ORKA
Getting From Here to There

(Orcinus orca), Life ofSea blogspot

Executive Summary

- The ORKA proposal is the 4th generation of a well understood and developed technique. The risks are correspondingly controlled.
- The accelerator resources required to mount ORKA are straight forward for the Fermilab complex. The required slow spill performance is comparable to what has been achieved with the BNL AGS and the Fermilab Tevatron, and less than the JPARC goal.
- The ORKA collaboration has worked with Fermilab to explore three options to site the experiment that do not require civil construction. The most attractive option for ORKA is siting the experiment in the former CDF collision hall.
- There is a compelling argument to judiciously deploy CDF D&D resources now to preserve the ORKA option and minimize impact on IARC operations. CDF D&D resources must be eventually borne by OHEP in all cases.

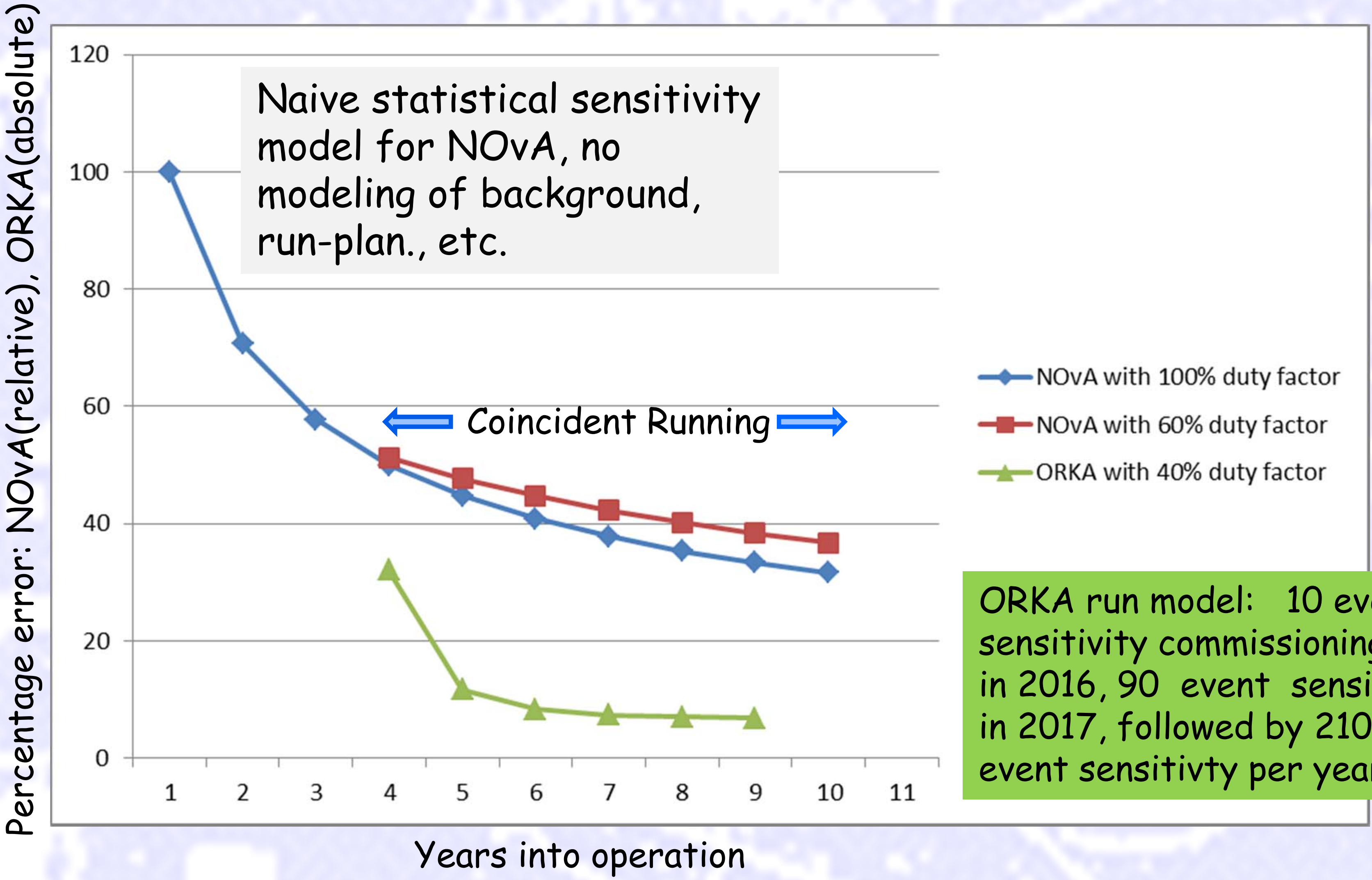
Possible Mixed-Mode Main-Injector Configurations.

ORKA is proposing a configuration that delivers 75kW with a 44% slow spill fraction to ORKA and a balance of Main Injector cycles to NOvA operations. Minimal impact on NOvA sensitivity for oscillation parameters.

E_{beam}[GeV]	T_{cycle} [s]	$t_{flattop}$	Duty Factor [%]	P_{ave}[kW]	P_{max}[kW]
120	15	2.5	16	62	377
120	20	3.3	16	46	283
120	25	4.1	16	38	232
120	30	4.9	16	31	189
100	10	3.5	35	77	222
100	15	5.0	33	52	154
100	20	6.5	33	39	118
100	25	8.1	32	31	96
95	**10**	**4.4**	**44**	**74**	**166**
95	15	6.3	42	49	116
95	20	8.3	41	37	89
95	25	10.1	40	29	73
90	10	5.9	59	70	118
90	15	8.3	56	46	83
90	20	10.8	54	33	61
90	25	13.3	53	28	52

*I. Kourbanis, personal communication

Consideration of NOvA and ORKA Joint Sensitivities



ORKA run model: 10 event sensitivity commissioning run in 2016, 90 event sensitivity in 2017, followed by 210 event sensitivty per year.

Estimated Cost

TPC: $53M (FY-2010,original estimate), $63M then-year

Table 10.2: Estimated project cost. All costs in FY10 $k.

WBS element		Description	Total Cost	60% conting.	Total w/cont.
1.0		**TPC**	**$33M**	**$20M**	**$53M**
1.1		**Accelerator and Beams**	**7,510**	**4,490**	**12,000**
	1.1.1	A0 to B0 transport*	2,200	1,300	3,500
	1.1.2	Target and Dump	940	560	1,500
	1.1.3	Kaon Beam	4,370	2,630	7,000
1.2		**Detector**	**22,390**	**13,430**	**35,820**
	1.2.1	Spectrometer Magnet	500	300	800
	1.2.2	Beam and Target	600	360	960
	1.2.3	Drift Chamber	1,900	1,140	3,040
	1.2.4	Range Stack	2,500	1,500	4,000
	1.2.5	Photon Veto	3,000	1,800	4,800
	1.2.6	Electronics	4,000	2,400	6,400
	1.2.7	Trigger and DAQ	2,000	1,200	3,200
	1.2.8	Software and Computing†	2,000	1,200	3,200
	1.2.9	Installation and Integration	5,890	3,530	9,420
1.3		**Project Management**	**2,740**	**1,640**	**4,380**
1.4		**OPC**	**700**	**420**	**1,120**
	1.4.1	R&D	300	180	480
	1.4.2	Commissioning	400	240	640

* Candidate for off-project Accelerator Improvement Project (AIP) funding.
† Included here although there is no uniform practice to do so.

