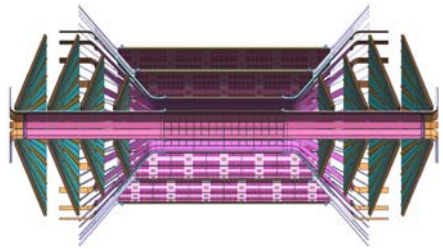
Update on the FVTX Proposal 1/13/06 – MJL (for FVTX group)



Reviewed by EC/DC on December 6th

- Draft report from John Haggerty (chair of review committee) sent to FVTX group, no final report, see slides and John's draft report at, http://www.phenix.bnl.gov/phenix/WWW/publish/leitch/fvtx/review_ecdc_dec05/
Working on list of homework, my version of the list is here FVTX_20Review_20mjl.ppt in above directory

Some of the major areas of advance in recent weeks:

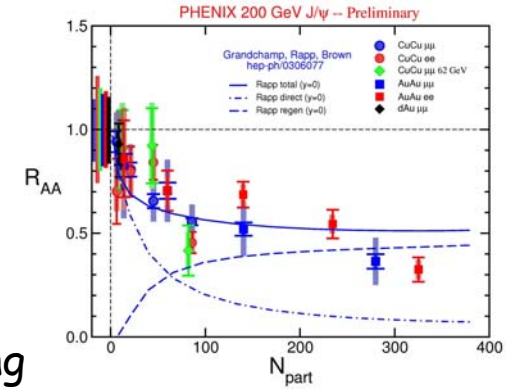
- FVTX – muTracker track matching in central AuAu collisions
- primary vertex resolution with FVTX for pp collisions
- Kalman filter tracker being developed
- updated rates, and calculations of level-1 trigger rejections needed
- discussions between ISU & LANL to develop concepts for level-1 triggers, including cross-subsystem level-1 triggers (e.g. FVTX + muTrigger + muID)
- Columbia taking lead on FEE-DAQ chain
- need discussion with VTX group about cable geometry – we need room to get FVTX Cu cables out!

(from the December review)

PHENIX FVTX (Forward Silicon Vertex) Proposal to DOE

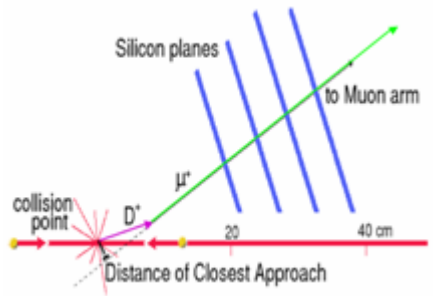
Enable a complete onia + open-heavy physics picture

- open-charm constraints on J/ψ regeneration
- consistent gluon saturation picture from onia and charm/beauty
- gluon polarization via charm & beauty over broad x range



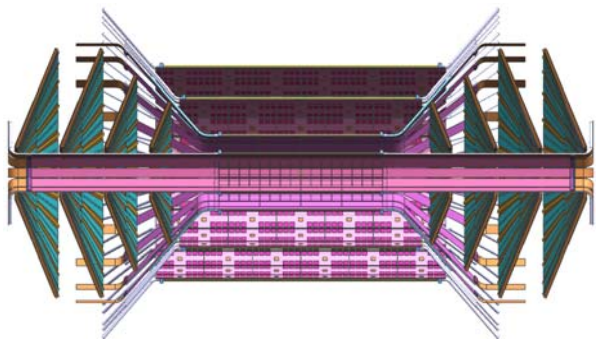
Identification of forward/backward detached vertices:

- rejection of π & K decays to clean single & pair spectra; including enabling continuum physics (e.g. D-Y) and multi-arm dimuons
- B → J/ψ X & open-heavy at large p_T
- improved J/ψ, ψ′ mass resolution/separation via improved position vectors at vertex



Detector/project synopsis:

- <200μm z_{vtx} resolution; <1.5% central AuAu occupancy
- fast trigger to enrich & enable timely physics
- 4 mini-strip silicon umbrellas in front of each muon arm
  - 50μm pitch in radial direction, 300 μm thick
- ~2M channels with PHX/FNAL chip
- $4.5M cost with completion target end FY10



Proposal draft: https://www.phenix.bnl.gov/phenix/WWW/publish/leitch/fvtx/fvtx_xx.doc

Updated rates for FVTX

pp process	1-arm Acc	BR	Lumi Type	Lumi (pb^{-1})	counts	with reality	eff_dzvtx	with dzvtx
D -> mu	0.0232	0.119	RHIC-II	33	3.4E+08	7.1E+07	1	7.1E+07
	0.0232	0.119	2008	9.9	1.0E+08	2.1E+07	1	2.1E+07
B -> mu	0.145	0.1087	RHIC-II	33	4.2E+06	8.8E+05	1	8.8E+05
	0.145	0.1087	2008	9.9	1.2E+06	2.6E+05	1	2.6E+05
B -> J/Psi	0.046	0.00065	RHIC-II	33	7.9E+03	1.7E+03	0.39	6.5E+02
	0.046	0.00065	2008	9.9	2.4E+03	5.0E+02	0.39	2.0E+02

AuAu process	1-arm Acc	BR	Lumi type	Lumi (nb^{-1})	counts	with reality	eff_dzvtx	with dzvtx
D -> mu	0.0232	0.119	RHIC-II	2.5	9.9E+08	1.8E+08	1	1.8E+08
	0.0232	0.119	2008	0.327	1.3E+08	2.4E+07	1	2.4E+07
B -> mu	0.145	0.1087	RHIC-II	2.5	1.2E+07	2.3E+06	1	2.3E+06
	0.145	0.1087	2008	0.327	1.6E+06	3.0E+05	1	3.0E+05
B -> J/Psi	0.046	0.00065	RHIC-II	2.5	2.3E+04	4.3E+03	0.39	1.7E+03
	0.046	0.00065	2008	0.327	3.0E+03	5.7E+02	0.39	2.2E+02

Assumptions (see proposal for details):

- cross-sections: 920 μb (D), 2 μ b (B)
- acceptances: 2.3% (D), 14.5% (B), 4.6% (B->J/Psi) for p>2.5 GeV in one arm
- Roser luminosities
- reality factors: 55% $|Z_{vtx}|$<10 cm, 60% PHENIX DF, BBC eff, etc.

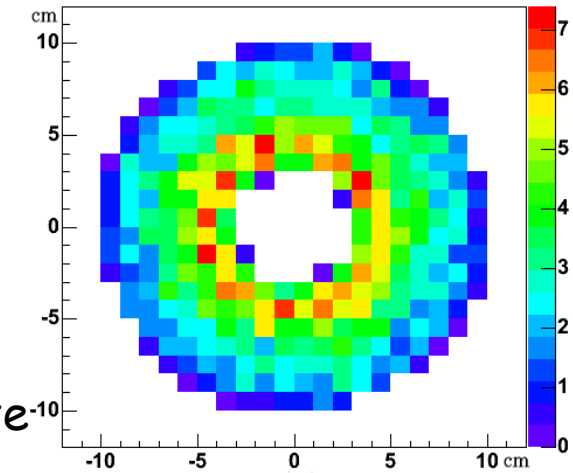
Primary vertex from the FVTX (Pat McGaughey)

- HIJET generator & PISA
- typical soft π momentum: 1.4 GeV/c (mean), 0.6 GeV/c (most probable)
- z_{vtx} resolution ~ 400 μm for these soft pions
- only FVTX hits available for level-1 trigger (no fast output for VTX)

