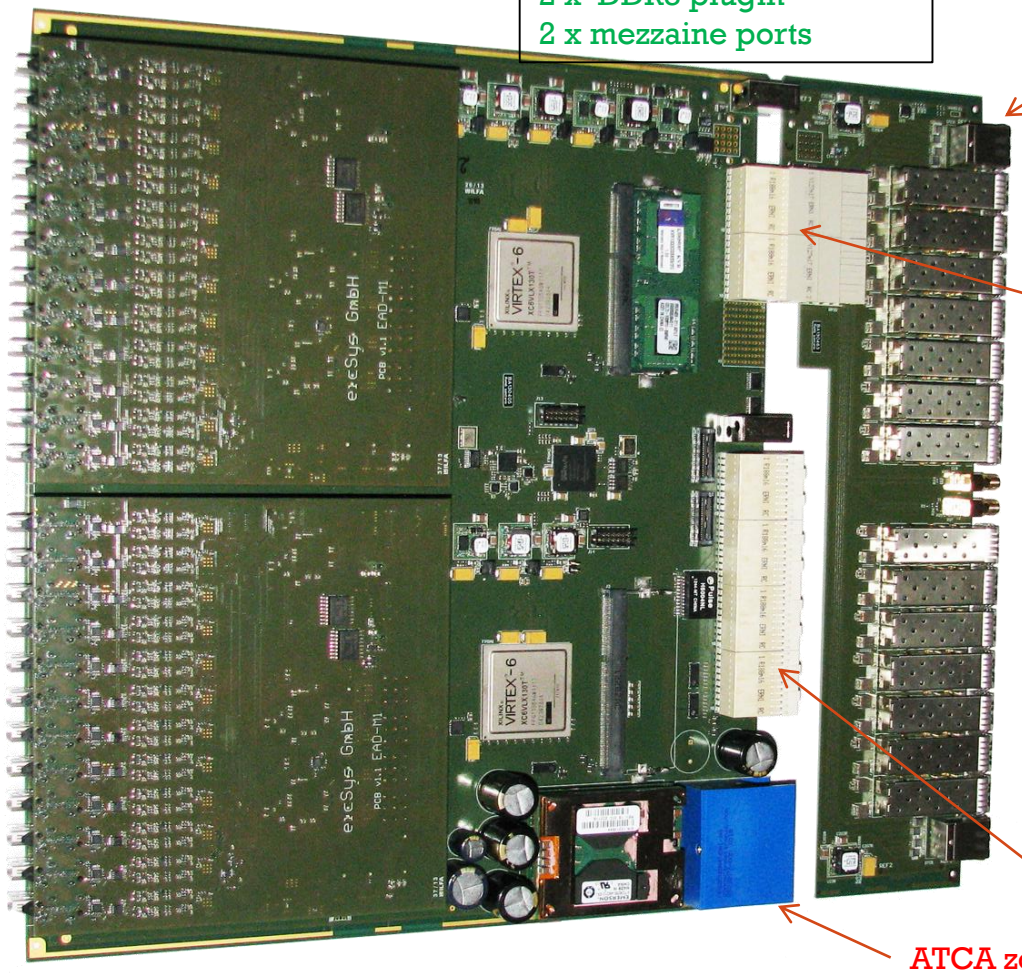
2x
SRS mezzanines
Left: optical
Right: ADC/HDMI

SRS ATCA OVERVIEW

Blade main board:
2 x Virtex 6 LX240 FPGA
2 x DDR3 plugin
2 x mezzaine ports

RTM I/O card:
2 x 8 SFP+ ports
(2x 10 GBE FPGA, 2 x 7 4Gbps to mezzanines)
2 x Rj45 (1 DTCC to each mezzanine)
2 x NIM (SMA)

2 x Mezzanines (ADC):