Sites considered:

- **Meson Center(MDB):**

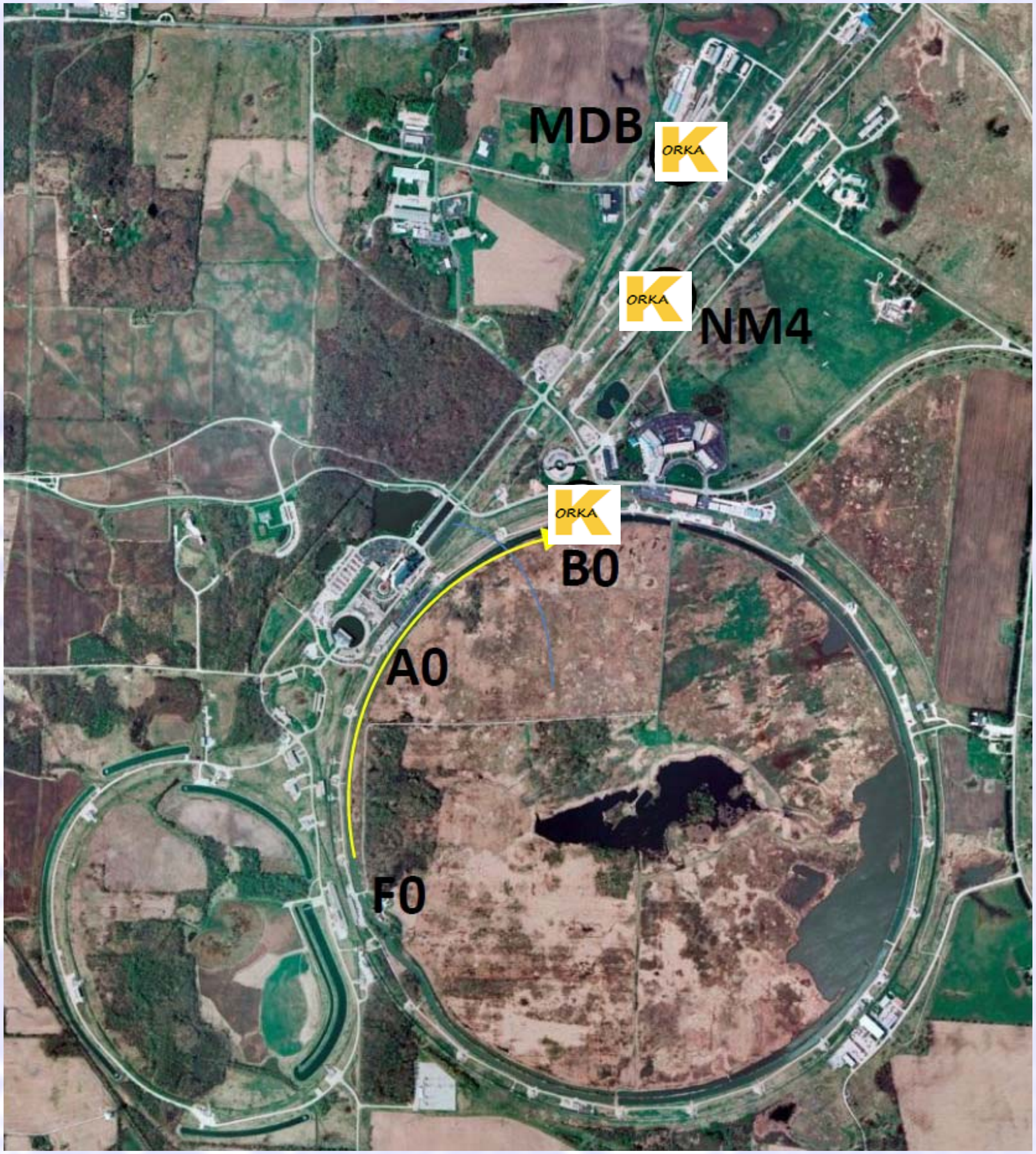
Existing beam transport,
Rad soft, large hall, no magnet,
existing and future test beam
program.

- **Sea-Quest(NM4):**

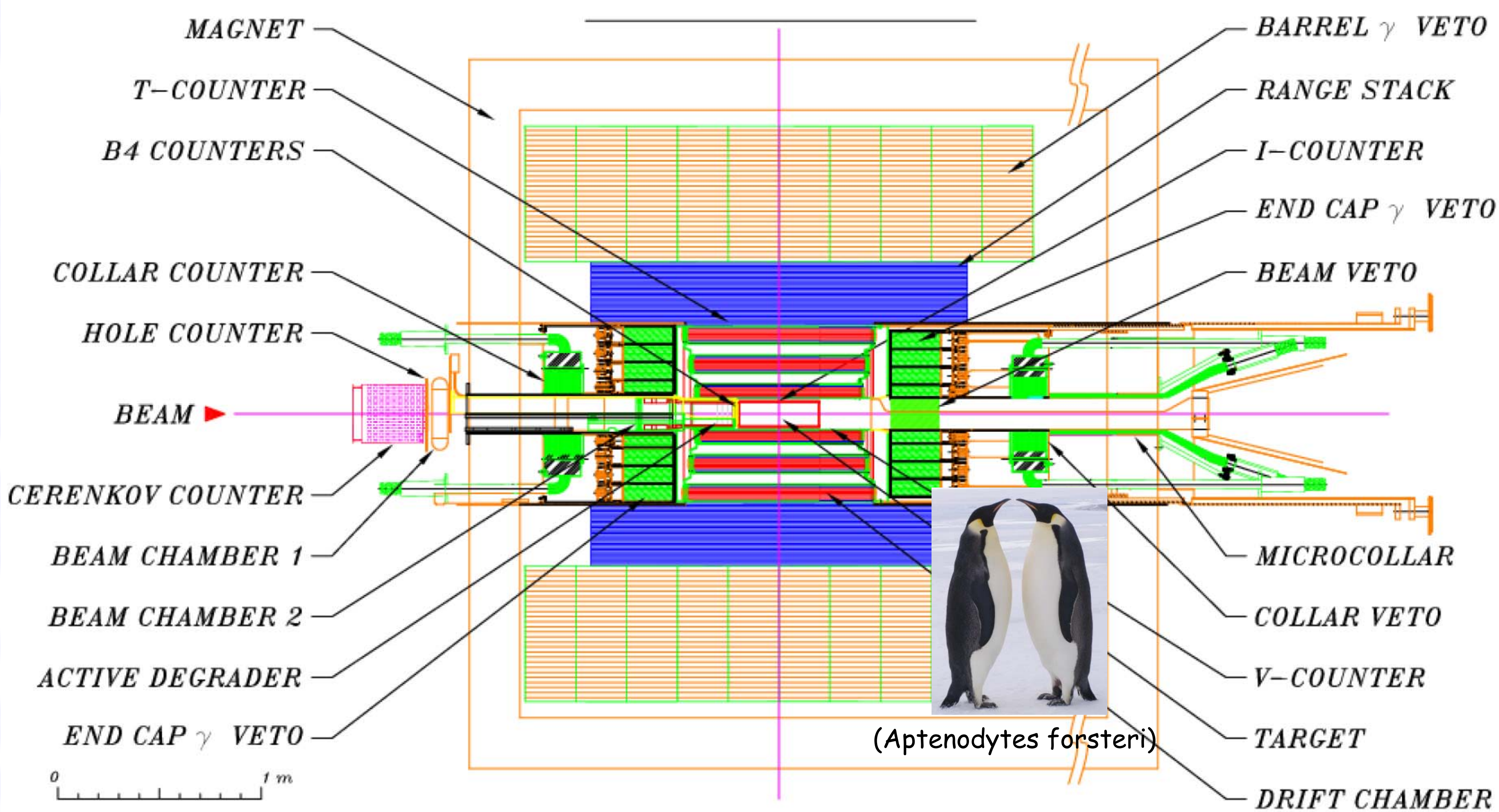
Existing beam transport,
Rad firm, small hall, no magnet,
existing and possible future
Drell-Yan program.