Collision species ($\sqrt{s}$ = 200 GeV)	#π's in FVTX	dZ_{vtx} FVTX	# π's in VTX
pp MB	5.8	168 μm	~3
pAu MB	11.2	120 μm	~6
AuAu central	1730	10 μm	~900

$$dZ_{vtx} = 400\ \mu m/(\sqrt{N_{\pi}})$$

µTracker & FVTX Matching (Pat McGaughey)



Schematic Tracking algorithm:

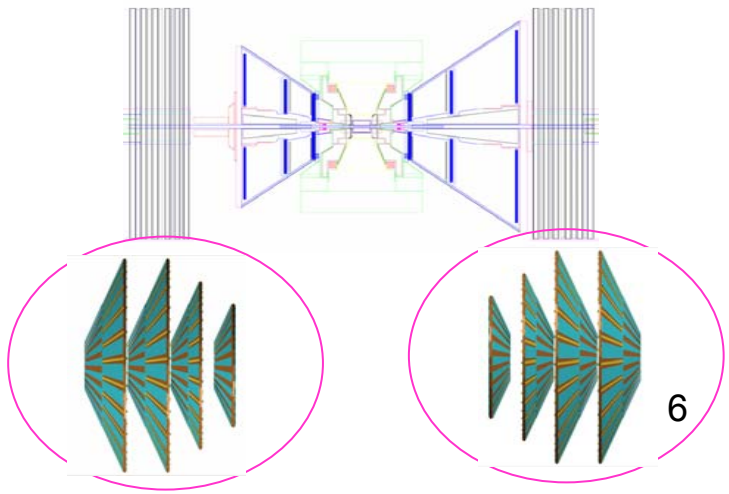
- µID seed & find µTracker track (as usual)
- find primary vertex with FVTX
- project station-1 track position to primary vertex
- put momentum dependent window on FVTX hits
- find FVTX track(s)
- use chisq and Kalman-filter fit to select and validate best track in FVTX

For 5.5 GeV µ in station-1

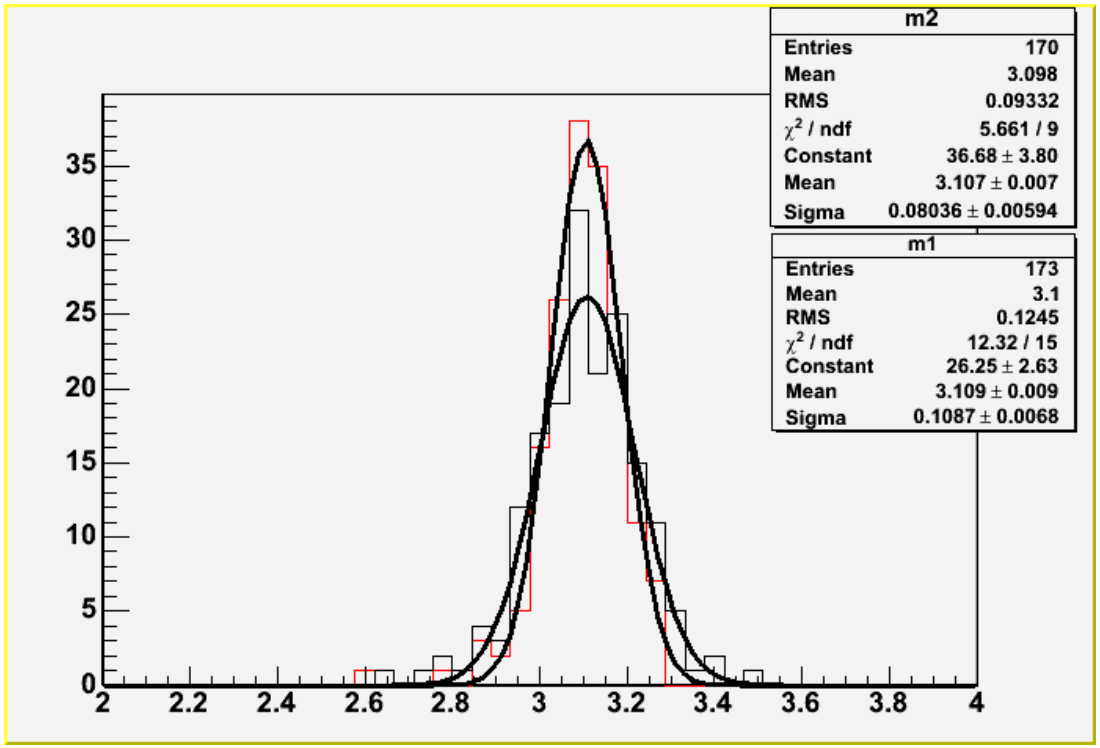
- projection rms error at rearmost FVTX plane is 0.45 cm
- average soft π density there is 0.38 π/cm^2 (central AuAu)
- for window size of 1.5 cm (~3 sigma)
    - 99% eff. for correct µ track; 2.7 extra soft π tracks in the window
- now fit FVTX track and require chisq/DF < 12 (soft π's multiple scatter more and produce less straight track)
    - 95% µ eff.; 1.1 soft π's left (39%)
- Kalman-filter fitter under construction – it will do better than this by cutting on combined chisq of FVTX+ µTr track

Kalman fitter (Melynda et al.)
Matching MuTr Tracks to Silicon Tracks

- For each good track found in the Muon System:
  - Search for tracks within a window in the silicon system
  - Add silicon hits to MuTr hits and do full Kalman Filter Fit
  - Try to discriminate good matches with bad matches with χ^2, etc.
- Work
  - Read silicon PISA hits into offline – DONE
  - Digitize silicon hits to add resolution – in progress (Xiaorong)
  - Nominally select hits which could match with MuTr track – DONE
  - Add to Kalman fit, clone tracks if more than one match – DONE
  - Test correctness of code – mostly done, I think
  - Put in accounting to make good/bad histograms – partially done
  - Study performance with different orientations
  - Study rejection of "punch-throughs"

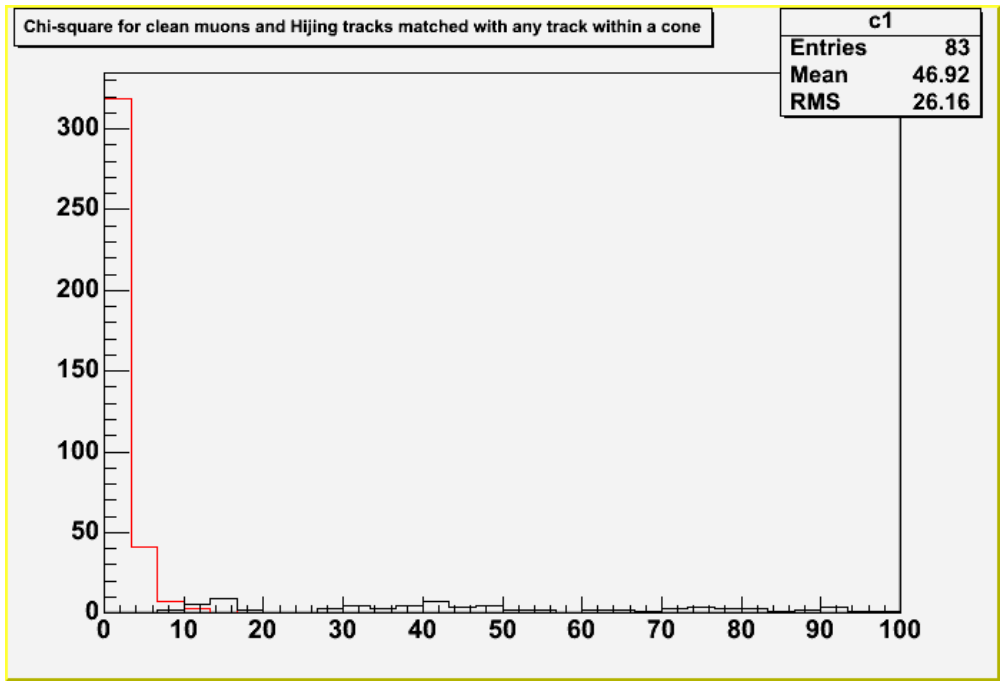


Kalman fitter (Melynda et al.)
Initial checks so Far — Reconstructed J/ψs



- See expected improvement in J/ψ mass
- Note: this is with perfect silicon resolution and using all silicon hits (barrel and forward), just to test Kalman fitting giving approximately right results