ATCA Zone 3
RTM comemctor

ATCA Zone 2
backplane connectors

ATCA zone 1 power connector

2 ADC mezzanines:
up to APV 6144 channels

ATCA - BASED SRS

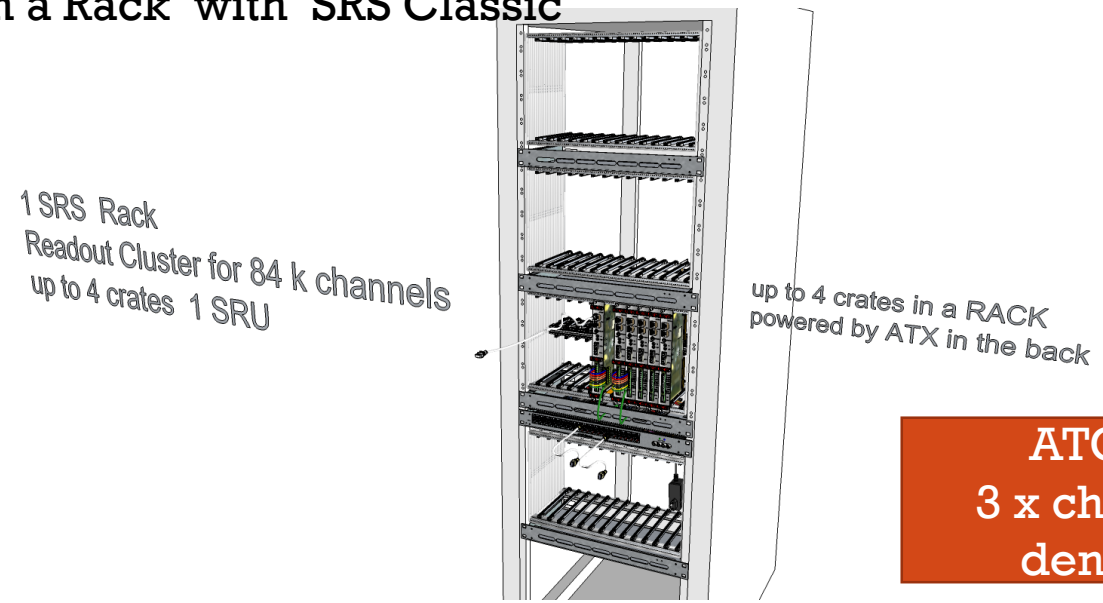
SRS
Scalable Readout System

- ATCA industry standard crates of different size
- Very high-speed linked backplanes between blade-slots
- 3 x channel density compared to FEC
- FEC => Blade with 2 x Adapter plugins
- Adapter card=> mezzanine card

Photo SRS Minicrate with 1 blade, 24 HDMI ports for 6 kchannels

SRS CLASSIC VERSUS SRS ATCA

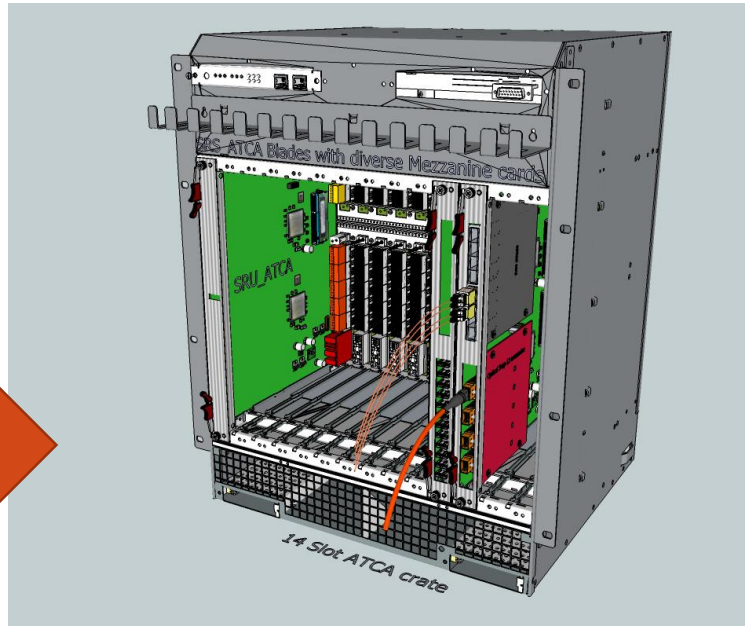
80 k APV channels 4 Eurocrates crates in a Rack with SRS Classic



FECs, ADC, SRU available
Eurocrates for 8 FEC/ADC require ATX power upgrade

ATCA:
3 x channel density

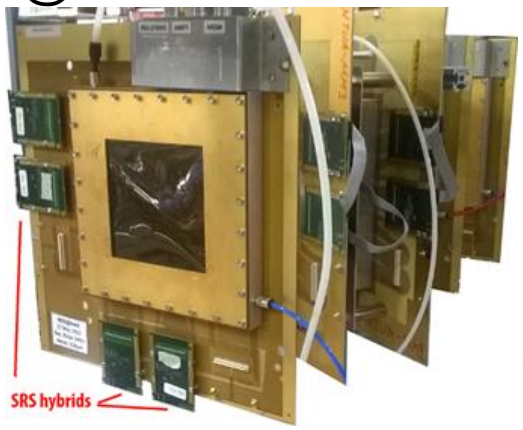
80k APV channels in one single 14 slot ATCA crate with ATCA SRU in slot 1