- **CDF(B0) collision hall:**

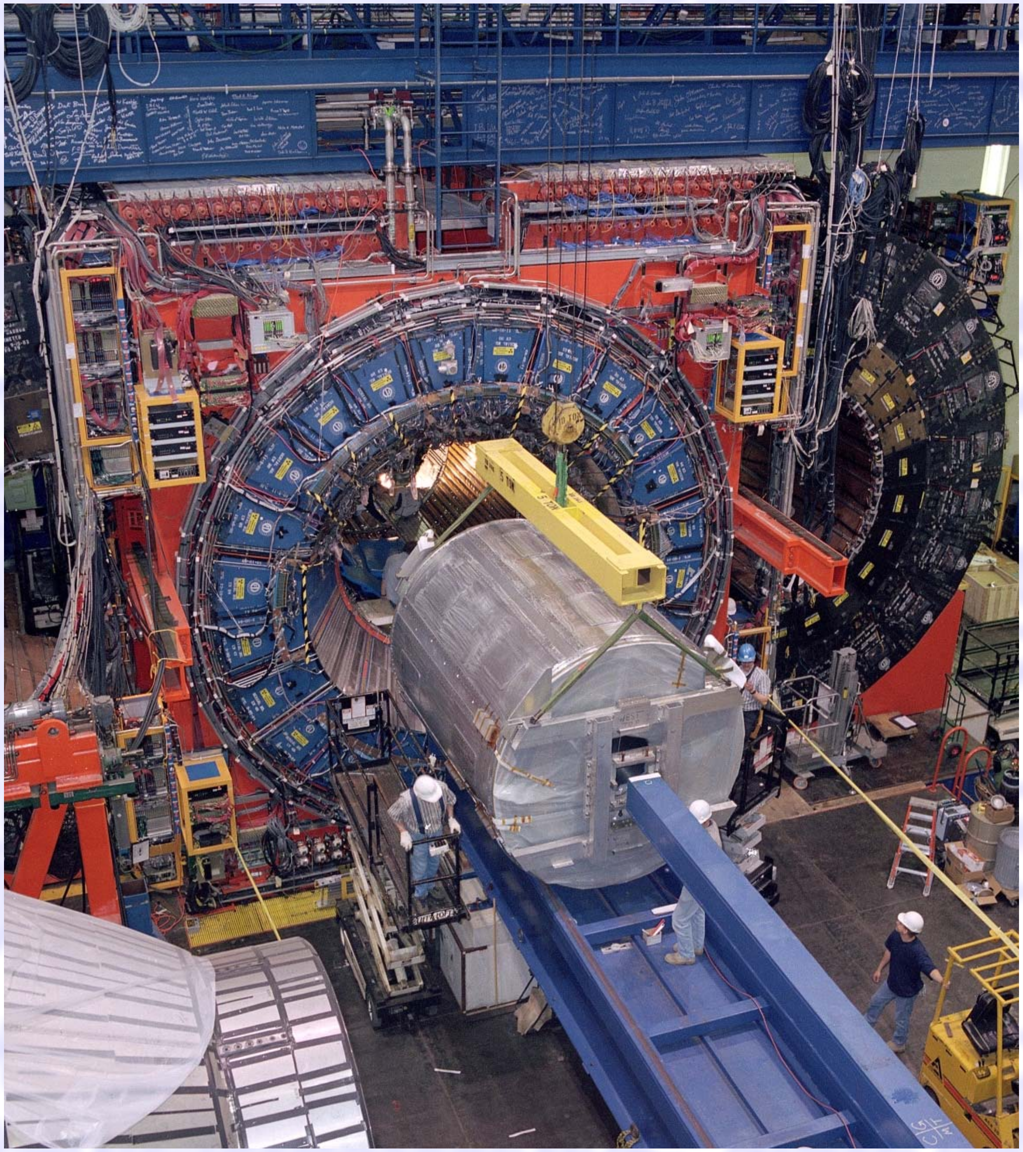
Existing tunnels and hall,
Rad hard, adequate hall, magnet,
A0->B0 beamline required,
interplay with IARC.