Kalman fitter (Melynda et al.)
Checks so Far — χ^2 Distributions

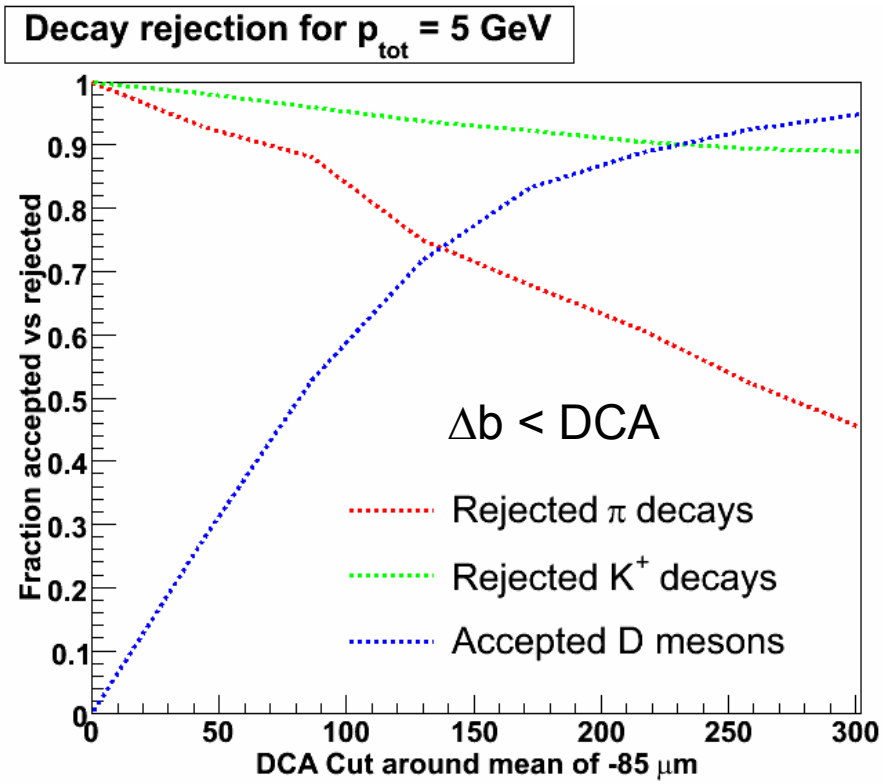


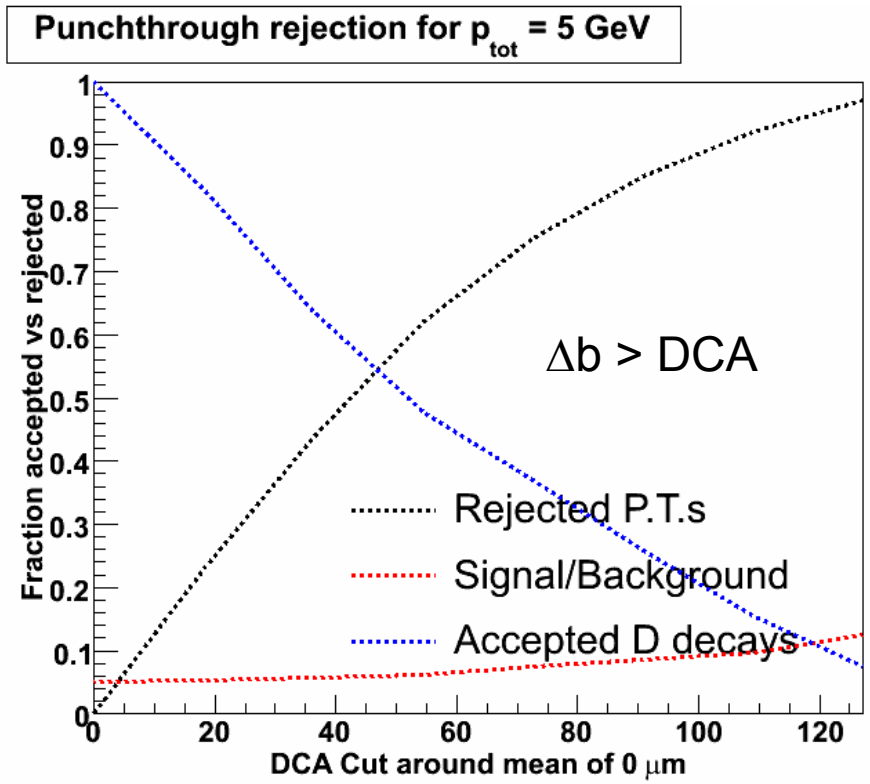
- χ^2 Distribution from 3 GeV muons (red); silicon + MuTr and one HIJING event (black) mixed with a single muon, and each MuTr track was matched with silicon tracks within a few cm cone
- Weighting will become more appropriate when digitization finished and tagging of good/bad tracks should be done very soon
- Will then run full set of HIJING events

DCA cuts for π,K decays and punch-throughs (Anuj & Hisham)

Increasing upper limit on DCA gives:
- more rejection of π's and K's
- larger acceptance for charm

Increasing lower limit on DCA gives:
- reduction in charm efficiency
- rejection of punch-throughs
- improved signal/noise for charm





Estimated trigger rates & additional rejection factors needed for pp & AuAu collisions at RHIC-II and in a 2008 RHIC-I run

- Even pairs need (some) additional rejection in pp for RHIC-II
- Rejection could come from super-level-1 trigger that combines information from FVTX, muTrig, muID, NCC, …

	era	lumi/wk (pb-1)	zvtx<10cm	lumi pk (10^32)	MB pk rate Mhz	evt size (kb)	1d pk rate (khz)	1d Mb/s	1d prescale needed	1d1s pk rate (hz)	1d1s Mb/s	1d1s prescale needed
pp	RHIC-II	33	0.55	1.34	5.65	180	23.63	4253	71	481	87	1.4
	2008	9.9	0.55	0.40	1.69	180	7.09	1267	21	144	26	0.4

	era	lumi/wk (nb-1)	zvtx<10cm	lumi pk (10^26)	MB pk rate khz	evt size (kb)	1d 1d pk rate (khz)	1d Mb/s	1d prescale needed	2d pk rate (hz)	μμ Mb/s	2d prescale needed
AuAu	RHIC-II	2.5	0.55	101.85	69.74	250	27.9	6974	116	8884	2221	37
	2008	0.327	0.55	13.32	9.12	250	3.65	912	15	1162	291	4.8

Assumptions:

- DAQ limit of 60 Mb/s per trigger - 10% of 600 Mb/s (no demultiplexing) limit
- muID rejection factors from recent runs
- luminosities from Roser with 55% eff for ±10 cm vertex cut added
- use typical peak/avg luminosity ~4.48

Triggering for the FVTX

Starting discussion with ISU group (John & Craig) – MJL will go to ISU next week

Apologies up front – just beginning to brainstorm on the blackboard – more questions than answers so far…