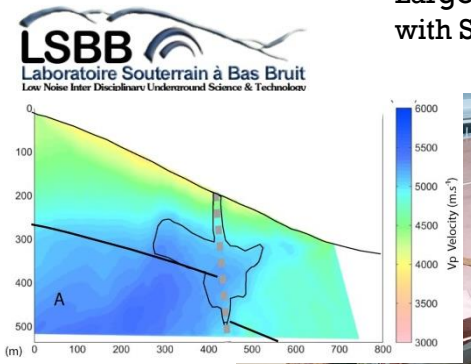


ATCA blades, RTMs and ADC mezzanines are available
ATCA SRU is a planned design

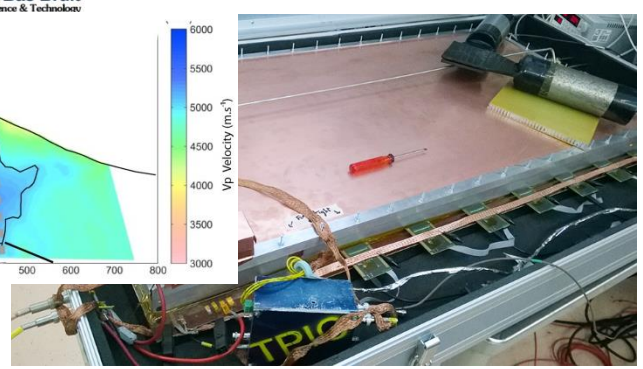
SRS IN EXPERIMENTS

Detector telescope with SRS readout @testbeam 2016

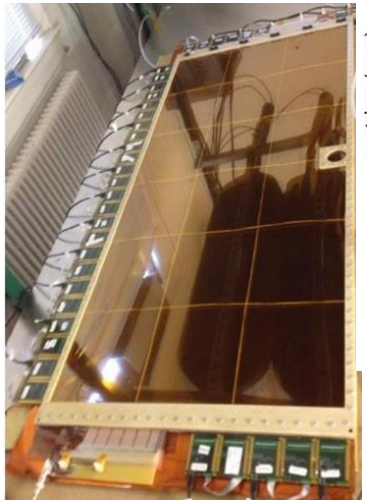


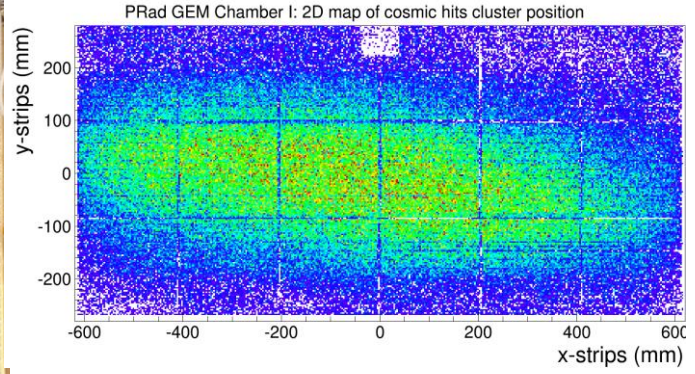


Large surface MUST detector with SRS Classic and APIC trigger

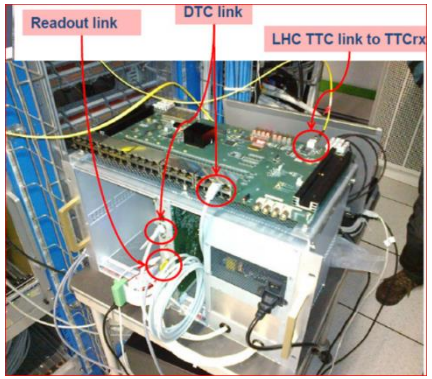


PRad GEM with SRS- APV frontend @ UVa

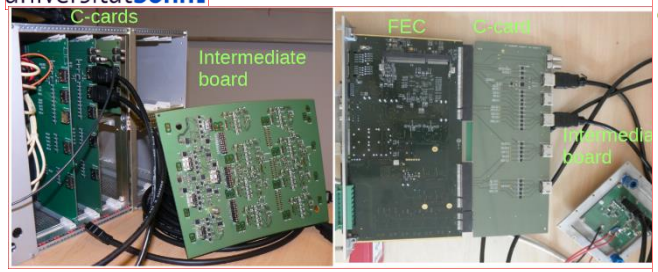


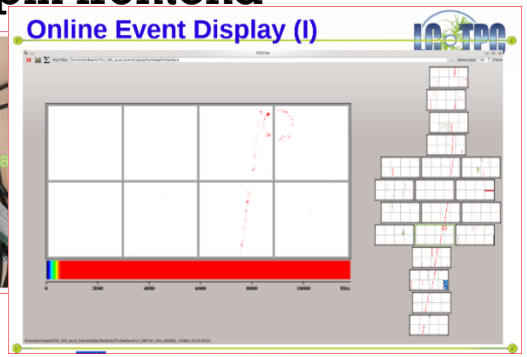


SRS Totem: optical readout DTC

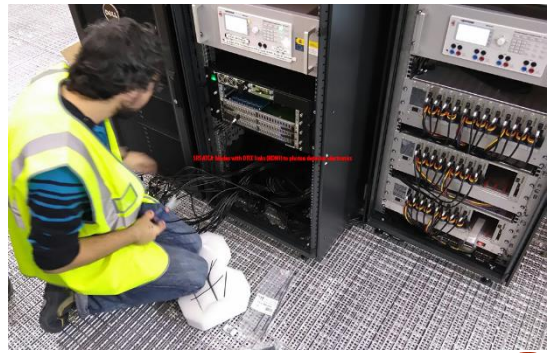


SRS with Timepix frontend



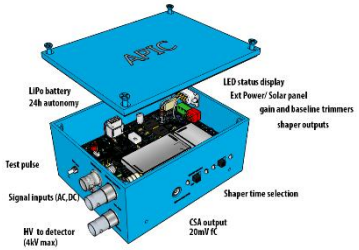


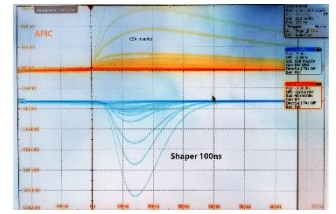
NEXT Collab. SRS-ATCA with photon Detector frontend



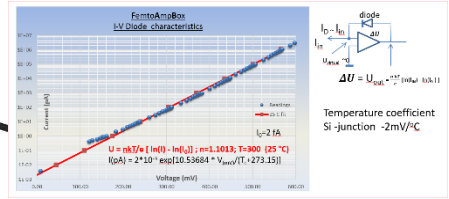
SRS SERVICE ELECTRONICS

- APIC: preamplifier -shaper box, solar chargeable



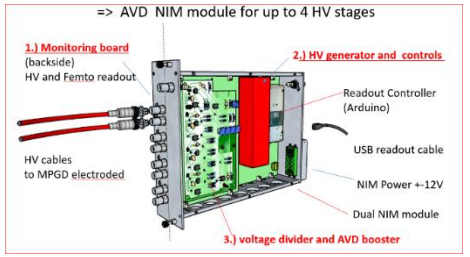


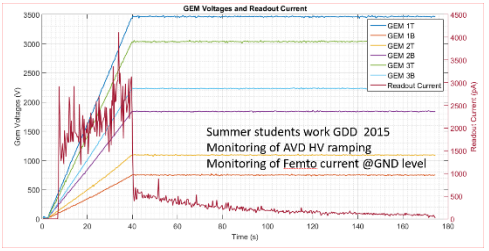
- Femto: Femto-ampere meter with realtime signal output



- AVD: Active Voltage Divider / generator for MPGD's

- ..and more





WHERE TO GET SRS

believe it or not, this was and still is, the most difficult about SRS

SRS procurement until 2016

INHOUSE production RD51 (basically all early systems)

CERN Store (from produces like Prisma, NEOHM etc)
https://edh.cern.ch/Document/SupplyChain/MAG

AVP hybrids, FEC + ADC cards, Minicrates, HDMI cables, SRS accessories
However !!! Only via team account, delivery only to CERN, APV purchase restrictions