ORKA is a 4th Generation Detector
- x100 sensitivity -
x10 from kaon flux, x10 from detector



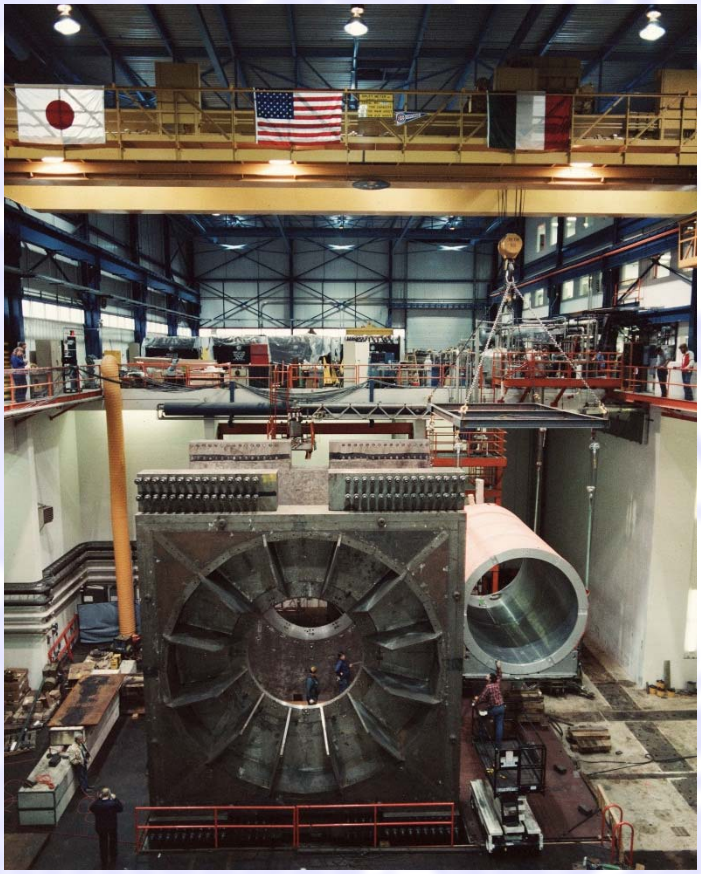
(Aptenodytes forsteri)

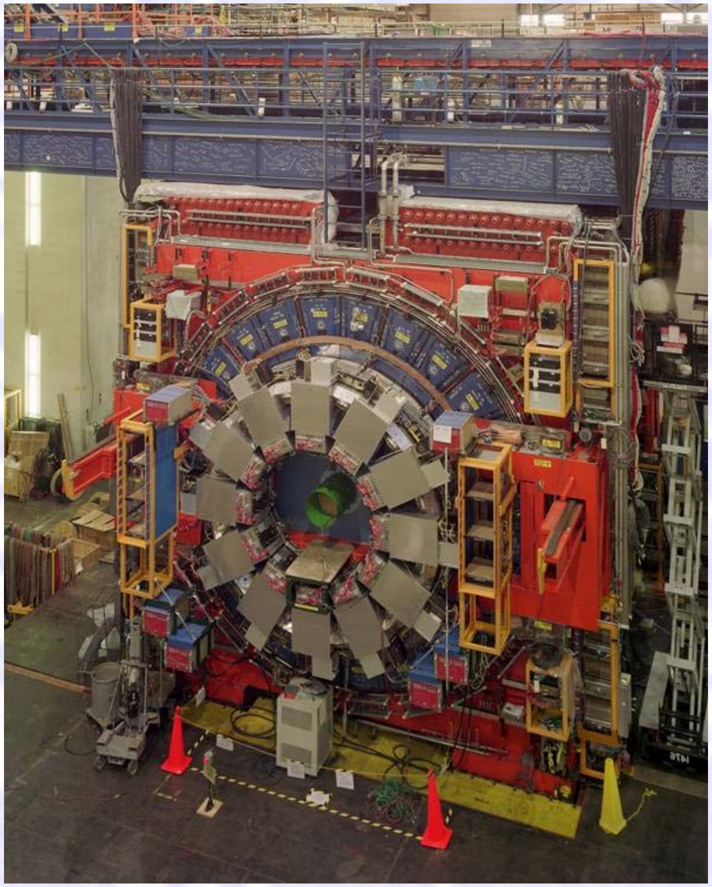


The ORKA new detector payload replaces the CDF tracker volume-ε.

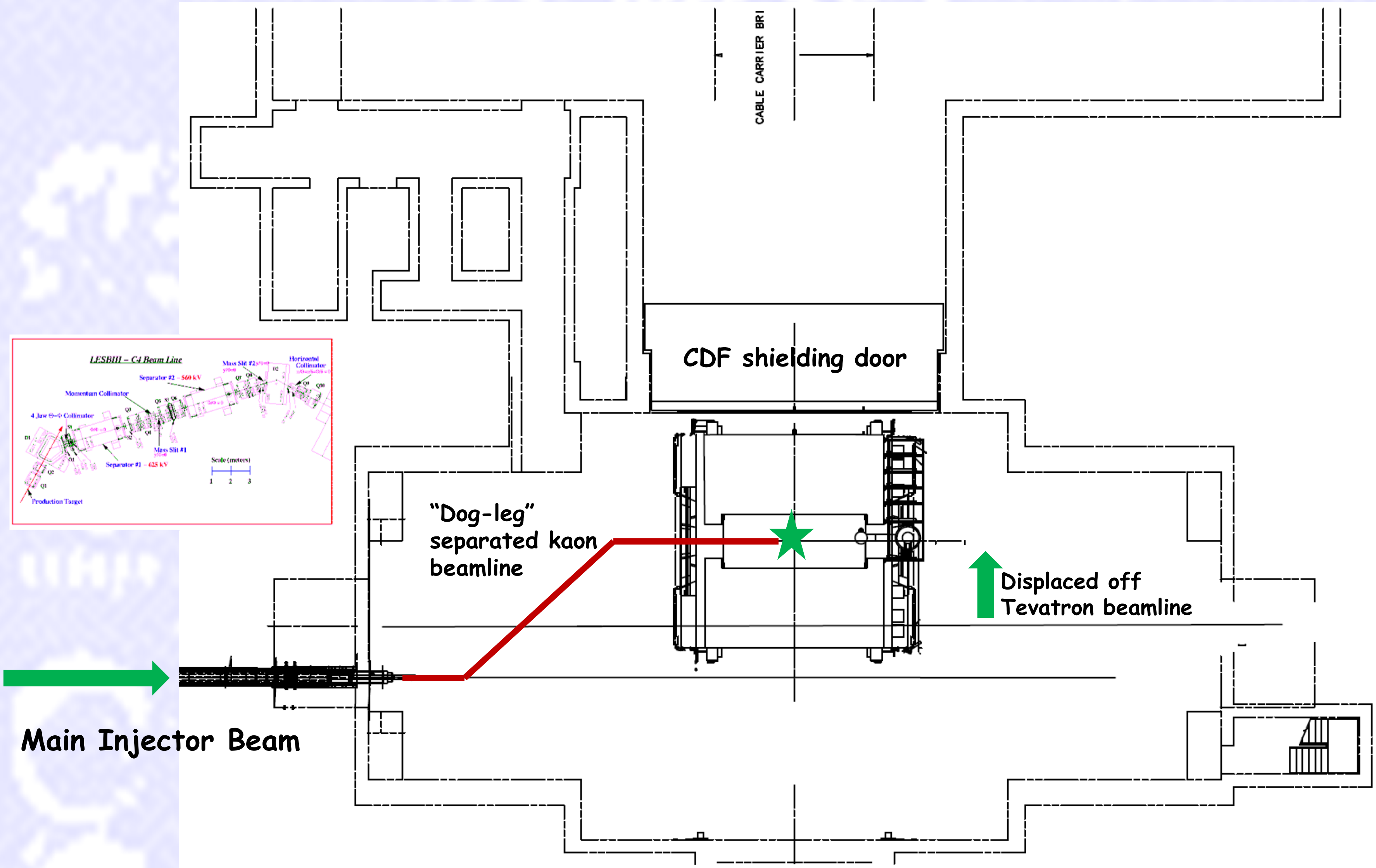
Steve Kettell with the BNL-E949 Central tracker (similar diameter to ORKA)