- FVTX PHX chip pushes fast trigger info out
- ISU has STTR grant with Northern Microdesign to develop FVTX trigger
- We need additional rejection, as shown on previous slide
  - ~1/100 for 1d muons & ~1/37 for AuAu dimuons needed at RHIC-II
  - ~1/20 for 1d muons & ~1/5 for AuAu dimuons for RHIC-I "2008"
  - can come from any combination of forward detectors (FVTX, muID, muTrig, NCC)
- muTrig upgrade could be quite helpful by providing rough momentum value
  - 1^o ϕ pad size, nominal W-trigger cut > 2^o $\Delta\phi$ (~10 GeV/c?); so can easily imagine determining rough momentum for p<10 GeV/c which would correspond to > 2 pads bend between RPC1 and 2 (careful of M.S. though)
  - allows momentum dependent prescales or vertex cuts & matching between RPC1 pad (1^o) and FVTX wedge (7^o) - maybe also in theta (24 RPC segments in theta)
  - could NCC also help with isolation cut to reject hadrons?
- Caviats
  - single muon triggers may already (with LL1) be pretty clean; how much more can even a perfect π/K/punch-through rejector gain?
  - the muTrig upgrade can make them cleaner yet (tighter geometrical and timing constraint to primary vertex)
  - might only be a factor of 4-5 to get at large momentum; maybe 10 at low momentum – needs study! (pairs would benefit as square of this)

(more) Triggering for the FVTX

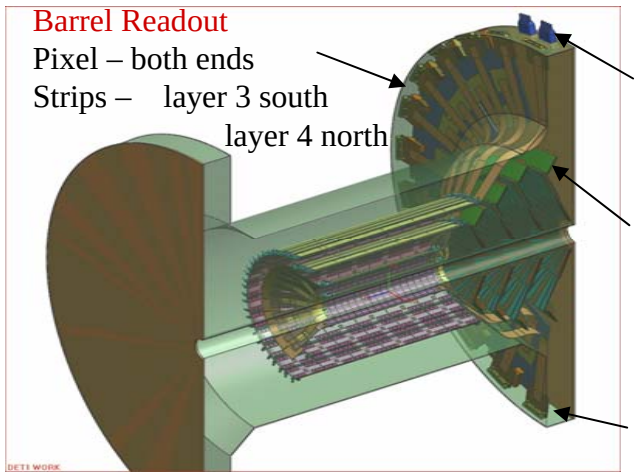
- LL1 could reduce FVTX tracks (soft pions) that match a muID/RPC road from 2.7 to 1.1 for central AuAu (see earlier slide) with straight-line fit "chisq/DF" cut
  - needs study to see if this will actually yield rejection in AuAu though
- Detached vertex cuts can reduce remaining prompt and light-meson decays (at the expense of some charm/beauty signal)
- Hardest problem is to capture all the low-p charm/beauty
  - important since large part of charm & beauty cross sections are there and this part is particularly important for J/ψ recombination models
  - but could potentially obtain substantial rejections from FVTX LL1 here
- again more questions than answers
  - but presently the FVTX LL1 is not included in FVTX proposal except as appendix (& not in FVTX $budget)
  - and it is a more global issue than just FVTX anyhow; we need a strategy that encompasses all forward upgrades

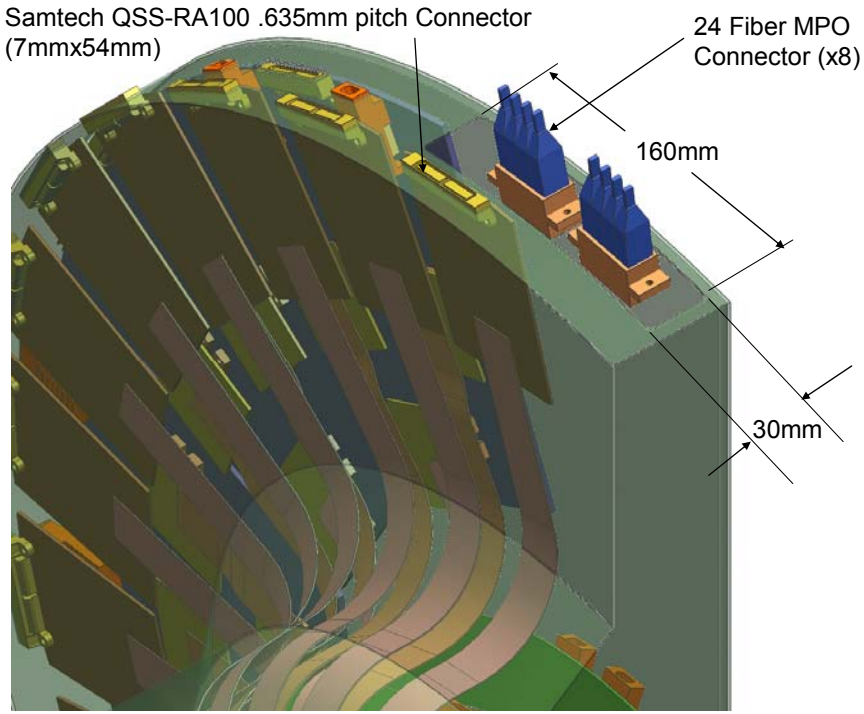
Copper or fiber – how to get FVTX data out

We really don't want fiber drivers inside

- heat
- complicated design in small space
- access difficult for repairs (remember the clink/glink in muTr?)

Need to layout VTX barrel Spiro boards and cables to use less of the circumference so that FVTX copper has room to get out!