EicSys **http://www.eicsys.eu/**

ATCA crates, blades, RTM cards; ADC mezzanines
However !!! No hybrids, waiting for news and testbeam qualification
NEXT and ATLAS NSW users have their your own experts for SRS ATCA

SRS procurement from 2017+

INHOUSE production RD51: stopped

CERN Store: continued

EicSys: no change reported

NEW SRS production licencies* 2017

SAMWAY Electronics: http://www.samwayelectronic.com
FEC and ADC cards, Eurocrates, SRS-ATCA mezzanines

SRS Technology: http://www.srstechnology.ch
VMM hybrids, DVMcards, SRU, APIC, AVD, Femto

MORE POSSIBILITIES

… possible with active support and collaboration from your team

For example:

- optical 3D frontend with CMOS cameras or Timepix-3 chips (>> 10 kHz frame-rate)
- multichannel, low noise photodetector frontend (APD's, SiPMs, MPCCs etc)
- calorimeter frontend with up to 16 bit dyn. range (high/low gain channel hybrids)
- SRS sensor frontends via I2C with new HRS connector (pressure, temperature, position, currents, gas purity, UV ps pulser, etc)

SRS RESOURCES AND REFERENCES

SRS documents and binaries database https://espace.cern.ch/rd51-wg5/srs

RD51 electronics school 2014 https://indico.cern.ch/event/283113/

MPGD Applications beyond Fundamental Science, 18 RD51 Collaboration meeting Aveiro 2016
https://indico.cern.ch/event/525268/timetable/#20160912

S. Martoiu, H.Muller, J.Toledo, Front-end electronics for the Scalable Readout System of RD51
IEEE Nucl. Sci. Symp. Med. Imag. Conf. (2011) pp.2036-2038.