CDF coil & flux return





ORKA in the CDF Collision Hall



B0 Assets for ORKA

- No civil construction required. The existing Tevatron shielding can manifestly support loss of a maximum (4.8×10^{13} p) Main Injector pulse. Beam-Loss Monitors can halt multi-pulse losses.
- Re-use of existing solenoid magnet and return steel, cryogenics, and magnet control systems. Value of solenoid and infrastructure is about $10M. Value of steel about $5M.
- Re-use of infrastructure for detector systems – power, cooling, etc.
- Work can start in the near future to develop a high intensity beamline and hall as an Accelerator Improvement Project. The ORKA Project would then be a good candidate as an experiment to use this high intensity beamline.

Lab Charges
"ORKA Preservation Task Force"
for the B0 solution

Task force membership:

Jonathan Lewis, David Christian, Robert Kephart, Kurt Riesselmann, Paul Czarapata, Panagiotis Spentzouris, Gueorgui Velev, Rhonda Merchut, Teri Dykhuis, Angela Sands, **Peter H. Garbincius (Chair)**

Charge elements from report:

"On January 31, 2012, Deputy Director Young-Kee Kim charged the panel "to analyze various scenarios for the ORKA detector to be installed in the CDF hall in the future. For each scenario, you are asked to provide a rough cost estimate and an analysis of technical difficulties." Young-Kee requested a written report by March, 2012."

Analysis of Effort Required to Strip Down and Prepare the CDF Detector to receive the ORKA Payload

Labor Type	Cost ($/hr)	Time (hr)	Burdened FY2013 Cost	Contingency	Total
Engineer - Mech	145	750	108,560	50%	162839
Scientist	170	1,556	265,268	30%	344848
Technician - Mech-Monthly	131	3,000	393,214	30%	511179
Technician - Elec-Wkly	92	12,176	1,119,921	50%	1679882
Technician - Mech-Wkly	90	12,329	1,114,782	50%	1672173
Technician - ES&H	105	48	5,025	50%	7537
Electrician-Foreman	115	16	1,842	50%	2763
Machine Shop	136	264	35,800	50%	53700
FESS Engineering	108	0	0	50%	0
Iron Worker-Foreman	161	6,848	1,100,043	100%	2200087
Subtotal		36,987	4,144,455		6635008
Other M&S			144,587	100%	289174
Total			4,289,042		6924182

15 FTE-years + 1.2M M&S = $6.9M (FY13)

Funding Profile Considerations for This Investment

- Task Force Estimate: $6.9M (mostly effort, 15 FTE-years)
- FY12 D&D budget $1.5M (SWF) + 0.5M M&S.
- Super-Phenix initiative is interested in the CDF central calorimeter arcs. Charging Super-Phenix for extraction would mitigate costs by $1.5M.
- The collision with IARC customers could be mitigated by "reserving" a minimal work space in the assembly hall or slower than anticipated IARC customer growth profile in the assembly hall.
- These costs have to be borne at some point if ORKA is mounted at B0, and now is the time to minimize impact on IARC operations which if successful will grow with time.

Strategy to Transport Beam From the Main Injector to the CDF Collision Hall.

- Replicate the existing transport from F0 to A0 (so called Main Ring remnant) with existing legacy Main Ring magnets.
- Sufficient Main Ring dipoles exist in the Tevatron tunnel, sufficient Main Ring quadrupoles are stored at the Nevada Test Site, awaiting return to Fermilab upon request.
- Costs to refurbish a single magnet is $32K, cost to rebuild a single magnet is $110K. Costs per piece will come down with volume.

Resources for building a beamline from A0 to B0.

Typical MR Dipole above Tevatron magnet

Dipoles and quardrupoles stored at Fermilab

Water & bus lines are cut

Most magnets will need to be refurbished, some will need to be rebuilt. This is a beamline, not a storage ring, with many spares so a greater failure/risk element can be carried to minimize initial capital investment.

Slow Spill Extraction from the Main Injector

- The ORKA experiment requires slow spill extraction of 5×10^{13} Main Injector protons per pulse.
- The SeaQuest experiment is approved for 1×10^{13} protons per pulse, and has recently completed a successful commissioning run.
- Work is necessary to achieve high quality extraction at the ORKA power level. This work is required for any competitive Main Injector slow-spill program in the future.

Near Term Technical Priorities for ORKA

- Continued focused effort on developing an integrated conceptual design for the kaon production target, separated kaon beamline and beam dump that fits within the constraints of existing best candidate sites at Fermilab (CDF/B0 and SeaQuest/NM4).

- **Develop a siting plan:**

We maintain that the best siting for ORKA at Fermilab is in the B0 collision hall driven with a high intensity beamline built from legacy Main Ring magnets. This beamline would be a new and unique asset for Fermilab,the US user community, and particle physics world-wide.

If a programmatic decision is made to not preserve an option for ORKA at B0/IARC, then a suitable solenoid will need to be acquired. Best existing match is the CLEO magnet. The ORKA collaboration has expressed interest in the CLEO solenoid.

Near Term Strategic Priorities for ORKA

- Achieve Critical Decision Zero in the fall of 2012.

- Continue to build the collaboration. Interest is high in the US and international community. Collaborating institutions need a signal from the agencies that ORKA is in the US particle physic portfolio.

- Identify and cultivate resource partners:

- International collaborators
- Resources from strategic partners e.g., SLAC on data acquisition, BNL and KEK on kaon separators & beamline elements.

Summary: Opportunities

- The focus of the Fermilab research program for the coming decades is accelerator driven intensity frontier research.
- Precision measurement of $K^+ \rightarrow \pi^+\nu\bar{\nu}$ is broadly recognized to be on the short list of the most compelling accelerator-driven intensity frontier research.
- The ORKA initiative can deliver this precision measurement and a broad portfolio of other measurements.
- The ORKA research program can engage a substantial sector of the US university community as major partners in developing and providing instrumentation and the eventual scientific output.

Summary: Risks & Resources

- The ORKA proposal is the 4th generation of a well understood and developed technique. The risks are correspondingly controlled.
- Nevertheless, resources are required to improve the cost estimate and reduce contingencies. Siting and beamline design are leading issues.
- The ORKA collaboration has worked with Fermilab to explore three options to site the experiment that do not require civil construction. The most attractive option for ORKA is siting the experiment in the former CDF collision hall.
- There is a compelling argument to judiciously deploy CDF D&D resources now to preserve the ORKA option and minimize impact on IARC operations. CDF D&D resources must be eventually borne by OHEP in all cases.