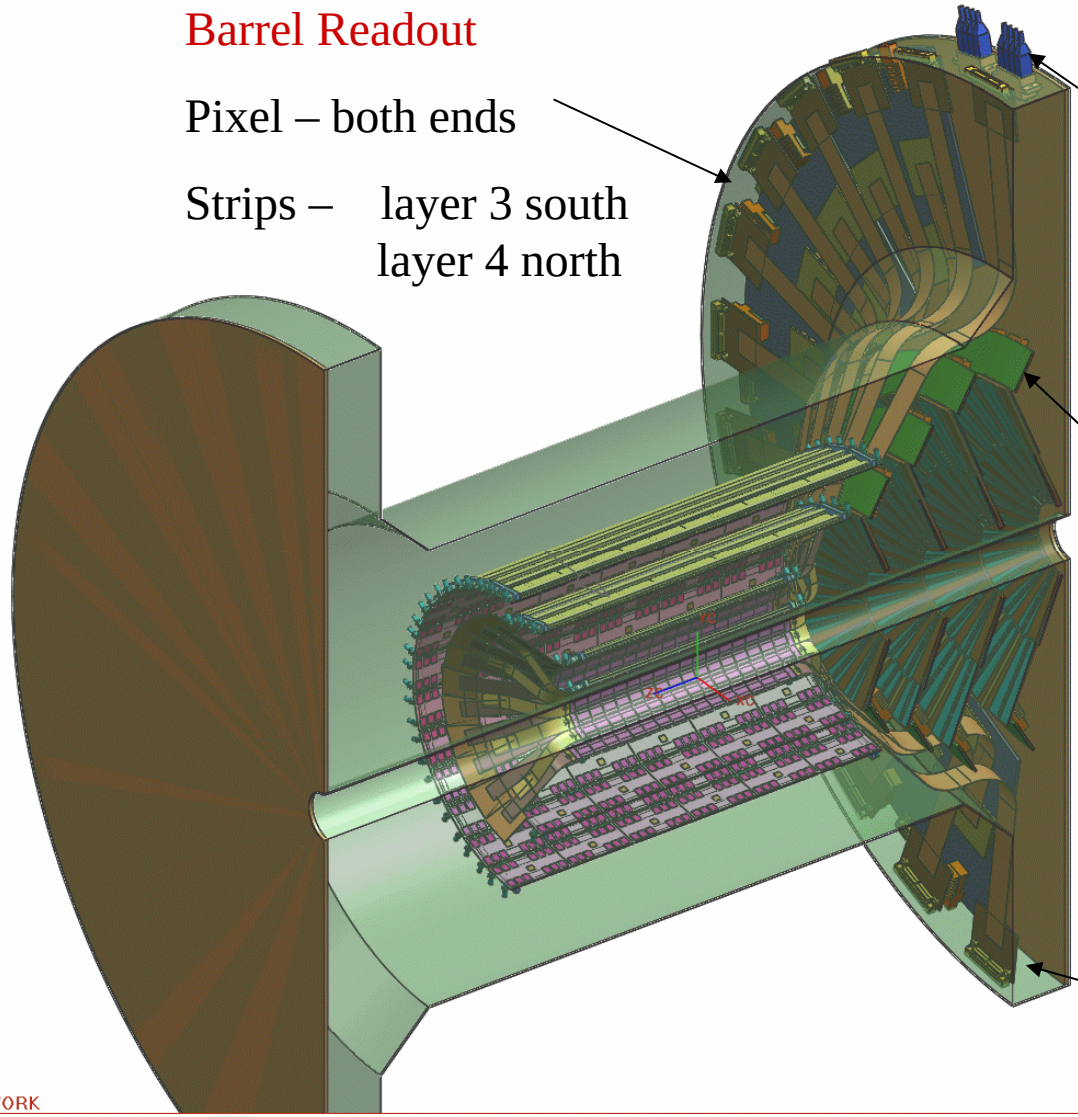




Barrel Readout

Pixel – both ends

Strips – layer 3 south
layer 4 north



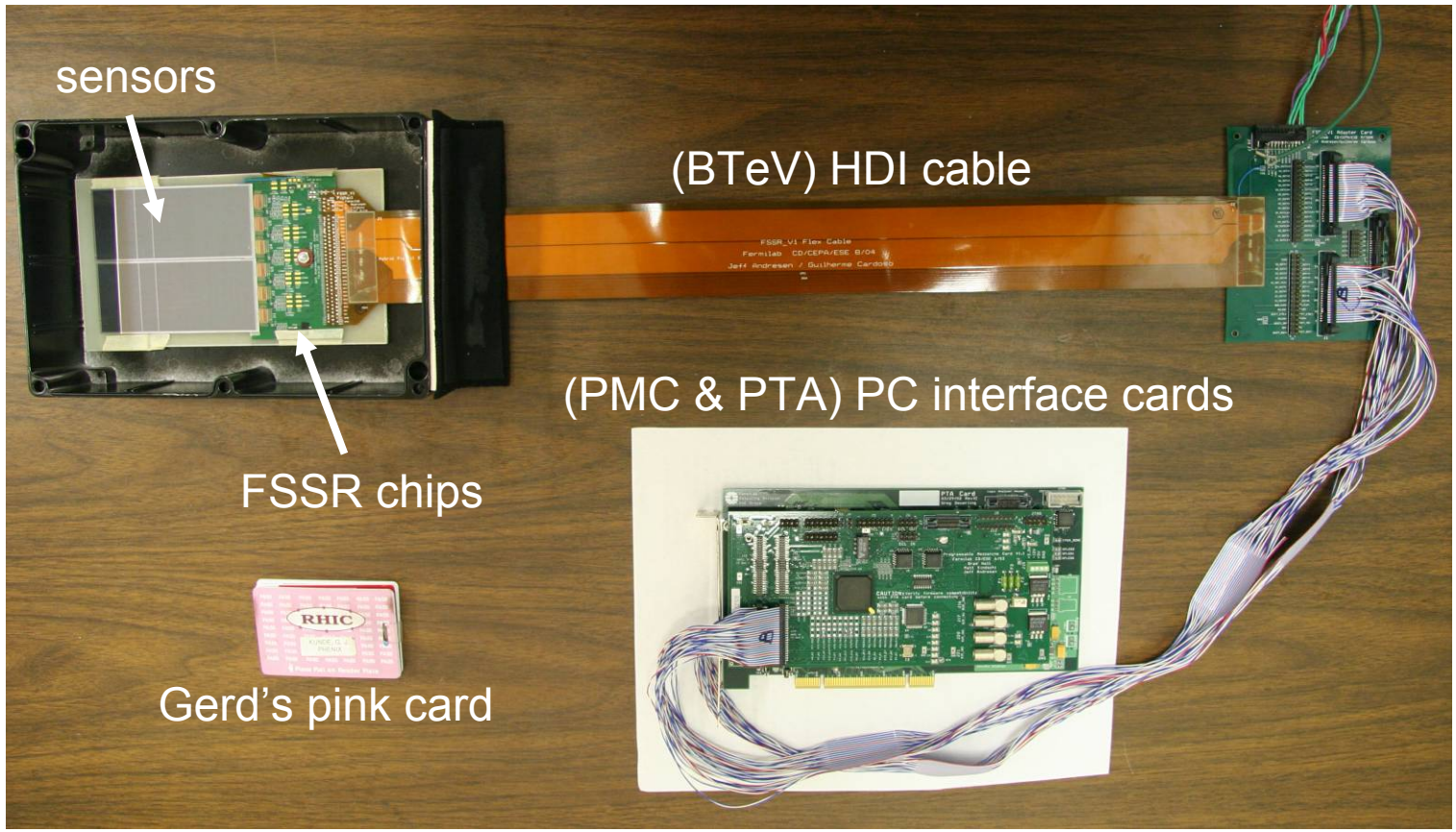
Endcap Fiber Optic Readout Molex Quad 24 fibers

FVTX bus and output interface

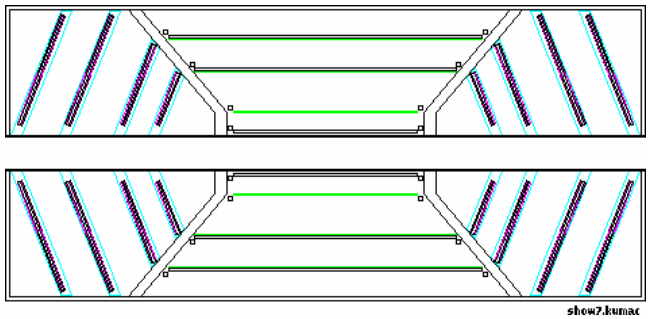
Strip layer 4 readout conn.

FSSR at LANL

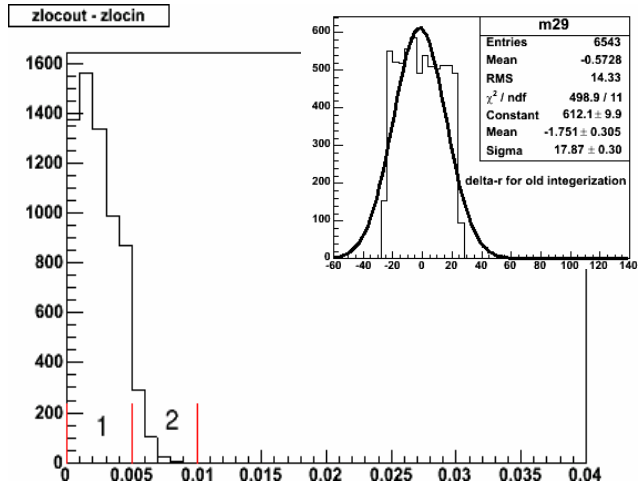
- 6-FSSR test setup wire bonded to 2 CDF sensors
- Same digital backend as PHX chip
- PHX design status → working towards detailed SOW