K. Gnanvo et al.,
Detection and Imaging of High-Z Materials with a Muon Tomography Station Using GEM Detectors
Nuclear Science Symposium Conference Record (NSS/MIC), Nov. 2010 IEEE

J. Toledo et al., The Front-End Concentrator card for the RD51 Scalable Readout System,
2011 JINST C11028.

S.Martoiu, H.Muller, A.Tarazona, J.Toledo,
Development of the Scalable Readout System for Micro-pattern gas detector and other applications,
2013 JINST 8 C03015

Ignacio Lázaro et al.
Muon telescope based on Micromegas detectors: from design to data acquisition,
IDUST 2014

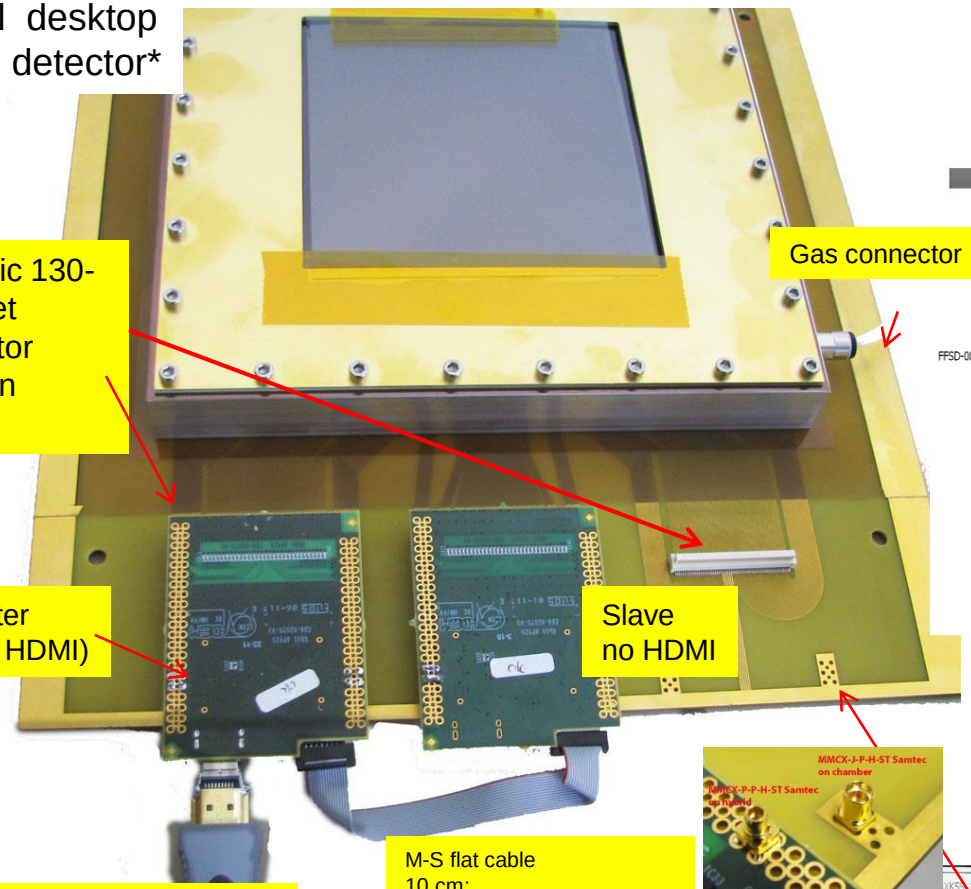
R. Esteve et al., Readout and data acquisition in the NEX-NEW detector based on SRS-ATCA
2015 JINST C01008

Gianluigi De Geronimo et al, VMM2 - An ASIC for the New Small Wheels,
TWEPP 2014 – Aix en Provence, France, September 2014