Spare Slides

Siting at SeaQuest hall

- Need a magnet!
- Moving CDF coil and steel is not a cost effective option--$10M to remove magnet and steel. The CDF Flux return iron is a monolithic heavy welded unit that is costly to disassemble with any care.
- We have surveyed possible 1+ Tesla solenoids world wide, the CLEO magnet is the only real choice, and is well suited. The CLEO flux return is bolted together and can be readily disassembled. The ORKA collaboration has expressed interest in this magnet, Super-Phenix and JLAB have expressed interest as well.
- The ORKA program in th SeaQuest hallwould prevent continuation of the Drell Yan program at Fermilab.
- Shielding is plausible, footprint is very limited, no solution yet for the secondary kaon beamline in this tight footprint.

Siting in the Meson Building

- Need a magnet!

- Moving CDF coil and steel is not a cost effective option--$10M to remove magnet and steel. The CDF Flux return iron is a monolithic heavy welded unit that is costly to disassemble with any care.

- We have surveyed possible 1+ Tesla solenoids world wide, the CLEO magnet is the only real choice, and is well suited. The CLEO flux return is bolted together and can be readily disassembled.   The ORKA collaboration has expressed interest in this magnet, Super-Phenix and JLAB have expressed interest as well.

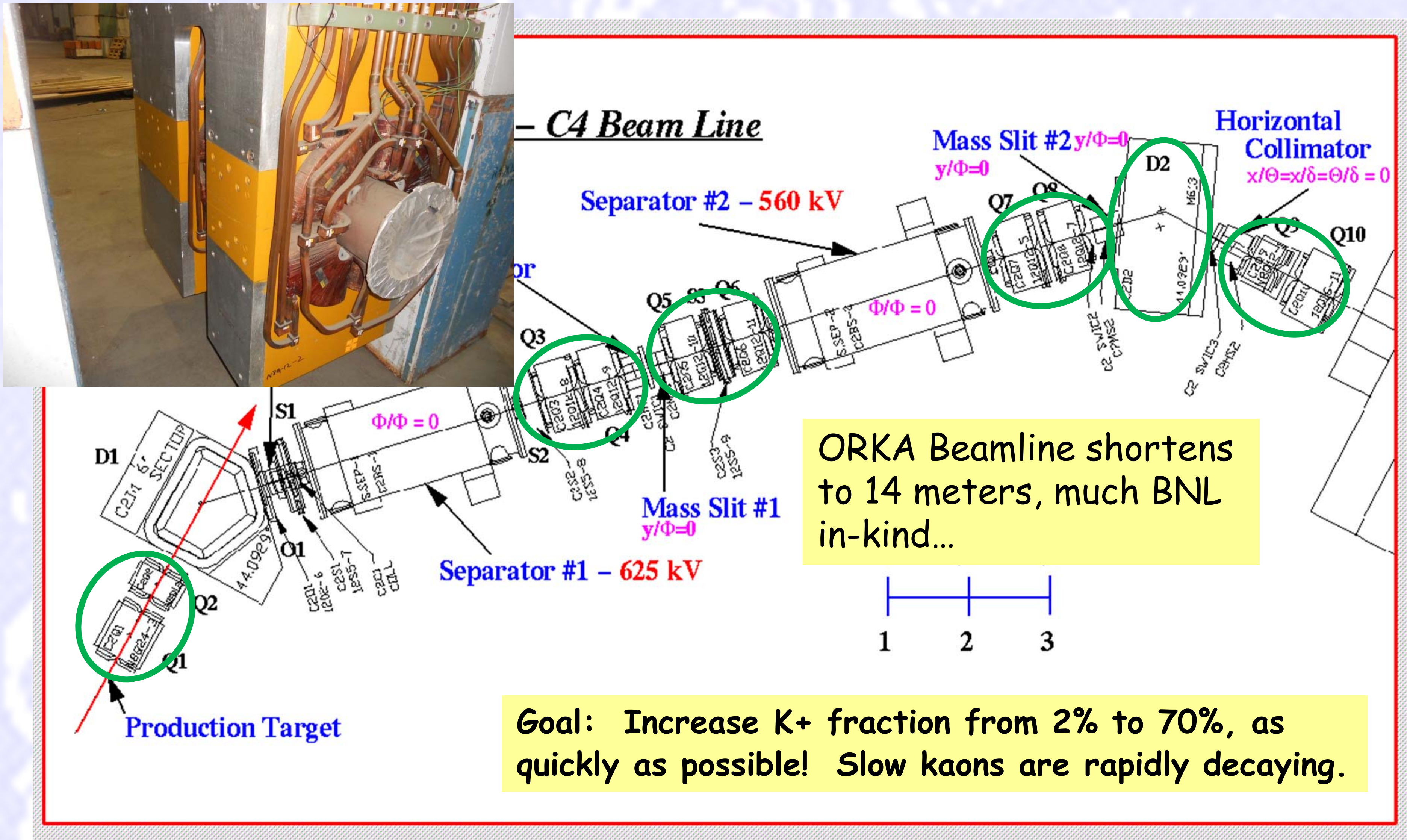
- Floor space is adequate, but would severely compromise the existing test beam program.

- Shielding is currently weak, can possibly be upgraded…needs study.

$K \to \pi\nu\bar{\nu}$... Past, Present, Future

Facility (Experiment)	Proton Power	Kaon Decay/stop rate	Kaon Properties	$K \to \pi\nu\bar{\nu}$ Sensitivity
BNL AGS (E787/E949):	50kW	1×10^6 K^+/sec	Pure stopped K^+ source	7 events
CERN (NA62):	20kW	10×10^6 K^+/sec	Un-separated 1- GHz $K^+/\pi^+/p^+$ beam	80 events
Fermilab: (ORKA):	**75kW**	**9×10^6 K^+/sec**	**Pure stopped K^+ source**	**1000 events**
Project-X $K^+ \to \pi\nu\bar{\nu}$	1500 kW	100×10^6 K^+/sec	Pure stopped K^+ source	>1000 events

K^+ Beamline: Focus a low energy separated charged beam on a stopping target. Measure kaon decays at rest!