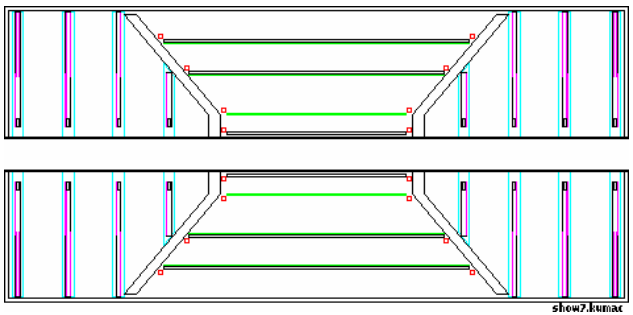


Studying Umbrella vs flat FVTX planes (Hubert)

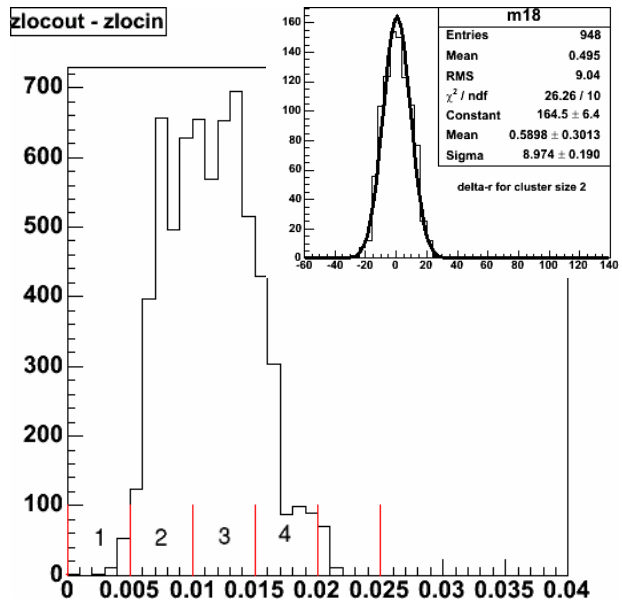


Umbrella configuration
- 1-hit per track
- 18 μm resolution



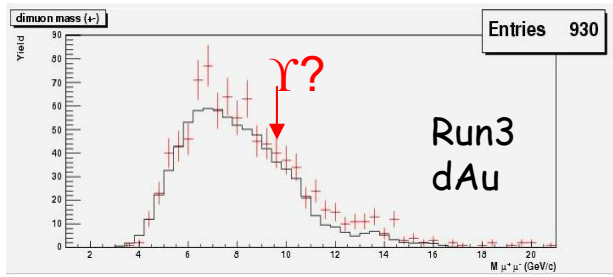


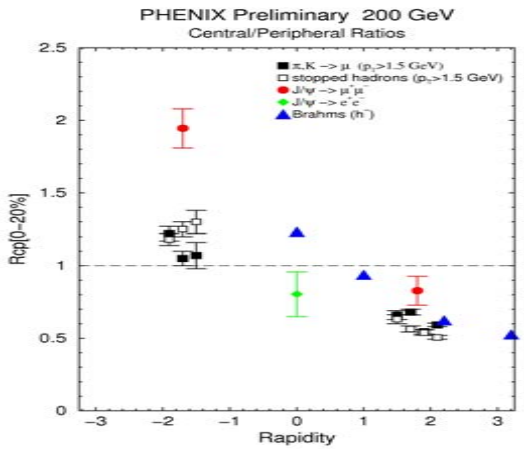
Flat configuration
- 2 to 4-hits per track
- 10 μm
- but "occupancy" is increased



FVTX: two endcaps vs one

- Simple increase in solid angle by x2 for rare probes that are in one arm – e.g. J/ψ, ψ', Υ, Drell-Yan, B $\rightarrow$ J/ψ X
- Pulling two-arm Υ's (& high mass continuum) out of the light-hadron decay & punch-through backgrounds
- Seeing the (different) physics of both sides at once in asymmetric collisions, e.g. in dAu
  - no need to have two runs, each with deuteron going a different way!
  - save 2-3 weeks to reverse beams -> $2-3M
  - systematic study over full rapidity range all at once
- Having both endcaps is quite important!

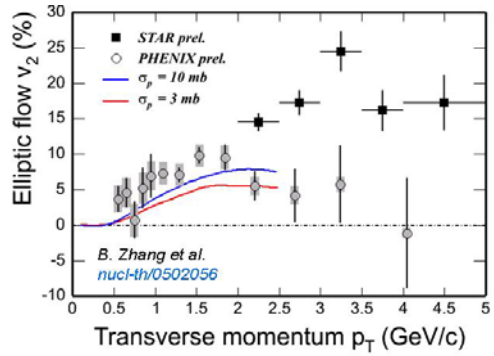




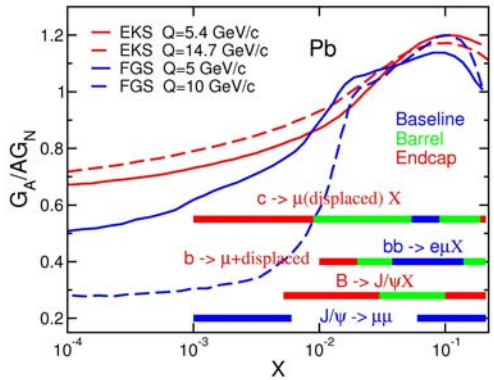
Extra slides

Highlights of physics advances with FVTX

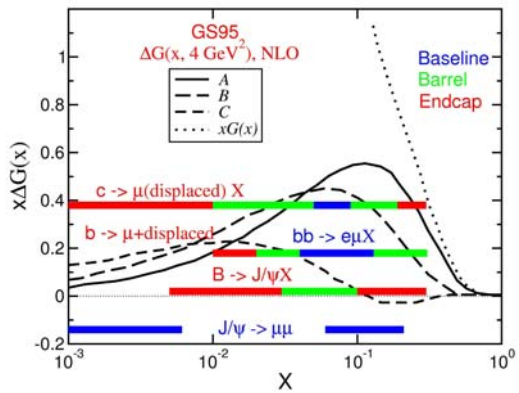
Study of dE/dx & flow for heavy-quarks into forward/backward rapidity
• geometrical and dynamical effects on heavy-quarks (and hadrons) of QGP contrasted with mid-rapidity



Precise comparison of open charm & beauty with onia
• isolation of common effects (e.g. gluon saturation at small-x & initial-state dE/dx)
• from those that are different (e.g. J/ψ absorption)



Pin down the gluon polarization over a broad range in x with charm & beauty measurements

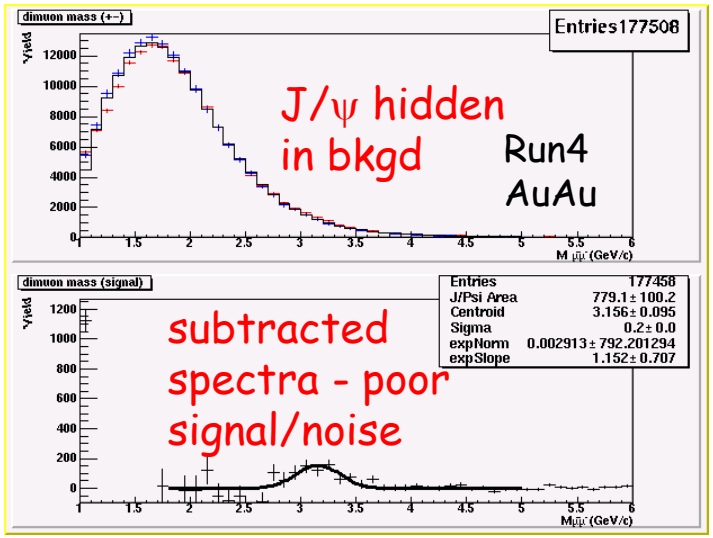


A few of the new or improved physics signals with FVTX

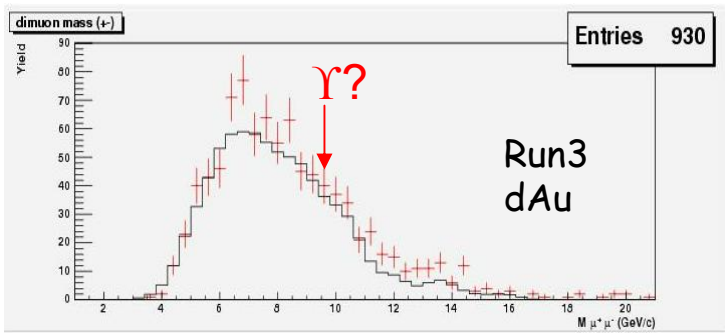
Identification & event-by-event rejection of long-lived meson (π & K) decays