BACKUP SLIDES

MPGD-DETECTOR-SPECIFIC HYBRIDS AND ACCESSOIRS

Typical desktop MPGD detector*



Panasonic 130-pin socket on detector header on hybrid

Gas connector

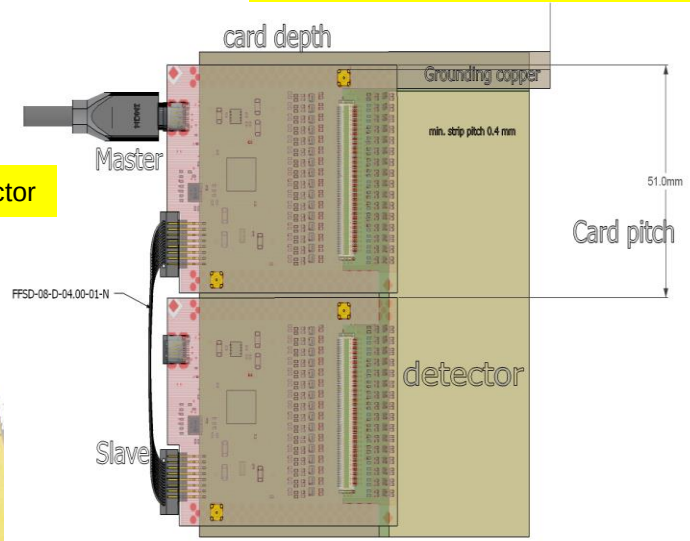
Master (has HDMI)

Slave no HDMI

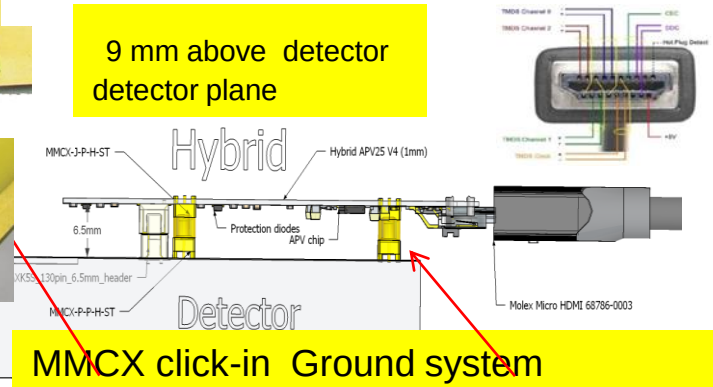
Master-Slave = 256 channels per HDMI A-D readout cable (Farnell 1786338) power via HDMI

M-S flat cable
10 cm:
SAMTEC FFSD-08-D0401N
20 cm:
SAMTEC FFSD-08-D0801N

128 channels for 0.4 mm continuous pitch

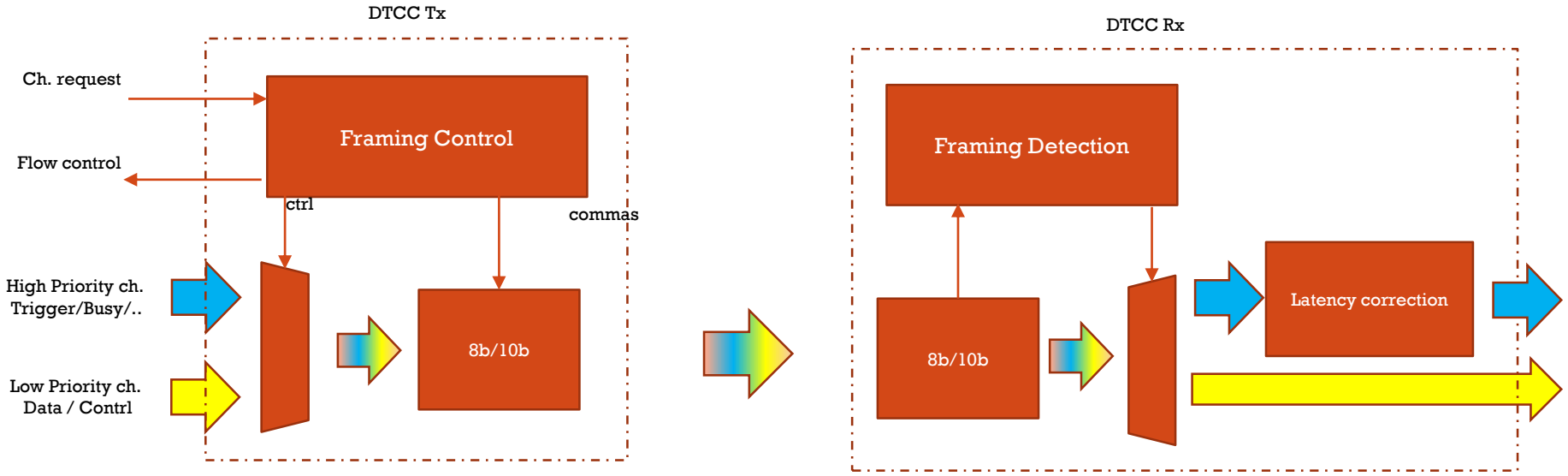


9 mm above detector detector plane



MMCX click-in Ground system on detector and hybrid, stackheight 6.5 mm

DTCC LINK PROTOCOL



Time multiplexed DTCC link

Trigger, Busy, Clock = high priority and low latency
Data = low priority
Controls = Ethernet frames @low priority