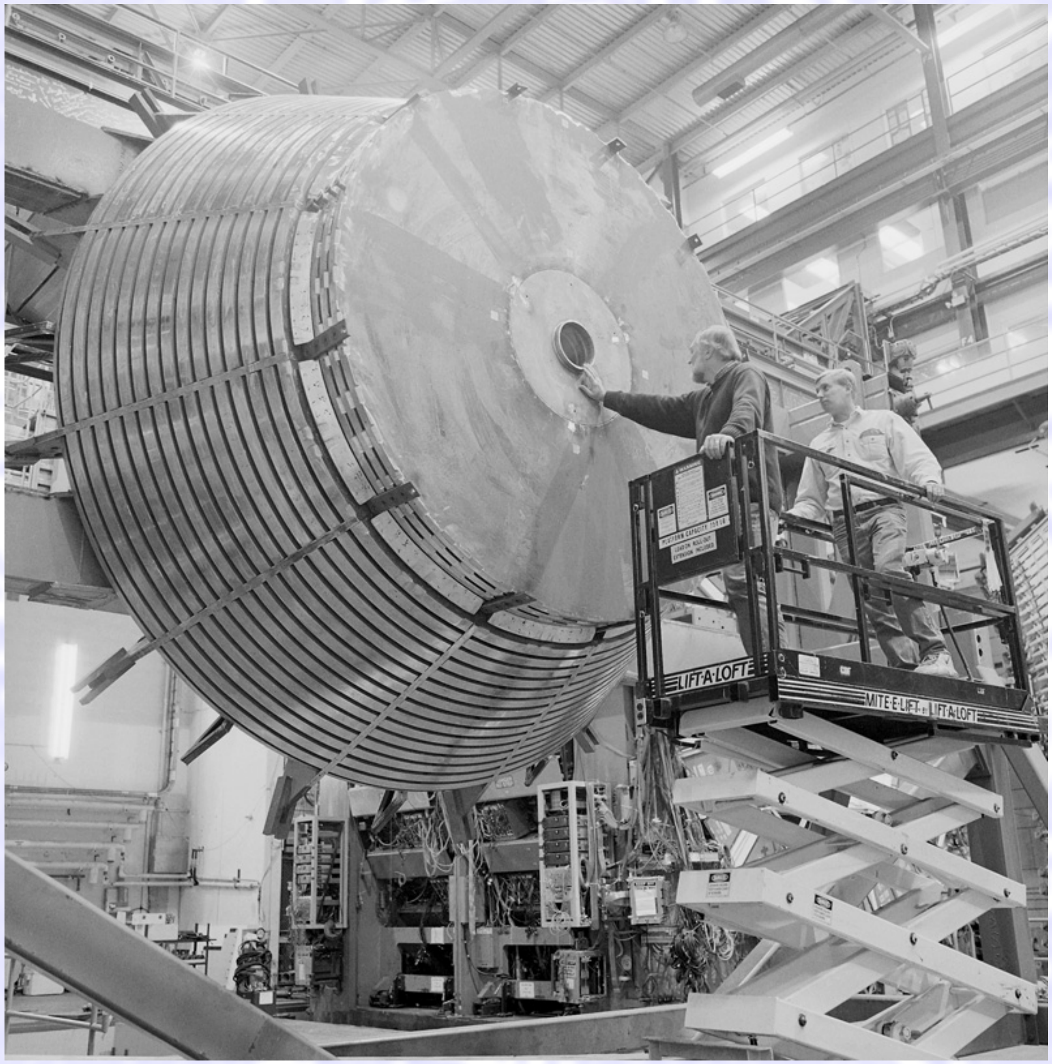


ORKA Beamline shortens to 14 meters, much BNL in-kind…

Goal: Increase K+ fraction from 2% to 70%, as quickly as possible! Slow kaons are rapidly decaying.

One Plug Must be modified to Transport kaon beam to the center of the CDF solenoid

Some Plug plates will be retained to Carry Magnetic Flux



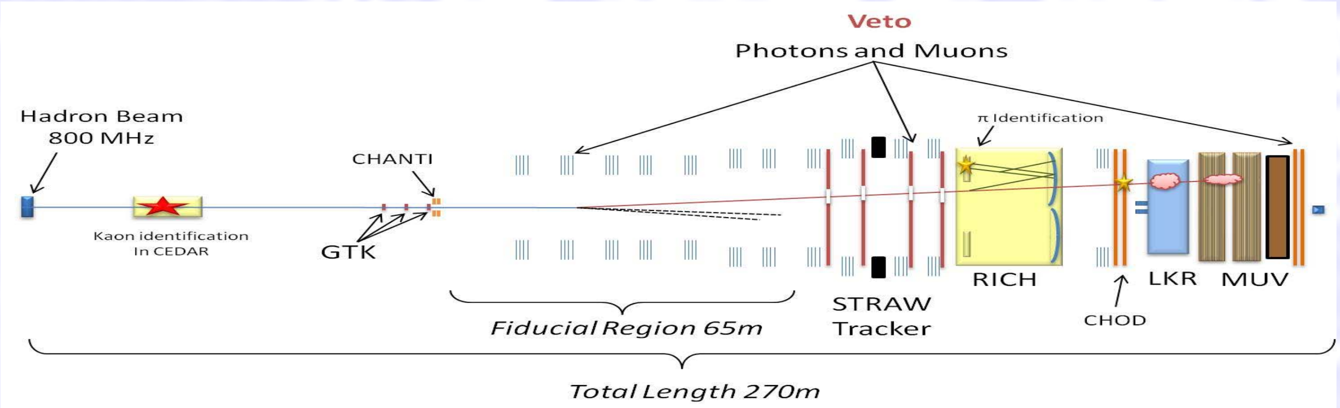
What about the Competition?