- robust open-heavy measurements with meson decays eliminated
- clean dimuon background allowing more accurate onia measurements, Drell-Yan & direct measurements of ϒs at mid-rapidity

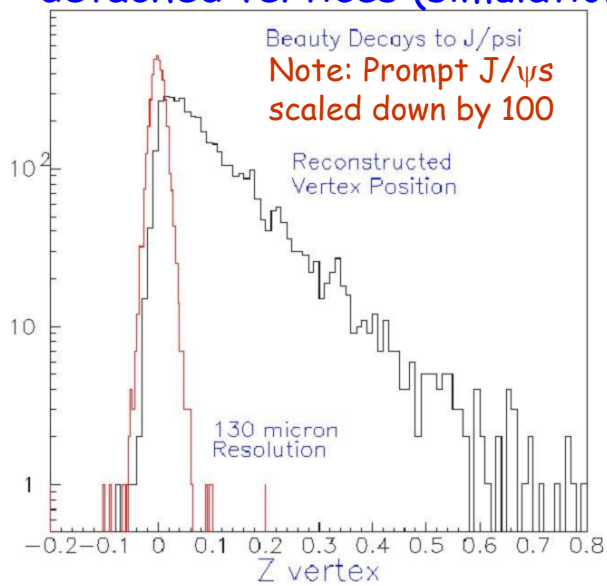
Huge combinatoric backgrounds for J/ψ in AuAu, mostly from π & K decays



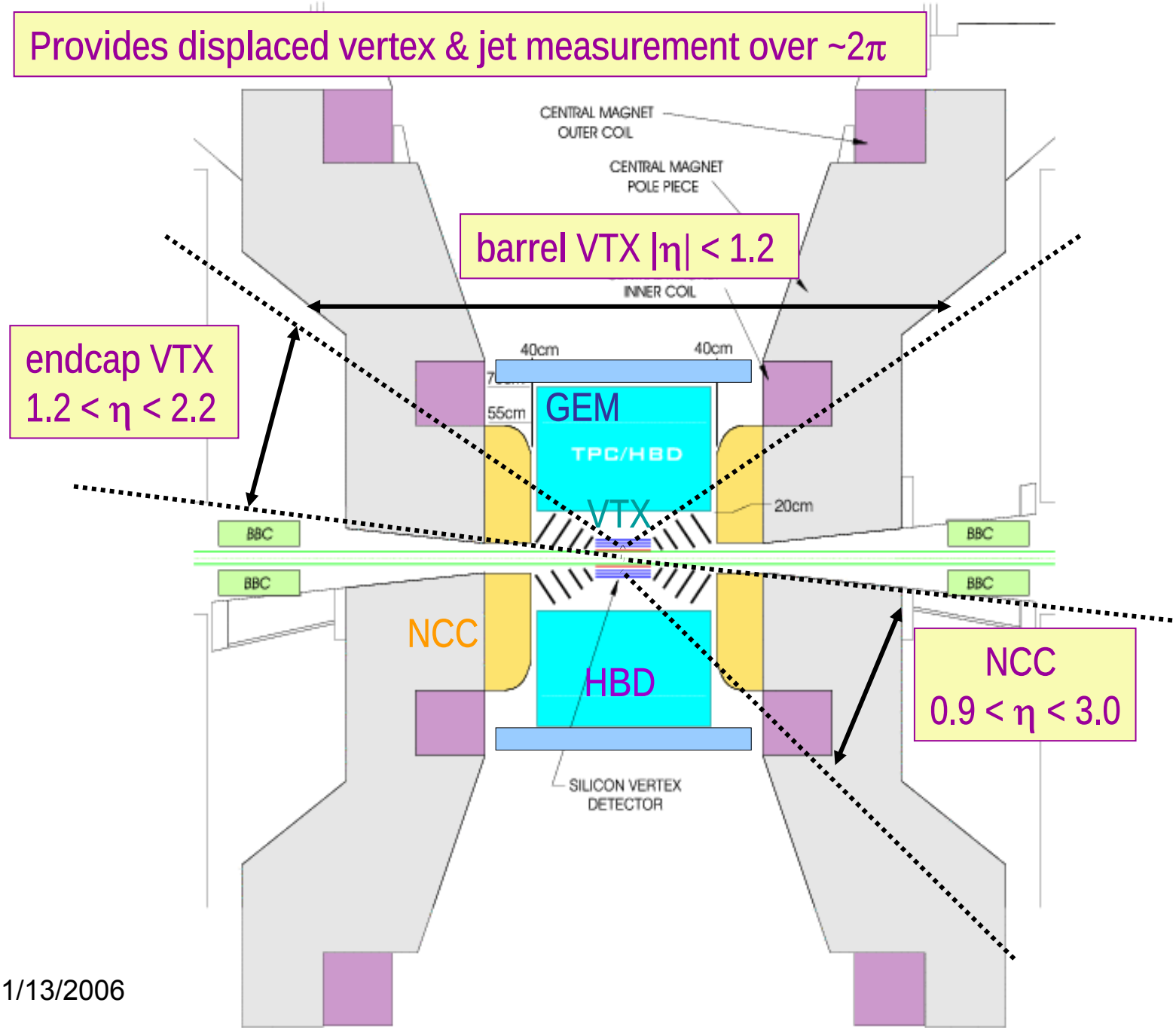
Copious backgrounds for dimuons with one muon in each arm, mostly from π & K decays