FRONTEND LINK (DTCCP)

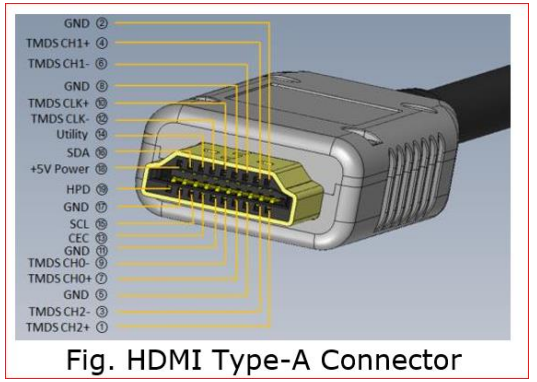
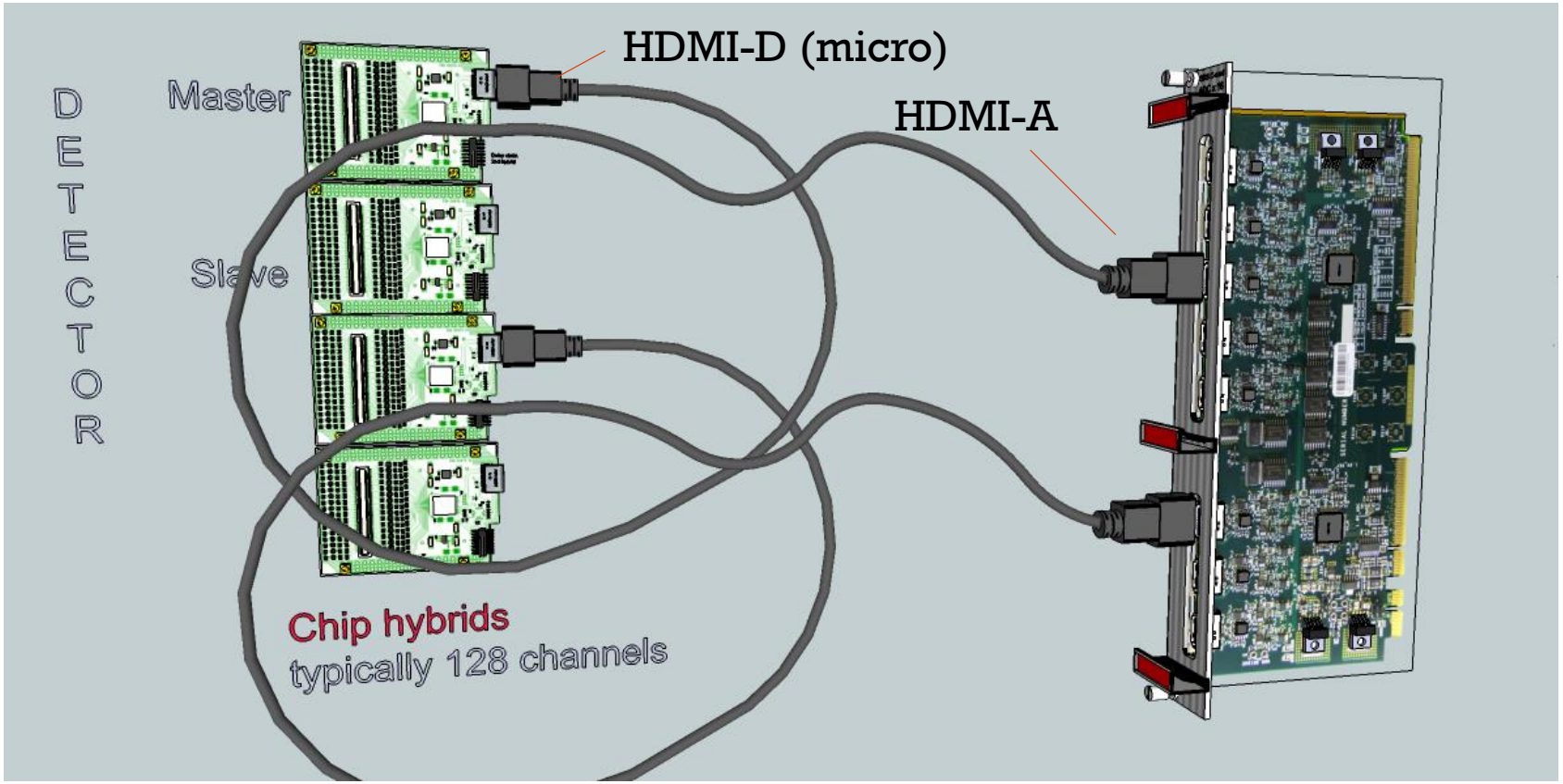