- **The CERN NA62 experiment:**

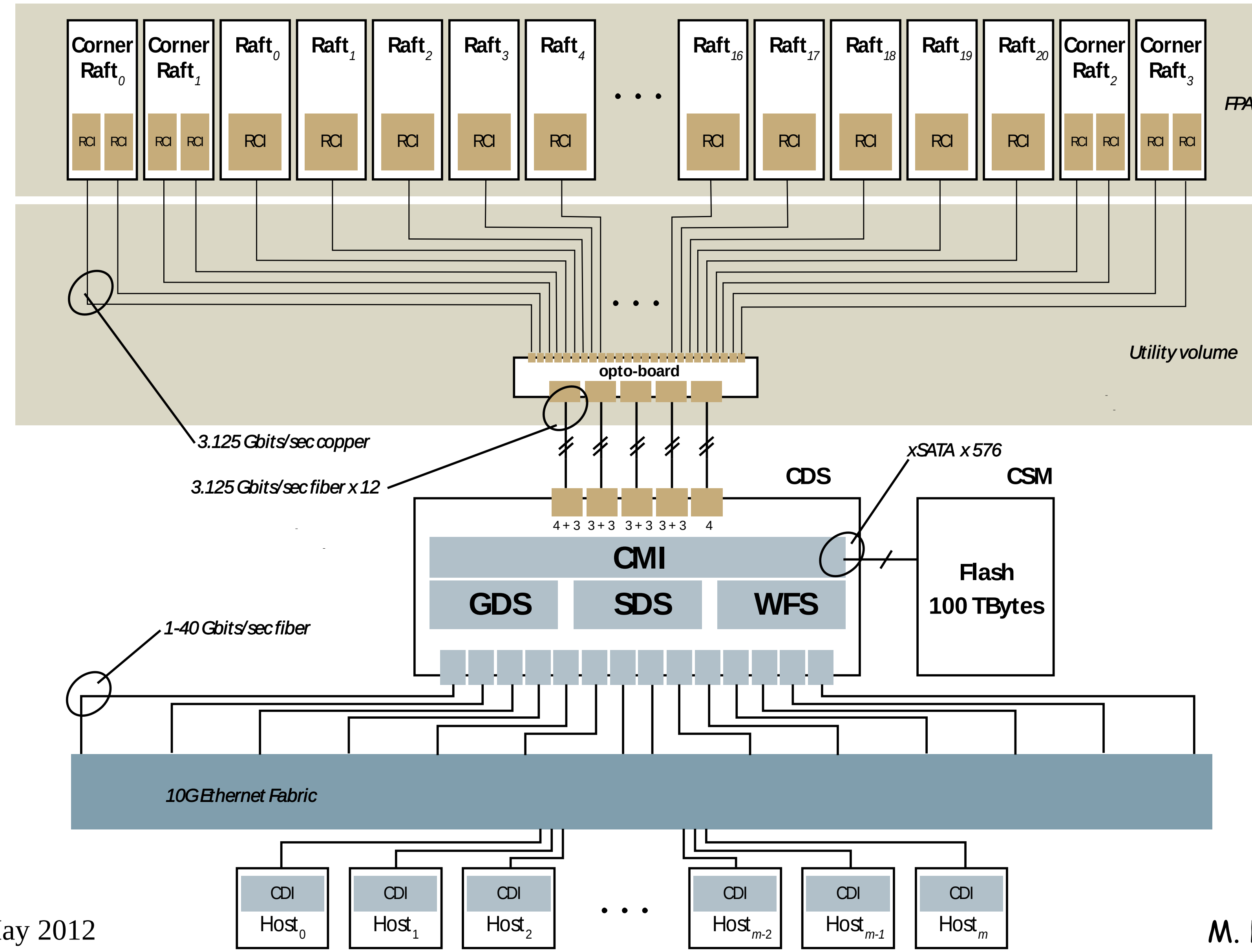
\- Strong group, evolution of existing assets, new in-flight technique, complimentary to the established ORKA technique.

\- Sensitivity goal: ~40 events/year.

\- Development run in summer 2012 with SPS beam. First results in 2017. Running must be coincident with LHC ops, splits run-time with CNGS.



Block Diagram of the LSST DAQ System



Mu2e Streaming DAQ

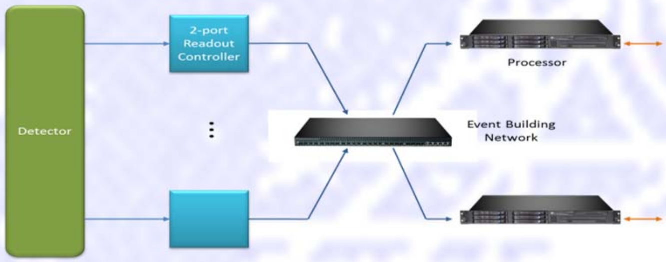


Figure 2a

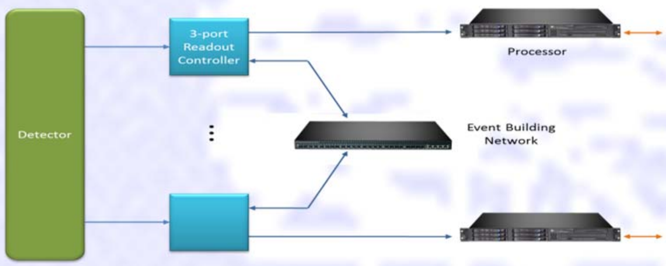


Figure 2b

In a switch based DAQ, the Readout Controller (ROC) collects data from the front-end systems and sends it through the Event Building (EVB) network to a Processor Farm. The typical ROC is a two-port device. Dataflow through the network is mostly unidirectional (Figure 2a) and final event assembly is done in the processors. Mu2e will use a three-port ROC. In this architecture the event building is done entirely in the ROCs and full events are then forwarded to the processors (Figure 2b). This has two advantages;

1) the EVB network connections are handled by an FPGA and can run at a full 10 Gbps wire speed (not usually possible with a processor running a software IP stack). Bidirectional data flow reduces the number of switch ports required.
2) the FPGA in the ROC has access to the fully assembled events, and can serve as a trigger pre-processor in addition to its function as readout controller and event builder. This offloads the farm and provides several TeraOps of supplementary processing power.

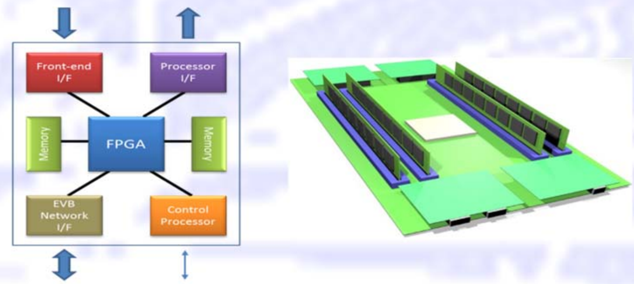


Figure 3

The Readout Controller I/O (Figure 3) is modular to support multiple applications. For Mu2e, the front-end interface is a 12-channel parallel optical receiver, and the EVB network interface is dual channel 10Gbps Ethernet (SFP+).

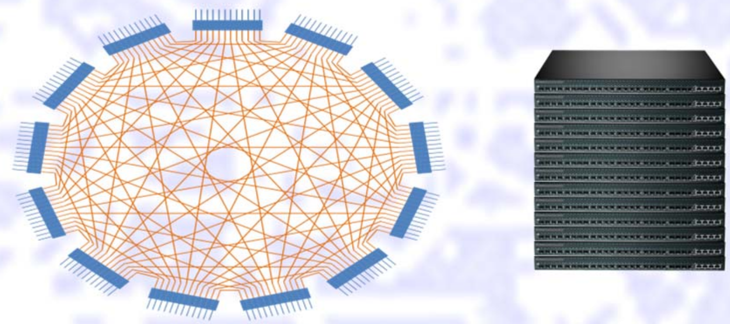


Figure 4

Figure 4 shows a 156 port EVB network using thirteen 24 port Ethernet switches. Each switch port is 10Gbps, for a total bandwidth capacity of 150 GBytes/sec. Interswitch connections are "direct attach" SFP+ copper cables. External connections are copper or optical depending on distance.

The Range Stack measures the π^+ energy, range, and progeny. BNL implementation based on 1980's technology…Ripe for upgrade.