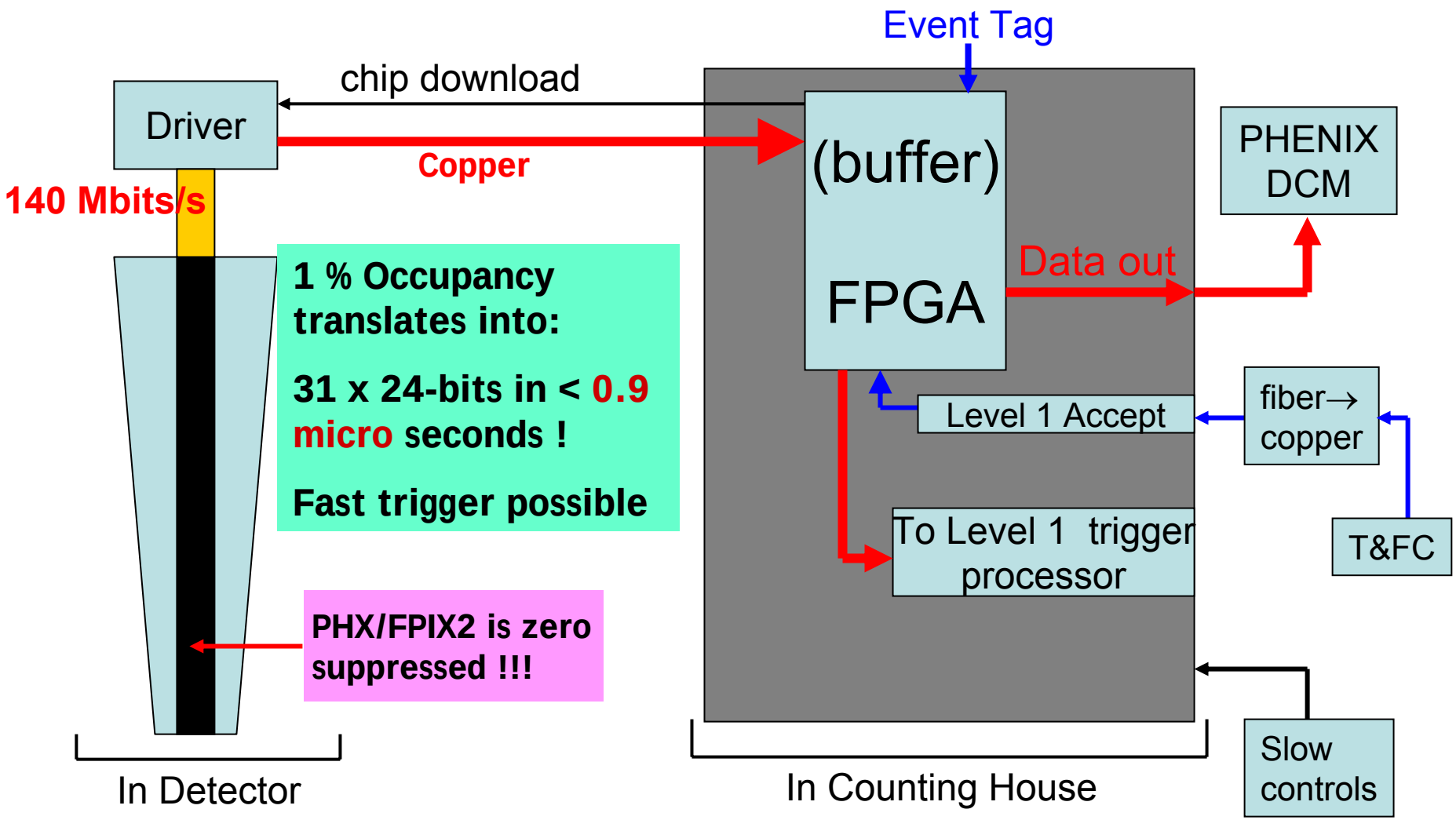
Identification of B → J/ψ X & of charm & beauty → μ via detached vertices (simulation)



Provides displaced vertex & jet measurement over ~2π



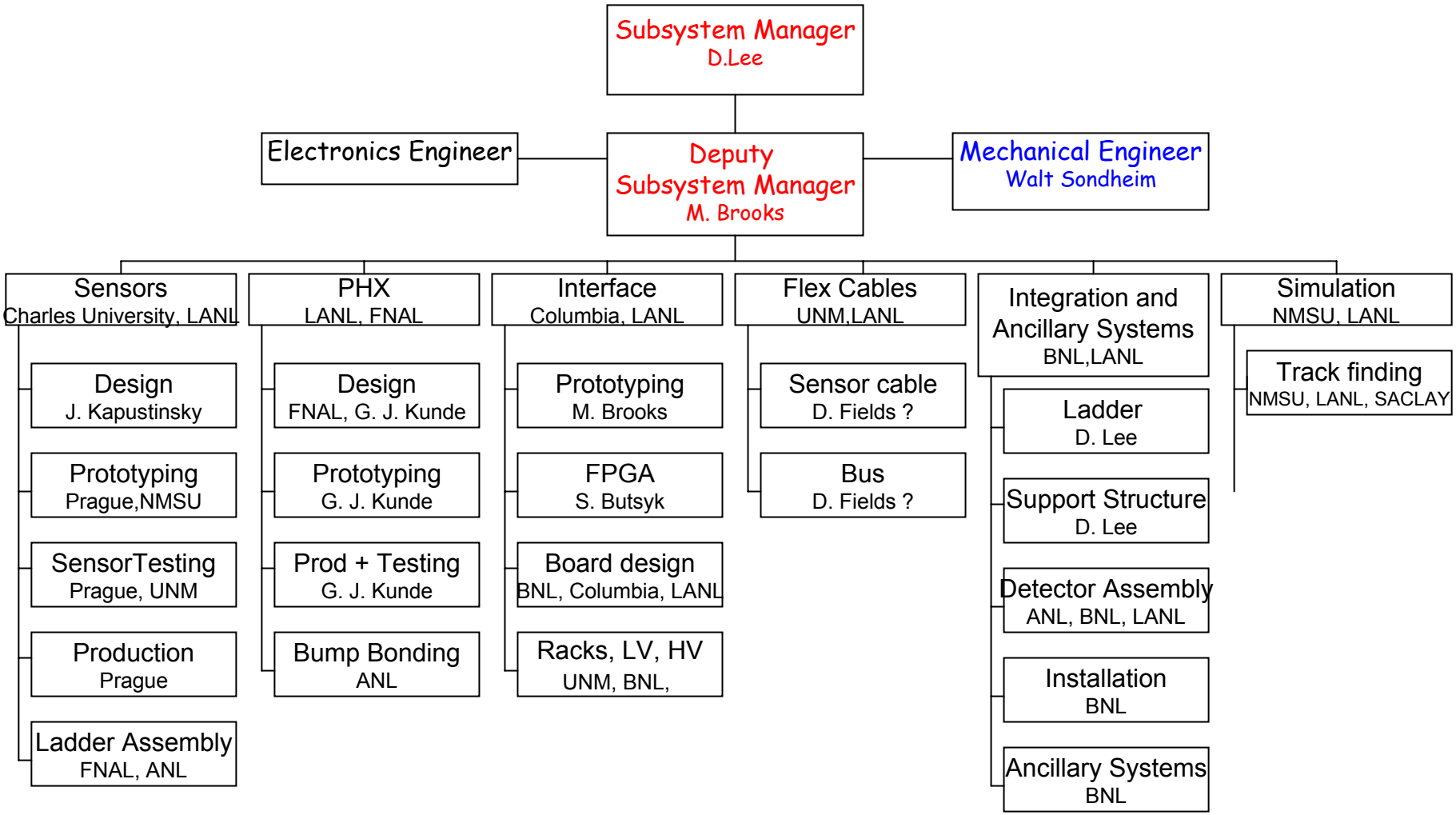
Electronics Readout Concept



The FVTX Team

- LANL – overall lead & LANL/LDRD
- Columbia – DAQ interface
- ISU – triggering
- Charles U., Czech Tech. U., Inst. Phys. Academy Sciences (Prague) – ATLAS Si experience & facilities
- NMSU - simulations
- UNM – Si expertise & facilities
- Others who are interested & may join
  - ANL (Paul Reimer et al) – E866/NuSea & Hermes
  - Ecole Polytechnique/LLR – muon arm, electronics
  - FSU – heavy-quark rates
  - Kyoto – muon arm, electronics
  - Saclay (Hugo) - simulations
  - Yonsei U., Korea U. – electronics & software, experience from muon arms
- Add your institution here!

Organizational Chart



FVTX Cost & Schedule Summary

- Cost
  - R&D - $360k LANL + $495k BNL
  - Construction - $3.56M + 27% contingency → $4.52M
  - LANL/LDRD prototype - $1.25M/yr for 3 yrs (including theory and includes $360k above R&D)
- Schedule
  - Installed & commissioning by end FY10
  - Construction start October 2007 (FY08)
  - R&D start January 2006
- Proposal schedule
  - PHENIX review Dec. 2005
  - BNL review ~ Jan 2005
  - Submit to DOE for FY08 budget planning ~March 2006