Fig. HDMI Type-A Connector



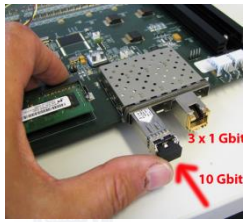
SRS uses HDMI cables A-D for connection of frontends to SRS

DTCCP =
Data uplinks
Trigger downlink
Clock downlink
Controls bidir I2C
Power 5V max. 1A

For distances 25m< L <150m
➔ active HDMI links
copper/ fibre under tests

SCALABLE READOUT UNIT (SRU)

SRS
Scalable Readout System



4 x SFP+ ports
3 x 3 Gbit
1 x 10 Gbit Ethernet XAUI

2 GB DDR3

4 x NIM in
4 x NIM out

Virtex 6
FPGA

TTCrx optical

Jitter cleaner
TTC clock

40 x DTCC links
2 LVDS in, 2 LVDS out

4 x LVDS
horizontal synchronization and Trigger

designed for use in magnetic field:
Alu chassis, no transformers, no DC-DC

PHOTO SRU

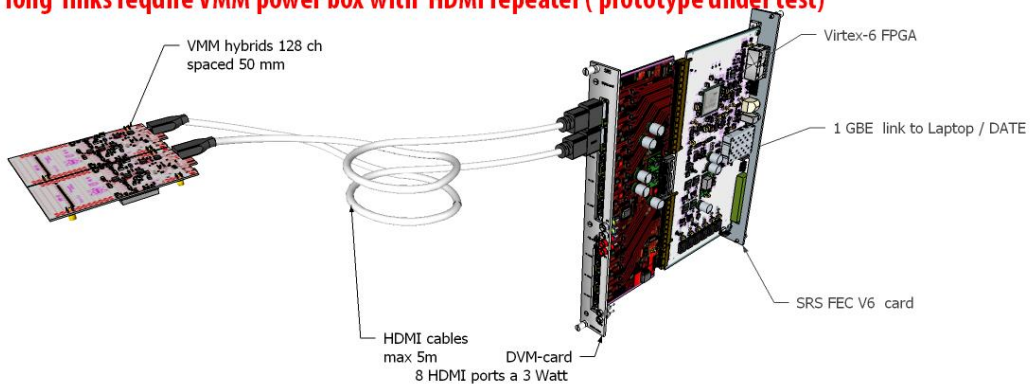
VMM ISSUES

3x power of APV frontend: direct powering via HDMI is limited in length
⇒ VMM Power and HDMI repeater box for long HDMI links is under works

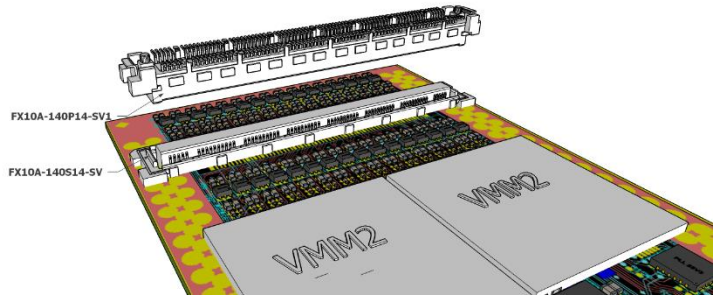
VMM requires cooling on the detector:
⇒ cooling strategies under discussion

Standard MPGD connector (Panasonic 130 pin obsolete)
=> new connector for both MPGD detector frames and VMM3 hybrid in 2017

VMM power via DTCCP HDMI cables: limited length
long links require VMM power box with HDMI repeater (prototype under test)



New 140 pin connector for VMM



SRS HISTORY RD51

- SRS, 2009+ standard readout system for MPGD detectors (GEM, MM, etc)
- CERN made MPGD detectors come with SRS connectors for SRS hybrids
- 2010+ SRS crates, electronics, accessories available trough CERN store
- Firmware, Software and Manual download from RD51 server
- DAQ systems : DATE (default), Labview
- O(100) deployed small and medium-sized SRS systems